Chapter 17: Accelerating the transition in the context of sustainable development

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Executive summary

Sustainable development offers a comprehensive pathway to achieving ambitious climate change mitigation goals. A deliberate approach to use sustainable development as a frame can enable its explicit integration into transition pathways (*medium confidence*).

Sustainable development requires the pursuit of synergies and the avoidance of trade-offs between the economic, social and environmental dimensions of development, thus providing pathways that accelerate progress towards ambitious climate change mitigation goals (Paris Agreement). In practice, jointly implementing broader policy agendas requires the establishment of cross-sectoral partnerships and long-term stable policy environments. Both climate change and sustainable development are complex and cross-cutting processes (*high confidence*). Climate change impacts will have implications for the achievement of sustainable development and can derail the implementation of sustainable development in systems that are dependent on natural capital (*high confidence*). Energy production and consumption, a key driver of climate change impacts, can both enable and disable sustainable development (*high confidence*).Sustainable development needs balanced actions in relation to impacts in both mitigation and adaptation. The co-benefits of mitigation alone are insufficient to enable adaptation, as enhanced sustainable adaption can lead to effective emission reduction benefits. Effective action is achieved when synergistic and virtuous collaboration between adaptation and mitigation are explored (*medium confidence*).

Sustainable development cannot function in a vacuum. It requires strong leadership, disruptive technological, transformative institutional changes, stringent regulation, and strong representational voices from political, civil-society and private-sector groups to support the economy, ecology and social evolutions, especially given the relatively slow progress and current gap in implementation.

Reducing sustainable transition to a single action will discount the multiple actors in this highly complex and multi-faceted process (*medium confidence*). Accelerating the transition to sustainable development using climate change as the main conduit can only be achieved if silos are broken down, synergies across sectors are exploited and policy coherence across scales is sought.

Theories, paradigms and approaches related to transitions towards sustainable development and low-carbon pathways tend to emphasize different drivers and mechanisms, focusing on welfare, system boundaries, policy objectives, technologies, innovation, markets, behavior and the institutional aspects facilitating decisions.

Reducing emissions down to 2ºC or 1.5ºC will necessitate a radical shift to transformational pathways to a low-carbon global economy, with implications for large structural changes in the economies, technologies and behavior. Meeting such ambitious goals will require short- and long-term targets to guide the direction, scale, speed and quality of the transition, as well as investments in long-term infrastructure to support climate-proofed infrastructure, energy supplies, industry and urban settlement that are climate-resilient.

Factoring in equity and distributional effects will be particularly important in the pursuit of sustainable policies and partnerships. Regional distributions of efforts across NDCs based on emissions- and cost-based comparability measures and the distributions of the consequences of meeting NDCs’ domestic mitigation components in line with a broader set of SDGs tend to differ and require targeted national policies, which are not only based on mitigation costs, but rather on policy integration with SDGs.

Low-carbon transitions need carefully designed portfolios of policies, which can help to enable a structural change in the economies and associated redirection of investment and consumption patterns in accordance with low-carbon societies. Short- and long-term transformation studies with macroeconomic models and other tools have been used to assess the economy-wide impacts of development pathways aligned with sustainable development and climate change.

Renewable energy will be critical in accelerating the transition process and redirecting low-carbon trajectories. Deployment of renewables, as well as research and demonstration projects, have resulted in driving down the cost of renewables significantly in recent decades.

Negative economic impacts in some regions can happen with increased energy costs and decreasing employment in some sectors, which will in turn slow down the transition process. Nonetheless, the deployment of renewable energy will generate a new industry and associated jobs and benefits, which will often not directly offset activities in industries and geographical areas that have been closely associated with the fossil-fuel industry. There is poor understanding of how governance at multiple levels may fail to make significant progress with a global climate agreement and may support or weaken the climate architecture, thus constituting a limiting factor.

Accelerating the transition to sustainable development will necessitate insights from multiple schools of thought, including factoring into our understanding psychological, community-based and social movements, technological innovations, not least information technologies, and social innovations, governance and institutions. Given the fact that transitions are complex and non-linear, there is also unlikely to be a one-size-fits-all prescription for what helps or hinders a transition. Transitions are not uniform but depend on, *inter alia,* development pathways, the speed of action and a myriad of contextual factors, not least political economy dynamics.

The speed, quality, depth and scale of the transition will depend on the developmental starting point, explicit goals and the enabling environment in terms of individual behavior, attitudes, beliefs and actions, social cohesion, governance, policies, institutions, social and technological innovations, policy instruments etc. The relationship between mitigation and adaptation is critical to designing holistic transition pathways. Enabling synergistic actions that target behavioral change, technology, energy systems, infrastructure etc. can help accelerate the transition, in the process avoiding maladaptation and mitigation.

Sustainable development in many parts of the world will also imply large-scale investments in new infrastructure due to its key role in economic growth processes and meeting SDGs (*medium to high confidence*). Investments in infrastructure can have a large influence on long-term sustainable development and carbon pathways. Various pathways exist for managing risk for both existing and future investments in infrastructure, as well as for phasing out existing infrastructures, with the associated risks of stranding existing assets.

Behavioral changes are also expected to be a major factor in aligning sustainable development with climate change and land management. For instance, reducing food waste can have positive implications for enabling food systems.

17.1 Introduction

This chapter looks at how climate policies are related to sustainable development and how transition and transformation pathways are linked to climate actions. It considers the inter-dependence, inter-relativity, connectivity, complexity and multi-directional and multi-faceted nature of interaction among the significant players, including equity issues and just transition processes. It assesses how climate actions could to be accelerated in a sustainable development context by examining the relationship, synergies and trade-offs between adaptation, mitigation and sustainable development (Section 17.1). It then considers sustainable development through alternative transition theories, assessing how long-term sustainable development and climate policy goals could be achieved, also taking into account how different actors are involved in various transitions (Section 17.2). It then looks at case studies in a context of short- and long-term sectoral and cross-sectoral transition processes, as well as the opportunities and challenges involved in accelerating the transition process (Section 17.3). Finally, the chapter synthesizes the findings and identifies the key enabling conditions for acceleration of the transition to sustainable development and to achieving climate targets (Section 17.4).

17.1.1 Sustainable Development as a key composite policy framework globally

Sustainable development has been a topic of great interest ever since it was articulated by the World Commission on Environment and Development (WCED) in its report “Our Common Future” in 1987. According to the WCED, “Sustainable development is defined in the Brundtland Commission report as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’” (WCED 1987). This definition is also used in the AR5 (Denton et al. 2014a) and the Special Report on 1.5 degrees C (Roy et al. 2018; IPCC 2018) linking the three dimensions of sustainable development to climate change. However, relationships between climate change impacts and global sustainability were examined by the IPCC as early as 2001 (IPCC, TAR Climate Change 2001: Mitigation, Chapter 1), concluding that "parties have a right to, and should promote sustainable development" as stated in the text of the UNFCCC (Article 3.4). One of the main approaches analysed at that time was to assess the climate challenge from a sustainable development perspective. In turn, the next assessment report (IPCC, AR4 Climate Change 2007: Mitigation of Climate Change, Chapter 12) added further perspectives by acknowledging the existence of a two-way relationship between sustainable development and climate change, that is, between development choices for climate change mitigation and vice versa, each mutually reinforcing the other.

Although climate change has traditionally been portrayed principally as an environmental problem, this definition has evolved to embrace the wider ramifications of a changing climate on the economy, ecology and people. It is a well-rehearsed notion that the climate change we see today is the result of many unsustainable practices in energy production, unsustainable land-use and land-use changes, as well as unsustainable production and consumption patterns, poor governance mechanisms and poor policies both within and across several disciplines, all of which tend to worsen its impacts. To address these concerns, and since climate change is a cross-cutting issue, countries have embraced the concept of sustainable development and started to integrate it into development planning (ECLAC 2017, 2018; Chimhowu et al. 2019; UN Women 2017; GGKP 2016; Fuseini and Kemp 2015). Therefore, sustainable development is perceived as a unifying concept that takes multiple elements of development into account, such as those identified as building the SDGs, and bringing a coherent, well-integrated and overarching approach to the problem of addressing issues of climate change.

After the SDGs were adopted, an extra boost to implementation of the goals was provided by adoption of the Paris Agreement. The Paris Agreement recognizes sustainable development as intrinsic to achieving the objectives of the Agreement (Sindico 2016; UNFCCC 2016). As part of the “Paris

Package", Nationally Determined Contributions (NDCs) were introduced as one of the key instruments through which countries demonstrate their commitment to climate action. NDCs include mitigation and adaptation efforts and showcase plans that align NDC commitments to national planning processes. However, assessment of the commitments (Rogelj et al. 2016; UNFCCC 2015a; Andries et al. 2017; Vandyck et al. 2016) showed that NDCs are falling short of delivering the Paris goals. One of the very urgent calls in Paris was to assess the impacts and efforts that needs to be undertaken to keep the global warming below 1.5°C in relation to pre-industrial levels and related global greenhouse-gas emission pathways (UNFCCC 2015b). Although the current rounds of NDCs fell short, the idea was that NDCs would be living documents. By design, the Paris Agreement takes a bottom-up approach as countries are free to choose their targets and the means and instruments with which to implement them. In the "Paris Package", an important and key feature of the NDCs was that countries had to submit their commitments every five years, which gives them an opportunity to assess themselves on the shortfall and increase their ambitions. Moreover, another key feature was that countries should not "back-slide" on the subsequent submissions of the NDCs, thus ensuring that countries should always be forward-looking in respect of increasing their ambitions to deliver the Paris goals. The IPCC special report (IPCC 2018) concluded that limiting the global temperature to the goals of the Paris Agreement could avert many severe climate disasters. It also noted that mitigation actions will have both positive and negative impacts on the achievement of the SDGs. The transitions required to bring about the necessary changes will have synergies and trade-offs (Roy et al. 2018). One of the important conclusions of the assessment was that sustainable development will enable and support fundamental systems and societal transformations, and that for these transformations to take effect rapid implementation is required to meet the long-term temperature goals.

The year 2015 was a noticeable turning point in developing the global governance, climate-change and environmental policy dynamics needed to set the globe on a more sustainable development path. Two remarkable stepping stones were laid down: approval of the sustainable development goals (SDGs), and the adoption of the Paris Agreement on Climate Change. Building on the Millennium Development Goals, and as a part of the 2030 Agenda for Sustainable Development, the Sustainable Development Goals (SGDs) were adopted in September 2015.

The SDGs were perceived as a novel approach to global governance and as universal agenda for transformation by building an integrated framework for action while addressing the three pillars, namely the economic, social and environmental dimensions (Biermann et al. 2017; Kanie and Biermann 2017). A comprehensive assessment on the linkages between sustainable development and climate change can be found in the previous assessment, AR5 (Olsson et al. 2014a; Fleurbaey et al. 2014; Denton et al. 2014b). AR5 argued that the link between climate change and sustainable development is cross-cutting and complex and that the impacts of climate change threaten the efforts made to achieve sustainable development thus far. Climate-change impacts can jeopardise sustainable development in systems which are dependent on natural capital. Moreover, drivers of climate change such as energy production and consumption also interact with sustainable development. One of the key messages was that the proper implementation of climate mitigation and adaptation actions could help promote sustainable development. Countries have started to report their progress with their SDG agendas (UNDESA 2018, 2017, 2016; Antwi-Agyei et al. 2018) and their reductions of emissions through the intervention of sustainable development in UNFCCC reports (GHG emissions inventories, Biennial reports, National Communications and others). The Sustainable Development Goals Report for 2019 indicates that 150 countries have developed national urban plans, almost half of them in the implementation phase.

The importance of these connections has led countries to start reconsidering their development policies and their relations with other policies, starting a process of integrating the concept of sustainable development into national plans (Galli et al. 2018; Haywood et al. 2019; Chirambo 2018; UNDESA 2018, 2017, 2016) and regional plans (Hess 2014; Gorissen et al. 2018; Shaw and Roberts 2017). Cross-cutting and integrated approaches, such as circular economies, have also been emphasized by some European countries (EESC 2015), and some countries are adjusting their existing policies to build on sustainable development principles (Lucas et al. 2016). This has also happened in different development areas such as renewable energy and energy efficiency (Kousksou et al. 2015; Fastenrath and Braun 2018), sustainable urban planning (Mendizabal et al. 2018; Loorbach et al. 2016; Gorissen et al. 2018), health systems (Pencheon 2018; Roschnik et al. 2017) and agricultural systems (Lipper and Zilberman 2018; Shaw and Roberts 2017). SDG implementation in national development processes reflect the different priorities, visions and plans of different countries (Hanson and Korbla P. Puplampu 2018; P. Puplampu et al. 2017; Tumushabe 2018; OECD 2016; Srikanth 2018; Ali et al. 2018).

Since sustainable development is about balancing between the three pillars, social economic and environmental, the concept of sustainable development in the Brundtland report gave a high priority to poverty alleviation, equity and justice (Lele and Jayaraman 2011). Inter-generational and intra-generational equity are both important elements in achieving sustainable development (Beder 2000; Dalziel and Saunders 2010). In the context of sustainable development and climate change, equity has been seen as a multi-dimensional challenge. Equity has to be included in climate mitigation and adaption policy formulations, as well as during transition processes, where the transition should be fair and just in sharing the benefits linking equity to developmental justice (Morgan and Waskow 2014; Ngwadla 2014). The important role of multi-level governance structures and the role of the private sector and civil society are crucial factors which should not be overlooked in obtaining equity as part of sustainable development (Mathur et al. 2014; Derman 2014). In addition, understanding why equity has to have a central part in climate policy was explained by Klinsky et al. (2017), as equity is an obligation regarding human well-being. This involves understanding that the trade-offs require equity be taken into account and that equity does not always counter strong collective climate action. It was shown in AR5 that climate change impacts on disadvantaged communities exacerbate their existing poverty and inequalities (Olsson et al. 2014b). Assessments by (Winsemius et al. 2018; also Hallegatte and Rozenberg 2017) show that in the future these impacts will be aggravated further. Realizing the importance of these concepts and the importance of equity in sustainable development, the issue of equity was made a central part of the Paris Agreement and the “Paris Rule Book” (Winkler 2019).

Other non-UN-led initiatives have also helped to raise the issue of sustainable development as a framework for mitigation involving international organizations or clusters of countries. G20 countries have drawn up action agendas with sustainable development at the core (UToronto 2016). The Petersburg Climate Dialogue, a political movement convened by major country-group representatives, has also called for sustainability to be an intrinsic part of the transition (BMU 2018).

17.1.1.1 Relationship between sustainable development, adaptation and mitigation

Climate change adaptation and mitigation are linked to sustainable development in many ways. In overall terms, the 2030 agenda for sustainable development is linked to climate change through its statement that “climate change is one of the greatest challenges of our time and its adverse impacts undermine the ability of all countries to achieve sustainable development”. Since the Paris Agreement and the Sustainable Development Agenda are at the heart of global development agendas, countries are pursuing the advantages of this centrality by adopting coherent and integrated approaches to achieve the goals of these agendas (Chimhowu et al. 2019). Advances in sustainable development (SD) need balanced actions for the impacts of both mitigation and adaptation: the co-benefits of mitigation cannot be expected to be enough to make adaptation occur, as enhanced sustainable adaption can lead to effective emission reduction benefits, showing that there is room for a virtuous collaboration between sustainable adaptation and mitigation (Dovie 2019;). (Fuso Nerini et al. 2019) show that climate change can both undermine and reinforce efforts in the direction of sustainable development. Increased CO_2 emissions levels disrupt associated food production, which in turn can hamper the efforts to reduce hunger and poverty (Smith and Myers 2018). Positive synergies and negative trade-offs are directly linked to sustainable development and climate mitigation and adaptation (Thornton and Comberti 2017; Obersteiner et al. 2016; Steen and Weaver 2017; Favretto et al. 2018). When implementing mitigation and adaptation policies, therefore, coherence between policies is key, as otherwise they could prove detrimental to sustainable development efforts (Scobie 2016; Sovacool 2018).

At the subnational level, cities are key actors in reducing both the causes of climate change (mitigation) and the preparations for its impact (adaptation), and many have developed separate mitigation (low emissions growth) and adaptation (climate-resilient) strategies and measures accordingly (Göpfert et al. 2019). In addition, several cities have become active in pursuing strategies for dealing with SD, mostly through the implementation of SDG-related agendas. However, thorough integration among these strategies to promote synergies and accelerate changes is still lacking.

In accelerating the transition to sustainable development, adaptation and mitigation, the development of a "response capacity" within a population, that is a collective set of factors enabling a population to adapt and mitigate, can serve to improve the capacity to both adapt and mitigate, while also helping to move towards sustainability (Harry and Morad 2013). However, the development of an effective "response capacity" within a society will be conditioned by its own level of development, predicated on its ability to draw on strong institutions, financial, human and technological resources and several other enablers.

17.1.1.2 Transition processes

Significant amounts of attention have been paid to the context of the sustainability transition since the urgency of the climate change problem was recognised (Chang et al. 2017; Markard et al. 2012; Turnheim and Nykvist 2019a). In the context of this chapter we are mainly referring to transition processes that address how to arrive at a given desired future stage. (Fazey et al. 2018) highlighted ten essential elements needed for transition: “consideration of shocks and stresses; working horizontally across all sectors; working on gradual vertical scales across social dimensions; drastic measures to reduce carbon emissions; inspiration from successes related to climate change/action; think future oriented; focus on climate disadvantage and reduce inequalities; focus on processes and pathways; and transformative change for resilience.” This points out that a holistic and systematic approach with complex interactions across multiple dimensions is needed for a sustainable transition. Climate decarbonisation is usually perceived as technological problem ignoring the equity and distributional issues that undermine people’s potential to bring about system change (O’Brien 2018). O’Brien stresses that for social transition and transformation to occur, leverage points in three relating and interacting ‘spheres’ of practical, political and personal needs to work in parallel such that people are treated as subjects or agents of change rather than objects to be changed. In addition to the social and technological changes, an important element of educating or learning approaches is also found to be crucial to the process of transition (Macintyre et al. 2018) in respect of collective decision-making in transition processes. (Hjerpe et al. 2017) stress that knowledge could act as a motor, emancipator and guiding beacon in the transition process. Transforming the urban community is also an important element in the transition process for sustainable development (Mendizabal et al. 2018). In addition, the accelerative and transformative potential of economic and technical interventions is highly dependent on social and political dynamics (Grandin et al. 2018; Roberts et al. 2018), as the level of acceptance of certain technologies depends on local cultural and discursive factors.

17.1.1.3 Relevant policy issues in different time-frames (2025, 2030 and 2050), opportunities and obstacles

Governments have a considerable role to play in accelerating transitions to reach a more sustainable level of development. "Sustainable development requires both radical disruptive technological and institutional changes, the latter including stringent regulation, the integration of disparate goals, and changes in incentives to enable new voices to contribute to new systems and solutions", since advances in achieving sustainable development may be slow and marginal in nature (Ashford and Hall 2018). Stringent regulation has the potential to encourage discontinuous and radical, rather than incremental evolutionary change (Ashford et al., 1985; Ashford and Hall, 2011). Governments need to play a strong role in stimulating both radical disrupting innovations and the diffusion of technology, since "neither future generations nor future technologies are adequately represented by the existing stakeholders and what is missing is political and private-sector will for technology adoption" (Ashford and Hall, 2018). Governments should not miss the opportunity to loosen the creative forces that bring about innovative changes that can simultaneously benefit the economy, the environment, and general welfare (Ashford and Hall, 2018). Other stakeholders may also play a role in transition processes.

Developing countries face the additional policy implementation challenges of their more limited resources (financial, environmental fragility, institutional, skills, etc.) and fewer experiences and knowledge of state-driven technological development and phase-in. While lock-in effects may be weaker in cases where robust and economically viable technologies exist, market failures may be more pronounced in others due to stronger information asymmetries and cost barriers (Kemp and Never 2017a), as well as institutional barriers.

The sustainable development agenda also calls for policy coherence (targets 17 and 14) as an inherent feature of its successful implementation. Policy coherence and integration between sectors are two of the most critical factors driving sustainable transitions. To break down the sectoral silo mode of working, policy coherence needs to be implemented across the board. Rather than working with individual policy instruments, a mix of policy instruments can provide the multiple policy effects needed for social and technological change (Edmondson, Kern, & Rogge, 2018; Köhler et al., 2019; Rogge & Johnstone, 2017).

Given the various actors, players, elements, frameworks and concepts that will play a part in the transition, a sustainable transition is likely to be a highly non-linear, complex and multi-faceted process which certainly cannot be reduced to a single dimension. If an accelerated transition is needed for purposes of sustainable development, a coherent approach among stakeholders at multiple local, national, regional and international levels needs to be established. This requires breaking out of sectoral silos and adopting policy-coherent integrated approaches to overcome the inconsistencies involved in promoting cross-sectoral synergies and trade-offs at multiple levels.

17.2 Transition Theories

17.2.1 Questions and Goals

A diverse literature has emerged on the factors enabling or undermining transitions that align sustainable development with the low temperature goals. This section surveys central claims and underlying assumptions in several theoretical and analytical approaches that explain how these transitions start and gain momentum (see Figure 17.1 for a visual representation of key enablers of transitions to more sustainable development models). It further demonstrates how these varying perspectives draw upon different sources of evidence to frame climate actions as contributing to sustainable development. In this overview, the section sheds light on the differences between these approaches' evidence and methods, their treatment of core concepts (co-benefits, breakthroughs, inertia, uncertainties and tensions), their shortcomings and their complementarities. The section's conclusions set the stage for the subsequent presentation of the study results and comparative assessments in section 17.3.

