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

Coordinating Lead Authors: Fatima Denton (Gambia), Kirsten Halsnaes (Denmark)

Lead Authors: Keigo Akimoto (Japan), Sarah Burch (Canada), Cristobal Diaz Morejon (Cuba), Fernando Farias (Chile), Joni Jupesta (Indonesia), Petra Schweizer-Ries (Germany), Ali Shareef (Maldives), Fei Teng (China), Eric Zusman (the United States of America)

Contributing Authors: Morten Andreas Dahl Larsen (Denmark), Antonethe Castaneda (Guatemala)

Review Editors: Diriba Korecha Dadi (Ethiopia), Hermann Held (Germany)

Chapter Scientist: Antonethe Castaneda (Guatemala)

Date of Draft: 17 January 2021

Table of Contents

Executive summary

Accelerating climate actions and the just energy transition are essential to reducing climate risks, as well as achieving water, food and human security, as well as other sustainability priorities (*robust evidence, high agreement)*. Acceleration is not merely about moving faster; it requires steadily broadening and deepening support for climate actions. The broader and deeper this support, the more likely the transition is to be sustainable and a more profound and sustainable system transformation can be enabled and implemented. {17.1.1}

A rapid transition to sustainable development pathways is as desirable as it is difficult. Climate change stems from decades of unsustainable energy production, land-use, production and consumption, as well as governance practices and patterns (*Robust evidence, high agreement*). Changing these practices and patterns requires a fundamental reframing of development. Sustainable development, by emphasising sectoral integration and social inclusion, offers just such a reframing. A sustainable transition must also be socially equitable and just. This equity principle also applies across countries. Developing countries often craft climate responses in decision-making environments with limited resources, deep social divisions and few advanced technologies (*medium evidence, high agreement*). {17.1.1.2}

This reframing must be backed by concrete actions and sincere efforts. Strengthening the "response capacities" of different actors to mitigate and adapt to a changing climate will be necessary (*robust evidence, high agreement*). Response capacities will increase with efforts to align multiple stakeholder interests across levels of decision-making. This alignment will also help achieve synergies and manage trade-offs between climate and other sectoral policies, thus breaking out of sectoral silos and adopting policy-coherent integrated approaches to overcome the challenges involved in promoting cross-sectoral synergies and avoiding trade-offs at multiple levels (*medium evidence, high agreement).*{17.1.1.1.}

Short- and long-term studies of transformation using macroeconomic models and integrated assessment models or IAM have been used to assess the economy-wide impacts of aligning development pathways with sustainable development and climate change. IAMs assess climate change mitigation and SDGs in a very aggregated manner, but many SDGs are strongly related to distribution issues not only between nations but also within them. IAMs have not been able to treat them sufficiently thus far, and there are still large limitations on assessments of sustainable development by using IAMs (*medium evidence, medium agreement*). {17.3.2}

Sustainable development and mitigation policies are closely linked in the agricultural, food and land-use sectors. Agriculture, Forestry, and Other Land Uses (AFOLU) sector offers many low-cost mitigation options, but they can also create trade-offs between land-use to produce bioenergy, food and biodiversity (*robust evidence, high agreement*). Some options can help to mitigate such trade-offs, for example, integrated land management and efficiency improvements. Lifestyle changes, including dietary changes and reduced food waste, have several synergies regarding climate-change mitigation and the SDGs. {17.3.3.1}

The water, energy and food nexus (WEFN) involves tight and complex interlinking. Within it, the implementation of options related to water management and water conservation and the added coherence of policies within the water, energy and food sectors (among others) will be critical in achieving the SDG targets (Rasul, 2016). Subsidised fertilisers, energy and crops can drive unsustainable levels of water usage and pollution in agriculture. {17.3.3.2}

Industrial transformation is a core component of accelerating progress toward sustainable development. 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, as well as reducing emissions. (*robust evidence, high agreement*). Many industrial mitigation options, like efficiency improvements, waste management and the circular economy, have synergies with the SDGs relating to access to food, water and energy, as well as costs (*robust evidence, high agreement*). Some options like renewable energy promotion and carbon capture and storage could have negative impacts on some of the SDGs. {17.3.3.3}

There are several examples of mitigation options which have synergies between mitigation and adaptation, including energy efficiency options, renewable energy, the circular economy, sustainable city planning, and efficiencies in industry and buildings. In general, many of the mitigation options are assessed as having synergies, with or without trade-offs, with SDGs, but some sectors are also reporting trade-offs. (*medium evidence, high agreement*). This includes some energy-sector options, which are assessed as having high costs and thus could have trade-offs with SDG1 no poverty. Several trade-offs have also been identified in relation to land-use, bioenergy production and access to food in SDG 2 and water in SDG 6 *(medium evidence, high agreement)*. {17.3.3.5}

The potential role of digitalisation as a facilitator of a fast transition to sustainable development and low-emission pathways is assessed based on sectoral examples. The contributions of digital technology could contribute to efficiency improvements, cross-sectoral coordination, including new IT services, and decreasing resource use, potentially implying several synergies with SDGs, as well as trade-offs, for example, in relation to reduced employment, increasing energy demand and increasing demand for services, all implying increased GHG emissions (*low evidence, medium agreement*). Especially in developing countries, a strong link exists between sustainable development, vulnerability and climate risks, as here limited economic, social and institutional resources often result in low adaptive capacities and high levels of vulnerability (*robust evidence, high agreement)*. Similarly, the limitations in resources also constitute key elements leading to weak capacity in relation to climate-change mitigation. {17.3.3.6}

The landscape of transitions to sustainable development is changing rapidly, and we are already witnessing multiple transitions. This creates the room to manage these transitions in ways that will prioritise the need for workers in vulnerable sectors (land, energy) to secure their jobs and to maintain secure and healthy lifestyles, especially as the risks multiply for those who are exposed to heavy industrial jobs and all the associated outcomes (*medium evidence, high agreement)*..The notion of a just transition incorporates key principles, such as respect and dignity for vulnerable groups, the creation of decent jobs, social protection, employment rights, fairness in energy access and use, and social dialogue and democratic consultation with relevant stakeholders, while coping with the effects of asset-stranding and the transition to green and clean economies *(medium evidence, medium agreement)*. The economic implications of the transition will be felt especially by developing countries, with their high dependence on hydrocarbon products as a revenue stream, as they will exposed to reduced fiscal incomes, given the low demand for oil, the fall in oil prices and the associated economic fallout resulting from the COVID-19 pandemic. This link with stranded assets is in danger of being overlooked, but it is important, as countries whose assets are becoming stranded may not have the relevant resources, knowledge, autonomy or agency to design a suitable orientation or decide on the transition. However, in the race to achieve carbon neutrality by 2050, some of the other priorities of the transition, like climate change adaptation and its inherent vulnerabilities, might be muted, given the urgency of achieving mitigation at all costs. Consequently, the transition imperative reduces the scope for local priority-setting and ignores the additional risks faced by countries with the least capacity to adapt. The just transitions will depend on local contexts, regional priorities, the starting points of different countries in the transition and the speed at which they want to travel. {17.3.2.3}

A wide range of factors have been found to enable sustainability transitions, ranging from technological innovations to shifts in markets, and from policies and governance arrangements to shifts in belief systems and market forces (*robust evidence, high agreement*). All this has been coming together in a co-evolutionary process that has unfolded globally, internationally and locally over several decades (*low evidence, high agreement*). Those same conditions that may serve to impede the transition (i.e., organisational structure, behaviour, technological lock-in) can also 'flip' to enable both it and the framing of sustainable development policies to create a stronger basis and policy support (*robust evidence, high agreement*). 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. {17.4}

Sustainable development and deep decarbonisation will involve people and communities being connected locally through various means, including globally via the internet and digital technologies, in ways that form social fields that allow sustainability to happen and prompt other shifts in thinking and behaviour consistent with the 1.5°C goal (*medium evidence, medium agreement*). Individuals and organisations, like institutional entrepreneurs, can function to build transformative capacity through collective action (*robust evidence, high agreement)*, but private-sector entrepreneurs can also play an important role in fostering and accelerating the transitions to sustainable development (*robust evidence, medium agreement*). Ultimately, the adoption of coordinated, multi-sectoral policies targeting new and rapid innovation can help national economies take advantage of widespread decarbonisation (*medium evidence, medium agreement*). Industrial policies that focus on building domestic supply chains and capacities can help states prepare for the influx of renewable, carbon-negative technologies, or mechanisms for carbon capture and storage. {17.4.2}

Accelerating the transition to sustainability will be enabled by explicit consideration being given to the principles of justice, equality and fairness. 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 (*low evidence, high agreement)*. Likewise, greater policy coherence between these three sectors is critical to moving to a sustainable and efficient use of resources. The nexus approach (a systems-based methodology that focuses attention on the many ways in which natural resources are deeply interwoven and mutually interdependent) can strengthen coordination and help to avoid maladaptation. {17.4.6}

17.1 Introduction

This chapter looks at how climate policies are related to sustainable development policies, as well as how transition and transformation pathways to sustainable development are linked to climate actions. It considers the interdependence, inter-relativity, connectivity, complexity, and multi-directional and multi-faceted nature of interactions among the significant players, including equality and poverty issues and process to achieve a just transition. It assesses how climate actions could 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 views sustainable development through alternative theories of the transition, assessing how long-term sustainable development and climate policy goals may be coordinated and can be achieved, as well as 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 processes of transition, as well as the opportunities and challenges involved in accelerating the transition process (Section 17.3). Finally, the chapter synthesises its findings and conclusions, and identifies the key enabling conditions for acceleration of the transition to sustainable development and to achieving the 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* of 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. 2014) and the Special Report on Global Warming of 1.5°C (Roy et al. 2018; IPCC 2018b) linking the three pillars of sustainable development: social, environmental, and economic, to climate change. The relationships between climate-change impacts and global sustainability policies have also been examined by the IPCC in previous assessment reports.

The First Assessment Report (FAR) highlighted the relevance of sustainable development to climate policy. The Second Assessment Report (SAR) went further to include sustainable development with equity and other issues. The Third Assessment Report (IPCC, TAR Climate Change 2001: Mitigation, Chapter 1) concluded that "parties have a right to, and should promote sustainable development" as stated in the text of the UNFCCC 2015 (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 different development choices for climate-change mitigation, each mutually reinforcing the other. IPCCs Fifth Assessment Report (AR5) emphasised the need for transformational changes for climate resilient development.