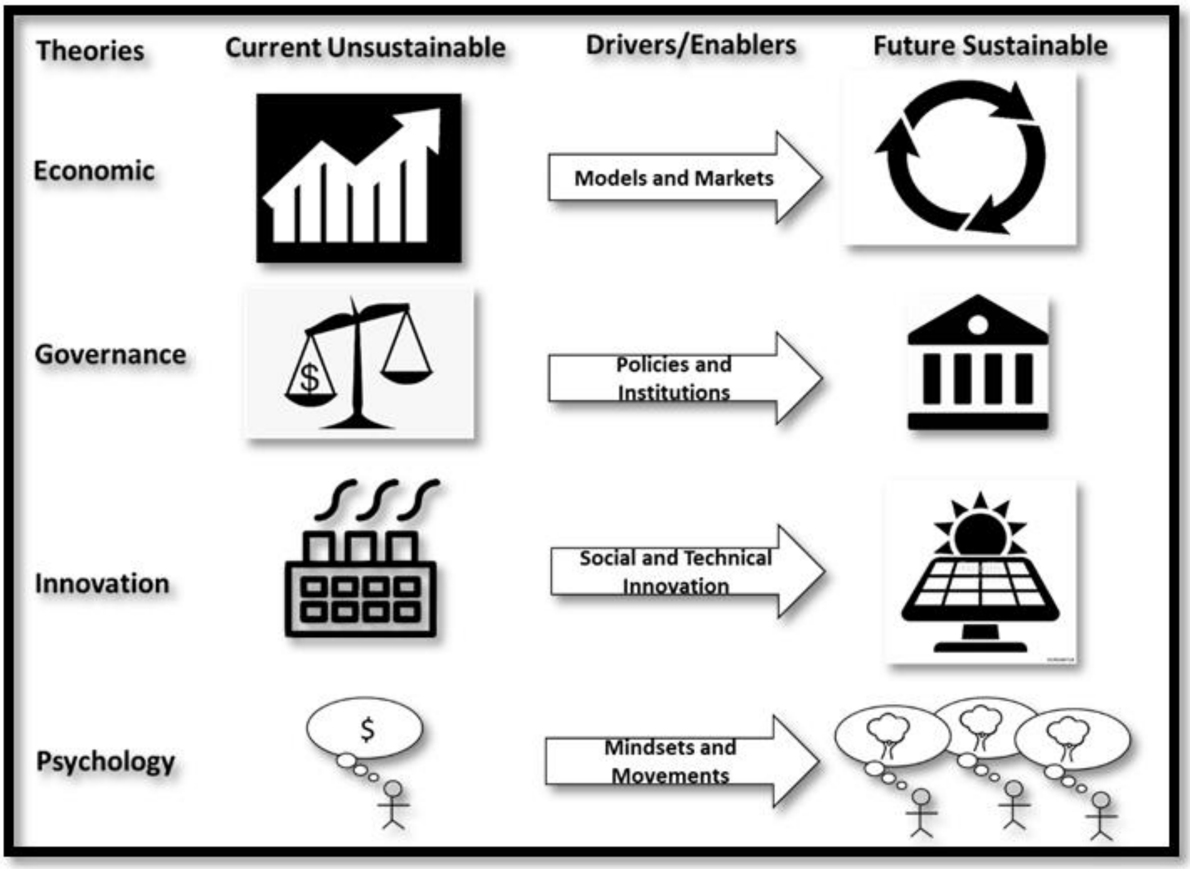


Figure 17.1 Overview of Relevant Theories and Enablers of Transitions Elaboration, of Chapter 17

17.2.2 Theories and approaches addressing SD and CC transitions

17.2.2.1 Psychological, community-based and social movement theories

The theories discussed in this subsection focus on changes (or transitions) within individuals as well as the collective consciousness of wider institutions, organizations and cultures that can help bring people closer to themselves, to each other, and to nature. Many arguments in this subsection therefore envisage the desired goal of a transition as being "world-citizenship" (e.g., Morin, 2018), "integrated sustainability" (Schweizer-Ries, 2013), "*sumak kawsay*," or "the good life" (Gauer, 2008). Each of these concepts has a strong and often communal commitment to improving the well-being of all people and creatures on this planet.

While more communal values appear to be losing favour in modern individualistic societies, the theories discussed in this subsection suggest considerable interest exists in eastern world views, aboriginal cultures (see e.g., Lockhart, 2011) and branches of neuroscience and psychology that place a premium on different notions of the self (Hüther, 2018; Seligman and Csikszentmihalyi, 2014; Lewis 2016). Further, to some extent these world views are emerging in novel forms with religious undertones such as new spirituality (Heelas and Woodhead 2005, Knoblauch 2009, Tacey 2003), 'religious hybrids' (Berger et al. 2013), inter-religious dialogue (Lockhart, 2011) and post-secularism (Habermas, 2008).

Often these quasi-religious world views are accompanied by practices that can bring about wider and deeper change. For example, “engaged Buddhism”, “practical spirituality” and “green yoga” (Feuerstein and Feuerstein 2007, Tacey 2003, Woiwode and Woiwode 2019) draw upon “transformative practice which leads to self-transformation, cultural transformation and world transformation” (Giri 2018: 14). Recognizing the potential for significant change, some faith groups are working to open opportunities for religious practices in public spaces. Thus, the House of One in Berlin is an example of an effort to remake urban areas as a focal point of spiritual and religious practice (e.g., (Beaumont and Baker 2011,Hegner and Margry 2017, MetroZones Ed.2011). At the same time, less spiritual transitions have also been unfolding, notions of a post-development era (Kothari et al. 2019) and degrowth (Sklair 2016) that challenge conventional development models by redefining relationships with urbanity, global citizenship and urban lifestyles that are gaining adherents without an emphasis on spirituality.

One of the main questions for work on transitions in this subsection is how to cultivate interconnectedness between people and between themselves and the natural environment that is central to retaining (or forming) shared values and joint actions. A critical distinction in this regard involves inner and outer transitions (see e.g., Banks, 2007, Power, 2016). An inner transition occurs within the self and involves a deepening sense of peace, acceptance and a willingness to support others and protect nature. This inner transition involves changes from deep inside that are closely related to sustainability (Banks, 2007; Woiwode, 2016, Hedlund-de Witt et al., 2014), adopting meanings, aspirations (Lewis, 2016) and values for transformations (Horcea-Milcu et al., 2019), as well as integrating politics and economics (Lawhon and Murphy 2012); Loorbach et al. 2017a). Outer transitions involve external changes to material well-being, infrastructure, organizations, technologies or geographical landscapes.

Inner and outer transitions are conceptually distinct but often related and deeply interlinked (Adger, W, Barnett Jon, Brown Katrina, Marshall 2013; Hulme 2009; Ives et al. 2019; O’Brien, 2018). For instance, when politicians or business people experience an inner transition, they may be motivated to champion wider changes to their surrounding environments. Support for these external changes may feed a virtuous cycle, promoting individual, community and planetary health and well-being (Lockhart, 2011; Day et al., 2014; Montuori 2018). By the same token, the same politicians or business people experiencing changes can also get a push from the development of a sustainability culture that connects people and communities locally via numerous means, as well as globally via the internet and digital technologies (Bradbury, 2015, Scharmer, 2018). The formation of such a culture can lead to the creation of social fields that allow sustainability to happen (see also Gillard et al. 2016) and that advance other shifts in thinking and behaviour that are consistent with the low-temperature goals (O’Brien, 2018; Veciana and Ottmar, 2018). Furthermore, these changes in thinking and behaviour apply to adults: as seen in the “Friday for Future” marches, children are starting to assume greater responsibility for the environment and become politically active on sustainable development and climate issues (Peterson et al. 2019)

A related but distinct line of thinking involves different forms of social innovation, especially “grassroots innovations” (Seyfang 2011: XVIII). For some observers, these social changes are related to technological changes because technological innovation often accompanies changes in social practices (Shove et al. 2014, p. 12) by altering personal routines, belief systems, authority patterns, etc. (Westley & Antadze, 2010, p. 2). A complementary line of reasoning stresses that social innovations can dampen the rebound effects that may arise from the increased use of new technologies. This is because they can ensure that efficiency improvements from new technologies are not offset by increased use those very technologies (see e.g., Paech, 2005; Gsell et al. 2015). Not every instance of social innovation is related to technological innovation, however. For instance, those drawing upon “new development economics” stress that small-scale innovation and experimentation can lead to more sustainable consumption habits and practices (Seyfang, 2011, p. 25). Other make the sociotechnical connection indirectly, suggesting the inherently dynamic nature of social innovations in facilitating their spread on social media platforms (Westley and Antadze 2014: 256). As many of the previous examples illustrate, different types of innovation frequently work together to facilitate changes in everything from individual beliefs to business models to the regulatory trends that will be important in achieving climate goals and sustainable development goals.

17.2.2.2 Governance, institutions and political economy theories

This subsection focuses on institutional and governance arrangements that influence which actors possess power and how they use that power in decision-making processes that shape development paths. While the climate policy literature once focused on multilateral agreements as helping to reorient those paths (Kok et al. 2008), the lack of effective global cooperation has yielded an increasingly fragmented international climate landscape (Van Asselt 2014). For some observers, that fragmentation has meant that national governments are increasingly steering development agendas in more sustainable directions, including by adopting national determined contributions (NDCs), voluntary national reviews (VNRs) and other climate and sustainable development strategies that encourage line agencies and subnational governments to make relevant policies that are compatible with climate objectives in ways that could drive a transition (Elder and Bartalini, 2019; Elder and King, 2018; Nachmany and Setzer 2018; Townshend et al. 2013).

Another view of this fragmented environment suggests that subnational governments have taken the lead (Rabe 2007; Koehn 2008; Doll and de Oliveira 2017). Local governments tend to be better positioned and more flexible than national governments when crafting innovative solutions to sustainable development and climate concerns (Bellinson and Chu 2019; van der Heijden et al. 2019). A complementary view is that these subnational innovations have significant impacts when coordination mechanisms are aligned with sectoral agendas and mobilize resources to bring them up to scale (Corfee-Morlot, J., et al 2009; Gordon 2015). Such cooperation may nonetheless not always be necessary if cities are already motivated to pursue pro-environmental agendas or if higher level governments lack the capacity to coordinate diverse interests (Amanuma et al. 2018; Bowman, A. O', M. Portney, K.E. and Berry J.M. 2017).

Though the above work tends to downplay the role of politics and businesses, others place these factors front and centre. Political economy research underlines how resource-intensive and fossil-fuel industries can undermine transitions (Moe, 2014; Zhao et al, 2013). These vested interests have proved adept at locking in status quo policies in countries where political systems have more veto points offering interest groups more opportunities to overturn proposals (Madden, 2014). This suggests that politics can be an impediment to change, though other studies turn that logic on its head by arguing that politics can be harnessed for the good of the environment. For example, some studies argue that building coalitions around green industrial policies and sequencing reforms to reward industries in such coalitions can help give transitions momentum (Meckling, J., Kelsey, N., Biber, E. and Zysman, J., 2015). Calls for side payments such as industrial tax incentives for changing production processes can lower industrial opposition to change and open sustainable low-carbon pathways (Goldthau and Sovacool, 2012). Similarly, there has been a proliferation of work on how more inclusive institutions that include organized labour, women’s groups, and youth movements in relevant processes can bring about a transition that is environmentally sustainable and socially just (Sovacool et al., 2017; UNRISD, 2019).

Another set of channels that can help overcome locked-in institutions and interests are transnational networks. Networks such as ICLEI or C40 can share decision-making tools and good practices that help counter the claims of domestic opposition to change (Betsill and Bulkeley, 2006). Further, sub-national governments often work together with civil-society groups to create new forms of governance that can drive transitions (Bäckstrand et al. 2012). In some ways, these new partnerships resemble global scientific communities or civic-minded advocacy groups that transmit knowledge across borders (Keck and Sikkink, 1999). Some combined insights into transnational networks and governance argue that less capable "following" and "laggard" cities needed greater support and engagement from national governments and regional organizations (Fuhr, H., Hickmann, T. and Kern, K. 2018). A related insight refers back to the international climate regime to indicate that there may be a role for a Global Framework for Climate Action (GFCA) in helping coordinate the multilateral climate regime and non-state and subnational initiatives (Chan and Pauw 2014).

17.2.2.3 Systems theories

Systems theories help explain the dynamics of transitions toward sustainable development while explicitly uncovering linkages between the human and natural worlds, the socio-cultural embeddedness of technology, and the inertia behind high-carbon development pathways. This line of thinking often envisions a transition as emerging from complex systems in which many different elements interact at small scales and spontaneously self-organize to produce behaviour that is unexpected, unmanaged and fundamentally different from the sum of the system's constituent parts.

Social-ecological systems theory describes the processes of exchange and interaction between human and ecological systems, investigating in particular non-linear feedback occurring across different scales (Folke, 2006; Holling, 2001). This approach has informed subsequent theoretical and empirical developments, including the 'planetary boundaries' approach (Rockström et al., 2009), conceptualizations of vulnerability and adaptive capacity (Hinkel, 2011; Pelling, 2010), and more recent explorations of urban resilience (Romero-Lankao et al., 2016) and regenerative sustainability (Robinson and Cole, 2015; Clayton and Radcliffe, 2018). Employing a systems lens to address the 'root causes' of unsustainable development pathways (such as dysfunctional social or economic arrangements) rather than the 'symptoms' (dwelling quality, vehicle efficiency, etc.) can trigger the non-linear change needed for a transformation to take place (Pelling et al. 2015). Exploring synergies between climate change adaptation, mitigation and other sustainability priorities (such as biodiversity and social equity, for instance) (Beg et al. 2002; Burch et al. 2014; Shaw et al. 2014) may help to yield these transformative outcomes, though data regarding the specific nature of these synergies is emerging only now.

Socio-technical transition theory, on the other hand, explores the ways in which technologies such as low-carbon vehicles or regenerative buildings are bound up in a web of social practices, physical infrastructure, market rules, regulations, norms and habits (see, for example, Loorbach et al, 2017). Radical social and technical innovations can emerge that ultimately challenge destabilized or increasingly ineffective and undesirable incumbents, but path dependencies often stymie these transition processes, suggesting an important role for governance actors (Holscher et al., 2019, Burch, 2017; Frantzeskaki et al., 2012). This also reveals the large-scale macro-economic, political and cultural trends (or contexts) that may reinforce or call into question the usefulness of current systems of production and consumption. One branch of this theory, transition management (Kern and Smith, 2008; Loorbach, 2010), explores ways to guide a socio-technical system from one path to another. In particular, it highlights actor-technology-institution interactions and the complex governance mechanisms that facilitate them (Smith et al, 2005). The challenge, in part, becomes linking radical short-term innovations with a longer-term sustainability vision (Loorbach and Rotmans, 2010) and creating opportunities for collaborative course-correction in light of new information or unexpected outcomes (Burch, 2017).

17.2.2.4 Economic theories

According to economic theories, economic development can deliver on multiple economic, social and environmental priorities, including climate change, when framed in sustainable development terms.

These theories nonetheless emphasize that free markets will not reach these non-market sustainability objectives left to their own devices; taxes or other regulatory interventions are needed to motivate firms and other entities to internalize GHGs and other pollutants (Arrow et al, 2004; Chichilnisky and Heal 1998). Economic theories also suggest a need to target investments at technological change, green growth, and research and development to encourage the substitution of exhaustible resources. Hartwick's rule, which calls for investments to be directed at renewable energy to offset the use of exhaustible fossil fuels (Hartwick, 1977), illustrates this targeting. Economic theory is therefore based "weak sustainability" principles where the substitution of exhaustible resources is feasible to some extent. This stands in stark contrast to the "strong sustainability" or "integrated sustainability" principles found in ecology-based approaches (Rockström et al., 2009) that suggest that absolute constraints on resources restrict this kind of substitutability (Arrow et al., 2004).

Economic theories form the methodological basis for integrated assessments and the macroeconomic and sectoral models that are widely applied to climate change mitigation (see Chapters 3 and 4 of this report). These models typically calculate mitigation costs based on the assumption that markets internalize externalities like GHG emissions through carbon prices. In this context questions can be asked on whether general equilibrium conditions in terms of efficient markets as employed in the models will apply in practice, as well as the impact on markets, and whether carbon taxes will be efficient (WB, 2017).e literature abounds with study results based on the economic modelling paradigm. The welfare economy approach is the main approach behind most climate change mitigation modelling, including integrated assessment models, as well as macroeconomic models and the partial general equilibrium models applied to sectoral studies (IPCC, 1996; IPCC, 2002).

Determining which mitigation technologies achieve climate goals and other sustainable development goals is gaining increasing attention from economic modelling. For example, recent work from IEA ETP2017 (IEA, 2017) shows how efficiency improvements, carbon capture storage (CCS) and renewables will contribute to emissions reductions of 40%, 14% and 35% respectively by 2060 for the 2 degrees scenario from a reference technology scenario. Importantly, many of these same low-carbon innovations help achieve other sustainability objectives, such as reductions in air pollution and improvements in energy access (IPCC SR15 2018; IEA WEO 2017).

In particular, innovations and improvements in end-use technologies in respect of energy innovations with low costs are considered to have a large potential for emissions reductions and sustainable development (Wilson et al., 2019). Currently information technologies are improving rapidly, and IoT, AI and big data will contribute to many areas, particularly in end-use sectors. The achievement and widespread deployment of fully autonomous cars, for example, will bring about broader car- and ride-sharing with negative or low additional costs compared to owned cars, which usually have very low road factors. (Grübler et al. 2018) estimate that the low energy demand (LED) scenario which assumes information technology innovations and induced social changes, including a sharing economy, shows a potential for harmonizing multiple achievements of SDGs with low marginal abatement costs compared with other scenarios (IPCC SR15, 2018).

Whether a technological innovation is wholly sustainable or not becomes less clear when considering it in terms of its effects on the wider economy. To illustrate, some models predict that CO_2 marginal abatement costs in the power sector will be 240 and 565 $/t$CO_2$ for the 2 and below 2 degree goals respectively (IEA, 2017). In theory, if marginal abatement costs meet marginal climate damage, mitigation measures are economically optimal in the long run. Yet marginal damage from climate change is notoriously uncertain, and economic theory does not always reflect a growing list of climate-related forms of damage. On the other hand, marginal abatement mitigation costs impose additional costs in the short term. These added costs can cause productivity in capital to decline through increases in the prices of energy and products in which energies are embodied. These increased costs can constrain the ability to achieve the priorities of the sustainable development agenda. However, precisely the opposite can occur when innovation reduces additional costs or achieves negative costs. If technological innovation leads to the accumulation of capital and productivity increases due to the substitution of energy, material and labour, these are likely to deliver sustainable development and climate mitigation benefits.

17.2.2.5 Conclusions

This section has surveyed key claims in psychological, technological and social innovation, governance, systems and economic theories (see Table 17.1 below for an overview). The review suggests that there are several differences between the theories. Whether individuals, technologies, institutions, markets or full sociotechnical systems are driving or undermining a transition is a key distinction. These differences have implications for the evidence these claims draw on in support of their arguments. For instance, psychological theories tend to employ qualitative and quantitative evidence to understand changes in attitudes at the individual or community level as paving the way for broader changes to cultures and belief systems. Economic theories, conversely, tend to use quantitative models based on welfare economics to identify policies that correct market failures and thereby catalyse broader changes to economies.

While there are indeed significant differences between the theories, there are also important parallels. Such parallels begin with a shared emphasis on the co-benefits. Most theories tend to underline the importance of co-benefits in aligning the climate with broader sustainability agendas. Similarly, many of the theories suffer from similar myopias, paying only limited attention to claims in other schools of thought. The possible exception here is the systems theories that tend to bring in many of the factors stressed elsewhere, though not focusing on any one element. Most importantly, many of the theories are complementary with the systems-level discussion in that they offer a broad framework, while the concentrated psychological, technological and social innovation, governance, systems and economic theories offer more specific insights. Hence, moving a transition forward will often require drawing upon insights from multiple schools of thought at the same time. Though is unlikely that a one-size-fits-all set of factors will drive a transition, there is a growing body of empirical results that can shed light on which factors matter under which conditions.