In the face of simultaneous interlinked challenges, the global community is confronted with decisions over alternative pathways for future transformations that constitute critical junctions for sustainable development (Lidskog et al. 2020). In 2019, the declaration of the high-level political forum on sustainable development, convened under the auspices of the UN General Assembly, called for accelerated action to fulfil Agenda 2030 and the SDGs (General Assembly of the United Nations, 2019). In this context, accelerating climate action and a just transition are essential to reducing the risks to human security, including health, water and food, and to achieve the SDGs (U.N.2015; Till Bunsen et al. 2019). Collective action against climate change by businesses, governments, and civil society, reinforced through partnerships and coalitions across departments, industries and in particular supply chains, can deliver impacts at scale and strengthen public policy advocacy (Hoyer 2020). To accelerate the impact of these actions and stimulate transformations (Rashid Sumaila et al. 2019) identify three processes: (1) prolonging or accelerating the impact of one specific initiative (*amplifying within*), (2) impacting more people and places (*amplifying out*), and (3) changing how initiatives create impact (*amplifying beyond*). Further, these amplification processes are described as stabilising, speeding up, growing, replicating, transferring, spreading, scaling up, and scaling deep. The key to successful acceleration are the so-called acceleration effects that describe the maximum compressed time-gaps between investment and desired outcomes by approaching structural constraints (UNDP, UNEP 2020; Roberts et al. 2018) conclude that opportunities for and obstacles to transitions are closely interconnected.

Hence, accelerating just transitions for purposes of sustainable development requires the involvement of several disciplines, actors and institutions (Delina and Sovacool 2018), whose roles need to be discussed more thoroughly. (Kern and Rogge 2016). (den Elzen et al. 2019), for instance, show that the full implementation of reported and quantifiable commitments made by non-state and subnational actors, like regions, cities or businesses, can be a strong driver for achieving the Paris climate goals. Furthermore, this involvement is crucial if different policy interests and design-innovative solutions adapted to specific contexts are to be reconciled (Fiack and Kamieniecki 2017).

In practice, an enabling environment for stakeholders to be engaged in climate action needs to be supported. For instance, more comprehensive climate-planning processes, financial support or highlighting the co-benefits of climate protection can enhance the engagement of local government (Krause 2013). Showing understanding and addressing the barriers to private-sector engagement in environmental issues – for example, by communicating the business benefits of addressing environmental issues (e.g., cost savings, reduced risks) – can attract businesses to become involved (OECD 2016 a). In sum, besides increasing its speed, accelerating the transition seeks to extend and deepen the transition, increase the range, and modify the modalities of climate action impacts. As a result, a more profound and sustainable systemic transformation can be enabled and implemented.

Although climate change has traditionally been portrayed by many authors as an environmental problem to be addressed by governments and their environmental ministries (Munasinghe 2007), as cited in Swart and Raes, (2007); Brown, Hammill and McLeman (2007), this definition has evolved to embrace the wider ramifications of a changing climate for the economy, ecology and people. Consequently, today addressing climate change is widely recognised as an opportunity to contribute to a just transition towards sustainable development (Zhenmin and Espinosa 2019). There is sound scientific evidence that the climate change we are witnessing 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, and unreliable and poor governance mechanisms both within and across several disciplines, all of which tend to worsen its impacts (IPCC, 2014). To address these concerns – and since acknowledging climate change as 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 meeting the SDGs, and that constitutes a coherent, well-integrated and overarching approach to the problem of addressing issues of climate change.

The year 2015 was a noticeable turning point in increasing the dynamics of global governance, climate change and environmental policy needed to set the globe on a path towards sustainable development. Two remarkable stepping-stones were laid down: the approval and adoption of the sustainable development goals (SDGs) and of Agenda 2030, which built on the Millennium Development Goals (MDGs); and the adoption of the Paris Agreement on Climate Change. 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 economic, social, and environmental dimensions of sustainable development (Biermann et al. 2017; Kanie and Biermann 2017).

After the SDGs were adopted, an extra boost to implementing the goals was provided by the adoption of the Paris Agreement, which recognises sustainable development as intrinsic to achieving its objectives (Sindico 2016; UNFCCC 2016). As part of the "Paris Package", so-called 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. 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 them every five years, giving them an opportunity to assess themselves on their shortfalls and increase their ambitions. Moreover, another key feature was that countries should not "backslide" in subsequent NDCs, thus ensuring that countries should always be forward-looking in respect of increasing their ambitions to deliver the Paris goals. Höhne et al. (2017) found that in developing countries especially, the NDC preparation process has improved national climate policymaking. However, several assessments of country's NDCs (Rogelj et al. 2016; UNFCCC 2015; Andries et al. 2017; Vandyck et al. 2016) have declared that they are falling short of delivering the Paris goals. One of the very urgent calls in Paris was to assess the impacts and efforts that need to be undertaken to keep global warming well below 2°C in relation to pre-industrial levels and related global greenhouse-gas emission pathways (UNFCCC 2015). Although the initial NDC rounds fell short, the idea was that NDCs would be living documents that increased their ambitions in every iteration of them.

Since 2015, several assessments have pointed out the gap in implementation with current national climate policies, possibly leading to an increase in average temperatures beyond the Paris Agreement (Rogelj et al. 2016; Peters et al. 2017; UNEP 2020; Wang and Chen 2019). (Roelfsema et al. 2020) estimate a gap of 22.4 to 28.2 $GtCO_2eq$ by 2030 with the optimal pathways to implement the well below 2°C and 1.5°C Paris goals". Nevertheless, den Elzen et al. (2019) conclude that, given the current status of their implementation of climate policy, six of all G20 members are expected to meet their unconditional NDCs. However, eight other countries need to take further action to meet their targets, while others have provided insufficient information to permit analysis. Since the US, China and the EU produce the majority of global GHG emissions their climate policies have a strong influence on the global GHG inventory and other countries' policies (Averchenkova et al. 2016). In addition, initiatives by non-state stakeholders can have an important role in implementing mitigation efforts globally (Hermwille 2018).

The IPCC special report on Global Warming of 1.5°C (Roy et al. 2018; IPCC 2018) concluded that limiting the global temperature to the goals of the Paris Agreement could avert many severe climate extremes. It also noted that mitigation actions will have both positive and negative impacts on achieving 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 policies will enable and support fundamental systems and social transformations, and that for these transformations to take effect, rapid implementation is required to meet the long-term temperature goals.

A comprehensive assessment of the links between sustainable development and climate change can be found in the previous assessment, AR5 (Olsson et al. 2014; Fleurbaey et al. 2014; Denton et al. 2014). AR5 argued that the link between climate change and sustainable development is cross-cutting and complex and that the impacts of climate change are threatening the efforts made to achieve sustainable development thus far. Climate change reveals the dependence of all systems on natural capital and jeopardises their sustainable development in terms of, for instance, health (Sweileh 2020), gender (Alston 2014), or existing poverty and inequalities (Olsson et al. 2014).

Moreover, drivers of climate change, such as energy production and consumption, also interact with sustainable development in positive and negative ways. One of the key messages of AR5 was that the proper implementation of climate mitigation and adaptation actions could help promote sustainable development. Countries have started to report on 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 SDG Report for 2019 indicates that 150 countries have developed national urban plans, almost half of them also being in the implementation phase) United Nations General Assembly 2019). Other countries might also be in the phase of development with a view to following suit.

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), extending also to regional and local plans (Hess 2014; Gorissen et al. 2018; Shaw and Roberts 2017). Cross-cutting and integrated approaches, such as circular economies, have been emphasised by some European countries (EESC 2015), and some countries are adjusting their existing policies to build on ideas for sustainable development (Lucas et al. 2016).

Most notably, the recent European Green Deal establishes the idea of the circular economy as one of the constituent elements in the deal (EC, 2019). 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). The implementation of the SDGs as part of national development processes reflects the different priorities, visions and plans of countries (Hanson and Korbla P. Puplampu 2018; P. Puplampu et al. 2017; Tumushabe 2018; OECD 2016a; Srikanth 2018; (Marcotullio et al. 2018). In order to transform them into action, a fundamental paradigm shift from a linear model of knowledge generation to an interdisciplinary model needs to be made that involves the co-production of knowledge by different stakeholders (Liu et al. 2019).

Other non-UN-led initiatives have also helped to raise the issue of sustainable development as a framework for mitigation involving international organisations or clusters of countries. The OECD, for instance, relates different types of investments and economic activities to their environmental sustainability (OECD, 2020), while G20 countries have drawn up action agendas with sustainable development at the core (UToronto 2016). The Petersberg Climate Dialogue, a political movement convened by major country-group representatives launched in 2010 by the German government, has also called for sustainability to be an intrinsic part of the transition (UNFCCO, 2020).

17.1.1.1 Relationships between sustainable development, adaptation, and mitigation

Climate change adaptation and mitigation are linked to sustainable development in many ways, presenting both opportunities and challenges, as described in Chapter 18 of the Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (AR6 WGII, 2021). For instance, many links between adaptation and mitigation can be found in agriculture, forestry, and landscape management (Locatelli et al. 2015). Conservation practices, like using crop residues to increase nutrient cycling and thus contribute to carbon sequestration, can help both to mitigate and to adapt to climate change (Lal et al. 2011). There are many ideas about how to harmonise adaptation and mitigation efforts to create co-benefits in different sectors, such energy, transportation, or forest management (Moser 2012).

The creation of synergies can increase people's long-term engagement with and acceptance of projects (S et al., 2016). However, apart from neutral and positive relationships, possible conflicts, trade-offs, or negative synergies are also possible (Landauer, Juhola and Söderholm 2015). 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 need balanced actions to accommodate the impacts of both mitigation and adaptation. Enhanced sustainable adaption can lead to effective emission-reduction benefits, such as climate-smart agricultural technologies (Nefzaoui et al. 2012; Poudel 2014) and ecosystem-based adaptation (IUCN 2017; Geneletti and Zardo 2016; Berry et al. 2015) have shown how increases in livelihoods can contribute to climate change mitigation. Comprehensive assessments such as that by Sharifi (2020) and Dovie (2019) showed that there is room for virtuous collaboration between sustainable adaptation and mitigation (Dovie 2019).

Fuso Nerini et al. (2019) revealed that climate change can undermine the progress towards other SDGs, while fighting climate change can reinforce efforts in the direction of sustainable development. For instance, climate change could hinder the progress towards SDG 1 – zero hunger – and put food systems at risk (Wheeler and Von Braun, 2013). In turn, reducing local air pollution and GHG emissions can, for example, improve the prospects of achieving SDG 3 and thus global health by decreasing the scope and pattern of medium- and long-term health risks (Haines and Ebi, 2019). 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).

Not only are climate actions occurring nationally as indicated before: sub-nationally too, a variety of key actors, including cities, counties and states, depending on each countries' administrative organisations, are working to reduce both the causes of climate change and the preparations for its impact, which are becoming central to the global governance of climate change (Hsu et al. 2019). Many have accordingly developed separate mitigation (low emissions growth) and adaptation (climate-resilient) strategies and measures (Göpfert et al. 2019). In addition, several cities have become active in pursuing strategies for dealing with sustainable development, mostly through the implementation of SDG-related agendas. However, a thorough integration of 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" enabling populations to mitigate, adapt and react is key. These capacities need to be created accordingly in response to climate change by implementing effective measures to change behaviour, while also helping in the move towards sustainability (Burch and Robinson 2007; Harry and Morad 2013). Initially seen as an artificial division of responsibility, with mitigation as the main challenge for developed countries and adaptation for developing countries, responses to climate change are now acknowledged to be a joint development issue affecting and requiring action from all countries (Swart and Raes 2007).

Though there are minor differences, the capacities for both mitigation and adaptation are supported by similar factors (IPCC, 2007). The development of an effective response capacity within a society is conditioned by its own level of development and predicated on its ability to draw on strong and integrated policies and institutions, financial, human and technological resources, and several other enablers (Yohe 2001; Tompkins and Adger 2005; Burch and Robinson 2007). For instance, Romero-Lankao et al. (2013) argue that information and knowledge, participation, networks and legal frameworks are important elements in enhancing institutional response capacities. Response capacities are time- and context-specific, and different social groups will need different characteristics and tools to respond to different hazards and types of climate change (Tompkins and Adger 2005).

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 2019). 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 suggests that a holistic and systematic approach with complex interactions across multiple dimensions is needed for a sustainable transition. O'Brien (2018) stresses that, for social transition and transformation to occur, leverage points in three related and interacting 'spheres' of practical, political and personal needs must work in parallel so that people are treated as subjects or agents of change, rather than as objects to be changed. These spheres of transformation are abstractions that capture both the complexity of the changes needed to realise a particular goal and an outcome such as a temperature target.

The practical sphere represents specific actions, interventions, strategies and behaviours that directly contribute to a desired outcome. The political sphere represents the systems and structures that facilitate or constrain practical responses to climate change, while the personal sphere of transformation represents the subjective beliefs, values, world views and paradigms that influence how people perceive, define or constitute systems and structures, as well as their behaviours and practices.

This implies paying less attention to the attempt to alter people's behaviour and instead work towards creating the conditions that promote the development and expression of social consciousness both now and in the future. In addition to the social and technological changes 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 process of transition. Nevertheless, a critical view needs to be taken of the power relations that are reflected in how certain sorts of knowledge frame an issue in the first place (Nightingale et al., 2020). This includes identification of the different knowledge and potential gaps that might exist (Hulme, 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.

Another key element of the transition process is the aspects of equity and justice at all levels. The Brundtland report gave a high priority to poverty alleviation, equity and justice (Lele and Jayaraman 2011). Agenda 2030 and the SDGs recognise the importance of leaving no one behind (LNOB) and of endeavouring to reach those left furthest behind in the search to end poverty, fight hunger, curb inequalities and prevent deaths from curable diseases, among other essentials. In this connection, the 193 UN member states have confirmed the pledge to improve the lives of the poorest and most disadvantaged and act so as to put this promise into action (UNDP 2018). 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, as it can consist, for instance, of spatial, distributional or intergenerational equity (IPCC 2012).

However, in AR5 it becomes clear that climate-change impacts on disadvantaged communities will exacerbate their existing poverty and inequalities (Olsson et al. 2014), and that these issues should be included in climate mitigation and adaption policies and economic goal-setting (Drupp 2018; Baumgärtner et al. 2017), 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).

This involves understanding that the trade-offs require equity to be taken into account, but equity does not always counter strong collective climate action. Yet, for instance, as economic analysis has shown, a more equal distribution of income increases the economic value society attaches to nature and can therefore have a substantial impact on people's attitudes (Drupp 2018, Baumgärtner et al. 2017). Since assessments by Winsemius et al. (2018) and Hallegatte and Rozenberg (2017) show that in the future these impacts will be aggravated further, the roles of multi-level governance structures and of the private sector and civil society should not be overlooked in achieving equity as part of sustainable development (Mathur et al. 2014; Derman 2014). Realising the importance of these concepts, the issue of equity was made a central part of the Paris Agreement and the "Paris Rule Book" (Winkler 2019).

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 and disruptive innovations and diffusions 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 will bring about the innovative changes to 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 challenges to policy implementation of their more limited resources (financial, environmental fragility, institutional, skills, etc.), social disparities and less experience and knowledge of state-driven technological development and phasing in. While lock-in effects may be weaker in cases where robust and economically viable technologies exist, market failures may be more pronounced in other cases due to stronger information asymmetries and cost barriers (Kemp and Never 2017), as well as institutional barriers. Furthermore, Pauw et al. (2020) concluded that financing for the implementation of conditional NDCs can be a vulnerability for some countries and their future ambition, and should be considered a potential bottleneck.

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 mixture of policy instruments can provide the multiple policy effects needed for social and technological change (Edmondson, Kern and Rogge, 2018; Köhler et al., 2019; Rogge and 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 Explaining Transitions

Many studies hold that integrating climate mitigation and sustainable development can increase the speed, scale, and quality of transitions. Views nonetheless differ on how individual beliefs and collective ethos, policymaking institutions and governance arrangements, economic markets and market-correcting policies, and sociotechnical and ecological systems influence transitions. This section describes this rich diversity of views by surveying how several prominent lines of psychological, institutional, economic, and systems thinking explain transitions. It demonstrates that different disciplinary perspectives often implicitly assume which dimensions of sustainable development are integrated with climate change and which actors, interventions, and enabling reforms feature in the integrative process that drives transitions.

The implicit assumptions in the theories surveyed below have implications for whether the main conclusions and recommendations are best suited to quickening the pace, expanding the scale, or improving the quality of transitions. Incorporating insights from psychological, institutional, and economic views into overarching system theories may allow us to arrive at recommendations that make transitions quick, scalable and ultimately sustainable. A multi-disciplinary lens on transitions may also enrich the cross-sectoral policies described in Section 17.3.

17.2.1 Psychology, Beliefs and Social Innovations

This subsection focuses on how transitions in individual beliefs and mindsets and related transitions in social consciousness and norms contribute to climate mitigation and sustainable development (Adger, W, Barnett Jon, Brown Katrina, Marshall 2013; Hulme 2009; Ives et al. 2019; O'Brien, 2018). These individual and collective changes often reinforce each other, potentially improving the health and well-being of the individual, community, and planet (Lockhart, 2011; Day et al., 2014; Montuori and Donnelly, 2018). More than the other views surveyed in Section 17.2, these perspectives emphasise how the shifts in individual and collective beliefs and consequent actions improve the quality of transitions.

Occurring within the self, an inner transition typically involves gaining a deepening sense of peace and acceptance, a willingness to help others, and an interest in protecting nature and the planet (see e.g. Banks, 2007, Power, 2016). This transition accompanies changes in one's beliefs and actions toward sustainability and climate change—such as a willingness to support sustainable energy initiatives in cities and universities (Banks, 2007; Woiwode, 2016, Hedlund-de Witt et al., 2014). Importantly, while these internal shifts may spur community-level actions, they arise from being "world-citizens" (e.g. Morin, 2016), a "higher-order superordinate identity", "[living according to the principles] of integrated sustainability" (Schweizer-Ries, 2013), and "[achieving] the good life" (See Section 1.6.4; Gauer, 2008). These values share a commitment to improving the well-being of all people and creatures (Chapter 1, Section 1.6.3.1 and Chapter 5; Hannis and Rawles 2013) and "moving from valuing nature only in market and monetary terms and strongly incorporating existential and non-material values"

(Neuteleers and Engelen, 2015). It also entails conscious-raising process wherein people feel closer to their true inner selves, each other, and nature (See Chapter 1, Section 1.6.4; Banks, 2007; Woiwode, 2016, Hedlund-de Witt et al., 2014).

Many of the above beliefs have spread with the growing interest 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). Often, as these mindshifts spread they are accompanied by social practices, like meditation or yoga, (Woiwode and Woiwode 2019). At the same time, they focus on the post-development era (Kothari et al. 2019) and de-growth (Sklair 2016; Paech, 2017), which have emerged to challenge carbon-intensive lifestyles and unsustainable development models (Chapter 1, Sections 1.5.1 and 1.6.4). The development of a sustainability culture connecting people and communities, often with help from the internet, digital technologies and or other means of sharing information, have helped these ideas spread (Bradbury, 2015, Scharmer, 2018).

Another channel through which these values and beliefs are disseminated is education and research (Scharmer, 2018; Schneidewind and Von Wissel, 2015, Fazey, Schäpke, Ciniglia et al. 2018, Ives, Freeth and Fischer, 2019; Chapter 1.6.4). In terms of research, "social experiments" or "real world labs" are helping to foster shifts in mindsets that can induce transitions in energy, food, transport and other systems (Berkhout et al. 2010; Hoffmann 2011; Bulkeley et al. 2015; Bernstein and Hoffmann 2018). In the above cases, the acquisition of knowledge and transformative learning (Williams, 2013; Pomeroy and Oliver, 2018; O'Neil and Boyce 2018,, Lange, 2018; Walsh, Böhme and Wamsler 2020) has helped contribute to alternative development pathways (Berkhout et al. 2010; Roberts et al. 2018; Turnheim and Kivimaa 2018; Lo and Castán Broto, 2019) (Chapter 1, Section 1.7.2). First-person and action research, in which researchers participate in the change they aim to achieve, can also facilitate widespread changes (see e.g. Dick, 2007; Streck, 2007; Hutchison and Walton, 2015; Bradbury et al. 2019).

The spread of these values can then form cultures of collaboration and sustainability. These broader shifts can in turn lead to the creation of social fields that allow change to happen (see also Gillard et al. 2016) or give rise to thinking and behaviour that are consistent with the low-temperature goals (O'Brien, 2018; Veciana and Ottmar, 2018). Often these shifts are not simply about the spread of values: Reese et al. (2020), for instance, show that policymakers and the media have an influence on social norms and their changes, especially during crises. They may also gain adherents due to social or "grassroots innovations" (Seyfang and Smith 2007: XVIII). Both social and technological innovations (Shove et al. 2014) can alter everything from personal routines to business models to authority patterns to the belief systems (Westley and Antadze, 2010) that help achieve the climate and sustainable development goals.

17.2.2 Institutions, Governance, and Political Economy

This section focuses on institutions and governance. Institutional and governance arrangements can influence which actors possess authority, as well as how motivated they are to act collectively in finding solutions to climate change and other sustainability challenges. Often collective action is enabled when institutions align climate change with the political and economic interests of national governments, cities, or businesses, and when institutional and governance arguments that support that alignment expand the scale of the transitions.

An extensive literature has examined how the international climate agreements and architecture influence collaboration across counties regarding climate and sustainable development concerns (Bradley, et al 2005). For example, international institutions offer opportunities for governments and other actors to share new perspectives on integrated solutions (Cole 2015). For some observers, however, decades of difficulties in crafting a comprehensive climate-change agreement and the resulting fragmented climate-policy landscape have been inimical to the collaboration needed for a transition (Chapters 1 and 13; van Asselt, 2014; Nasiritousi and Bäckstrand 2019). Yet others see the potential for more incremental cooperation across countries, even without a single, integrated forms of climate governance (Keohane and Victor, 2016).