Table 17.1 Comparing Theories

	Psychological, community-based, and social movement	Governance, institutions, political economy	System theories	Economic theories
Evidence and methods	Qualitative and quantitative analysis of changes in beliefs, organizations, cultures, movements, and social innovations	Qualitative analysis of institutional change (often using case studies)	Qualitative analysis of changes in sociotechnical systems (often using case studies)	Integrated assessment models

Drivers of change	Inner peace, awareness and acceptance; willingness to protect nature; improved well-being (inner transition); infrastructure, organizations, technologies or geographical landscapes (outer transition)	Changes in institutions that align interests of stakeholders within and beyond government	Interaction between multiple social, technological and institutional factors opening opportunities for niches to spread and grow and transform markets, policies, institutions	Policies target investments in key technologies
Co-benefits	Improved well-being, health and happiness; quality of surrounding infrastructure supporting pro-environmental and socially fair behaviour	Multiple social, environmental, and economic benefits; liberalization and engagement; taking over of responsibility	Multiple social, environmental, and economic benefits; strengthening of self-regenerating capacities; resilience	Multiple social, environmental, and economic benefits
Breakthroughs	Self-enlightenment leads to change within individuals and communities; changes to the external environment; culture of sustainability	Institutional change opens opportunities for more sustainable policies, technologies and participatory cultures	Pressures from one level of the system (niche, regime, landscape) places pressure on another level, leading to a transition	Targeted policies open opportunities for technological and social innovations
Inertia	Not explicit but implies that consumerism and materialism can impede a transition	Existing institutions and/or vested interests can prevent major changes	Existing sociotechnical systems can lock in unsustainable policies and practices	Not explicitly considered in many modelling frameworks
Uncertainties and tensions	Uncertainty not featured; tensions with unawareness	Uncertainty not featured	Uncertainty not featured	Uncertainty measured and presented

Shortcomings	Relatively less focus on technologies or institutions	Relatively less attention to technological or social changes	Emphasis on multiple factors may make it difficult to understand the important role of any single factor	Relatively less attention to how enabling environment and individual/collective belief systems influence policy design and implementation; often individuals are assumed to be interested only in maximizing individual utility
Complementarities	Detailed explanation of changes within individual beliefs and organizational cultures can illuminate how people and world views can change	Concentrated discussion of institutions and governance can shed light on desirable features of the enabling environment	Offers a broad framework to improve understanding of different factors highlighted in how other theories work together	Quantified analysis can estimate the impacts of policy or technological change; other factors may be considered as part of a feasibility framework

17.3 Assessment of the results of studies where deep decarbonisation transitions are framed in the context of sustainable development

17.3.1 Introduction

The section assesses studies based on sustainable development as a framework for transitions to low-carbon societies in order to facilitate generic conclusions across methodologies, models and sectors. Cross-cutting conclusions will be developed based on national, sectoral and cross-sectoral short- and long-term transition studies based on studies assessed in previous chapters of this report and on additional literature. The key question is whether sustainable development and deep decarbonization transitions can be synergetic or, in the case of studies of major trade-offs, how these can be mitigated.

Section 3 focuses initially on issues related to short- and long-term transitions and on transitions in the context of the UNFCCC and the UN 2030 agenda for sustainable development. Global-modelling results and economy-wide studies are then assessed, followed by a discussion of sectoral and cross-sectoral examples of transition issues, which are selected as illustrative examples of key synergies and trade-offs between sustainable development and deep decarbonization transitions.

The assessment of study results in Chapter 17 will finally be discussed in relation to the conclusions in Chapters 3 and 4, and in light of the sectoral and cross-sectoral chapters (5-12) on sustainable development and deep decarbonization; an overview of the study results will also be provided, which as far as possible will be structured in relation to a common set of scenarios and pathways following a common framework across the report's chapters. Since the overview of results relies on the FOD of the individual chapters, the chapter FOD has not yet been updated with the cross-chapter results.

17.3.2 Short-term and long-term transitions

Sustainable development policy goals have played an increasing role in climate change policies since the World Commission on Environment and Economy defined sustainable development as a form of development "that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Climate change has been recognized as a key threat to achieving inclusive and sustainable development, and in this spirit the Paris Agreement also emphasized that climate change policies should be integrated into sustainable development agendas. As the UN 2030 agenda for sustainable development includes a specific SDG target on climate actions (target 13), it and the Paris Agreement have the potential to support each other. The achievement of the Paris Agreement's goals will require a rapid and deep worldwide transition in all GHG emission sectors, including land use, energy, industry, buildings, transport and cities, as well as in consumption and behaviour (UNEP, 2019). Meeting the goals of such a transformation requires that the long-term targets and pathways to fulfil the stabilization scenarios play an important role in guiding the direction and pathways of short-term transitions. There is therefore a need for the close coordination of long- and short-term policies and investment decisions (IPCC, 2018).

Countries have submitted their first plans for the decarbonization of their economies to the UNFCCC in the form of National Determined Contributions (NDCs). The ambitions of the NDCs are closely related to the ongoing UNFCCC negotiation process on financial measures and compensation. Although the Paris agreement emphasizes the links between climate policies and sustainable development, the UN 2030 agenda and the SDGs are at present not very well represented in the NDCs according to Nerini et al. (2019). Very few of the NDCs include any reference to the SDGs, which Nerini et al. highlight as a barrier to the successful implementation of the Paris Agreement, and they therefore call for a more holistic policy approach. Campagnolo et al. (2019) assessed the impacts of the submitted NDCs on poverty eradication and income inequality based on empirical research and a global CGE model. One conclusion is that the NDCs in the LDCs would tend to reduce poverty alleviation, but this can be offset if international financial support is provided for the mitigation actions.

The alignment of climate policy targets in the NDCs with sustainable development has also been assessed by Integrated Assessment Models (IAMs), that is macroeconomic and sectoral modelling. Gokul et al. (2018), based on IAM studies, assessed the implications of SD considerations for comparability across NDCs and concluded that some SDGs can be supported by the implementation of climate policy targets in NDCs, while others are degraded. Furthermore, the regional distributions of efforts across NDCs based on emissions- and cost-based comparability measures and the distributions of the consequences of meeting the NDCs' domestic mitigation components for a broader set of SDGs are not necessarily the same. This points to the need to design national policies which are not only based on mitigation costs, rather on policy integration with the SDGs.

In the near term, the 2030 Agenda and the Paris Agreement provide joint opportunities for systematic transitions in support of both climate change and sustainable development. However, the NDCs submitted to the Paris Agreement have demonstrated that there is a lack of progress in meeting the temperature goals, and in the context of the UN 2030 agenda the UN Sustainable Development Report 2019 (Sachs et al., 2019) also concluded that there is a particular lack of countries' progress in relation to SDG 13 Climate Action, SDG 14 Life below water and SDG 15 Life on land. Given the close link between the SDGs and climate change policies, the current obstacles in meeting the SDGs could also be a barrier to realizing transitions to low-carbon societies. Conversely, opportunities to leverage the SDGs could involve climate actions, since policies enabling climate adaptation and mitigation could also support food and energy security and water conservation if they were well designed (IPCC, 2018). These findings point to a specific need to align economic and social development perspectives, climate change and natural systems.

A key barrier to the development of national plans and policies for how the UN 2030 SDG goals can be achieved is a lack of finance. Sachs et al. (2019) conclude that meeting the SDG transformations worldwide would require 2-3% of global GDP and that it will be a huge challenge to ensure that finance is targeted to the world's poorest countries.

The UN Secretary General has called for the allocation of finance to meet the UN 2030 agenda with a strong emphasis on the private sector, but to date there no governance frameworks or associated financial modalities have been established in the UN or the UNFCCC context for a formal alignment of sustainable development and transitions to take place in accordance with the low global temperature-stabilization targets in the Paris Agreement.

Based on the Paris Agreement, the UNFCCC has invited countries to communicate by 2020 their mid-century and long-term low greenhouse gas emission development strategies (UNFCCC, 2019).

National long-term low emission development strategies and their global stock-take in the UNFCCC context provide a platform for informing the long-term strategic thinking on transitions towards low-carbon societies. A specific value of these plans, which are to be submitted during 2020, is that they reflect how specific transition pathways, policies, and measures can work in a different parts of the world in a very context-specific way, that is, by taking context-specific issues and stakeholder perspectives into consideration. As a result, the national plans could add important dimensions to the stylized and uniform representation of options in models like IAM models with high regional aggregations (IPCC AR5, Mitigation policies, Chapter 6 section 6.6.1). Only a few countries have until now submitted such plans. There are, however, already examples of country plans which demonstrate how sustainable development and climate policy goals could be aligned in a long-term perspective.

In the spirit of the Paris Agreement, the plan for Germany emphasizes that its climate targets will be part of a broader set of economic and social development goals and that by setting a longer-term policy framework, planning and investment certainties will be created (Germany, 2016). Similarly in its long-term low emission scenario plan, Fiji stresses that long-term sustainable and resilient economy-wide mitigation pathways have been created through a participatory process ensuring that synergies with sustainable economic growth can be provided. (Fiji, 2019). More plans will be added when they become available.

17.3.2.1 Economy wide analysis: low-carbon development pathways

Low-carbon transitions are to be supported by a portfolio of policies that can help enable a structural change in economies and the associated redirection of investment and consumption patterns in accordance with the demands of low-carbon societies. Short- and long-term studies of transformation using macroeconomic models and other tools have been used to assess the economy-wide impacts of aligning development pathways with sustainable development and climate change. These economy-wide studies have been used to assess how economic development can be more sustainable with a focus on short-term economic policies, decadal time perspectives and long-term perspectives. Focal modelling areas include green investments, technological change, employment generation and the performance of policy instruments such as green taxes, subsidies, emission permits, investments and finance.

An example of a project that assesses the economy-wide impacts of linking sustainable development with deep decarbonization is the deep decarbonization project DDDP (Bataille et al., 2016), which is undertaking a comparative assessment of studies of sixteen countries representing more than 74% of global energy emissions and the pathway to 2 degree stabilization scenarios. The DDDP's methodology is to combine scenario analysis in different national contexts using macroeconomic models and sectoral models and to facilitate a consistent cross-country analysis using a set of common assumptions. Top-down hybrid models are called for, which encompass macroeconomic completeness and microeconomic realism supplemented by technological explicitness as included in bottom-up models (Hourcade et al., 2006). Key conclusions on economy-wide impacts by the DDDP team are that country studies like that for South Africa demonstrate that it is possible simultaneously to improve income distribution, alleviate poverty and reduce unemployment while transitioning to a low-carbon economy.

The reduction of uncontrolled fossil-fuel emissions has significant public health benefits according to the Chinese and Indian DDDPs, as fossil-fuel combustion is the major source of air pollution. For example, in the Chinese DDP, deep decarbonization resulted in reductions of 42–79% in primary air pollutants (e.g., SO_2, NOx, particulate matter (PM2.5), volatile organic compounds (VOCs), and NH3), which met air-quality standard goals in major cities. The deep decarbonization scenarios included large and fast energy-efficient improvements required in order to improve improve energy access and affordability. The DDDP studies are thus an example of an approach in which national deep carbonization scenarios are linked to the development goals of income generation, energy access and affordability, employment, health and environmental policy.

Markandya et al. (2018) assessed the health co-benefits of air pollution and the mitigation costs of the Paris Agreement using global scenarios up to 2050. They concluded that the health co-benefits substantially outweighed the policy costs of achieving NDC targets as well as 2°C stabilization and 1.5°C stabilization. The ratio of health co-benefits to the mitigation costs ranged from 1.4 to 2.45, depending on the scenario. The extra effort of trying to pursue the 1·5°C target instead of the 2°C target would generate a substantial net benefit in some areas. In India the co-health benefits were USD3·28–8·4 trillion and in China USD 0·27–2·31 trillion. These positive results were not seen in all regions.

Sustainable development scenarios have also been developed by the Low-Carbon Society’s (LCS) assessments (Kainuma et al., 2012), where multiple sustainable development and climate change mitigation goals were assessed jointly. The scenario analysis was conducted for Asian countries including South Korea, Japan, India, China and Nepal with soft linked IAM using an economy-wide and sectoral models, and linked to very active stakeholder engagement in order to reflect national policy perspectives and priorities. Some of the models are global economy-wide IAMs, while others are national partial equilibrium models.

In addition to more conventional mitigation policies like renewable energy and efficiency improvements, the analysis also included city development options with structural economic changes in the direction of a larger share of the service sectors in the economy, and consumer behaviour options were also included. The studies concluded that the carbon price in the LCS scenarios would be lower if a range of development co-benefits were included in the scenarios compared with the carbon price in scenarios that only focused on mitigation targets (Shukla and Chaturvedi 2012). In relation to decision-making, it was concluded that the LCS approach of using a range of soft-linked models representing different geographical scales and sectoral details had been successful in creating more realistic and policy-relevant information. However, the consistency of the scenarios and modelling efforts relies on the use of coordinated data and storylines. These conclusions were further elaborated by (Waisman et al. 2019), who argued that more detailed bottom-up approaches like the LCS studies would benefit from being linked to a consistent interface with global IAMs.

The LCS scenarios also include a specific attempt to include ongoing dialogues with policy-makers and stakeholders in order to reflect governance and enabling factors and to enable the modelling processes to reflect political realism as far as possible. Diverse stakeholders who acted as validators of the scientific process were included, stakeholder preferences were revealed, and recipients and users of the LCS outputs were included in ongoing dialogues on outputs and interpreting the results. The aim of the LCS was thus to fill the gap between typical laboratory-style integrated modelling assessments and downscaled but unaligned practical assessments performed om disaggregated geographical and sector-specific scales.

There is an emerging modelling literature focusing on synergistic benefits and trade-offs between low-carbon development pathways and various aspects of sustainable development. The early literature including IAMs, that is macroeconomic and sectoral models, which mainly focused on the co-benefits of mitigation policies in terms of reduced air pollution, energy security and to some extent employment generation (IPCC, AR 5, 2004 WG III, chapter 6). Some models have been further developed with assessments of a broader range of joint benefits of mitigation, health, water and land use, and food security (IPCC 2014, AR 6 WGIII, Chapter 6; IPCC, 2018, 1.5 report).

The World in 2050 initiative (TWI) includes a comprehensive assessment of technologies, economies and societies embodied in the SDGs (TWI, 2018). The assessment addresses social dynamics, governance and sustainable development pathways within the domains of human capacity and demography, consumption and production, decarbonization and energy, food, the biosphere and water, smart cities and digitalization.

Studies using global IAMs that were presented in the GEO6 report (UNEP, 2019, Chapter 22) concluded that transitions to low-carbon pathways will require a broad portfolio of measures, including a mixture of technological improvements, lifestyle changes and localized solutions. The many different challenges require dedicated measures to improve access to, for example, food, water and energy, while at the same time reducing the pressure on environmental resources and ecosystems. A key contribution may come from a redistribution of access to resources, where both physical access and affordability play a role. The IAMs cover large countries and regions, and localized solutions are not well covered in the modelling results. This implies that, for example, trade-offs between energy access and affordability are not fully represented in aggregate modelling results.

The strengths and limitations of IAMs and more detailed bottom-up models have been extensively discussed in the literature. (Waisman et al. 2019) suggest that modelling scenarios to support the Paris Agreement could benefit from a hybrid approach, which combines the global consistency provided by the IAMs with national models, which, based on bottom-up analysis, can provide more localized relevant insights into policies that can be aligned with national strategies and that provide an overview of the links between decarbonization strategies and a broader set of economic, social and environmental development goals (Von Stechow et al. 2015) conclude in a review of IAMs and sectoral and national modelling studies that these studies generally agree on the great potential of the co-benefits of decarbonization policies in particular in relation to health and energy security. Localized models are usually relatively strong in their assessments of a range of policy-relevant co-benefits of climate policies, but it is very difficult to aggregate these results into a consistent welfare-based global aggregate, this being considered a key limitation of using only localized models. Global policies could accordingly suffer from limitations and uncertainties in understanding the key benefits associated with aligning deep decarbonization with the sustainable development goals, which is important in order to avoid trade-offs between, for example, renewable energy deployment, high costs,and other objectives related to food and energy access, and to health and education. Like (Waisman et al. 2019;von Stechow et al. 2015) suggest developing consistent frameworks for integrated global IAM modelling and localized bottom-up models.

The relevance of the IAM modelling results in relation to policy implementation has been addressed in the IPCC special report on stabilization at 1.5°C (IPCC, 2018). Governance here has been highlighted as an enabling factor in order to support the implementation of policies with synergetic impacts across decarbonization and sustainable development. Jakob and Steckel (2016) conclude that a key barrier to policy implementation is the lack of a governance framework to enable joint policy implementation to meet both local and global goals in terms of low stabilization targets and sustainable development.

17.3.3 Sectoral and cross-sectoral transition

Transitions will involve multiple sectoral- and cross-sectoral policies. Section 17.3.3. presents a range of examples in order to illustrate the key potential synergies and trade-offs between sustainable development and deep decarbonization policies.

17.3.3.1 Renewable energy penetration and fossil-fuel phase-out

The achievement of long-term temperature goals in line with Paris Agreement requires the rapid penetration of renewable energy and a timely phase out of fossil fuels, especially coal, from the global energy system, as pointed out in Chapter 6. The limited carbon budget implies that global annual emissions must achieve "net zero" in 2050/2060 (IPCC, 2018). Net zero emissions imply that the unrestricted use of fossil fuels needs to be fully phased out and replaced by renewables and other low-carbon alternatives. The 1.5°C consistent scenario requires a 2-3% annual improvement rate in carbon intensities till 2050, though the historical record only shows a slight improvement in the carbon intensity of the global energy supply, far from what is required to meet the low temperature targets.

Phasing out fossil fuels from energy systems is technically possible and is estimated to be relatively low in cost (Chapter 6). The cost of low-carbon alternatives, including onshore and offshore wind, solar PV and electric vehicles, has been reduced substantially in recent years and has become competitive with fossil fuels. However, studies show that replacing fossil fuels with renewables can have both major synergies and trade-offs with a broader agenda of sustainable development, which has to be addressed. These synergies and trade-offs are related to energy and water access, land use and food security. IPCC, AR 5, Mitigation Policies, Table 6.7 (IPCC, 2014) includes a detailed mapping of the sectoral co-benefits and adverse side-impacts of and linkages to transformation pathways, and it concludes that the potential co-benefits of energy end-use measures clearly outweighs adverse impacts in most sectors, though this is not the case for all supply options or for the AFOLU sectors. Some locally negative economic impacts can result in terms of increased energy costs and rivalry over land areas and water resources. Some sectors can also experience decreasing employment as a consequence of the transition process. Although renewable energy deployment will generate a new industry and associated jobs and benefits in some areas and economies, these impacts will often not directly replace or offset activities in areas that have been heavily dependent on the fossil-fuel industry.

Even though the transition away from fossil fuels is desirable and technically feasible, the transition is still largely constrained by existing fossil fuel-based infrastructure and stranded investments. The "committed" emissions from existing fossil-fuel infrastructure may consume all the remaining carbon budget related to the 1.5°C scenario or two thirds of the carbon budget consistent with 2°C. The early phasing out of this infrastructure will result in a significant share of stranded assets with an impact on workers, local communities, companies and governments. The challenge is thus to manage a transition which delivers the rapid phasing out of existing fossil fuel-based infrastructure and that develops a new energy system based on low-carbon alternatives within a very short opportunity window.

Examples from various countries show that, compared with top-down decision-making, bottom-up policy-making involving local stakeholders could enable regions to benefit and reduce their resistance to transition. Kainuma et al. (2012) conclude that social dialogue is a critical condition for engaging local workers and communities in managing the transitions with the necessary support from transition assistance. It is pointed out that macro-level policies, training programmes, participatory processes and specific programmes to support employment creation for workers in the fossil-fuel industry are needed. Examples of challenges in transitions away from using coal are given in Box 17.1.

Box 17.1 Case Study: coal transitions

The role of coal in the global energy system is changing fast. Given the global temperature goals of the Paris Agreement, the world coal sector needs a transition to near zero by 2050 (IPCC 1.5 SR, IEA WEO 2017, Bauer et al. 2018). Other global trends, including air quality, water shortages, the improved cost efficiencies of renewables, the technical availability of energy storage and the economic rebalancing of emerging countries are also driving global coal consumption towards a trend of plateau and reverse (Sator, 2018, Spence et al., 2018). The world should be prepared for a managed coal transition and identify appropriate transition options for the future of coal.

The coal transition will impose challenges not only in the power sector, but even more importantly on coal-mining industries. The less diversified local economy, low labour mobility and heavy dependence on coal revenues make the closure of coal particularly challenging from a political economy perspective. Policy is needed to support and invest in impacted areas to smooth the transition, absorb the impact and incentivize new opportunities. A supportive policy for the transition could include both short-term support and long-term investment. Short-term compensation could be helpful for local workers, communities, companies and government to manage the consequences of coal closures. Earlier involvement with local stakeholders in a structured approach is crucial and will make transition policy more targeted and better administered. The long-term policy should target support to the local economy and workers to move beyond coal, including a strategic plan to transform the impacted area, investment in local infrastructure and education, and preference policies to incentivize emerging business. Most importantly, ex-ante policy implementation is far better than ex-post compensation. Even without the climate imperative, historical evidence shows that coal closures can happen surprisingly fast.

Coal has hitherto remained the dominant energy source in China and has accounted for more than 70% of its total energy consumption for the past twenty years, falling to 64% in 2015 (NBS, 2018). In the 13th Five Year Plan (2016-2020), for the first time China included the target of a national coal consumption cap of 4.1 billion tons for 2020, and a goal of reducing the primary energy share of coal to 58% by 2020 from the level of 64% in 2015 (The National People's Congress of the People's Republic of China 2016). The main driving forces of the coal transition in China are increasing domestic environment concerns and pressure to reduce greenhouse gas emissions. Coal combustion contributes about 90% of total SO_2 emissions, 70% of NOx emissions and 54% to primary $PM_{2.5}$ emissions in China (Yang and Teng, 2018). The early phasing out of coal also delivers a co-benefit in terms of air pollutant reductions consistent with China's goal to improve air quality. The coal transition in China will change the future value of coal-related assets, and both coal power generators in China and coal producers outside China need to identify appropriate responses to avoid and manage the potentially substantial stranding of fossil-fuel assets.