A related argument suggests that fragmentation at the global level provides opportunities for cooperation at the national level (Kanie and Biermann 2017). For example, in contrast to the relatively top-down Kyoto Protocol, the bottom-up pledge and review architecture of the Paris Agreement has prompted national governments to integrate climate change with other sustainable development priorities (Nachmany and Setzer 2018; Townshend et al. 2013). Concrete examples included incorporating the SDGs into NDCs as an international response to climate change (TERI, 2017) or bringing climate into sustainable development strategies and so-called voluntary national reviews (VNRs) as part of the SDG and 2030 Agenda process (Elder and Bartalini, 2019; Elder and King, 2018).

Another branch of institutional research is concerned with the interactions between multiple levels of governance. In this multi-level perspective, cities and other subnational governments often lead transitions by devising innovative solutions to climate and local energy, transport, environmental, resilience and other sustainability challenges (Rabe 2007; Koehn 2008; Doll and Puppim de Oliveira 2017; Bellinson and Chu 2019; van der Heijden et al. 2019). A complementary perspective suggests that national governments can help scale up transitions by allocating resources and provide technical support that can spread innovative solutions (Corfee-Morlot, J., et al 2009; Gordon 2015), though such cooperation may not always be necessary for motivated, well-resourced cities (Bowman, A. O', M. Portney, K.E. and Berry J.M. 2017). This line of thinking is supported by calls to strengthen vertical and horizontal integration within and across government agencies and stakeholders in ways that can enhance policy coherence (Amanuma et al. 2018; OCED 2018; OCED 2019). Others have seen greater potential for collaboration and innovation with less linear or more polycentric forms of governance that lead to the formulation and dissemination of transformative solutions (Ostrom, 2008).

Yet another set of channels facilitating integration between climate and other concerns are networks of like-minded actors working across administrative borders and physical boundaries. For instance, city networks such as the Global Covenant of Mayors for Climate and Energy (Covenant of Mayors 2019), the World Mayors Council on Climate Change (2019), ICLEI (2019), C40 (2019) and UNDRR (2019) have agreed to share decision-making tools and good practices, and sponsor ambition-raising campaigns that help align climate and sustainable development concerns within and across cities (Betsill and Bulkeley, 2006) (see also Chapter 8 and Section 17.3.3.5). This can be particularly important for less capable "following" and "laggard" cities needing greater support (Fuhr, H., Hickmann, T. and Kern, K. 2018).

Further, sub-national governments may often work together with civil-society groups to create new networked forms of governance (Bäckstrand et al. 2012). Other forms multi-stakeholder partnerships focusing on issues with strong climate synergies, such as forms of air pollution known as short-lived climate pollutants (Climate and Clean Air Coalition (CCAC)) or transport (Sustainable Low Carbon Transport Partnership (SLoCaT)), take their cue from global scientific communities or civic-minded advocacy groups that transmit knowledge across boundaries (Keck and Sikkink, 1999). There is also scope for suggesting that international climate regime serve a Global Framework for Climate Action (GFCA) in helping orchestrate the multilateral climate regime and non-state and subnational initiatives (Chan and Pauw, 2014), though questions remain about its actual impacts on mitigation (Michaelowa and Michaelowa, 2017).

Though the above work tends to downplay politics and business, others suggest that political economy should feature prominently in transitions. Some branches of political-economy research underline how resource-intensive and fossil-fuel industries leverage their resources and positions so as to undermine transitions (Chapter 1; Moe, 2014; Zhao et al, 2013; Newell and Paterson 2010; Geels 2014; Jones and Levy 2009). These vested interests can lock in *status quo* policies in countries where political systems offer interest groups more opportunities to veto or overturn climate- or eco-friendly proposals (Madden, 2014). This suggests that politics can be an impediment to change; other studies argue instead that politics can be harnessed to drive transitions forward. For example, some observers contend that building coalitions around green industrial policies and sequencing reforms to reward industries in such coalitions can align otherwise divergent interests and inject momentum into transitions (Meckling, J., Kelsey, N., Biber, E. and Zysman, J., 2015). Side payments, such as industrial tax incentives to change production processes can reduce industry's opposition to change and open up sustainable low-carbon pathways (Goldthau and Sovacool, 2012). Similarly, more inclusive institutions empowering organised labour, women's groups, and youth movements can bring about sustainable and socially just transitions (Sovacool et al., 2017).

17.2.3 Systems theories

Systems theories help explain the dynamics of transitions toward sustainable development while explicitly uncovering links 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 envisages transitions emerging from complex systems in which many different elements interact at small scales and spontaneously self-organise 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), conceptualisations 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 still emerging.

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 destabilised 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 of guiding a socio-technical system from one path to another. In particular, it highlights interactions between actors, technologies, and institutions and the complex governance mechanisms that facilitate them (Smith et al, 2005). The challenge, in part, becomes linking radical short-term innovations with longer-term visions of sustainability (Loorbach and Rotmans, 2010) and creating opportunities for collaborative course-correction in light of new information or unexpected outcomes (Burch, 2017).

17.2.4 Economic theories

This section concentrates on economic theories. Economic thought figures prominently in studies using climate models such as integrated assessment models (IAM), macroeconomic and sectoral models. Some lines of economic thought suggest economic development can complement technological innovation and climate change mitigation, but require interventions to correct for potential market failures. In part because of their reliance on models, economic theories may also miss trade-offs between climate and difficult to model or quantify goals. Economic thought may lend itself best to increasing the speed of transitions.

A core argument in economic theory is that, without the application of economics instruments such as CO_2 taxes or regulatory options, markets will fail to motivate profit-maximising firms to reduce emissions. Market-correcting interventions are therefore often required to induce firms to internalise climate and other externalities (Arrow et al. 2004; Chichilnisky and Heal 1998). A similar internalising logic is also often offered to support public investments in low or zero emissions technologies and research. Furthermore, there can be a need to promote a redirection of investments to renewable energy technologies and other low-emission technologies. Based on this, a key issue in studies based on economic models is their assumptions about market adjustment instruments and innovation policies.

The above economic arguments and their underlying assumptions are important, as they underpin integrated assessments and the macroeconomic and sectoral model research that informs many climate policy decisions (see Chapters 3 and 4). Other models assume climate mitigation levels should be set where mitigation costs meet estimated reductions in climate change damages, which reflects the social costs of carbon (Nordhaus, 2008; see Chapter 1, Section 1.6.2 on cost-benefit analysis based on aggregated global IAMs). Yet, this view focuses only on the damage of climate change at a very aggregate level and excludes catastrophic climate events and other difficult-to-model adverse impacts on sustainable development (Weitzman, 2009; also see Chapter 1, Section 1.5.2).

There have been efforts to expand the scope of IAMs, for example, by incorporating improved improvements to air quality and public health into models (IEA, 2019; 2020; literature), but their coverage of a larger range of impacts on sustainable development is still limited. There is a need to move beyond simple cost-benefit analysis to incorporate issues and enablers featured in this and other chapters, including a wider range of non-climate risks, cost-effective delivery of multiple objectives, varying forms of innovation, and possibilities for behavioural, social change, and feasible policies (Chapter 1, Executive Summary).

IAMs and macroeconomic models typically calculate mitigation costs based on the assumption that markets internalise externalities like GHG emissions through carbon prices (IEA, 2017; 2019) (ETP2017, WEO2019 Barker, T. et al.) GDP and employment effects of policies to close the 2020 emission gap, Climate Policy, (2016),16:4, 393-414). The use of GHG emission taxes as an effective instrument based on modelling results has implications for public policies and private-sector investments. Yet, there are legitimate questions to ask about whether carbon pricing will be efficient if markets are inefficient (WB, 2017). Making this more problematic is the fact that IAMs and macroeconomic models typically do not reflect market inefficiencies. How GHG emissions taxes would actually work is quite uncertain based on the modelling studies (Barker et al., 2016; Fontana and Sawyer, 2016; Meyer et al., 2018), though there have been efforts to factor in the impacts of promoting green finance in some recent models (Dafermos, Y. et al., 2017).

Despite the shortcomings of conventional economic thoughts and models, some views are beginning to demonstrate a potential for addressing climate and other sustainable development concerns in improved models. For instance, while a conventional perspective might suggest that climate-change mitigation costs can limit investments in sustainability because they reduce the productivity of capital by increasing energy prices and the products in which energies are embodied, another perspective is that innovation can imply increases in efficiency and that the substitution of energy, material and labour can lead to the accumulation of capital and productivity gains. This appears to be occurring with innovations in end-use energy applications generating emissions reductions and delivering on other sustainable development benefits (Wilson et al., 2019).

Moreover, Grübler et al. (2018) have developed a climate-friendly, low energy demand (LED) scenario which assumes information technology innovations (such as the internet of things or IOT) and induced social changes (such as the sharing economy) can achieve many SDGs with low marginal abatement costs compared with other scenarios (IPCC SR15, 2018). Nonetheless there are still very important limits on the degree to which these models can integrate ethics, equity, and several other kinds of factors that will determine well-being or happiness (Easterlin et al., 2010; Koch, 2020; Chapter 1, Section 1.5.3).

17.2.5 Conclusions

This section has surveyed psychological, governance, economic, and systems theories. The review suggests that there are several differences between the theories. Whether individuals, 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 levels as paving the way for broader changes to cultures and belief systems. Economic theories tend to use assessment models to identify policies that correct market failures and thereby act as a catalyst of 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 these theories suffer from similar myopias, paying only limited attention to claims in other schools of thought. The possible exception here is systems theories, which tend to bring in many of the factors stressed elsewhere, without 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, 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. Though is unlikely that a one-size-fits-all set of factors will drive a transition, there is a growing body of empirical evidence that can shed light on which factors matter under which conditions.

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

17.3.1 Introduction

This section assesses studies based on sustainable development as a framework for transitions to low-carbon societies in order to facilitate robust conclusions across methodologies, scenarios, and sectors. Cross-cutting conclusions will be developed based on national and sub-national, sectoral and cross-sectoral, and short- and long-term transition studies based on other studies that have been assessed in previous chapters of this report and on additional literature, including the special reports of the IPCC. The key question is whether sustainable development and decarbonisation 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 1) of cross-sectoral examples of transition issues, which are selected as illustrative examples of key synergies and trade-offs between sustainable development and decarbonisation transitions, and 2) of the key cross-sectoral factors from the viewpoints of the just transition and finance.

The assessment of the 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 (Chapters 5-12) on sustainable development and decarbonisation. An overview of the study results will also be provided with a mapping of synergies and trade-offs between mitigation options and the SDGs.