Kefford et al. (2018) assess the early retirement of fossil-fuel power plants in the US, EU, China and India based on the IEA 2° scenario and conclude that a massive early retirement of coal-fired power plants is needed, and that two to three standard 500 MW generators will need to come offline every week for fifteen years. This high rate is the result of a very large deployment of coal-fired power plants from 2004 to 2012.

Presently, coal-fired power plants play a key role in the German energy system, providing almost 46% of the electricity consumed in Germany. These coal power plants play a crucial role in balancing fluctuations in the electricity production of renewables (Parra et al. 2018). Politico-economic considerations, at least regionally, are also of great importance in the coal sector due to the approximately 35,000 people employed in this sector (including coal mining and the power stations themselves). For a long time, coal-fired power plants could protect their position in the regime, but against the background of decreasing public acceptance, economic problems resulting from the growing use of renewables and ambitious GHG reduction targets, the coal-fired power sector cannot resist the pressure coming from the regime any longer. The governing parties have agreed on the establishment of a commission called "Growth, structural change and employment" to develop a strategy for phasing out coal-fired power plants (E3G, 2018). This commission consists of experts and stakeholders from industry, associations, unions, the scientific community, pressure groups and politicians. Its establishment shows that the phasing out process deserves close attention and that management policies must be implemented to ensure a soft landing for the electricity sector.

Stranding assets is not without its complications. The urgent global need to reduce greenhouse gas emissions and global warming has increased the demand for clean renewable energy resources like wind and solar to replace fossil fuels (Manthiram et al. 2015). The transition towards a high penetration of renewable systems also faces various challenges in the technical, environmental and social economic dimensions. The integration of renewables into the grid not only requires sufficient flexibility in power grids and intensive coordination with other sources of generation, but also a fundamental change in long-term planning and grid operation.

The transition towards a high-penetration renewable system also raises concerns over the availability of rare metals for batteries. The effective utilization of these renewable energy resources requires efficient, low-cost energy-storage systems. Rechargeable batteries have proved the most viable storage options. The rise in the use of electric vehicles and solar panels has increased the demand for rechargeable batteries. There have been advances in research to produce economical, high-energy, high-power and high-capacity rechargeable batteries (Manthiram et al. 2015). Lithium ion batteries are by far the most commonly used rechargeable batteries (Rosenberg, 2019). They continue to gain increased interest as the next generation of energy-storage solutions due to their high capacity, high energy densities and low cost (Liang et al. 2016). Global lithium production rose by roughly 13% from 2016 to 2017 to 43,000 MT in 2018 (Golberg et al. 2019). Africa has rich reserves of lithium and is expected to produce 15% of the world's supply soon (Rosenberg, 2019). Rich reserves of lithium can be found in Zimbabwe, Botswana, Mozambique, Namibia, South Africa (Steenkamp, 2017) and the DRC (Roker, 2018).

The move to renewable energy sources to reduce GHG emissions has increased the demand for non-fossil resources like lithium and cobalt. The Democratic Republic of Congo (DRC) possesses half the cobalt reserves (Whitehouse, 2019) in the world and has the largest hard rock lithium resources (Roker, 2018). It is the world's largest source of cobalt (Conca, 2019). The demand for these resources as ingredients in rechargeable batteries is growing rapidly, with global demand for cobalt set to quadruple to over 190,000tn by 2026. The DRC is a mineral-rich country (Smith and 2018) with rich reserves of fossil fuels (coal and oil) (Democratique, International Energy Statistics, 2015). The equally large reserves of lithium and cobalt for rechargeable batteries provide an opportunity for the DRC to switch to greener, economic opportunities. However, the technological revolution in non-fossil fuels is itself raising environmental concerns and provoking social issues (UPS, 2018).

The extraction of lithium can be environmentally damaging, though its use as a principal component in most rechargeable batteries for electric vehicles and electronic smart grids affords it high sustainability value. There are currently three li-ion mega factories with a further 33 to be completed by 2023 (Goldelberg, 2019). Will lithium mining replace the economic value of oil and coal extraction in resource-rich countries in Africa?

17.3.3.2 Agriculture, food and land use

Sustainable development is strongly linked to the implementation of policies for low stabilization targets in the agriculture, food and land-use sectors, and several authors have concluded that particularly strong potential trade-offs between development and climate policy goals exist within this sector.

The Global Assessment on Biodiversity and Ecosystem Services Report (IPBES, Chapter 5, 2019) assessed the relationship between meeting the goals of the Paris Agreement and SDGs 2 (zero hunger), 7 (affordable end clean energy) and 15 (life on land). It concluded that a large expansion of the land used for bioenergy production is not compatible with the biodiversity targets. However, combining bioenergy options with other mitigation options like more efficient land management and restoration of nature could contribute to welfare improvements and to food and water access. Demand-side climate mitigation measures like energy efficiency improvements, reduced meat consumption and reduced food waste are assessed to be the most economically attractive and efficient options in order to support low GHG emissions, food security and biodiversity objectives. Implementing such options can imply challenges in terms of lifestyle changes (IPBES, 2019).

Bases on IAM modelling Bleischwitz et al. (2018) conclude that the temperature targets of the Paris Agreement can be achieved by intensifying agricultural production and by reduced meat and dairy consumption, which will imply a reduced demand for land and thus more space for nature and biodiversity. Such a pathway could provide more SDG co-benefits than land-use scenarios with increased land demand for bioenergy. The authors conclude that implementing these pathways critically depends on demographics and governance in terms of behavioural changes and other critical transformation elements in different parts of the world.

Fujimori et al. (2019), in a study of six global IAMs, have assessed the consequences of meeting the goals of the Paris Agreement on global temperature stabilization of 1.5 degrees and 2 degrees in terms of people being at risk of hunger. They conclude that meeting these temperature targets, if framed as a climate mitigation effort, could significantly increase the number of people with hunger by 2050. The major arguments are that the carbon prices included in the modelling results would increase food costs, which could compromise food access in low-income countries. Another major drawback is that the climate change mitigation scenarios imply a large land demand for bioenergy crops, which again would increase food prices. The authors suggest that the negative consequences of mitigation policies on food access can be offset by agricultural subsidies or aid programmes.

The potential joint contribution of food and land-use systems to sustainable development and climate change has also been addressed in policy programmes by the UN, local governments and the private sector. These programmes address options in pursuing sustainable development and climate change jointly, such as agroforestry, agricultural intensification, better agriculture practices and avoided deforestation. Griggs and Smith (2013) assess production- and consumption-based methods for joint sustainability and climate change mitigation in food systems, concluding that efficiency improvements in the agricultural production system can provide large benefits. Given the high expected population growth and the high expected increase in the demand for meat and dairy products, there is also a need for the careful management of dietary changes, as well for those areas which could be used most effectively for livestock and plant production.

The IPCC Special Report on Land Use (IPCC, 2019) emphasizes the need for governance in order to avoid conflict between sustainable development and land-use management and states that "Measuring progress towards goals is important in decision-making and adaptive governance to create common understanding and advance policy effectiveness”. The report concludes that measurable indicators are very useful in linking land-use policies, NDCs and the SDG's. Various governance issues are highlighted as being necessary to address in order to avoid land degradation and conflicts between ecosystems services and climate change policies.

Special governance across sectors has been called for in relation to the protection of forestry, ecosystem services and local livelihoods in a context of the large-scale deployment of high-value crops like palm oil, first-generation bioenergy crops (maize) and soya protein for animal feed in order to avoid conflicts between potential short-term high-income generation activities and sustainable development. Serious challenges are already being seen within these areas according to (IPBES 2019).

Box 17.2 provides examples of how land degradation can arise as the outcome of rivalry between income generation and ecosystem protection.

Box 17.2 Case study: oil palm

Oil palm is one of the most productive oil crops in the world in term of oil yield per area. It is used in a wide range of processes, from fast food, chocolate spread and cereals to toothpastes and animal feed (Rochmyaningsih, 2019). This crop has nonetheless become one of the most controversial today because, despite its high productivity, high applicability and ability to alleviate poverty, the palm-oil development is most often at the cost of deforestation, which causes greenhouse gas (GHG) emissions and biodiversity loss (Curtis et al., 2018). Currently the area under oil-palm production is showing a tremendous increase, mostly in forest conversion to oil-palm plantation, (Gaveau et al., 2016, Austin et al., 2019, Schoneveld et al., 2019). The conversion of peat swamp forest and mineral forest to oil palm will yield different amounts of CO_2. The study conducted by Novita et al. (2019) shows that the carbon stock of primary peat swamp forest was 1,770 Mg C/ha compared to carbon stock of oil palm 759 Mg C/ha. The study conducted by Guillaume et al. shows the carbon stock in mineral soils from rain forest was 284 Mg C/ha compared to 110.76 Mg C/ha (Guillaume et al., 2018).

Oil palm requires significant fertilizers, which might be lost to the environment because of volatilization into the atmosphere and leaching into rivers, both of which cause climate change and eutrophication. To reduce the environmental impact of fertilizers, the utilization of residues from oil palm such as using empty fruit bunches as organic fertilizer might reduce GHG emissions significantly from 123.6 kgCO_2eq./ 1,270 kg Crude palm oil +Palm Kernel Oil +Palm Kernel Cake to become 81.7 kgCO_2eq./ 1,270 kg CPO+PKO+PKC (Wiloso et al., 2015).

In Indonesia, oil palms are mainly owned by corporate and state-owned enterprises (59%), the rest by smallholder (41%). Smallholders need particular attention due to low yields as the result of a lack of know-how and financial capability. The yield of smallholder production is roughly three to four tonnes oil/ha/year compared to five to six tonnes oil/ha/year by companies (Woittiez et al. 2018) due to lower applications of chemical and organic fertilizers.

Alternatively, the conversion of pasture to oil palm might be a solution to ecologically devastating deforestation as a form of land-use change, since it does not alter ecosystem carbon storage (Quezada et al., 2019). In addition, multi-stakeholder collaboration between oil-palm plantations, local communities and local governments might be one of the most effective ways to reduce the deforestation impact of oil palm (Jupesta et al., to be published in 2020).

Behavioural changes are also expected to be a major factor in aligning sustainable development, climate change and land management. Springman et al. (2018) conclude that reductions in food waste could be a very important option for reducing agricultural GHG emissions, the demand for agricultural land and water, and nitrogen and phosphorous applications. In addition to the option of reducing food waste, the study analysed several other options for reducing the environmental effects of the food system, including dietary changes in the direction of healthier, more plant-based diets and improvements in technologies and management. It was concluded that, relative to a baseline scenario for 2050, dietary changes towards healthier diets could reduce GHG emissions and other environmental impacts by 29% and 5–9% respectively for a dietary-guideline scenario, and by 56% and 6–22% respectively for a more plant-based diet scenario. The authors also concluded, across the options, that aligning sustainable development and climate change policies within agriculture would require a range of policies to be included: GHG emissions cannot be sufficiently mitigated without dietary changes towards more plant-based diets; cropland and blue water use are best addressed by improvements in technologies and management that close yield gaps and increase water-use efficiency; and reducing nitrogen and phosphorus applications will require a combination of measures, including more efficient production technologies, increased shares of plant-based food, reductions in food loss and waste, and also more efficient use and recycling of nitrogen and phosphorus.

Box 17.3 describes a national programme to reduce food waste.

Box 17.3 Case study: food waste

In 2007, Britain launched a nationwide initiative to reduce household food waste, achieving a 21% reduction within five years (FAO, 2019). The basis of this initiative was the “Love Food, Hate Waste” radio, TV, print and online media campaign run by a non-profit organization, the Waste and Resources Action Programme (WRAP). The campaign raised awareness among consumers about how much food they waste, how it affects their household budget and what they can do about it. This initiative collaborated with food manufacturers and retailers to stimulate innovation, such as re-sealable packaging, shared meal-planning and food storage tips. The total implementation costs during the five-year period were estimated to be GBP 26 million, from which households derived the majority of the benefits, which were estimated to be worth GBP 6.5 billion. Local authorities also realized a substantial GBP 86 million worth of savings in food-waste disposal costs. As for the private sector, benefits took the form of increased product shelf life and reduced product loss. While households started to consume more efficiently and companies may have experienced a decline in food sales, the companies stated that the non-financial benefits, such as strengthened consumer relationships, offset the costs.

The Asia Pacific Economic Cooperation (APEC) group of countries have also created several types of public–private partnership for food waste and loss reduction projects. Most of these partnerships are focused on food-waste recycling in both developed and developing countries (Rogelj et al., 2018). APEC members stated that knowledge-sharing and improved policy and project management were the most important advantages of public–private partnerships.

17.3.3.3 Water

SD is strongly linked to the potential for implementing policies to achieve low stabilization targets in the water sector. Here we will address water management in terms of water conservation. Subsidized fertilizers, energy and crops can drive unsustainable levels of water usage and pollution in agriculture. More than half the world’s population, roughly 4.3 billion people in 2016, live in areas where demand for water resources outstrips sustainable supplies for at least part of the year. Irrigated agriculture already uses around 70% of the available freshwater, and the large seasonal variations in water supply and the needs of different crops can create conflicts between water needs across sectors at different time scales (Wada et al., 2016). However, as there is little potential for increasing irrigation or expanding cropland (Steffen et al, 2015), food-production gaps must be closed by increasing productivity and cropping densities on currently harvested land by increasing either rain-fed yields or water-use efficiency (Alexandratos and Bruinsma, 2012).

Coordination of water use across different sectors and deltas are important factors in sustainable water management. Examples of instruments and policies to support this are given in Box (17.4), Water Conservation Fund in Kenya, and Box, (17.5) Kenya and India.

Box 17.4 Case study: Water Conservation Fund in Kenya

The Upper Tana-Nairobi Water Fund was created to help protect and restore the quality and supply of water to one of Kenya's most productive and economically important regions. The Upper Tana River basin covers approximately 17,000 km^2 and is home to 5.3 million people. The water it provides is of critical importance to the Kenyan economy (Geertsma et al., 2014).

Forests and wetlands in the Upper Tana play an important role in maintaining water quality and quantity, providing areas where run-off water and sediment can be stored and filtered naturally. However, since the 1970s, forests on steep hillsides and areas of wetlands have been converted to agriculture. As a result, sedimentation is becoming a serious problem, reducing the capacity of reservoirs and increasing the costs of water treatment. Today, 60% of Nairobi's residents are water-insecure, and this could be further challenged by climate change.

Water funds are based on the principle that it is cheaper to prevent water problems at the source than it is to address them further downstream. A water fund is a financial mechanism to fund land-conservation measures upstream. A public-private partnership of donors and major water consumers 'at the tap' contributes to the endowment. Funds are then used to support water and soil conservation measures 'at the top'. These measures benefit local farmers through increasing agricultural yields by reducing the soil erosion that is so damaging to both crop production and downstream water quality and supply. A study to assess the economic viability of a water fund for the Upper Tana River basin was commissioned by a public-private partnership managed by an international NGO, the Nature Conservancy (TNC) (Colin TCN, 2018). Conservative results demonstrate a viable return on investment for the creation of a water fund to reduce sediment concentration in rivers (varying by watershed and time of year), increase annual water yields across the priority watersheds during the dry season, increase agricultural yields for smallholders and agricultural producers up to US$3 million per year, improve water quality and increase revenue from cost savings avoided on filtration and increasing hydropower generation capacity. Overall, a US$10 million investment in Water Fund interventions is expected to return USD21.5 million in economic benefits over the thirty-year timeframe. The viability of the investment in the water fund was also assessed by (Vogl et al. 2017), stressing that a well-designed and managed fund will produce greater benefits than costs. These results are based on integrated participatory research as part of a stakeholder engagement process in order to provide results which are more likely to be decision-relevant within the local context because they navigate stakeholder expectations and data limitations. The benefits of using a water fund in Kenya to create incentives for the private sector to invest in ecosystem services has been assessed by Mulatu et al. (2015), who concluded that studies of companies' willingness to pay for water are a key element in creating an efficient institutional design of mechanisms such as the water fund.

Box 17.5 Case Study: groundwater crisis in India

India is the world's largest user of groundwater for irrigation, which covers more than half of the total irrigated agricultural area, responsible for 70% of food production and supporting more than 50% of the population (700 million people). However, excessive extraction of groundwater is depleting aquifers across the country, and water table declines have become pervasive. Improved water-use efficiency in irrigated agriculture is being considered, both globally and in India, as a way of meeting future food requirements with increasingly scarce water resources (Fishman et al, 2015). However, the incentives for conservation and efficiency are lacking in India, since electricity for pumping is highly subsidized and groundwater use is not regulated. India is currently promoting the adoption of water-saving technologies in order to reduce the pressure on aquifers and to stabilize falling water tables, but these options have still not been widely adopted. Using proven technologies such as drip and sprinkler irrigation could reduce the unsustainable over-extraction of groundwater by half. Removing the subsidy for groundwater pumping is also being considered as a way of promoting these options.

17.3.3.4 Water-Energy-Food-Nexus

The nexus of water, energy and food (WEFN) (Zhang et al. 2018a) is closely interlinked in a complex manner and needs careful attention and deciphering across spatio-temporal scales, sectors and interests for proper management and trade-off balancing and to pursue sustainable development (Hamiche et al. 2016; Biggs et al. 2015; Dai et al. 2018). The WEFN touches upon the majority of the UN's SDGs and deals with basic commodities ensuring the basic livelihoods of the global population. The task of gaining an improved understanding of WEFN processes across disciplines such as the natural sciences, the economy, the social sciences and politics, has been further exacerbated by climate change, population growth and resource depletion. In light of the system interlinkages involved, the WEFN concept essentially covers also land (Ringler et al. 2013) and climate (Brouwer et al. 2018; Sušnik et al. 2018), hence the water-energy-food-land-climate nexus.

Climate change is projected to impact on the distribution, magnitude and variability of global water resources. A global yearly precipitation increase of 7% is expected by 2100 in a high-emissions scenario (RCP 8.5), although with significant inter-model, inter-regional and inter-temporal differences (Giorgi et al. 2019). Similarly, extreme events related to the water balance such as droughts and extreme precipitation are projected to shift in the future (RCP4.5) towards 2100, for example, the number of consecutive dry days is projected to increase in the Mediterranean region, southern Africa, Australia and the Amazon (Chen et al. 2014). In impact terms, an increase of 20-30% in global water use is expected until 2050 due to industrial and domestic water use, and four billion people currently experience severe water scarcity for at least one month per year (WWAP-UNESCO 2019). Globally climate change has been shown to cause increases of 4%, 8% and 10% in the population being exposed to water scarcities under 1.5°C, 2°C and 3°C of global warming respectively (RCP8.5) (Koutroulis et al. 2019). At the same time, climate change is projected to cause a general increase in extreme events and climate variability, posing a substantial burden on society and the economy (Hall et al. 2014). Other than the human influence on the global hydro-climate, human activities have been shown to surpass even the impact of climate change in low to moderate emission scenarios of the water balance (Haddeland et al. 2014). Similar conclusions have been found by (Destouni et al. 2013; Koutroulis et al. 2019).

An obvious consequence of the climate change impact on future hydro-climatic patterns is that the energy system is projected to experience vast impacts through climate change (Fricko et al. 2016; van Vliet et al. 2016b, a). In the short run, where fossil fuel sources make up a significant share of the global energy grid, climate impacts related to water availability and water temperatures will affect thermoelectric power production, as these rely mainly on water cooling (Pan et al. 2018; Larsen and Drews 2019), and they also use water for pollution and dust control, cleaning etc. (Larsen et al. 2019). Currently, 98% of electricity generation relies on thermoelectric power (81%) and hydropower (17%) (van Vliet et al. 2016a). Of these thermoelectric sources, the vast majority employ substantial amounts of water for cooling purposes, although there is a tendency towards a greater implementation of hybrid or dry cooling (Larsen et al. 2019).

For the 2080s compared to 1971-2000, an increase of 2.4% to 6.3% in the global gross hydropower potential, from the hydrological side alone, is seen across all scenarios (van Vliet et al. 2016a). Alongside the global increase in hydropower potential, the global mean water discharge cooling capacity, which also relates to water temperature, will experience a decrease of 4.5% to 15% across scenarios. These changes combined, in very general and global terms, support the shift towards renewable energy sources, including hydropower, in the energy mix. In relation to ensuring stability in the management of the electricity grid, hydro-climatological extremes have the potential to pose vast difficulties in certain regions and/or seasons depending on the nature of the energy mix. (Van Vliet et al. 2016) showed significant reductions in both thermoelectric and hydropower electricity capacities, exemplified by the 2003 European drought, which resulted in reductions of 4.7% and 6.6% respectively. In terms of damage costs, the energy sector is found to be especially vulnerable because of the production losses caused mainly by heatwaves and droughts. However, coastal and fluvial or river floods are also responsible for a large relative share of the energy sector's vulnerability as assessed by (Forzieri et al. 2018) for Europe in 2100. In total, heatwaves and droughts will be responsible for 94% of the damage costs to the European energy system compared to the 40% today. Along these lines (Craig et al. 2018) shows that, despite potentially minor spatiotemporally aggregated differences for various energy system components such as demand, thermoelectric power, wind etc., the aggregated impact of climate change across these components will cause a significant impact on the energy system, as currently exemplified by the USA. In terms of investments and management, it is important to unravel these cross-component relations in relation to the projected nature of the future climate.