17.3.2 Short-term and long-term transitions

Sustainable-development policy goals have played an increasingly important 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 recognised as a key threat to achieving inclusive and sustainable development, and in this spirit the Paris Agreement also emphasised 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. 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, 2020). Meeting the goals of such a transformation requires that the long-term targets and pathways to fulfil the stabilisation 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 initial plans for the decarbonisation of their economies to the UNFCCC in the form of their so-called national determined contributions (NDCs). The ambitions of the NDCs are closely related to the ongoing UNFCCC negotiations over the financial measures and forms of compensation. Although the Paris Agreement emphasises the links between climate policies and sustainable development, the UN's 2030 Agenda and the SDGs are not very well represented at present in the NDCs according to Fusso Nerini et al. (2019). Very few of the NDCs include any reference to the SDGs, which Fusso 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) have 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 of less developed countries would tend to reduce poverty alleviation, but this can be offset if international financial support is provided for the mitigation actions.

As described in Section 1.3.2, (Dubash 2020) emphasises the importance of placing the need for urgent action on climate change in the context of the Paris Agreement, with its emphasis on sustainable development and the approaches that reinforce domestic political priorities and considerations.

The alignment of climate-policy targets in the NDCs with sustainable development has also been assessed by means of integrated assessment models (IAMs), i.e. macroeconomic and sectoral modelling. Iyer et al. (2018), based on studies using IAMs, assessed the implications of considerations of sustainable development for comparability across NDCs and concluded that some SDGs can be supported by the implementation of climate-policy targets in NDCs, while others cannot. Furthermore, the regional distribution of efforts across NDCs using emissions-based 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, but 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 the lack of progress that has been achieved in meeting the temperature goals, and, in the context of the UN's 2030 Agenda, the UN Sustainable Development Report 2019 (Sachs et al., 2019) also concluded that there is a particular lack of progress in achieving 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 realising 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 regarding how the UN 2030 SDG goals can be achieved is a lack of finance for climate actions. Sachs et al. (2019) conclude that meeting the SDGs to achieve social transformations worldwide would require 2-3% of global GDP and that it would be a huge challenge to ensure that finance is targeted to the world's poorest countries and people.

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

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

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. one 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 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 stylised and uniform representation of options in models like IAM, with their high regional aggregations (IPCC AR5, Mitigation policies, Chapter 6 Section 6.6.1). Only a few countries have until now submitted such plans. However, there are 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 states 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 security of investments will be created (Germany, 2016). Similarly, in its long-term low-emissions 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 Model assessments on the sustainable development pathways for decarbonisation

This section assesses the model evaluations of the sustainable development pathways for decarbonisation, including the co-benefits and trade-offs. There are several synergies and trade-offs on many agendas regarding sustainable development, while quantitative and systematic analyses using models will support understanding the sustainable development pathways for decarbonisation. Short- and long-term studies of transformations 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.

Meanwhile, development pathways that focus narrowly on climate mitigation or economic growth will not lead to achievement of the SDGs and long-term climate stabilisation objectives. The best chances of doing this lie in development pathways that can maximise the synergies between climate mitigation and broader sustainable development (Chapter 1, Section 1.3.2). Areas of focal modelling include green investments, technological change, employment generation and the performance of policy instruments, such as green taxes, subsidies, emission permits, investments and finance.

There is an emerging modelling literature focusing on the synergistic benefits and trade-offs between low-carbon development pathways and various aspects of sustainable development. The early literature, including that on IAMs, that is, macroeconomic and sectoral models, 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 the joint benefits of mitigation, health, water and land-use, and food security (IPCC 2014, AR 6 WGIII, Chapter 6; IPCC, 2018, IPCC SR 1.5 report).

An example of a project that assesses the economy-wide impacts of linking sustainable development with deep decarbonisation is the deep decarbonisation project or DDPP (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 two-degree stabilisation 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).

The key conclusions form the DDPP team on the economy-wide impacts are that country studies like South Africa's demonstrate that it is possible to improve income distribution, alleviate poverty and reduce unemployment while simultaneously transitioning to a low-carbon economy (Altieri et al., 2016). The DDPP in Japan explores whether energy security can be enhanced through increases in renewable energy (Oshiro et al., 2016). The reduction of uncontrolled fossil-fuel emissions has significant public-health benefits according to the Chinese and Indian DDPPs, as fossil-fuel combustion is the major source of air pollution.

For example, in the Chinese DDDP, deep decarbonisation has resulted in reductions of 42–79% in primary air pollutants (e.g. SO_2, NO_x, particulate matter (PM2.5), volatile organic compounds (VOCs), and NH3), this meeting air-quality standards in major cities. The deep decarbonisation scenarios include the large and fast energy-efficient improvements required to improve energy access and affordability. The DDPP studies are thus an example of an approach in which national deep-carbonisation scenarios are linked to the development goals of income generation, energy access and affordability, employment, health and environmental policy.

Sustainable development scenarios have also been developed by the Low-Carbon Society's (LCS) assessments (Kainuma et al., 2012), in which multiple sustainable development and climate change-mitigation goals were assessed jointly. The scenario analysis was conducted for Asian countries such as South Korea, Japan, India, China and Nepal with a soft linked IAM using 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 economy-wide global 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 compared with only focusing on mitigation targets due to the co-benefits (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 coordination of 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 policymakers 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 in 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 at disaggregated geographical and sector-specific scales.

The World Energy Outlook by International Energy Agency (IEA 2019; 2020) issued a Sustainable Development Scenario (SDS), which assessed not only SDG 13 (climate change) but also SDG 7 (energy access) and SDG 3.9 (air pollution). This scenario takes its starting point in the policy goal of meeting these SDGs and then assesses the costs of meeting an emissions reduction target of 70% of CO_2 from the energy system by 2030. Retrofitting coal-fired power plants with pollution controls is the cheapest option of dealing with local pollution in the short term, but it may lead to long-term emissions to meet the Paris Agreement's long-term goals. Concentrations of the major air pollutants drop dramatically in the SDS: energy-related emissions of NO_X, SO_2 and PM2.5 fall by 40–60% by 2030, leading to 2.5 million fewer premature deaths from air pollution in 2030 than in the Stated Policies Scenario (STEPS) (IEA, 2020).

The costs of energy-system transitions have been assessed by several energy-system studies. The economic costs of meeting different goals depend on the stringency of the mitigation target, economic (fuel prices etc.) and technological developments (technology availability, capital costs etc). In addition, required changes in infrastructure and behavioural patterns and lifestyles matter. Model-based assessments vary depending on these assumptions and differences in modelling approaches (Krey et al., 2019; Chapter 6, Section 6.7.7). Country characteristics determine the social, economic and technical priorities for low-emission pathways. Domestic policy circumstances impact pathways and costs, e.g. when affordability and energy-security concerns are emphasised (Oshiro et al., 2016). There are several challenges involved in balancing the trilemma of energy security, equity, and sustainability. Fossil fuel-dependent developing countries cannot transit to low carbon without considering the economy-wide effects of doing so (Chapter 3, Section 3.7.3).

Climate change has negative impacts on food productivity in general, including unequal geographical distribution. However, climate-change mitigation aimed at achieving stringent climate goals could also negatively affect food access and food security (Akimoto et al., 2012; Hasegawa et al. 2018; Fujimori et al., 2019. If not managed properly, the risk of hunger due to climate policies such as large-scale bioenergy uses increases remarkably if the 2°C and 1.5°C targets are implemented (Chapter 3, Section 3.7.1). As a median value across SSPs and IAMs, required carbon dioxide removal (CDR) reaches up to -14.9 $GtCO_2\ yr^{-1}$ for BECCS and -2.4 $GtCO_2\ yr^{-1}$ for afforestation in 2100. Across the different scenarios, median changes in global forest area throughout the 21st century reaches the required 7.2 Mkm^2 increases between 2010 and 2100, and agricultural land used for second-generation bioenergy crop production may require up to 6.6 Mkm^2 in 2100, enhancing competition for land and potentially affecting sustainable development (Chapter 7, Executive Summary).

Reducing climate change can reduce the amount of population exposed to increased stress from reductions in water resources (Arnell and Lloyd-Hughes, 2014) and therefore to water scarcity as defined by a cumulative abstraction-to-demand ratio (Hanasaki et al., 2013). Byers et al. (2018) show that 8–14% of the population will be exposed to severe reductions in water supply if average temperatures increase between 1.5°C and 2.0°C (also see Chapter 3, Section 3.7.2). Hayashi et al. (2018) assess the water availability for different emission pathways, including the 2°C and 1.5°C targets, in light of the various factors on availability. There are very different impacts among nations. In Afghanistan, Pakistan and South Africa, water stress is estimated to increase by 2050 mainly due to increases in irrigation water associated with the rising demand for food; climate change also has relatively large impacts on water stresses after 2030. Other factors, such as changes in the demand for municipal water, water for electricity generation, other industrial water, and water for livestock due to climate change mitigation, are of limited importance.

Vandyck et al. (2018) estimate that the 2°C pathway would reduce air pollution and cause the avoidance of 0.7–1.5 million premature deaths in 2050 compared to current levels. It is generally agreed that in both developed and developing countries there are additional benefits to be had from the mitigation of GHG emissions in terms of improved air quality (Chapter 3, Section 3.7.4). 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 the NDC targets, and 2°C stabilisation and 1.5°C stabilisation. 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 valued at USD 3.28–8.4 trillion and those in China USD 0.27–2.31 trillion. These positive results were not seen in the other regions. Gi et al. (2019) also show that developing countries such as India have a huge potential to produce co-benefits. In addition, it implies that the cost advantages of simultaneously achieving reductions of CO_2 emissions and of PM2.5 are clear, but the advantages for integrated measures could be limited, the costs greatly depending on the CO_2 emission reduction target.

Grübler et al. (2018) demonstrate a pathway below 1.5°C without CCS, taking end-use changes into account, including innovations in information technologies and changes to consumer behaviour apart from passive consumption. The pathway estimates 245 EJ yr^{-1} of global final-energy demand in 2050, which is much lower than in existing studies (also see Chapter 5, Section 5.3.3), and also shows the possibilities of increasing the index regarding multiple SDGs like hunger, health, energy access, and land-use. Integrated technological and social innovations will increase the opportunity to achieve sustainable development.

The co-benefits and trade-offs of several kinds of SDGs in synthesised modelling results with the 1.5°C target can be seen in Chapter 3, Figure 3.43. While achieving the 1.5°C target would induce a lot of co-benefits, it would also induce some adverse effects, such as decreases in biodiversity and food security due to competition over land resources. In addition, according to many studies, there are very different consequences between nations and regions, and therefore careful policies will be required given the integrated impacts for SDGs targets, nations and regions over time.

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 areas of human capacity and demography, consumption and production, decarbonisation and energy, food, the biosphere and water, smart cities and digitalisation. The report concludes that the 17 SDGs are integrated and complementary and need to be addressed in unison.

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 localised 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 localised 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 IAMs assess climate-change mitigation and SDGs with a stylised manner, but many of the SDGs are closely related to distribution issues not only between but also within countries. As the IAMs cannot sufficiently treat them so far, there are still large limitations in assessing sustainable development by using IAMs. The relevance of the IAM modelling results in relation to policy implementation has been addressed in the IPCC special report on stabilisation 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 on decarbonisation and sustainable development, and Chapter 3 includes an assessment of the enabling factors. Jakob and Steckel (2016) conclude that a key barrier to policy implementation is the lack of a governance framework to enable joint policy implementation that meets both local and global goals in terms of low stabilisation targets and sustainable development.

17.3.2.2 Renewable energy penetration and fossil-fuel phase-out

As pointed out in Chapter 6, the achievement of long-term temperature goals in line with Paris Agreement requires the rapid penetration of renewable energy and a timely phasing out of fossil fuels, especially coal, from the global energy system. Limiting the carbon budget implies that global annual emissions must achieve "net zero" in 2050/2060 (IPCC, 2018). Net-zero emissions imply that fossil fuels need to be fully phased out and replaced by renewables and other carbon-neutral primary forms of energy, or else the residue emissions from fossil fuels need to be offset by negative emission technologies (NETs). The 1.5°C 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 rate of global energy supplies, far from what is required to meet the low temperature targets. While CCS can reduce the pressure to phase out fossil fuels (IEA, 2019), it will not change the carbon budget, and deploying large-scale CCS technologies is no easier than introducing renewables (Sgouridis et al, 2019).

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 (Shen et al. 2020). However, studies show that replacing fossil fuels with renewables can have major synergies and trade-offs with a broader agenda of sustainable development (Swain and Karimu 2020), which have to be addressed. These synergies and trade-offs are related to energy and water access (Swain and Karimu 2020), land use and food security (McCollum et al, 2018), decent jobs and economic growth (Swain and Karimu 2020).IPCC, AR 5, Mitigation Policies, Table 6.7 (IPCC, 2014) gives detailed mapping of the sectoral co-benefits and adverse side-impacts of and links to transformation pathways. In section 17.3.3, this is supplemented with a mapping of synergies and trade-offs between the deployment of renewable energy and the SDGs.

The general conclusion is that the potential co-benefits of renewable energy end-use measures outweighs the adverse impacts in most sectors and in relation to the SDGs, though this is not the case for the AFOLU (Agriculture, Forestry and Other Land Uses) sectors. Some locally negative economic impacts can result in increased energy costs and competition over land areas and water resources. Some sectors may also experience increasing unemployment as a consequence of the transition process. Although the deployment of renewable energy 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.

The transition to low emission pathways will require policy efforts that also address the emissions locked into existing infrastructure like power plants, factories, cargo ships and other infrastructure already in use: for example, today coal-fired power plants account for 30% of all energy-related emissions (IEA, 2019). Over the past twenty years, Asia has accounted for 90% of all coal-fired capacity built worldwide, and these plants have potentially long operational lifetimes ahead of them. In developing economies in Asia, existing coal-fired plants are just twelve years old on average. Three options to bring down emissions from the existing stock of plants: to retrofit them with carbon capture, utilisation and storage (CCUS) or biomass co-firing equipment; to repurpose them to focus on providing system adequacy and flexibility while reducing operations; or to retire them early. In the Sustainable Development Scenario, most of the 2080 GW of existing coal-fired capacity would be affected by one of these three options.

Even though the transition away from fossil fuels is desirable and technically feasible, it 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 with the 1.5°C scenario or two thirds of the carbon budget consistent with the 2°C scenario (Tong et al. 2019). The early phasing out of this infrastructure will result in a significant share of stranded assets (Ansari et al. 2020) with an impact on workers, local communities, companies and governments (van der Ploeg 2020). 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 window of opportunity.

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 the 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. They also point 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 global coal sector needs a transition to near zero by 2050 and earlier in some regions (IPCC 1.5 SR, IEA, 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 tendency to plateau and then go into reverse (Sartor, 2018, Spencer et al., 2018). The world should be prepared for a managed transition away from coal and should identify appropriate transition options for the future of coal, which can include both the penetration of renewable energy and improvements to energy efficiency (Shah et al. 2015)

The coal transition will impose challenges not only in the power sector, but even more importantly on coal-mining industries. A less diversified local economy, low labour mobility and heavy dependence on coal revenues will make closing down coal production 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 incentivise 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 governments to manage the consequences of coal closures. Earlier involvement with local stakeholders in a structured approach is crucial and will make the 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 incentivise emerging businesses. 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 been 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 environmental concerns and the pressure to reduce greenhouse gas emissions. Coal combustion contributes about 90% of total SO_2 emissions, 70% of NO_x emissions and 54% to primary PM2.5 emissions in China (Yang and Zhang 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 (Zhang et al. 2019), as well as the reduction of methane (Pfaff et al. 2010) and black carbon (Zhang et al. 2019). 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. A rapid transition away from coal is critical for China to reach the peak in its emissions (Cui et al., 2019). Despite the deployment of CCS and extending the use of coal, retrofitting CCS plant may be more expensive than deploying renewables (EIA, 2019).

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° C 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. 2019). Political and economic considerations, at least regionally, are also of great importance in the coal sector due to the approximately 35,000 people employed within it (including coal mining and the power stations themselves). For a long time, coal-fired power plants were able to protect their position in Germany, but against the background of decreasing public acceptance, economic problems resulting from the growing use of renewables and ambitious GHG reduction targets, the sector cannot resist the political pressure against them any longer. The governing parties have agreed to establish 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 transition towards a high penetration of renewable systems faces various challenges in the technical, environmental and socio-economic fields. The integration of renewables into the grid requires not only 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 (see Chapter 6 for more details on these issues).

The transition towards a high-penetration renewable system also raises concerns over the availability of rare metals for batteries. The effective utilisation of these sources of renewable energy requires efficient, low-cost energy-storage systems. Rechargeable batteries have proved to be the most viable storage options, but the rise in the use of electric vehicles and solar panels has increased the demand for them. 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 (Kazhamiaka et al.,2019). They are attracting increasing 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 percent from 2016 to 2017 to 43,000 MT in 2018 (UNCTAD, 2020). Africa has rich reserves of lithium and is expected to produce 15% of the world's supply soon (Kazhamiaka et al., 2019). Such reserves are found in Zimbabwe, Botswana, Mozambique, Namibia, South Africa (Steenkamp, 2017) and the Democratic Republic of Congo (Roker, 2018).

Chapter 10 includes a more detailed assessment of the issues with mining these rare metals, as well as the associated social problems, including exploitative working conditions and child labour, the latter a major issue that needs to be taken into consideration in transitions. Recycling batteries is also highlighted as a major supplementary policy if negative environmental side impacts are to be avoided (Rosendahl and Rubiano 2019).

The move to renewable energy sources to reduce GHG emissions has increased the demand for non-fossil-fuel resources like lithium and cobalt. While metal reserves are unlikely to limit the growth rate or total amount of solar and wind energy, used battery technologies and the known reserves currently being exploited are not compatible with the transition scenario due to insufficient cobalt and lithium reserves (Månberger and Stenqvist 2018). The Democratic Republic of Congo (DRC) possesses half the cobalt reserves (van den Brink et al. 2020) in the world and hosts the largest hard rock lithium mine (Roker, 2018), the world's largest source of cobalt (Conca,2018). The world's largest lithium brine deposits are situated in the so-called lithium triangle straddling Chile, Argentina and Bolivia (Roker, 2018). 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 et al.,2020) 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). In the future, more attention should be paid to reducing vulnerability through the development of technologies that utilise abundant metals and increase recycling (Rosendahl and Rubiano 2019).

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 (Shelley 2019). Will lithium mining replace the economic value of oil and coal extraction in resource-rich countries in Africa?

17.3.2.3 Stranded assets and just transitions

As the momentum towards achieving carbon neutrality grows, the risk of assets becoming stranded is on the increase. International policies and the push for low-carbon technologies in the arena of climate change are reducing the demand for and value of fossil-fuel products. Stranded assets are assets that become devalued before the end of their economic lifetime or that can no longer be monetised as a result of changes in policies and regulatory frameworks, technological change, security or environmental disruption. The risks attached to the stranding of fossil-fuel assets have increased with the recent and sustained plunge in oil prices because of the global health pandemic (COVID-19) and the concomitant economic downturn, forcing demand to plummet to unprecedented low levels. Many economies in transition and countries dependent on fossil fuels are going through turbulent times where asset and transition management will be critical (UNEP Production Gap Report, 2020). However, COVID-19 provides a foretaste of what a low-carbon transition could look like, especially if assets become stranded in an effort to respond to the call for action in 'building back better' and putting clean energy jobs and the just transition at the heart of the post-COVID-19 recovery (IEA 2020; United Nations Secretary-General 2020).

As climate change gathers new momentum and ambition increases, the expectation is that there will be winners and losers across fossil fuel producing countries (Lahn and Bradley, 2016). Findings from University College, London assert that 'globally, a third of oil reserves, half of gas reserves and over 80 per cent of current coal reserves should remain unused from 2010 to 2050 in order to meet the target of 2°C' (McGlade and Ekins, 2015). Stranded assets are a reminder for most oil producing countries that fossil fuel assets do not have a durable value and are vulnerable to politico-economic forces and fluctuations. The goal of staying within the 1.5°C temperature goal and in-line with the Paris agreement is already part of the policy vision and planning of large fossil fuel consuming economies – but for early fossil fuel producers the reality that their resources may not yield desired returns is often perceived as bad news, particularly in the context of increasing depreciation in value of fossil fuel products.

Fossil fuel-dependent countries are doubly exposed to the vulnerability related to climate change impacts and are subjected to the global effort to address the problem (Peszko et al., 2020). Countries that are heavily reliant on oil, coal and gas are also the most at risk from a low-carbon transition that may curtail the activities of their fossil-fuel industries and render the value chains and economies associated with the exploitation of fossil fuels unviable (Peszko et al., 2020). Developing countries in Latin America and Africa that are reliant on revenue streams from fossil fuels may not see these returns converted into much needed infrastructure and other social and economic amenities that can reduce poverty.

With global investment in energy expected to shrink by 20% this year, this has created fiscal challenges for countries that are heavily reliant on fossil-fuel products as their main source of revenue. Other disruptions are linked to redundant contracts and postponed or cancelled explorations, as many oil companies are diversifying their production in the wake of the pandemic and are cutting back on planned hydrocarbon investments. These failed concessions and disruptions have implications for the just transition, especially in developing countries without the financial ability to pull out of fossil fuels and diversify with the same urgency as the industrialised nations (Peszko et al. 2020). For instance, in South Africa, which is seeking to divest away from coal and decarbonise the energy sector, if the transition is not properly managed, this could lead to a loss in revenue of R1.8 trillion (USD125 billion), thus compromising the government's ability to support social spending (Huxham et al. 2019). Emerging oil producers like Uganda are having to postpone the start of production. Eni and Total, two of the largest international oil and gas majors in Africa, have already signalled they are making 25% cuts to their investment in exploration and production projects in 2020, representing a €4bn reduction in foreign direct investment for Total and a USD2bn reduction for Eni (Le Bec 2020).