In the ongoing transition towards renewable energy sources, the impact of the hydro-climate on energy production continues to be highly relevant (Jones and Warner 2016). As the shares of thermoelectric energy production in the energy grid go down alongside the introduction of thermoelectric cooling technologies using smaller amounts of water, new energy sources and technologies are being introduced and existing sources being scaled up. Of these, hydropower, wind and solar energy are the current and near-future key energy sources, making up 2.5% and 1.8% of the total global primary energy supply in 2017 (IEA 2019). Wind and solar energy are directly independent of water in themselves, but are dependent on atmospheric conditions related to processes that also drive the water balance and circulation. Hydropower, on the other hand, is directly influenced by and dependent on water supply, while at the same time being an essential counter-component to seasonality and climatological variability, as well as to current and future demand curves and diurnal variations against wind and solar energy (De Barbosa et al. 2017). Furthermore, policy instruments in power system management, here exemplified by hydropower in a climate change scenario setting, have been shown to enhance energy production during droughts (Gjorgiev and Sansavini 2018). The significant influence of variability in 21st-century energy planning of renewable energy has also been highlighted by (Bloomfield et al. 2016). At the same time, the integration of renewables must account for lower thermoelectric efficiencies and capacities due to increases in temperatures (van Vliet et al. 2016b), power-plant closures during extreme weather events due to a lack of cooling capacity (Forzieri et al. 2018) and further efficiency reductions and penalties following the implementation if CCS technologies in the effort to reach GHG mitigation targets (Budinis et al. 2018) alongside higher water usage (Byers et al. 2015).

The extraction, distribution and wastewater processes within anthropogenic water management systems similarly use vast amounts of energy, which makes the proper management of water essential to reduce energy usage and GHG emissions (Nair et al. 2014). One study reports that the water sector accounts for 5% of total US GHG emissions (Rothausen and Conway 2011).

Within the WEFN there is an obvious trade-off between water availability and food production, competing demands that pose a risk to the supply of the basic commodities of food, energy (and water) in line with the SDGs (Bleischwitz et al. 2018) and all form a potential for inter-sectorial or inter-regional conflicts (Froese and Schilling 2019). Currently, 24% of the global population live in regions with constant water-scarce food production and 19% experience occasional water scarcities (Kummu et al. 2014). To counterbalance the demands for food and comestibles in regions that experience constant or intermittent supplies, transportation is needed, which in itself requires proper infrastructure, energy supplies, a well-functioning trading environment and supportive policies. Of the 2.6 billion people who experience constant or occasional water scarcities in food production, 55% rely in international trade, 21% on domestic trade, and the remainder on stocks (Kummu et al. 2014).

The relationship between the influence of hydro-climatic variability and socio-economic conditions and patterns of water scarcity has been addressed by (Veldkamp et al. 2015). A key finding of this study was the ability of the hydro-climate and the socio-economy to interact, enforcing or attenuating each other, though with the former acting as the key immediate driver and the influence of the latter emerging after six to ten years.

The trade-offs between competing demands have been investigated at the continental scale over the US Great Plains, highlighting the influence of irrigation in mitigating reductions in crop yields (Zhang et al. 2018b). Despite crop-yield reductions of 50% in dry years compared to wet years, a key conclusion was that the irrigation should be counterbalanced against general water and energy savings within the nexus of trade-offs. In East Asia, the WEFN has been quantified, highlighting obvious trade-offs between economic growth, environmental issues and food security (White et al. 2018). This same study also highlights the concept of the virtual WEFN encompassing water embodied within products which are traded and shipped. (Liu et al. 2019) find an urgent need for proper assessment methods, including of trade within the WEFN, due to the significant resource allocations.

Applying an integrated approach to water-energy-climate-food-resource management and policy-making has been argued to be highly beneficial in properly addressing benefits and trade-offs (Howells et al. 2013; Brouwer et al. 2018). To do so, a number of modelling approaches, tools and frameworks have been proposed (de Strasser et al. 2016; Smajgl et al. 2016; Larsen and Drews 2019; Brouwer et al. 2018). Common to all of these efforts is the challenge involved in making comparisons across studies due to the combined complexity in assumptions, model codes, regions, variables, forcings etc. To accommodate these challenges (Larsen et al. 2019) suggest employing shared criteria and forcing data to enable cross-model comparisons and uncertainty estimates, as also highlighted by (Brouwer et al. 2018). Other limitations within current WEFN research are partial system descriptions, the failure to address uncertainties, system boundaries and evaluation methods and metrics (Zhang et al. 2018a). The lack of proper WEFN data accessibility and quality has been highlighted by (D'Odorico et al. 2018; Larsen et al. 2019). Furthermore, gaps have been identified between theory and end-user applications in the lack of focus on food nutritional values as opposed to calories alone, in the understanding of water availability in relation to management practices, in integrating new energy technologies and in the resulting environmental issues (D'Odorico et al. 2018). Therefore, looking ahead, future fields of WEFN research should offer greater insights into all these aspects.

17.3.3.5 Cities: urbanization, city planning, low-carbon cities

Urbanization is a key future driver of economic growth, and 80% of the world population is expected to live in cities by 2050 (United Nations, 2018). The challenge is to combine sustainable development goals with city development in terms of prosperous and liveable cities, a clean environment etc. and low GHG emissions. The IPCC 1.5 report concluded that some new urban developments are demonstrating combined carbon-related and SDG benefits (Wiktorowicz et al., 2018), and it is also in towns and cities that building renovation rates can most easily be accelerated to support the transition to 1.5°C pathways (Kuramochi et al., 2018), including through voluntary programmes (Van der Heijden, 2018).

The large expected growth in cities implies great challenges in terms of sustainable development when it comes to addressing the needs of large populations, as well as opportunities for investing in infrastructure, houses and green livelihoods offering attractive space and social life (IPCC, 2014). Cities can also face several climate risks in the form of both heatwaves and flooding events, which threaten cities globally. To adapt to the future challenges, several international city networks are jointly working on supporting the development of plans for sustainable development and climate actions (e.g., the Global Covenant of Mayors for Climate and Energy (Covenant of Mayors 2019), the World Mayors Council on Climate Change (World Mayors Council on Climate Change 2019), ICLEI (ICLEI 2019), C40 (C40 2019), UNDRR (UNDRR 2019), etc.). Today, thousands of local government bodies are members of the EU's Covenant of Mayors for Climate and Energy, and many more belong to other global city networks, reflecting a strong city interest in the development of climate policies and risk management strategies. The majority of cities are only in the very initial phases of climate planning, and the existing plans are mostly only at the initial stage (Climate-ADAPT, 2019); D. Reckien et al., 2014; D. Reckien et al., 2018). There is therefore a great potential for creating synergies between several policy objectives in future city plans.

Tozer (2018) has studied the alignments of sustainable development and climate change in the plans of fifteen Canadian cities and concludes there are synergies and tensions between the respective discourses of sustainability and climate change. Both policy arenas shape local governance rationalities, though climate change response logics are not necessarily highlighted even where the action could result in greenhouse gas (GHG) emission reductions. In some cases, existing GHG-intensive practices are being rebranded as 'sustainable'. This suggests a tension between discourses of sustainability and climate change that may complicate attempts to address climate change through local sustainability planning.

(Choksi et al. 2014) in a sustainable urban transport transition study, have made assumptions about the transport intensity of alternative urban forms, as well as the co-benefits of green transportation pathways in terms of local air quality, mobility, energy security and GHG emissions. The scenario includes placing high priorities on collective transportation and electrification and gas fuels. The authors conclude that without these measures rising incomes and population growth would lead to increasing city sprawl and a high growth in the number of private vehicles.

The integrated management of sustainable development and climate change in cities includes a wide range of space for actions and policies. The World Business Council on Sustainable Development (WBSD) has mapped spaces for interactions in the city context as illustrated in Figure 17.2.

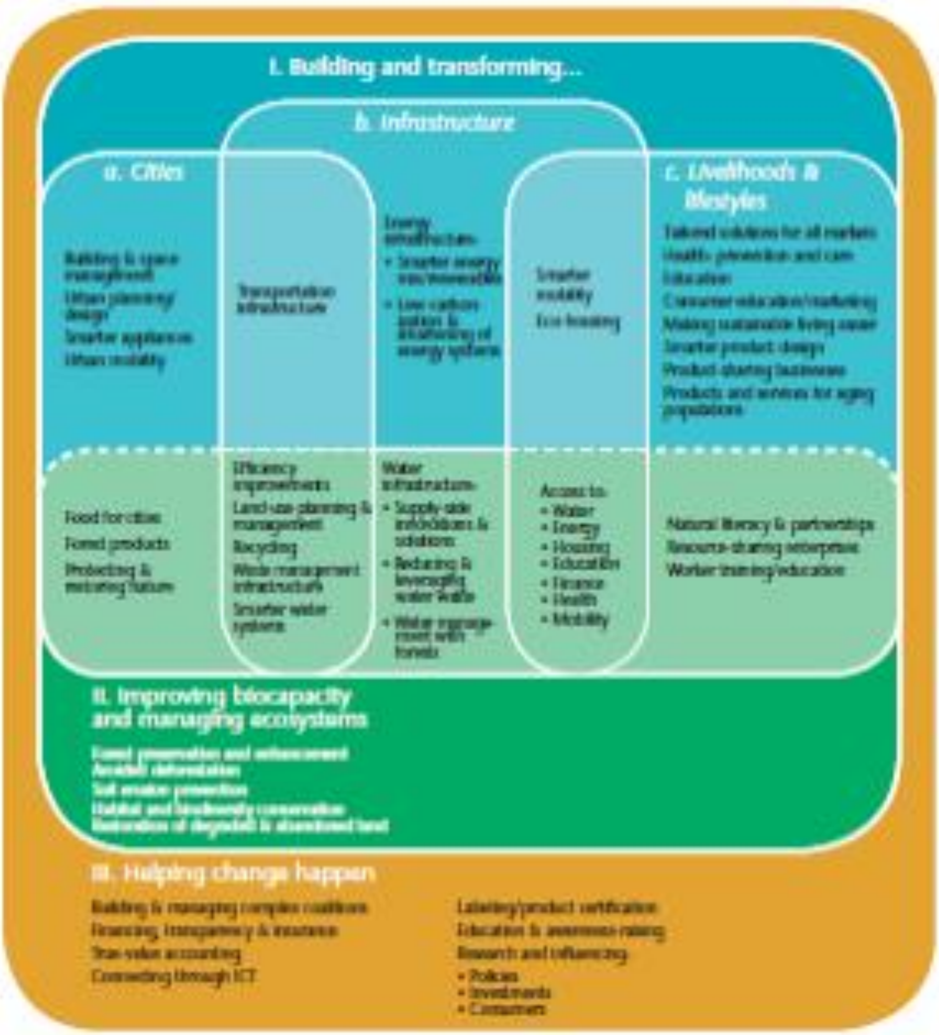


Figure 17.2 based on WBSD, 2019 Development of The World Business Council on Sustainable Development (WBSD) p. 38.Vision 2050. New Agenda for business. (see the reference (Development 2010) and grey literature.

The space for sustainable and climate compatible management of cities according to WBSD, 2019 includes the four categories: Building and transforming; Improving biocapacity and managing ecosystems; helping change happen

The space for the sustainable and climate-compatible management of cities according to WBSD, 2019 includes the following four categories: building and transforming; improving biocapacity; managing ecosystems; and helping change happen.

Box 17.6 describes a case study of carbon and water monitoring.

Box 17.6 Case study: carbon and water footprint monitoring in Quito

Rising temperatures, decreased rainfall and more frequent extreme weather events are forcing Quito in Ecuador to manage its energy and water use more efficiently. The carbon and water footprint measurement tool helps city officials sculpt policies and projects that will lower Quito's energy use. Quito is a leader among cities worldwide, as evidenced by its involvement in horizontal government leadership initiatives such as C40 and ICLEI. In 2009, the city introduced a robust and coherent framework to address climate change through targeted mitigation and adaptation strategies (Marcotullio et al., 2018) Of three Andean cities, Quito has the highest carbon footprint compared to other two, Lima and La Paz (CDKN, 2015).

The use of a carbon and water footprint assessment tool led the city of Quito to develop a targeted Action Plan of initiatives to lower its CO_2 emissions and water use. The plan is divided into two portfolios: carbon and water. The carbon portfolio includes actions to reduce Quito's CO_2 emissions by 20% by 2032. As one of the many initiatives planned to achieve this goal, Quito will complete a landfill biogas project that will reduce CO_2 emissions by almost 5.5 million tons each year. Other initiatives include the creation of solar power plants, which will avoid the generation of 1.42 million tons of CO_2 emissions annually (Go Explorer, 2019).

Similarly, in order to reduce its water footprint by 68%, the city plans to avoid 1.5 billion cubic meters of water use by 2032 by instituting policies to promote the use of water-efficient appliances, ecological toilets, vacuum systems and water reuse. Through these carbon and water footprint tools, the city is demonstrating how to translate energy assessments and observations into customized and measurable targets and policies. Quito plans to expand these mechanisms to the private sector in the coming years to make an even greater impact on the city's carbon and water footprints.

Since cities are the focal points of social challenges, as enshrined in SDG 11, building reliable and robust urban data platforms will enable cities to address the challenges of climate change. This needs public-private cooperation across continents, regions and countries (Creutzig et al., 2019, Yarime 2017).

Apart from its energy and water footprint, other mitigation options in Quito are related to sustainable buildings where Net-Zero Energy Building (NZEB) offers a window of opportunity towards an annual value of zero energy consumptions (Ordonez et al., 2019). The simulation results show that, for Quito city, the use of passive house design concepts, passive solar heat gains, thermal insulation according to the climate and high levels of compactness help the house to avoid presenting a demand for heating or cooling.

17.3.3.6 Infrastructure and transportation

About USD90 trillions of infrastructure investment will be needed globally from now to 2030 (The New Climate Economy 2016). How this investments will be created will largely determine future emission trajectories. In many parts of the world sustainable development also implies large-scale investments in new infrastructure due to its key role in economic growth and meeting the SDGs. Investments in infrastructure can have a large influence on long-term sustainable development and carbon pathways. Various pathways exist to manage risk for both existing and future investments in infrastructure, as well as for phasing out existing infrastructure, with associated risks of stranding existing assets.

It is critical to evaluate the potential benefits of investments in new infrastructure, as well as the requirements to manage and mitigate the risks associated with the stranded assets in existing infrastructure, including payments for early retirement, decommissioning, alternative uses of existing assets etc.

The low-emission development strategies that countries must submit to UNFCCC by 2020 can send a strong signal guiding system-wide infrastructural choices. However, the inclusion of climate in infrastructure assessments is vital to incentivize the transition towards a low-carbon infrastructure. In the technical assessment stage, the best practice includes establishing a quantitative emission performance standard (EPS) that only permits the financing of low-carbon technology, guidelines and toolkits to ensure climate resilience, and "no-go" policy for high-carbon projects. In financial assessment stages investors respond to a risk-adjusted return on investments, meaning that the best practice of infrastructure financial assessment is to include the climate in the cost analysis. The EIB, for example, uses a shadow price of carbon of 30 euro/tCO_2, while ADB uses a shadow price of 43 \$/tCO_2 (Rydge, 2015).

Reducing transport-related emissions has often proved challenging due to infrastructure investments, urban planning decisions and fossil-fuel subsidies that favoured motorization. Nonetheless, there have been growing efforts to move onto more sustainable, low-carbon pathways. One of the decision-making frameworks contributing to such a transition is the Avoid-Shift-Improve or ASI approach. The ASI approach placed a greater emphasis on the "A" (avoiding unnecessary travel through mixed land-use planning) and "S" options (shifting to more efficient modes through investments in public transport) than the "I" option (improving vehicle technology) (Dalkmann and Brannigan 2007; Wittneben et al. 2009).

The emphasis on the on "A" (in avoiding travel) and the "S" (in shifting modes) drew some of its inspiration from parts of Europe, Japan and Singapore that have avoided dependence on personalized motorized transport. As a result, some cities looked more closely at compactness and mixed land-use planning to reduce the demand for motorized transport (Cervero 2016). In other cases, cities placed a premium on improved public transport as part of their climate strategies (Situmeang et al. 2011). While there are some successful cases of work on the A and S elements, it has been often difficult in developing country contexts to build transport models that resemble those of Europe (Pojani and Stead 2015).

In recent years, the "I" in the ASI approach has gained more traction in part due to difficulties with the A and S elements. The clearest sign of this increasing interest is the sharp growth in the manufacture and purchase of electric vehicles. The transition to electrification has been driven by advances in technologies making it possible to drive longer distances with electric vehicles and by significant savings in fuel costs and energy imports. Electric vehicles also deliver significant reductions in greenhouse gases (GHGs) and air pollution if the electricity needed to operate the cars comes from renewable resources. Importantly, governments from Norway to South Korea have become more and more adept at using a combination of increasingly stringent regulations (fuel economy standards) and pricing policies (tax incentives for purchases). They have also received a boost from forward-looking companies such as Tesla that are looking to expand the market for electric vehicles with recent efforts targeting China. Additional advances in battery technology and engine performance appear primed to accelerate the transition to electrification in the decades to come (IEA, 2019; Crabtree 2019).

17.3.3.7 Industry

Industrial transformation is a core component in meeting SD. Across all industrial sectors, the development and deployment of innovative technologies, business models and policy approaches at scale will be essential to accelerate progress in meeting both economic and social development goals, and low emissions.

Green innovation in industry critically depends on regulations. Gramkow and Anger-Kravi (2018) have assessed the role of fiscal policies in greening Brazilian industry based on an econometric analysis of 24 manufacturing sectors. They concluded that instruments like low-cost finance for innovation and support to sustainable practices effectively promote green innovation.

A number of business associations have developed strategies for sustainable development and climate Change, including Cooperate Social Responsibility (CSR) strategies. International initiatives have included the promotion of CSR initiatives by international investors in low-income countries to support a broad range of development priorities, including social working conditions, child labour and climate change (Lamb et al. 2017). Leventon et al. (2015) has evaluated the role of mining industries in Zambia in supporting climate-compatible development and concludes that although the industry has played a positive role in avoiding migration and pressure on forest resources, there is a lack of coordination between government and industry initiatives. Several emerging economies and developing countries have been very successful in developing new exporting sectors based on green products. Examples from Ethiopia, Morocco and Ghana illustrating ongoing activities in Africa are provided in Box 17.7.

Box 17.7 Case study: greening African industries

Ethiopia's eco-industrial park in Hawassa: the Hawassa Industrial Park (UNIDO, 2018) (HIP), is a nation-level textile and garment industrial park in Ethiopia with "zero emission commitment". HIP is currently Africa's largest textile and garment industrial park and the first zero-emission textile industrial park. The Ethiopian government is trying to develop HIP into Africa's first sustainable industrial park with state-of-the-art infrastructure and equipment. HIP uses renewable hydroelectric energy sources. It has a dedicated 75 MW power line and uses light-emitting diode (LED) technology that achieves energy savings of up to 90% over traditional light bulbs and thus reduces the carbon dioxide footprint. LED-based light also produces less heat, helping achieve savings on air-conditioning. HIP has also invested in a state-of-the-art zero-liquid-discharge treatment plant to become Africa's first park with a zero-liquid discharge facility (ZLD). In this technology, 90% of the water is recycled and reused, and the final waste is crystallized.

Morocco's 2009 National Energy Strategy: Accelerating Development of Renewable Energy, (U.N. 2019) targets a 42% share of THE total mix for renewables by 2020, or 2 GW each of wind, solar and hydro capacity. Since then, the government has invested in research and development for renewables and attracted major investments, including Africa's largest solar power plant, the Ouarzazate Solar Complex, the first phase of which came on line in 2016, and roughly 750 MW of new wind capacity. The Noor-Ouarzazate created approximately 1,800 jobs in the construction process and 250 permanent operating jobs. Noor II, III and IV, with concentrated solar power, are expected to go online in 2017 and 2018. The African Development Bank estimates that the construction of Noor 2 creates 2,000 to 2,500 jobs temporarily in the construction sector with 400 to 500 permanent operating jobs. Noor I reduces carbon dioxide emissions by up to 280,000 tonnes a year, equivalent to nearly one percent of Morocco's CO_2 emissions. Additional projects have been completed in Tarfaya, where Africa's largest wind farm was established. The wind farm went online in 2014, creating 700 construction jobs during the construction process. Additionally, 50 operating jobs were established by the Tarfaya Wind Farm. In 2016, a consortium was awarded a concession to build 850 MW of wind-power capacity over five projects. As part of the deal, Siemens, one of the consortium partners, will invest USD 110 million in a domestic manufacturing facility for turbine blades intended for both domestic use and export to Africa and Europe. Siemens (2016) estimates that its new factory will create up to 700 jobs. The country plans to produce 15% of electric capacity from solar power by 2020. Morocco's government not only encourages foreign direct investment in solar and wind energy projects, it also supports related skills development and the emergence of domestic supplier industries. Moreover, policy-makers foster both high-tech investments in concentrated solar power plants and low-tech rooftop solar thermal and photovoltaic projects to develop various segments of the labour market.