A poorly managed transition will reproduce inequalities contradicting the very essence of a just, sustainable, inclusive transition. Revenues from oil and gas have been ploughed into social safety nets and are supporting free senior high-school education in countries such as Ghana, thus enabling the realisation of SDG 4 on quality education (UNU-INRA, 2020). The move from fossil fuels towards a low-carbon economy has economic implications for lower income countries that are dependent on hydrocarbon resources, are endowed with significant untapped oil and gas reserves, and may not have the transitional tools to move towards low-carbon technologies or economies (Peszko et al, 2020).

The energy transition landscape is changing rapidly, and we are witnessing multiple transitions. This creates room to manage the transition in ways that will prioritise the need for workers in vulnerable sectors (land, energy) to secure their jobs and to maintain a secure and healthy lifestyle, especially as the risks multiply for those who are exposed to heavy industrial jobs and all the associated outcomes. The shift to carbon neutrality is driven by convergent factors related to energy security and the benefits of climate mitigation, including the health impacts of air pollution and consumer demand (Svobodova et al., 2021).

The 'Just Transition' concept has evolved over the years (Sweeney and Treat 2018) and is still undergoing further evolution. It emphasises the key principles of respect and dignity for vulnerable groups, the creation of decent jobs, social protection, employment rights, fairness in energy access and use, and social dialogue and democratic consultation with relevant stakeholders, whilst coping with the effects of asset-stranding or the transition to green and clean economies. The concept has come under increased scrutiny, with its protagonists emphasising the need to focus on the equality of the transition rather than the race to achieve it (Forsyth 2014). The emphasis on justice is also gaining in momentum with a growing recognition that the sustainability transition is about justice in the transition and not simply about economics (Williams and Doyon 2020, Newell and Mulvaney 2013, Swilling and Annecke 2010).

From labour to social inclusion, definitions of 'Just Transitions' can be quite broad, ranging from energy to land systems, and covering climate and energy security and well-being. The preamble to the Paris Agreement makes reference to the Just Transition with a strong focus on well-being, equity and justice, as well as pointing out the potential inherent disruptions that will result in disproportionate suffering for communities that are dependent on fossil-fuel industries. The concept embraces environmental justice, climate justice, energy justice and even identity justice (McCauley and Heffron 2018). Consequently, the phrase 'Just Transition' also alludes to distributive justice (where and how costs and benefits are distributed), procedural justice (whose agency is considered, and who defines 'just' and 'transition,' and recognition (how recognition, misrecognition and non-recognition are dealt with) (Williams and Doyon 2020).

The economic implications of the transition will be felt by developing countries with high degrees of dependence on hydrocarbon products as a revenue stream, as they are exposed to reduced fiscal incomes, given the low demand for oil and low oil prices and the associated economic fallout of the pandemic. This link with stranded assets is important, but it may be overlooked, as countries whose assets are becoming stranded may not have the relevant resources, knowledge, autonomy and agency to design a fresh orientation or decide on the transition.

However, in the race to carbon neutrality by 2050, some of the other priorities of the transition, like climate-change adaptation and its inherent vulnerabilities, might become muted, given the urgency of mitigation at all costs. Consequently, the transition imperative reduces the scope for local priority-setting and ignores the additional risks faced by countries with the least capacity to adapt. Equally, the 'Just Transition' is often seen through the prism of job losses and the attendant retooling and reskilling imperatives necessary to re-dynamise local businesses, especially those that may fail as a result of mine closures.

The 'Just Transition' will depend on local contexts, regional priorities, the points of departure of different countries in the transition and the speed at which they will want to travel. Hence, the timing and the scope are important elements that are associated more with a quality transition than a race to the bottom. To date the debate has had some obvious blind spots, not least considerations of power, politics and political economy. Certainly, the transition will create winners and losers, as well as stakeholders that can frame their economic interests to determine the orientation, pace, timing and scope of the transition.

The determination of a just transition is complex and not simply dependent on the allocation of perceived risks or solutions, but rather on how risks and solutions are defined (Forsyth). Adopting urgency to environmental solutions or transition imperatives have risk implications given the need to go beyond commonplace definitions of just transition with the emphasis placed on distributive or procedural justice (Forsyth, 2014). The framing of policies to align with fast and low-cost mitigation without sufficient attention to social and economic resilience creates its own potential risks and can enhance social vulnerability rather than address it (Forsyth, 2014). As Forsyth argues, the need to distribute climate change solutions must not delegitimise appropriate economic growth strategies or indeed create additional risks from policy imposition. Imposing fast solutions is not necessarily just, argues Forsyth. Perceptions of justice with regard to environmental problems and solutions matter equally. Hence, the types of transition pathway chosen may have equity implications. Mitigation at all cost, done "cheaply and crudely" can create additional problems for social justice and inclusive development (Forsyth, 2014).

The assumption that mitigation benefits are enough to offset trade-offs with other policy objectives can be questioned. If one accepts the argument that not all adaptation address vulnerability concerns (Kjellen, 2006) and that some adaptation strategies can heighten vulnerabilities if there are flaws in the design and implementation, then the same logic applies that not all mitigation is necessarily beneficial, and hence the emphasis on the transition resulting from mitigation should be placed not only on speed or cost effectiveness, but also on legitimacy of the actions, and whether the transition is well designed or not. In short, justice is not always a shorthand for acting ethically, but rather a point of reasoning on what is considered legitimate (Forsyth, 2014). Planning for the transition often discounts human rights and social inclusivity that can occur as a result of a rapid transition. Emphasis should be placed on the management of the transition rather than the speed – for instance, if in the rush to build new hydropower energy sources implies that populations find themselves displaced, then this constitutes human rights violations (Piggot et al, 2019; Castro et al, 2016).

Ambitious climate goals can increase the urgency of mitigation and accelerate the speed to arrive at carbon neutrality. However, if the transition is done with speed, then this will leave diversification efforts stymied particularly in developing countries that are highly dependent on fossil fuel revenue streams (Production Report, 2020). Transition decisions and policies, furthermore may have far reaching gendered implications as the closure of mines is often linked to several ancillary businesses impacts, where men are laid off, and women may have to take on multiple jobs to compensate for reduced household income (Piggot et al, 2019, UNU INRA 2019).

A just transition holds prospects for alternative high-quality jobs, public health improvements, an opportunity to focus on well-being and prosperity with spill-over benefits to urban areas and economic systems. Nonetheless, countries that transition from fossil fuels experience different challenges, different levels of dependency and have different capacities to transition. There will be countries with lower capacity and higher dependence and countries with higher capacity and lower dependence (UNEP/SEI 2020).

Deciding on matters of justice is essential to the transition and there are several inherent questions to consider when thinking through the allocation of costs and benefits as is the case in distributive justice. How matters are defined and who defines matters such as the timing of a phase-down, prioritising which energy sources need to be phased down and who might be affected are political economy questions (Piggot et al, 2019).

Similarly, when considering procedural justice, there are matters related to interests, participation and power dynamics that are essential to the process, and these matters may also subvert the process depending on whose rights, whose participation, and whose power are being put in jeopardy (Forsyth, 2014 and Piggot et al 2019). Hence, both distribution and procedure matter as does inter-generational and intra-generational equity in transition planning. Six critical variables can shape or inhibit the transition process. These are dependency, timing, capacity, agency, scope and inclusion.

Dependency- the extent to which a country may depend on revenue streams from fossil fuels will determine their ability to manage the transition from fossil fuels. Countries who rely on proceeds from hydrocarbon resources as economic rents to support fiscal income and spending on public service related needs such as education, health and infrastructure, export earnings and foreign exchange reserves will have greater difficulties to forego their fossil fuel resources.

Timing – the transition pathway has to be aligned with a timetable which is anchored in national development priorities. For example, the South African Integrated Resource Planning indicates that the transition away from coal, if not aligned with national development priorities, will reproduce new forms of inequalities. In addition, if transition is imposed and its timing is not organic then this might also incur social inequalities.

Capacity – Transitions need to reflect spaces and planning. If knowledge on the transition pathway is not adequately mastered or in place this can disable the process or steer it in the wrong direction. Capacity also relates to several attributes including technical, governance, institutional, technologies, economic resources to manage the transition. Poorer countries will have difficulties managing all these resources as well as absorbing the costs associated with the transition (UNEP/SEI 2020).

Agency – transitions are inherently about sovereign rights to determine one's orientation towards low carbon development. However, with the urgency to stick to the Paris Agreement and new conditionalities related to the post COVID stimulus packages, the absence of agency to deal with the transition might jeopardise the flow, orientation and pace of the transition (Newell et al. 2013).

Scope – the extent to which the transition is rolled out and its potential impacts. If transition policies are ambitious with commensurate diversification investments this may enable job creation, but it may also affect employees who are insufficiently prepared for new jobs and skills.

Inclusion. – Who is considered in the transition process and how their interests and risks are assessed are important aspects of the transition pathways. Stakeholders with strong vested interests may resist transition especially as they move towards diversification activities and policies.

17.3.3 Cross-sectoral transitions

Transitions will involve multiple sectoral- and cross-sectoral policies. Section 17.3.3 presents a range of studies and conclusions on the relationship between climate-change mitigation goals and meeting the SDGs in order to identify major synergies and trade-offs. Here we draw on conclusions from sectoral chapters and add additional studies as a basis for drawing more general conclusions about agriculture, food and land use, the water-energy-food nexus, industry, cities, infrastructure and transportation, cross sectoral digitalisation, and mitigation and adaptation relations.

17.3.3.1 Agriculture, Forestry, and Other Land Uses (AFOLU)

Sustainable development and mitigation policies are closely linked in the agriculture, food and land-use sectors. We assess synergies and trade-offs between meeting the SDGs and reducing GHG emissions within the sectors based on modelling studies and case studies illustrating how trade-offs between SDG 2 (zero hunger, biomass for energy) and SDG 15 (life on land) can be addressed by cross-sectoral mitigation options.

The IPCC Sixth Assessment Report, Chapter 7, emphasises the high expectations on land to deliver mitigation, yet the pressures on land have grown with population, dietary changes, the impacts of climate change and the conversion of natural land to agriculture and other land uses. Agriculture, Forestry and Other Land Uses (AFOLU) are expected to play a vital dual role in the portfolio of mitigation options across all sectors. The AFOLU sector is also the only one in which it is currently feasible to increase large-scale atmospheric carbon removals, including sequestration in biosystems and CCS/BECCS. The AFOLU sector has a significant mitigation potential, with many scenarios showing net 40 negative GHG emissions already in this century. Total cumulative AFOLU CO_2 emissions vary widely across scenarios, with as much as 415 $GtCO_2$ sequestered between 2010 and 2100 in the most stringent mitigation scenarios. The largest share of GHG emissions reductions from AFOLU in the 1.5°C and 2°C scenarios is from forestry-related measures, such as afforestation, reforestation and reduced deforestation. Afforestation, reforestation and forest management result in substantial negative CO_2 emissions in many scenarios. CO_2 and CH_4 show larger and more rapid declines than N_2O, an indication of the difficulty of reducing N_2O emissions in agriculture (Chapter 3).