One District One Factory (1D1F) initiative in Ghana

The 'One-District-One-Factory' programme is aimed at establishing at least one factory or enterprise in each of Ghana's 216 districts as a means of creating economic growth poles that would accelerate the development of those areas and create jobs for the country's increasingly youthful population.

The policy aims to transform the structure of the economy from one dependent on the production and export of raw materials to a value-added industrialized economy driven primarily by the private sector (Yaw 2018).

The programme is expected to facilitate the creation of between 7,000 to 15,000 jobs per district and between 1.5 million and 3.2 million jobs nationwide by end of 2020 (Ohene-Kanadur, 2019).

Sunda Ghana Diaper Ltd is the largest diaper-making factory in sub-Saharan Africa. With an investment of some $84 million, it will be one of the largest projects operating under the One District One Factory (1D1F) initiative, and will be exporting its products to markets in sub-Saharan Africa (Ohene-Kanadur, 2019). Operating under the 1D1F initiative, the company is currently receiving incentives such as tax holidays, import duty waivers and an interest rate subsidy to help build its capacity and competitiveness, thus giving it greater productivity and efficiency.

Ekumfi Fruits and Juices Company Limited was the first factory to be established under the One District One Factory initiative (Yaw 2018). It has the capacity to process and package about 80 tonnes of fruit a day and is expected to process a total of about 25,600 tonnes of fruit a year. A total of 250 persons will be employed at the factory, with over 5,000 jobs, direct and indirect, being created as a result.

Recycling and cleaner materials are a key option in industry's role in sustainable development and deep decarbonization, and one of the materials with potentially high future growth in GHG emissions is plastic. Global life-cycle GHG emissions from conventional plastics were 1.7 Gt of CO_2 eq. in 2015 and could grow to 6.5 Gt CO_2 eq. in 2050 as a continuation of the current trajectory according to Zheng and Suh (2019), implying that GHG emissions could reach 15% of the global carbon budget.

Box 17.8 provides details of the EU's plastic management strategy and African plastic reduction strategies.

Box 17.8 Case study: reduction of the carbon footprint of plastics

There are several options for reducing the GHG emissions from plastics, including bio-based plastics, renewable energy use in their production, recycling and demand reductions. According to Zhen and Suh (2019) none of these strategies can stand alone, though a particularly important measure is to introduce renewable energy into the production and to increase the plastic recycling rate.

The demand for plastics in Europe in 2016 was 49.9 million tonnes according to the European Strategy for Plastics of the European Commission (EU, 2018), and the plastic waste collected in Europe in 2016 was 27.1 million tonnes. Plastic packaging, which has a shorter lifetime (a few days to a few weeks), quickly becomes waste and accounts for a large share of the EU's plastic waste. But many plastic articles have a longer lifetime, more than a year (e.g., construction materials, automotive parts, household appliances etc.). This plastic waste becomes available only after several years, and for various reasons is often more difficult to recycle. Of the 27.1 million tonnes of plastic waste collected in Europe in 2016, 31.1% went to recycling facilities, or 8.4 million tonnes.

The remaining 68.9% share of plastic waste is not recyclable in a cost-effective manner with current technology, so it is sent to landfills or incinerators (disposal or energy recovery).

A key action on the part of the European Strategy for Plastics is to call for voluntary pledges to use more recycled plastic materials in Europe by 2025. In Annex III of the Strategy, the European

Commission called on industry to submit voluntary pledges in order to ensure that by 2025 ten million tonnes of recycled plastics find their way into products on the EU market.

By the end of 2018, seventy pledges had been submitted to the European Commission by companies and business organizations, including business organizations that represent the full supply chains for the major plastic materials currently recycled in Europe, namely polyolefins (POs), including polyethylene (PE) and polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC) and expanded polystyrene (EPS).

Thirty-four African countries have banned single-use plastics. Knoblauch et al. (2018) have assessed what is driving these policies and conclude that reduced plastic consumption in terms of bags have mainly been implemented based on taxes in industrialized countries. In developing countries the policies have been driven more by the aim of avoiding visible litter and its local environmental impacts, and the major policy instrument to reduce the waste have been bans. In terms of governance it was also concluded that the plastic reduction strategies of industrialized countries were greatly influenced by international political movements, including NGOs, while strategies in developing countries were mainly driven by national policy priorities.

17.3.3.8 Cross-sectoral digitalization

Digital technologies could potentially disrupt production processes in nearly every sector of the economy, from agriculture (precision agriculture), transport (self-driving cars), mining (autonomous vehicles), manufacturing (robotics, sensors) and retail (e-commerce) to finance (e-trading), etc., possibly creating the next generation of sustainability challenges. The contributions of digital technology could raise labour, energy, resource and carbon productivity, and lower production costs, expand access, dematerialize production (from physical books to e-books), enable the use of big data (disease epidemiology and drug design) and provide online services (procurement, licenses, and permits), and there could be an attractive potential for coupling digitalization and transitions to decarbonization pathways. An essential priority would then be to develop innovation roadmaps to improve understanding of the potential sustainable development benefits and risks of digitalization.

Over the past two centuries, the trend towards urbanization has rapidly accelerated (TWI2050, The World in 2050, 2018). The Shared Socioeconomic Pathways (SSP) scenarios assume that around 60% of the human population will live in urban areas by 2030 and around 70% by 2050. The emergence of smart cities in conjunction with the digital revolution facilitates the rapid uptake of more localized technologies and production processes such as energy, waste, transportation and water. Digital technologies could also help to drive decarbonization in sectors with high GHG emission intensities, such as energy, transport, agriculture and industry. Smart water management through smart pipes, for example, could reduce water consumption by up to 15%. Smart energy through energy efficiency and greater access to renewable energy could save 1.3 billion W/Mh in 2030. Smart agriculture could save 251 trillion m^3 of water in 2030. All these digital solutions with sustainability benefits could cut 20% of global CO_2 equivalent emissions in 2030 (Global e-Sustainability Initiative 2016).

The digital revolution, including virtual and augmented reality (virtual reality and AR), additive manufacturing (AM), artificial intelligence (AI), deep learning, robotics, big data, the Internet of Things (IoT) and automated decision-making systems, has entered the public discourse in many countries (TWI2050, The Digital Revolution and Sustainable Development, 2019). The digital transformation could radically alter all dimensions of global societies and economies, and it could therefore change the interpretation of the sustainability paradigm itself.

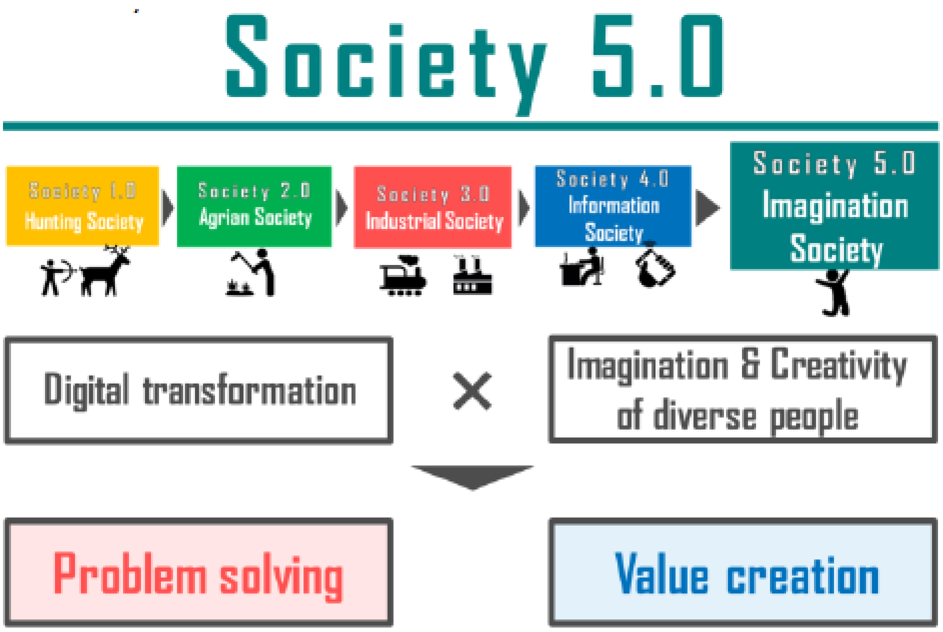
(WBSD 2019) has assessed the potential of communication technologies (ICT) in the energy, transportation, building, industry and other sectors to contribute to the transition to a global low-carbon economy (Energy, 2019). The potential is estimated to be around 15% CO_2 equivalent emission reductions in 2020 compared with a business as usual scenario. A range of ICT solutions have been highlighted, including smart motors and industrial process management in industry, traffic flow management and efficient motors in transport, smart logistics and smart energy systems.

An example of how digitalization could change the future in terms of the Japanese Society 5.0 vision is provided in Box 17.9.

Box 17.9 Case study: Digitalization plans in Japan

In its 2018 Policy and Action document, the Japanese Business Federation (Keidanren) launched Society 5.0 (Keidanren Japanese Business Federation 2018). In the past humanity lived in Hunting Society (Society 1.0), Agrarian Society (Society 2.0), Industrial Society (Society 3.0) and the Information Society (Society 4.0), while the future will be the Imagination Society (Society 5.0). Society 5.0 will be an Imagination Society where digital transformation combines with imagination and the creativity of diverse people to solve social problems and create value, as illustrated in Figure 2.

The aim of Society 5.0 is to enable all people to pursue their own happiness and lifestyles and play their parts by unleashing imagination and creativity to achieve sustainable development in harmony with nature through the resolution of social issues. This concept is aligned with the Sustainable Development Goals in order to solve global issues and create sustainable societies. The concept will be realized as Society 5.0 brings about creative problem-solving is several key sectors (city, energy, health-care, agriculture and food, logistics, manufacturing and services, finance and public services) supported by digital transformation.



Box 17.9 Figure 1 The nature of Society 5.0 (Keidanren, 2018)

See (Actions) and Grey Literature

To achieve smart cities, Society 5.0 aimed to facilitate diverse life-styles and business success while the quality of life offered by these options will be enhanced. It is also its aim to offer high-standard medical and education services. Autonomous vehicles will be available and integrated with smart grid systems in order to facilitate mobility and flexibility in energy supply with a high share of renewable energy. The energy system will include microgrids, renewable with demand-side controls aligned with local conditions.

Artificial intelligence (AI) will be used to facilitate a low-cost and effective health system providing medical and wellness support services and telemedicine. It is expected that these systems can be used to facilitate welfare improvements in both high- and low-income countries.

Agriculture and food systems will benefit from remote management and monitoring systems, and food waste and losses will be minimized through the coordination of stock, delivery times and volumes, and transportation routes. Smart logistics can also be used to facilitate the rapid growth of e-commerce and the globalization of supply chains. AI could be used to manage data on procurement, production, transportation and sales on real-time platforms and to predict supply and demand.

AI is also expected to be a useful tool in relation to the financial system, including both finance for new value-creating activities and the creation of new flexible international currency systems such as cryptocurrencies.

Seen from a Japanese perspective, it is expected that bringing Society 5.0 forward could help speed up partnerships around the world (Keidanren, 2018).

17.3.3.9 Mitigation-adaptation relations

Climate change impacts at various spatial and temporal scales, calls for new approaches in order to integrate climate mitigation and adaptation in sustainable development. The working group II of the IPCC Fifth Assessment report (AR5) on climate change impacts and adaptation concluded that the development of climate resilient pathways could support the implementation of joint sustainable development and climate mitigation and adaptation policies in a way where synergies are created and tradeoffs avoided or mitigated (Denton et al, 2014). It was established that climate change already today constitutes a threat to sustainable development for some sectors and regions, and that the negative consequences will only increase in the future. Sustainable development could be threatened in key areas, which are also main areas targeted in the UN 2030 framework on sustainable development for all. These areas include access to food-, water-, and energy, health and poverty alleviation, and they are closely interlinked with decarbonization strategies. In this context climate change mitigation and adaptation responses are important means to avoid that sustainable development is impeded.

Climate actions, including climate change mitigation and adaptation, are highly scale dependent and solutions are very context specific. Likewise, sustainable development depends on socioeconomic-, cultural-, institutional- and bio-physical- contexts at different scales, from local to regional or even continental. This calls for alternative and complex approaches for studying how sustainable development and climate actions can me aligned.

Especially in developing countries, a strong link exists between sustainable development, vulnerability and climate risks as limited economic, social and institutional resources here often result in low adaptive capacities and high vulnerability. Similarly, the limitations in resources also constitutes key elements leading to a weak capacity in relation to climate change mitigation (Jakob et al., 2014)). Societal transitions to climate resilient societies require transformational or systemic changes, which also have important implications for the suite of available sustainable development pathways (Kates et al., 2012; Lemos et al., 2013). (Thornton and Comberti 2017) points to the need for social-ecological transformations if synergies between mitigation and adaptation are going to be captured based on the argument that incremental adaptation will not be sufficient, when climate change impacts can be extreme or rapid, and when deep decarbonization simultaneously involve societal transformations.

Examples of interactions between sustainable development and climate change mitigation and adaptation will be given in the following as a basis for identifying cross sectoral interactions, key synergies and tradeoffs, and policy implications.

The Land use sectors have been highlighted as major areas, were cross sectoral interactions can exist. Berry et al., (2015) based on literature review identified water saving and irrigation techniques in agriculture as attractive adaptation options in agriculture, which could have positive synergies with mitigation in terms increased soil carbon, reduced energy consumption, and reduced CH_4 emissions from intermittent rice paddy irrigation. The measures could, however, reduce water flows in rivers and could adversely affect wetlands and biodiversity. The study also concluded that afforestation could reduce peak water flows, and imply increased carbon sequestration. but tradeoffs could emerge in relation to increased water demand.

Bryan et al., (2013) identified a range of synergies and tradeoffs across adaptation, mitigation and sustainable development goals given diverse climatic and ecological conditions in Kenya. Improved management of soil fertility and improved livestock feeding practices could provide benefits to both climate change mitigation and adaptation, and could also increase the income generation of farming. However, other improvements in agricultural management in Kenya, as for example soil water conservation, could only provide benefits across all three domains in some specific sub-regions. In order to harvest the full value of more triple win strategies in agriculture, it was concluded that more context specific research is needed.

Hydro power dams are among the low cost mitigation options, but could have serious tradeoffs in relation to key sustainable development aspects since the dams in terms of water and land availability can have negative effects on ecosystems and livelihoods, and thereby could imply increased vulnerabilities. For example, dam building will impact downstream flooding, ecosystem functioning and agricultural production of communities at a catchment scale. Sivongxay et al., (2017) found that the construction of a central dam in Laos could have considerable positive impacts on downstream communities, including benefits to employment and income generation from tourism as a consequence of investment in transport infrastructure in relation to the construction. The dam could ,however, also have adverse impacts to for example, river fisheries, but it was concluded that the benefits in total would be greater than the costs. Okuku et al., (2016) examined the impacts to livelihoods of reservoir construction for hydropower generation on the Tana river in Kenya and observed that negative impacts further downstream clearly outweighed the benefits in the vicinity of the reservoir. Agricultural practices near the river, including floodplain pastoralism and wetland agriculture were in particular affected. It was finally concluded that increased stakeholder involvement in relation to the planning of the reservoir could have minimized some the negative impacts.

There is an increasing number of cities involved in voluntary actions and networks aiming at the development of integrated plans for sustainable development and climate change mitigation and adaptation and mitigation, and the cities involved both belong to high- and low income countries of the world. Grafakos et al., (2019) and Sanchez Rodriguez et al., (2018) concluded that cities are an obvious place for the development of plans, which can capture several synergies between sustainable development and climate resilient pathways. Kim and Grafakos, (2019) and Landauer et al., (2019) along the same lines concluded that cities are an obvious platform for the development of integrated planning effort because the scale of policies and actions which potentially could match the different policy domains. Kim and Grafakos, (2019) assessed the level of integration of mitigation and adaptation in urban climate change plans across 44 major Latin American cities, and it was concluded that the integration of climate change mitigation and adaption plans were very weak in about half of the cities and limited donor finance was a main barrier. In addition to limited finance for integrated policy implementation Kim and Grafakos, (2019) and Landauer et al., (2019) also mentioned barriers in relation to governance, and to missing- or weak legal frameworks. Integration of SDGs with adaptation could help to increase the will of politicians to implement climate actions, and could accordingly provide stronger arguments for investing the required resources (Sanchez Rodriguez et al., 2018).

The local integration of planning and policy implementation practices were also studied by Newell et al., (2018) in a study for eleven Canadian communities. It was concluded, that in order to put plans into practice a deeper understanding needs to be established about potential synergies and tradeoffs between sustainable development, and climate change mitigation and adaptation. A model was applied to the evaluation of key impacts area including energy innovation, transportation, greening of the cities, and city life, and the impact evaluation came to the conclusion that multiple benefits, costs, and conflicting areas could be involved, and that it therefore was recommended to involve a broad range of stakeholders in policy implementation.

Several studies have highlighted that the lack of finance for integrated policy implementation across sustainable development and climate change mitigation and adaptation, and Locatelli et al., (2016) point to similar conclusions in relation to finance based on interviews with multilateral development banks, green funds, and government organizations in relation to the agricultural and forestry sectors. International climate finance has been totally dominated by mitigation projects, and the interviewed were asked about their willingness to change this balance and to commit more resources to projects, which both address climate change mitigation and adaptation. The interviewed agreed that there could be several synergies between climate change mitigation and adaptation, and that it could be effective to go for more integrated projects. More than two-thirds among the interviewed, however, raised concerns about that integrated project could be too complicated and that more alignment of financial models across different policy domains could impose larger financial risks. Another barrier mentioned by the finance was, that mitigation projects primarily were aimed as GHG emission reduction, while adaptation projects had more national benefits and also responded to community development, equity and fairness.

The financial sector

The financial sector is considered to be a main sector in managing the transition to a low-carbon society. On the one hand the sector may face serious asset risks, including transitional risks, physical risks and liability risks. On the other hand it also stands to gain from participation in green finance and investments (Dikau and Volz, 2019). The transition risks refer to cases where international climate policies induce changes in asset values, prices or economic structures, making investments less profitable. The physical risks refer to climate change hazards for assets, while liability risk refers to lost asset values, for example in term of stranded assets.

Examples of how the financial sector has addressed these issues are given in what follows, including the risk management approach being developed by central banks and financial institutions, the financial strategy of the Multilateral Development Banks (MDBs) and public–private partnerships, and the issue of how sustainable development priorities and the management of stranded investments can be aligned.

Dikau and Volz (2019) distinguish risk management approaches in relation to whether central banks and financial institutions react to potential climate risks in their portfolios, or whether they choose to be proactive in supporting a green transition and the more general policy objectives of sustainable development. It is argued that going for a proactive role requires a specific legal mandate, which is in conflict with the traditional mandate of many advanced economies to work for financial and price stability. This is different from what happens in many developing and emerging economies, where the central banks have taken a more active role in green finance. Going for a broader mandate of central banks could be based on the argument that climate change and other environmental impacts are externalities and that the financial markets suffer from market failures within these areas, a failure that might somehow be corrected by central-bank finance.

Battiston et al (2017) conducted a climate stress test of financial systems in the US and the EU, which concluded that investment and pension fund portfolios in particular are very sensitive to climate policies and associated financial risks. Energy-intensive industries are a very large proportion of the vulnerable sectors, much larger than the fossil-fuel industry. Based on this it is concluded that a climate stress test should be implemented in the financial sector.

The Multilateral Development Banks (MDBs) have taken a leading role in promoting international climate finance (MDB, 2019). A. Bhattacharya et al. (2018) conclude that they could have a particularly strong international strong position in helping to tackle a broad range of challenges like climate change, peace and migration based on both their local project engagements and their international position, but that gaining the full benefits of this role requires that a strong mandate for these activities should be in place rather than the present situation, where the mandates within different policy priority areas are more ad hoc. MDBs have official mandates for allocating a given share of their investment to climate change, which for most of them has been a share of 25% up to 2018 (MDB, 2019). Climate finance is linked to meeting the goals of the Paris Agreement, and it also refere to more general development goals in terms of just transitions in partnership with national development banks and other financial institutions. Another goal is to mobilize co-finance from the private sector.

Just transitions

Deep decarbonization will necessitate far reaching economy-wide transformations that will have implications beyond the fossil-fuel industry. The term “just transition” has become synonymous with social justice issues involving social groups and communities that have been marginalized and excluded from the resource wealth of fossil fuel-driven economies or communities affected by racial or gender-based discrimination and inequalities.

Just transition knits environmental justice to climate action, thus signalling the drive for social change to respond to a stronger social impetus to enable climate policy.

Over the last few years, the topic of “stranded assets” resulting from a transition to a low-carbon economy and environment-related risk factors has emerged. The risk of assets becoming stranded is linked to various economic, social and environmental factors. However, climate change and changing regulations remain a key catalyst for stranding (IISD, 2018). Several countries are putting in place a carbon policy. As climate change becomes more substantive, and with increased climate shocks, this, coupled with evolving social norms and the condemnation of fossil fuels, there will be a tendency to divest from fossil fuels (Bretschger et al., 2018).

Stranding resource wealth as a result of complying with environmental regulations to reduce GHG emissions may be a way to safeguard intergenerational equity (or just transitions). This is mainly because stranding presents an important opportunity for environmental sustainability by tapping into a rich land resource base that most countries, especially oil-producing countries, can take advantage of. Mining already competes with food security and other productive uses of land, especially in smaller countries. Mining is also a major contributor to land degradation. Hence, accelerating efforts towards sustainability will need to accompany other land restoration and renewal efforts.

Keeping temperatures down to below the goals of the Paris Agreement will have implications for resources in the energy sector that will face heightened risks of becoming stranded, as climate policies, social norms and pressure continue to mount. For many developing countries, however, extractives-led growth can be perceived as a route to a prosperity that will enable resource rents to fund broad-based sustainable development priorities. Below-ground resources in the poorer countries in the Global South are seen from the lens of economic growth, being viewed a ticket out of poverty and aid dependence. as a result, the transition away from fossil fuels may prove more difficult as a result of misallocations of capital due to delayed disinvestment (IPCC 2014). Also, unexpected tightenings of carbon emissions policies could trigger a re-pricing of carbon-intensive assets and a negative supply shock due to changes in 'energy use and second round effects of financial markets' (Batten et al., 2016). The mispricing of stranded assets is also considered to be a systemic risk and a threat to financial viability.

The just transition paradigm is gaining ground, as it makes explicit the burden that divestments from fossil fuels will pose to those communities who are reliant on high-carbon industries. Critics of the just transition argue that the debate has been narrowly skewed to labour rights. To a large degree, attention is given to challenges faced by workers in the coal-mining industry and other carbon-intensive sectors. However, some critics argue that the demand for a low-carbon future is being conflated with coal fines and workers' rights. For example, in some poorer countries that are especially reliant on fossil-fuel production, the latter generates a significant fraction of overall direct and indirect employment, supports a major portion of spending power, drives a significant share of GDP and may provide a large share of foreign exchange or public-sector revenues.

Nonetheless, a policy of deliberately leaving fossil fuels in the ground has been put forward as a way to support climate action and to avoid harmful emissions as a result of greenhouse gas emissions. Beyond the deliberate approach of stranding assets, the latter have suffered from unanticipated or premature write-downs, devaluations or market failure, with resultant conversion to liabilities (Ansar et al., 2013). They can come about as a result of various, often environment-related factors, including especially climate change, as in the case where risks are not taken into consideration in valuing assets, and mispricing can result. This may lead to significant over-exposure to environmentally unsustainable assets in financial and economic systems, as is evident in those parts of the world economy that have either ignored the inherent risks of relying on such assets or failed to transform economic production and benefits to reduce the risk of such assets attaining liability status.

Accelerating the process of integrating environmental externalities into asset valuations will inevitably demand a focus on climate change as the largest market failure. The introduction of a carbon tax is one way to introduce a shift in global energy systems and to increase efforts to keep 'dirty' fuels in the ground (WB, 2017; McGlade and Ekins, 2015).

Some estimates suggest that to arrive at a fifty percent chance of keeping global warming below 2°C in the course of the 21st century, cumulative emissions between 2011 and 2050 must be reduced to 1,100 Gt CO_2.

In addition, if mineral resources are stranded, this will provide significant scope for avoided emissions and will enable environmental sustainability. Estimates suggest that a third of oil reserves, half of gas reserves and more than 80% of known coal reserves should remain unused in order to meet the global temperature targets of the Paris Agreement (McGlade and Ekins 2015). Shutting down the fossil-fuel industry will have winners and losers, and leapfrogging will depend on where countries are on the energy ladder. Banks, shareholder companies, faith groups, large insurance companies, pension funds and non-profit organizations and investors are divesting away from fossil fuels. For instance, Amundi, the tenth largest asset manager in the world, with investments from pensions and savings worth 1.4 trillion EURs, recently announced that it will not invest in companies that make more than 30 per cent of their business from coal (Environmental Finance, 2019). The same divestment trends can be observed with sovereign wealth funds, with Ireland which possesses EUR 8 billion, becoming the first country in 2018 to commit to divest away from fossil fuels (The Guardian, 2018).

Nonetheless, much emphasis is placed on the demand for fossil-fuel energy and how to reduce it, rather than supply. In addition, investments are equally important in the transition process. Not making the right investment choices will determine either a climate-smart pathway or enable an inefficient high-carbon future. In short, investments in mineral exploration, the development of fossil fuel reserves, new constructions of pipelines and coal-fired power plants will run the risk of becoming stranded assets under the aspirations of the Paris Agreement (IISD 2018).

In addition, accelerating the transition and treating stranding assets as part of the policy mix has implications for equity and extraction cycles, particularly for countries that have already taken part in the carbon depletion cycle. For instance, many developing countries that have recently discovered oil tend to view the extraction of mineral resources as one of their sovereign rights (IISD 2018). In Africa, fairness and equity with respect to global negotiations will be a concern and may have to continue significantly longer to support development goals.

Developing countries with considerable fossil-fuel reserves might not have the advantages of developed economies able to read and respond to the market and policy signals that may favour a seamless divestment transition. “The transition to a low carbon development will be dependent on international assistance to compensate the displacement of fossil fuel sector and climate finance to support green growth in poorer economies” (Bradley et al. 2018).Building the capacity for the transition away from fossil fuels will depend on the extent of the resources, its share in terms of global export markets and whether it is an early stage producer or an established mature fossil-led growth economy. Indeed, transitions towards green economies might be easy for the early-stage producers, as they can be designed from the outset as one of their strategic national goals(Bradley et al. 2018). The pathway towards a just transition will also mean enabling the relevant infrastructural, regulatory and macro-economic and governance frameworks that will support countries in transition to deal with exposure to market risks and to blunt potential negative challenges.

An international global agreement is needed to support asset owners who have to forego their fossil-fuel exploration and perhaps compensate countries that may have to stop digging (Harstad, 2012; Peterson and Weitzel, 2014; Collier and Venables, 2014). There are export market risks to consider for countries that may have to live with fossil fuels they cannot burn and that will incur considerable losses if they are left unable to exploit their resources.

17.3.4 Overview of study conclusions on synergies and trade-offs between sustainable development and deep decarbonization

Tables 17.2 and 17.3 provide an overview of the main synergies and trade-offs between sustainable development policy goals and deep decarbonization pathways based on the report’s conclusions in Chapters 3, 4, and 6-12. The Tables will be developed after the FOD, when the results from the other chapters become ready.

Table 17.2 Overview of the results of economy-wide models of links between low stabilization scenarios and SDGs (impacts will be marked by arrows)

SDG link	2 degrees	1.5 degrees	Other targets?
Land occupation electricity			
Forest area			
Biodiversity loss			

Freshwater ecotoxicity			
Marine ecotoxicity			
Marine Eutrophication			
Fossil resource			
Mineral resource			
Unemployment			
GDP per capita			
Energy efficiency			
Renewable energy			
Energy access			
N fertilizer			
Water land			
Water energy			
Human toxicity			
Premature death			
PM 2.5 emissions			
Food price			
Risk of hunger			

Table 17.3 Overview of the results of sectoral links between low stabilization scenarios and SDGs (impacts will be marked by arrows)

Sectoral Mitigation measures	Stabilization scenario	Economic			Social			Environmental		
		Energy security	Sectoral productivity	Local/sectoral employment	Reduced health	Thermal comfort,	Safety disaster	Reduced ecosystem	Reduced water use/pollutio	Reduced land use
Energy	Nuclear									

	Renewable (excluding bioenergy)									
	Coal with CCS									
	BECCS									
	Bioenergy									
Transport	Fuel-switching									
	Technical energy efficiency									
	Energy demand reduction by other means									
Buildings	Fuel-switching									
	Technical energy efficiency									
	Energy demand reduction by other means									
Industry	Fuel-switching									
	Technical energy efficiency									
	Energy demand reduction by other means									

17.3.5 Conclusions on opportunities and challenges to accelerate the transition

The review points to the general conclusions that framing deep decarbonization pathways in the context of sustainable development implies a different set of policy options than in studies, which are primarily driven by climate change mitigation options.

A number of important synergies and trade-offs emerge in relation to sustainable development policy objectives, and there is a general tendency in the studies to stress that meeting low-temperature stabilization levels could imply trade-offs between the rapid penetration of renewable energy options, including large-scale bioenergy use, energy access and food and water provision, and biodiversity. In this way, fast and deep decarbonization, including the deployment of more renewables, could imply increasing energy costs, which in some parts of the world could be in conflict with several SDGs. This is also the case in relation to food access, where climate prices could increase prices. It is therefore important to develop cross-cutting plans, including coverage of energy, water, agriculture and economic development, and to employ a broad cross-sectoral policy perspective when policies are implemented.

Deep decarbonization implies that large and economically very important sectors related to the fossil-fuel industry will have to be reduced and that similar challenges are related to stranded assets. Some studies have addressed how stakeholders might be involved in finding new development opportunities, but there is still a limitation in the literature when it comes to linking formal modelling results to feasibility issues and broader decision-making perspectives, including equity and finance.

The UN SDG framework and the UNFCCC have helped ensure that countries, regions, the private sector and the research community are all in the process of developing studies on how a broader range of policy objectives can be aligned. Stakeholder interactions and partnerships are emphasized as an important element in making policies both realistic and capable of implementation. However, at present key barriers to implementation have bene identified, in particular in relation to finance.

The opportunities to accelerate the transition are many, from industry to infrastructure to deep decarbonisation, as has been demonstrated in this chapter. The process of transition is non-linear and complex, and may involve weighing several co-benefits against trade-offs and possible maladaptation or mal-mitigation choices. Some of the sectors that currently display unsustainable practices constitute the greatest opportunity for change and for technological disruption: the possibility of moving to climate-smart cities, greening current infrastructure to avoid locked in negative emissions and enabling green industrialization, especially in regions where industrialization has not been fully developed, all represent important transition pathways. Nonetheless, none of these opportunities offers a perfect solution, as actions must be balanced against key national development priorities and net gains from adaptation and mitigation actions. Governments will have to consider both short- and long-term benefits and will be sensitive to taking action that may reduce their policy manoeuverability or their ability to create new jobs and afford the relevant social protection systems.

Challenges that may affect food, water and energy security may not just require technological and financial resources, but also localized solutions that may enable the transition process. Indeed, the challenge is not to take one response option to the detriment of the other, but to consider both mitigation and adaptation as composite strategies. Indeed, mitigation and adaptation opportunities must be regarded as part of a chain that enables sustainable development and supports a development trajectory towards safe, clean and secure growth.

It is equally important to assert that, in spite of technological progress, rapid change with digitalization and the ability of social groups to organize themselves into veritable power groups that can exert pressure and speak truth to power are becoming key indicators of transformational change. Across the globe there are increasing signs that social behaviour and culture can act as a force for change in that social groups can either support the acceleration towards greater climate action or inhibit the process.

Experiences show that framing sustainable development can help to accelerate transitions, though in practice implementing broader policy agendas jointly requires the establishment of cross-sectoral partnerships and long-term stable policy environments.

It can be argued that accelerating the transition will be context-specific and will also necessitate well-coordinated sets of policies across several sectors. Many governments have made commitments to the 2030 Agenda and to the Paris Agreement, but have not made significant inroads in leveraging synergies between these agendas, especially with regard to climate action. Policy is a key enabler in making the low-carbon transition happen. This means putting in place the relevant macroeconomic framework models and tools that will enable regulation to be aligned with sustainable development principles.

17.3.5.1 Robust findings, uncertainties and missing areas in the literature (sectors, regions, time frame)

Based on the studies reviewed in this chapter and the conclusions of other chapters, the robust findings include the following:

There is a growing literature, including modelling studies, addressing the various side impacts of climate change stabilization scenarios, including access to energy, food and water, health, land use and equity.

There is a high level of agreement about the impact areas, where there could be synergies and trade-offs between low-stabilization scenarios and the impacts on different sustainable development dimensions. Addressing the trade-offs in particular is a necessary condition for implementing low-temperature stabilization targets with the large-scale global participation of countries and stakeholders. Increasing attention is being given to just transitions and compensation in studies of implementation challenges.

It is not very clear, based on the studies, whether linking policies for sustainable development will help to implement deep decarbonization policies. However, it is clear that deep decarbonization influences more general economic policies and structural changes that need to be addressed in policies and governance frameworks.

Cross-sectoral issues also need to be addressed urgently in policy implementation, for example in relation to the water-land-energy nexus.

Transformation away from fossil fuels is playing a major role in policy implementation, while just transitions and finance are also playing a role, and there is now an emerging literature addressing the scale of the challenges.

There is a difference between how sustainable development policies have been designed in low- and developed countries respectively. Examples of these differences are seen in relation to food-waste reduction, plastics and green industries. Governments have taken a leading role in low-income countries, while more is left to the market in developed countries (including green taxes and CSR).

New actors are being given a more important role in the implementation of deep decarbonization pathways, including the financial sector, companies and international city networks.

Areas with limited studies:

NDCs and SDG policies are not yet so well covered by national plans and studies. Research on achieving a coherent implementation framework for the Paris Agreement and the UN 2030 targets is also limited.

Economic development in regions and countries that are still very dependent on fossil fuels is scarce.

Urban sustainability, including climate change adaptation and mitigation plans and related implementation issues, have not been comprehensively reviewed in the literature.

Social innovation and behavioural changes are highlighted as important in the literature, but few studies have actually evaluated development trends and experiences.

The engagement of society at large in all parts of the world in stabilization scenarios for low-temperature targets has not been comprehensively assessed.

The literature on implementation strategies that can close the gap between modelling studies and policy feasibility is limited.

17.4 Key barriers and enablers of the transition: synthesizing results

This section provides a deep and broad synthesis of theory (section 17.2) and evidence (section 17.3) to identify factors enabling or inhibiting the transition to sustainable low-carbon futures. Following the literature on sustainability transitions, the section finds that there is rarely a single factor promoting or preventing such a transition. Rather, such a marked departure typically entails several factors, ranging from technological innovations to shifts in markets, and from policies and governance arrangements to shifts in belief systems and market forces. All this comes together in a co-evolutionary process that unfolds at the global, transnational and local scales over several decades (Hansen and Nygaard 2014; Rogge et al. 2017). While transitions necessarily follow context-specific trajectories, more general lessons can be distilled by comparing the empirical details with both the system level and narrower explanations for change.

Sections 17.2 and 17.3 confirm that transitions often confront multiple barriers. Previous sections also underline a related need to move beyond focusing on “rational” assessments of the costs and benefits of policies and technologies to overcome these multiple barriers. For example, the case of coal-fired power in China (section 17.3) shows that a transition to a lower carbon system is unlikely to happen even if models find it to be technically feasible and cost-effective with a carbon tax and feed-in tariffs. Rather, this requires breaking locked-in high-carbon technological trajectories, path dependencies and resistance to change from industries and actors that benefit from the current systems (Rogge et al. 2017). Lock-in effects may be weaker in sectors and policy areas where fewer technologies exist, potentially opening the door to innovations that embed the climate into broader sustainability objectives (i.e., technologies and innovations that support the integration between food, water and energy goals). They may still arise when there are significant information asymmetries and high-cost barriers to action, as can occur when working across multiple climate and development-related sectors (Kemp and Never 2017b).

However, those same factors that may serve to impede a transition (i.e., organizational structure, behaviour, technological lock-in) can also ‘flip’ to enable it (Burch, 2010; Lee et al., 2016), and the framing of policies in relation to a sustainable development agenda can also create a stronger basis and policy support. The technological developments and broader cultural changes that may generate new social demands on infrastructure to contribute to sustainable development, like sustainable infrastructural transitions, will involve a process of social learning. But it is also important to note that strong shocks to these systems, including accelerating climate change impacts, economic crises and political changes, may provide crucial openings for accelerated transitions to sustainable systems through fundamental institutional changes (Broto, et al. 2014). Key enabling factors appear to be individual and collective action, including leadership and education; financial, material and technical contexts that foster innovation; supportive policy and governance dynamics (at multiple levels) that allow for both agility and coherence; measures to recognize and address the equity challenges inherent in the transition; and long-range, holistic planning that explicitly seeks synergies between climate change and sustainable development while avoiding trade-offs. The sections that follow integrate and assess these key categories of barriers to, and enablers of, an accelerated transition to sustainable development pathways.

17.4.1 Individual and collective action

Transitions toward more sustainable development pathways are both an individual and a collective challenge, requiring an examination of the role of values, attitudes and beliefs in shaping behaviour, and the dynamics of social movements and education. In these domains, actors with conflicting interests will compete to frame renewable energy to either 'build or erode' the legitimacy of the technology, and these contested framing sites can occur between incumbent and emerging actors or between actors in new but competing energy spaces (Rosenbloom et al., 2016). How narratives are built around specific emerging technologies and how local values are integrated into visions of the future have relevance for how these experiments are managed and enabled to expand.

17.4.2 Social movements and education

Sustainable development and deep decarbonization will involve people and communities being connected locally through various means, including globally via the internet and digital technologies (Bradbury, 2015, Scharmer, C, Kaufer 2015, Scharmer, 2018), in ways that form social fields that allow sustainability to happen (see also Gillard et al. 2016) and prompt other shifts in thinking and behaviours consistent with the 1.5°C goal (O'Brien, 2018; Veciana and Ottmar 2018).This does not apply only to adults: as seen in the "Friday for Future" marches, children are also starting to take over responsibility and involve themselves politically (Peterson, 2019).

It was Theory-U (Scharmer, 2008, building on the work of scholar's like Schein, Lewin or Senge) that inspired a so-called "mass open online course" (MOOC) jointly initiated by the Buthan Happiness Institute and German Technical Assistance (GIZ) in 2015, since when it has been developed further and adapted to transform business, society and self. It joins people from different professions, cultures and continents in shared discussions and practices of sustainability. The Presencing Institute at the Massachusetts Institute for Technology (MIT) has also employed action research and cultivated a large international community of change toward similar ends.

Moreover, approaches like the "Art of Hosting" (Sandfort and Quick, 2015) and qualitative research methods like storytelling and first-person research, as well as second-person inquiries (e.g., Varela, 1999; Scharmer and Kaufer, 2015), have been employed to bridge differences in cultures and science, as well as to forge connections between those working on climate change and sustainable development.

The results from this research community shows how experiential learning takes place and how it develops bonding between people, society and nature. Just to mention a few examples, this can be achieved by going jointly and consciously into nature (Gioacchino, 2019) and by creating spaces for intensive dialogue sessions with colleagues (Goldman-Schuyler et al., 2017) in one country and across continents, working with people from North and South America, Europe, Asia and Africa (Schuyler et al., 2017) and forming an u.lab hub, which means following the MIT-u.lab course with a local community (Pomeroy and Oliver 2018). Others have pointed to social networks such as the "transition initiative" (Hopkins, 2010), eco-village networks (see e.g., Barani, et al. 2018), civil-society movements (Seyfang and Smith, 2007) and intentional communities (see e.g., Grinde, et al. 2018) generating the shared understandings that are central to inner and outer transitions.

In some cases, these networks build on principles like permaculture to encourage people to "observe and interact," "produce no waste" and "design from patterns to details" not only in agriculture and gardening, but also in sustainable business and technologies (see e.g., Lessem, 2018; Ferguson and Lovell, 2014).

A related of line of inquiry involves education for sustainable development. One of the core insights from this research is that education is not only about working with children and students in the classroom; rather, it entails fostering a lifelong learning process that involves sustained interactions across all ages and social segments (e.g., Hume & Barry, 2015). Some authors have pointed to good communication directly or through the internet as the key to facilitating this learning (Sandfort and Quick, 2015). Others have noted that transformative learning—a deepening of the learning process—is critical because it helps to induce both shared awareness and collective actions (e.g., Brundiers and Wiek, 2010; Singleton, 2015; Wamsler et al., 2018). A final area of work points to the importance of moving from awareness-raising knowledge production (Pelling et al. et al., 2015). The accumulation of applied knowledge is leading increasingly to the co-designing of participatory research with local stakeholders who are investigating and transforming their own situations in line with climate action and sustainable development (see e.g., Wiek et al., 2012; Abson et al., 2017; Fazey et al., 2018).

17.4.3 Habits, values and awareness

Many of the cases that explore transitions to sustainable development point to engrained habits, values and awareness levels as among the most persistent yet least visible barriers to a transition. For example, in the transport sector individuals can quickly become accustomed to personal vehicles, making it difficult to transition to sustainable, low-carbon public transport modes. This is made all the more challenging because car manufacturing “incumbents” utilize information campaigns directed at the public, pursue lobbying and consulting with policy-makers, and set technical standards to privilege and prevent the entry of more sustainable innovations (Smink et al. 2015; Turnheim and Nykvist 2019b).

Complicating the problem further is that even well-intentioned top-down programmes initiated by an external actor may in some cases ultimately hinder transformative change (Breukers et al. 2017). For instance, in Delhi, India, attempts to introduce ostensibly more sustainable bus rapid transit (BRT) programmys failed in part due to an arguably top-down approach that had limited public support. It nonetheless may be difficult to gather public support (Bachus and Vanswijgenhoven 2018), and even grassroots initiatives may themselves may be contested and dynamic, making it difficult to generate the collective push to drive a bottom-up transition forward (Håkansson 2018).

However, dominant, top-down approaches and local, grassroots "alternative" approaches and values do overlap and interact. In Manchester, UK, dominant and alternative discourses interact with each other to create sustainable transformations through re-scaling (decentralizing) energy generation, creating local engagement with sustainability, supporting green infrastructure for purposes of cost reduction and the re-claiming of local land, transforming industrial infrastructure, and creating examples of sustainable living (Hodson et al., 2016).

Embedding local values into higher level policy frameworks is similarly of significant concern for forest communities in Nepal and Uganda. Even so, policy intermediaries are not confident that these values will be advanced due largely to an emphasis on carbon accounting and the distribution of benefits (Reckien et al., 2018). In this case, however, norm entrepreneurs were able to promote the importance of local values through the formation of grassroots associations, media campaigns and international support networks (ibid.).

17.4.4 Leadership and innovation that foster collective action

Individuals and organizations, like institutional entrepreneurs, can function to build transformative capacity through collective action (Brodnik and Brown 2018). The transition from a traditional water management system to the Water Sensitive Urban Design (WSUD) model in Melbourne offers an illustration of how whole systems can be changed in an urban system (ibid.).

Private-sector entrepreneurs also play an important role in fostering and accelerating transitions to sustainable development. Sustainable entrepreneurs (SE), for instance, are considered to be those who participate in the development of an innovation, but are also rooted in the incumbent energy-intensive system. SE actors that have developed longer term relationships (formal and informal) with public authorities can have considerable influence on developing novel renewable energy technologies (Gasbarro et al. 2017). Institutions and policies that nurture the activities of sustainable entrepreneurs, in particular small- and medium-sized enterprises (Burch et al. 2016), can facilitate and strengthen transitions toward more sustainable development pathways.

The creation and growth of sustainable energy and clean-tech clusters enable economic development and transformation on regional scales. Clusters can put pressure on incumbent technologies and rules to potentially accelerate energy transitions. Successful clusters are nurtured by multi-institutional and multi-stakeholder actors building institutional support networks, facilitating collaboration between sectors and actors, and promoting learning and social change. Notably, regional economic clusters generate a buzz, which can have a strong influence on public acceptance, support and enthusiasm for sociotechnical transitions (McCauley and Stephens 2012).

In Norway, many incumbent energy firms have already expanded their operations into alternative energy sectors, including producers as well as suppliers (who often follow the lead of producers). Producers are responding to perceived larger-scale changes in the energy landscape (i.e., the green shift), along with uncertainties in their own sectors. While these firms are expanding out of self-interest, the expansion provides more legitimacy to new technology and enables transfer knowledge and resources to be introduced to the developing niche (Steen and Weaver 2017).

Many large, well-established firms are pursuing sustainability agendas, opting for transparency with regard to their greenhouse gas emissions (Kolk et al. 2008; Guenther et al. 2016), supply chain management (Formentini and Taticchi 2016) and sustainable technology or service development (Dangelico et al. 2016).

Transition experiments open pathways that can lead to energy transitions on broader scales. Experiments can build capacity by developing networks and building bridges between diverse actors, leveraging capital from government funds, de-risking private- and public-sector investment and acting as hubs of public education and engagement (Rosenbloom et al, 2018).

17.4.5 Financial, technical and material dynamics

Market-oriented policies, such as carbon taxes and green finance, can promote low-carbon technology and encourage both private and public investment that enables transitions. Policies that are currently being tested include loan guarantees for renewable energy investments in Mali, policy insurance to reduce credit default for the feed-in tariff regime in Germany, or pledge funds to fully finance or partner private firms in order to advance renewable energy projects (Roy et al, 2018). However, there may be some limitations in using carbon pricing alone due to market failures hindering low-carbon investments (Campiglio, 2016) and the high political costs (van der Ploeg, 2011).

Many forms of transformational change to energy systems are not possible when financial systems still privilege investing in unsustainable, carbon-intensive sectors. To a significant degree, the root cause of the failure of traditional financial systems is the undervaluation of both human and natural capital. The exclusion of proper rents for scarcities or for global and local externalities, including climate change, can undermine the larger-scale changes to energy systems (Clark et al. 2018). But even smaller scale low-carbon energy and infrastructure projects can fail to get off the ground if uncertainty and investment risk does not find its way into project planning and bank-lending programmes (Bolton et al. 2016). The EU's previous actions on the "shareholder maximisation norm" and on non-binding measures have created path dependencies, approaches that have limited the EU's flexibility in creating sustainable finance legislation. However, the Sustainable Finance Initiative and the Single Market may prove to be "policy hotspots" for encouraging sustainable finance (Ahlstom, 2019). Taking advantage of these hotspots may be crucial in overcoming path dependencies and setting new ones in motion.

A possible positive turn in this regard is the acceleration in environmental investing (impact and ESG) globally: for instance, evidence that some institutional investors are divesting in coal auguring potentially well into the future. The encouragement of governance and policy reforms that could facilitate greater similar expansions of investment in sustainable firms and sectors (Owen et al. 2018; Clark et al. 2018) could contribute to the dynamic feedback that gives lift and injects momentum into a transition. Also, the degrowth movement, with its focus on sustainability over profitability, has the potential to speed up transformations using alternative practices like fostering the exchange of nonmonetary goods and services (Chiengkul, 2018). However, the movement may thus far be in focus because it has not grappled with the underlying structures of the international political economy.

Ultimately, the adoption of coordinated, multi-sectoral policies targeting new and rapid innovation can help national economies take advantage of widespread decarbonization. Industrial policies that focus on building domestic supply chains and capacities can help states prepare for the influx of renewable technologies (Zenghelis, 2019). Policies that govern green finance need to guide and regulate investment better to prevent asymmetries of information and to balance ecological and financial goals better (Wang and Zhi, 2016).

Material barriers and spatial dynamics are other critical obstacles: often infrastructure and built environments change more slowly than policies and institutions due to the inherently long lifespan of fixed assets (Turnheim and Nykvist 2019b). The example of transport infrastructure in Ontario, Canada, illustrates the need to integrate climate change into these infrastructural decisions in the very short term to combat the risk of being left with unsustainable planning features long into the future, especially combustion engines, significant road networks and trends towards suburbanization (Birch, 2016).

Complicating matters further is that pulling together different projects may require complementary changes to policies and institutions. To illustrate, decentralized renewable energy in Argentina is in an advanced stage of development, but electricity subsidies for consumers handicap supporters of renewable energy, as they compete with the existing firms. A lack of government funds to cover ongoing maintenance costs over the geographical expanse of the country, along with resource shortages in rural locations, poses an additional set of constraints (Schaube et al. 2018).

17.4.6 Governance and institutions

Sustainability transition policies place high demands on the public sector, and a lack of consensus can result in a tension between institutional accountability and stability (Haley, 2017). One of the ways in which institutions acquire influence is by determining whether government agencies with climate and other sector-specific remits work together over the design and implementation of policies. In some contexts, the absence of structures that could build a consensus across different agendas has undermined policy changes that may be conducive to such a transition. In developing megacities, the lack of mechanisms promoting vertical integration across levels have proved to be a constraint (Canitez 2019). Crafting an acceptable cross-agency agreement is often challenging because of mutually reinforcing interactions between institutions and ideas: that is, long-standing, dominant discourses (i.e., grow-now-clean-up later) are embedded within the agency rules and standard operating procedures that shape narrowly focused development plans. These rules and procedures can also determine the interests of key decision-makers (e.g., the head of an environmental agency) in a policy process, leading to incoherent outcomes or policy conflicts. For some, this suggests a need to look not just at ideas and interests, but at broader institutional changes, recognizing that there is a no 'one size fits all' but rather carefully crafted institutional reforms (Kern 2011).

However, introducing these reforms may not be purely a technical exercise. Political, economic and other prevailing power relations can lock in structures, making it difficult to integrate the climate and development agendas. To cite an example where this appears to the case, the distinct lack of integration and movement on energy transition in Australia has developed historically from the country's politico-economic contexts, including the polarization of climate policy, the perception that energy is a national jurisdiction and a matter of national security, neoliberal policies in the energy sector, reliance on fossil fuels and traditional priorities in energy management (supply and affordability) (Warren et al. 2016).

While prices, subsidies and other economic factors influence sustainable development both positively and negatively, Arranz (2017) found that intentional higher-level (or, in the language of socio-technical transitions, "landscape") pressures were the most effective in destabilizing transitions to sustainable development (Falcone and Sica 2015). This suggests that the state can play a key role in destabilizing incumbent energy regimes, a role which is significantly strengthened when there is also public support (Arranz 2017; Avelino et al. 2016). However, regime outsiders have also played a role in destabilizing regimes by being able to combine persuasive narratives with considerable market influence (Arranz 2017). Regulatory taxation, especially if applied at the "acceleration" phase of a transition, can be an important enabling factor by influencing change in long-term social practices and behaviours. Environmental taxes can remove 'locked-in' technology and pressure dominant regimes (Bachus and Vanswijgenhoven 2018).

It is clear that political coalitions affect the speed of transition (Hess 2014). Incumbent industry coalitions, once monolithic due to their financial resources, are now competing with 'green' coalitions in terms of campaign spending. The capacity to attract monetary support for green ballot proposals is crucial to the ability of these green coalitions to compete with industry coalitions (ibid).

In South Korea, where the state was the initiator and enabler of the electricity transition, the latter initially took much longer than anticipated and encountered private-sector resistance. However, when policy-makers took adaptive learning and flexibility into their decision-making processes, public- and private-sector co-evolution occurred, emphasizing the need for collaboration as well as top-down policy-making (Lee et al. 2019).

Ultimately, complementary policies that address the multiple jurisdictions and dimensions of a carbon-intensive energy system simultaneously are more likely to succeed (Burch 2010). In addition, a realistic exit strategy for incumbents is required, as are interventions (or a lack thereof) to provide long-term incentives for renewable energy firms (de Gooyert et al. 2016; Hamman 2019). Despite the transformative potential of novel governance approaches, however, and a trend in climate governance towards greater integration and inclusivity, traditional governance approaches and incrementalism remain dominant (Hölscher et al, 2019). Institutions and organizations must play a key role in the prioritization of climate change across all sectors and scales, and thorough mainstreaming that prioritizes climate is needed in order to destabilize the influence of entrenched interests and pressure existing norms, rules and practices (ibid.).

At least three themes require further research in scholarship on transitions: the role of coalitions in encouraging amenable conditions for transitions, positive and negative feedback resulting from certain policies, and the importance of local contextual factors (governance structures, culture, etc.) (Roberts et al, 2018). Importantly, these themes can emerge as either barriers to or opportunities for transitions.

17.4.7 Equity in a just transition

Energy justice includes affordability, sustainability, equity (accessibility for current and future households) and respect (that innovations do not impose further burdens on particular groups) (Fuso Nerini et al., 2019). Looking at climate change from a justice perspective places the emphasis on a) the protection of vulnerable populations from the impacts of climate change, b) mitigating the effects of the transformations themselves, and c) envisaging an equitable decarbonized world. Neglecting issues of justice risks a backlash against climate action generally, particularly from those who stand to lose from such action (Patterson et al, 2018). Energy justice has been under-represented in the literature on sustainability transitions and in debates on energy transitions. Combining the concept of energy justice with a multi-level perspective framework reveals the dynamics of justice versus injustice at the niche, regime and landscape scales (Jenkins et al., 2018). Explicit interventions to promote sustainability transitions that integrate local spaces into the whole development process are necessary but not sufficient in creating a just transition process (Ehnert et al. 2018; Breukers et al. 2017).

Renewable energy transitions in rural, impoverished locations can simultaneously reinforce and disrupt local power structures and inequalities. Policy interventions to assist the most impoverished individuals in a community gain access to the new energy infrastructure are critical in ensuring that existing inequalities are not reinforced. Individuals who are empowered by energy development projects can influence the onward expansion of sustainable energy to other communities (Ahlborg 2017). In Denmark, for example, grassroots windmill cooperatives in the 1970s opened a pathway to the creation of one of the world's largest wind-energy markets. The unique dynamics of grassroots-led change mean that new technologies and low-carbon initiatives develop strong foundations by being designed, tested and improved in the early stages with reference to the socio-political contexts where they will later grow (Ornetzeder and Rohracher 2013).

Intersectional theory can shine a light on the hidden costs of resource extraction, which go beyond environmental or health risks to include socio-cultural impacts on both communities adjacent to and the workers at these sites (Daum et al, 2018). Indeed, development decisions often do not appropriately integrate the burdens and risks placed on marginalized groups, like indigenous peoples, while risk assessments tend to reinforce existing power imbalances by failing to differentiate between how benefits and risks would impact on certain groups (Kojola, 2018; Healy et al., 2019).

17.4.8 Holistic planning and nexus approach

Poor sectoral coordination and institutional fragmentation have triggered an unsustainable use of resources and threatened the long-term sustainability of food, water and energy security in South Asian countries (Rasul 2016). Greater policy coherence among the three sectors is critical to moving to a sustainable and efficient use of resources. The nexus approach can strengthen coordination. A major shift in the decision-making process in the direction of taking a holistic view and developing institutional mechanisms to coordinate the actions of diverse actors and strengthen complementarities and synergies is required (Rasul, 2016). However, currently the application and implementation of nexus approaches are in their infancy. (Liu et al., 2018) proposes a systematic procedure and provides perspectives on future directions. These include expanding nexus frameworks that take into account interaction linkages with SDGs, incorporating overlooked drivers and regions, diversifying nexus toolboxes, and making these strategies central to policy-making and governance for integrated SDG implementation.

For the processes, (Seyfang & Haxeltine 2012) found a lack of realistic and achievable expectations both among members (internally) and among the wider public (externally), which hampers movement development and growth. The movement could strategically concentrate on developing and promoting short-term steps towards shared long-term visions. Sustainability science must link research on problem structures with a solutions-oriented approach that seeks to understand, conceptualize and foster experiments in how socio-technical innovations for sustainability develop, diffuse and are scaled up (Miller et al. 2014).

Various strategies and processes have been explored that might facilitate the translation of barriers into enablers, accelerating a transition to sustainable development. Common themes include frequent monitoring and system evaluation to reveal the barriers in the first place, collaborative co-creation and visioning of pathways, ambitious goal-setting, strategic tackling of sources of path dependency, iterative evaluations of progress, adaptive management and building in opportunities for agile course-correction at multiple levels of governance. Given the political infeasibility of stable, long-term climate policy, the better choice may be to embrace uncertainty in specific policies but entrench the low-carbon transition as the over-arching goal. Framing climate policy too narrowly, rather than taking a more holistic, sustainable development-oriented approach, may tie success to single policies, rather than allowing for system-wide change. Decarbonization may be encouraged by embedding the transition in a broader socio-economic agenda, focusing on constructing social legitimacy to justify the transformation, encouraging municipalities with a material interest in the transition, and reforming institutions to support long-term transition goals (Rosenbloom et al. 2019). While other factors may also be impeding the energy transition in Australia, in jurisdictions where climate and energy policy have been integrated and harmonized, such as the UK, progress has been made towards transitioning to sustainable energy, perhaps indicating a way forward for Australia and other countries (Warren et al. 2016).

Developing countries that are rich in fossil fuels have the opportunity to reset their development trajectories by focusing on opportunities that will offer resilient development in land-use change, renewable energy generation, and not least more efficient resource planning. (UN- UNDRR 2019) Resource-rich developing countries can chose an alternative pathway and decide to monetize carbon capital and diversify away from high-carbon elements of risk. Countries rich in hydrocarbons can diversify their energy mix and maximize their renewable energy potential. For instance, Namibia, a net importer of electricity, is seeking to reduce its current dependency on hydrocarbons by promoting solar energy. The government has issued permits allowing independent power producers (IPPs) to sell directly to consumers, thus ending the monopoly hitherto enjoyed by the state utility company NamPower.

Cities are important spaces where the momentum can be built to achieve low-carbon transitions (Shaw et al. 2014; Holscher et al. 2019; Burch 2010), especially where centralized energy structures and national governance and politics create deep-rooted challenges for change (Dowling et al. 2018; Meadowcroft 2011). Cities can enter networks and partnerships with other cities and multilevel actors, spaces that are important for capacity-building and accelerating change.

Addressing the uncertainties and complexities associated with local, regional and national sustainable development pathways requires creative methods and participatory processes. These may include powerful visualizations that make the implications of climate change (and decarbonization) clear at the local level (Sheppard et al. 2011; Shaw et al. 2014), other visual aids or ‘progress wheels’ that effectively communicate context (Glaas et al. 2018), storytelling and mapping, and both analogue and digital games.

17.5 Conclusions

- There are as many visions of a sustainable low-carbon future as there are pathways for reaching them. These pathways are characterized by inherent complexities, messiness and uncertainties that are integral to the transition.

- Experiences show that framing sustainable development can help to accelerate transitions, but in practice implementing broader policy agendas jointly requires the establishment of cross-sectoral partnerships and long-term stable policy environments.

- Policy instruments that can green and climate-proof investments and the concomitant infrastructure will secure new green jobs and give sway to the technological innovations that will help accelerate the transition. However, these decisions can be taken in addition to other synergistic actions related to policy and governance coherence. Indeed, if policy is key to the transition, policy coherence across sectors and across national, regional and global plans remain critical factors in enabling, sustaining and supporting transition processes.

- Furthermore, sustainable development and deep decarbonization will involve people and communities that are locally connected through numerous levers of communication, as well as globally via the internet and digital technologies. These modes of communication will help to advance other shifts in thinking and behaviour that are consistent with the 1.5 degree goal.

- The transition process is non-linear and complex, and may involve weighing several co-benefits against trade-offs and possible maladaptation or mal-mitigation choices. Some of the sectors that are currently displaying unsustainable practices represent the greatest opportunity for change and for technological disruptions: the possibility of moving to climate-smart cities, greening current infrastructure to avoid lock-in negative emissions and enabling green industrialization, especially in regions where industrialization has not been fully developed, all represent important transition pathways.

- Accelerating the transition must embrace the multiplicity of responses and the fact that there is no one–size-fits-all approach. Both mitigation and adaptation are composite strategies and relevant parts of the solutions. Indeed, mitigation and adaptation opportunities must be considered as part of a chain that enables sustainable development and supports a development trajectory towards safe, clean and secure growth.

- While the transition can gain traction through the deployment of renewable energy, deep decarbonization and emissions avoided through the stranding of assets, the fact remains that sustainable development provides us with a new lens on how green industrial development deploys innovative technologies and pursues low-carbon emission pathways. Equally, the recycling and use of cleaner materials are key options enabling industry-led development. In addition, digital technologies have a new role to play in displacing material-intensive technologies and enabling cleaner and smarter production processes ranging from agriculture to transport to manufacture. However, while practical solutions abound, behavioural change and shifting norms through pressure groups can also support growth in climate-resilient low-carbon development.

- Indeed, the ability of social groups to organize themselves into veritable power groups that can exert pressure and speak truth to power is becoming a key indicator of transformational change. Across the globe, there are increasing signs that social behaviour and culture can act as a force for change in that social groups can either support the acceleration towards greater climate action or inhibit the process. Transitions are both tangible and intangible. Key enabling factors appear to be leadership (both technical and political); an organizational culture (at multiple levels of governance) of innovation, risk-taking and agility; policy coherence at the local, regional, national and international levels; and a long-range, holistic planning and nexus approach that explicitly seeks synergies between climate change and sustainable development by taking the trade-offs into account (Section 17.4). Synergistic action across the sustainable development value chain will support the transition pathway.

- Transitions are not problem-neutral. They often come with multiple barriers. The chapter has shown that transitions will be dependent on contextual realities, equity considerations and overall rational assessments of the proposed actions and their perceived value or opportunity costs. Transitions will happen discretely almost marginally unless deliberate actions are taken that will scale out low-carbon development processes, enable disruptive technologies and behaviour patterns, and allow for growing social pressures supporting divestment away from fossil fuels to cleaner technologies. Radical shifts towards the greater deployment of renewables and other forms of safe growth will demand bold and deep transformations in behaviour, systems, infrastructure, governance and policy. Adaptation and mitigation are both essential ingredients of transition processes, and short- and long-term strategies are complementary approaches when it comes to supporting the drive towards accelerated and inclusive low-carbon growth.

Frequently Asked Questions

FAQ 17.1 What are the differences and similarities between transition and transformation?

FAQ 17.2 What are the differences and similarities between sustainability, low carbon and just transitions?

FAQ 17.3 Will decarbonization efforts slow or accelerate sustainability transitions?

FAQ 17.4 To what extent are governments integrating the SDGs into their NDCs? To what extent are NDC targets and plans integrated into SDG strategies (and VNRs)?

FAQ 17.5 Are energy systems the most crucial targets for accelerating the transition? What other emissions-intensive sectors offer good prospects?

FAQ 17.6 Are there specific drivers that will offer greater prospects for accelerating the transition? Are there barriers that can reduce the pace, scale and depth of the transition?

Other options:

How are low-carbon technologies, individual behaviour and collective decision-making connected in the context of the transition toward sustainable development?

Will scaling up (or scaling out) existing technologies and practices matter more to the transition to sustainable development than inventing new ones?

What role do considerations of justice and inclusivity play in accelerating the transition toward sustainable development?

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