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 amount of land used for bioenergy production would not be compatible with these SDG's. However, combining bioenergy options with other mitigation options, like more efficient land management and the restoration of nature, could contribute to welfare improvements and to access to food and water. Demand-side climate-mitigation measures like energy-efficiency improvements, reduced meat consumption and reduced food waste were considered to be the most economically attractive and efficient options in order to support low GHG emissions, food security and biodiversity objectives. Implementing such options, however, can involve challenges in terms of lifestyle changes (IPBES, 2019).

Fujimori et al. (2019), in a study of six global IAMs, assessed the consequences of meeting the goals of the Paris Agreement for stabilising the global temperature increase at 1.5 °C and 2 °C respectively in terms of people being at risk of hunger. They conclude that, if framed as a climate-mitigation effort, meeting these temperature targets could significantly increase the number of people suffering from hunger by 2050. The major arguments are that the carbon prices included in the modelling results would increase food costs and thereby food prices, potentially compromising food access for low-income groups in the least developed countries (Brown et al., 2015). Another major drawback is that climate-change mitigation scenarios imply increased demand for land 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. Food prices and affordability would be at risk in the case of all shared socioeconomic pathways (SSPs), but it is SSPs 2, 3 and 4 that exhibit the greatest risks to food access and its stability.

Basing themselves on integrated assessment, (Bleischwitz et al. 2018) modelling conclude that the temperature targets of the Paris Agreement can be achieved by intensifying agricultural production and reducing 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-related co-benefits than land-use scenarios featuring increased demand for land devoted to bioenergy. The authors conclude that implementing these pathways critically depends on demographics and governance in terms of behavioural changes and other critical elements of the transition in different parts of the world.

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 for 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 agricultural production systems can provide large benefits. Given the expectations of high levels of population growth and the strong 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.

Loss of biodiversity has been highlighted in several studies as a major trade-off of the low stabilisation scenarios (Prudhomme et al., 2020). A wide range of mitigation and adaptation responses – for example, preserving natural ecosystems such as peatland, coastal lands and forests, reducing the competition for land, fire management, soil management, and most risk management options – have the potential to make positive contributions to sustainable development, ecosystems services, and other social goals (McElwee et al.,2020; Smith 2019) also stressed that agricultural practices (e.g. improving yields, agroforestry), forest conservation (e.g. afforestation, reforestation), soil carbon sequestration (e.g. biochar addition to soils) and the removal of carbon dioxide (e.g. BECCS) could contribute to climate-change mitigation (Smith , 2019). However, there are also options that could improve biodiversity if they were implemented jointly with climate-change mitigation in AFOLU. In a study, Leclere et al. (2020) show that increasing conservation management, restoring degraded land and generalised landscape-level conservation planning could be positive for biodiversity. In general, the ambitious conservation efforts and transformations of food systems are central to an effective post-2020 biodiversity strategy.

The IPCC Special Report on Climate Change and Land (IPCC, 2019) emphasises the need for governance in order to avoid conflict between sustainable development and land-use management. It states: "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, the NDCs and the SDGs. Various governance issues are often associated with industrial oil palm expansion by large multinational and national companies, and therefore with social problems, such as land-grabbing and conflicts, labour exploitation, social inequalities and declines in village-level well-being (Meijaard et al., 2020; Andrianto, 2020).

One example of an area where special governance efforts have been called for is the protection of forestry, ecosystem services and local livelihoods in a context of the large-scale deployment of high-value crops like palm oil, short-term, high income-generating activities and sustainable development. Serious challenges are already being seen within these areas according to (IPBES 2019).

Palm oil is one example of a product with potentially major trade-offs between meeting the SDGs and climate-change mitigation in agriculture, forest and other land uses (AFOLU) sector. Palm oil is one of the most productive oil crops in the world in term of oil yield per unit of area. It is used in a wide range of processes, from fast foods, chocolate spread and cereals to toothpastes and animal feed (Rochmyaningsih, 2019). Furthermore, palm oil has become one of the major feedstocks for biofuels in the European Union (Jupesta et al., forthcoming 2021). This crop has nonetheless become one of the most controversial today because, despite its high productivity, high applicability and ability to alleviate poverty, palm-oil development is most often pursued at the cost of deforestation, which causes greenhouse gas (GHG) emissions and loss of biodiversity (Curtis et al., 2018).

Currently the area under oil palms is showing a tremendous increase, mostly in forest conversions to oil-palm plantations (Gaveau et al., 2016, Austin et al., 2019, Schoneveld et al., 2019). The conversion of peat swamp forest and mineral forest to oil palms will yield different amounts of CO_2. A study by Novita et al. (2020) shows that the carbon stock of primary peat-swamp forest was 1,770 Mg C/ha compared to a carbon stock of oil palm of 759 Mg C/ha. The study conducted by Guillaume et al. shows that the carbon stock in mineral soils was 284 Mg C/ha compared to that in rain forest, which was 110.76 Mg C/ha (Guillaume et al., 2018).

Given that the frequent peat-land fires in Indonesia were caused by land clearing in the replanting season, the multi-stakeholder collaboration between oil-palm plantations, local communities and local governments over practices such zero burning when clearing land might be one of the most effective ways to reduce the deforestation impact of oil palm (Jupesta et al., 2020). Behavioural changes as a mitigation option have been suggested as a major factor in aligning sustainable development, climate change and land management. These options are extensively discussed in Chapters 3 and 5.

Economy-wide mitigation costs can be effectively limited by lifestyle, technology and policy choices, but can benefit from synergies with the SDGs. Synergies come from the consumption side *by* managing demand. For example, reducing food waste leads to resources being saved because water, land-use, energy consumption and greenhouse gas emissions are all reduced (Chapter 3).

IPCC Sixth Assessment Report Chapter 12 emphasised that diets high in plant protein and low in meat, in particular red meat, are associated with lower GHG emissions. Emerging food-chain technologies such as microbial, plant, or insect-based protein promise substantial reductions in direct GHG emissions from food production. The full mitigation potential of such technologies can only be realised in low-GHG energy systems.

Demand-side, service-oriented solutions vary between and within countries and regions, according to living conditions and context. Avoiding food waste reduces GHG emissions substantially. Dietary shifts to plant-based nutrition lead to healthier lives and reduce GHG emissions (Chapter 5).

The inextricably intertwined factors in decision-making are influenced by the characteristics of the person, in interaction with the characteristics of more sustainable practices and products, which interacts with a particular context that includes the immediate environment (e.g., household, farm), the indirect environment (e.g., community) and macro-environmental factors (e.g., the political, financial and economic contexts) (Hoek et al., 2021). Hence, to influence people to make decisions making in favour of sustainable food production or consumption, a wider perspective is needed on decision-making processes and behavioural change, in which individuals are not targeted in isolation, but in interaction with this wider systemic environment.

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, their 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 in the direction of 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.

A similar study also found a positive impact form zero food waste. The 'no food waste' scenario could decrease global average food calorie availability by120 kcal person^{-1} d^{-1} and protein availability by 4.6 g protein person−1 d^{-1} relative to their baseline levels, thus reducing required crop and livestock production by 490 and 190 Mt respectively. This lower level of production reduces agricultural land use by 57 Mha and thus mitigates the associated side effects on the environment. The lower levels of production also reduce the requirements for fertilisers and water by 10 Mt and 110 km^3 respectively, and GHG emissions are reduced by 410 $MtCO_2eq$ yr^{-1} relative to the 2030 baseline. Reducing food waste can contribute to lessening the demand for food, feed and other resources such as water and nitrogen, reducing the pressure on land and the environment while ending hunger (Hasegawa et al., 2019).

In 2007, Britain launched a nationwide initiative to reduce household food waste, and the programme achieved a 21 percent 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 organisation, the Waste and Resources Action Programme (WRAP). The campaign raised awareness among consumers about how much food they waste, how it affects their household budgets 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 at GBP 26 million, from which it was households that derived the most benefit, estimated to be worth GBP 6.5 billion. Local authorities also realised a substantial GBP 86 million worth of savings in food-waste disposal costs. As for the private sector, the benefits took the form of increased product shelf lives and reduced product loss. While households started to consume more efficiently and companies may have experienced a decline in food sales, the latter also stated that the non-financial benefits, such as strengthened consumer relationships, had offset the costs.

The Asia Pacific Economic Cooperation (APEC) group of countries has also created several types of public–private partnership for food waste and reducing losses. Most of these partnerships are focused on food-waste recycling in both developed and developing countries (Rogelj et al., 2016). APEC members stated that knowledge-sharing and improved policy and project management were the most important advantages of public–private partnerships. Table 17.1 provides an overview of the synergies and trade-offs between the mitigation options and SDGs assessed in this section based on the authors' own assessments.

Table 17.1 The synergies and trade-offs between mitigation options and SDG's assessed in this section based on the authors assessment

AFOLU mitigation option	Mitigation	Food	Energy	Biodiversity	Poverty /economy	Remarks
Carbon sequestration in forestry	+	+	-	+	+/-	Refer to Chapter 7. Less land for agriculture and biomass for energy
BECCS etc.	+	-	+	+	+/-	Refer to Chapter 12. Smart fertiliser, Drones, Sensors, Biochar, Artificial Intelligence, etc. Could be high cost due to not yet massive utilisation.
Improved land management and efficiency	+	+	+	+	+	Studies in Chapter 17
Lifestyles and dietary changes (decreased meat)	+	+	+	+	+	Chapters 3 and 5 and studies in Chapter 17
Shifting diets into microbe, plant and insect-based proteins	+	**n.a**	**n.a**	**n.a**	-	Expensive due to low scale
Reduced food waste	+	+	+	+	+	Case study

Dark blue means that synergies are expected, light blue that both synergies and trade-offs could be expected, and brown/red that trade-offs can be expected. Grey is used to indicate that the measure is not applicable, based on the available studies.

As shown in Table 17.1, the AFOLU sector offers many low-cost mitigation options, which, however, can also create trade-offs between land-use for food, energy and forest allocations. Some options can help to mitigate such trade-offs, like agricultural practices (e.g. improved yields, agroforestry), forest conservation (e.g. afforestation, reforestation), soil carbon sequestration (e.g. biochar addition to soils) and removal of carbon dioxide (e.g. BECCS) could contribute to climate change-mitigation. Lifestyle changes, including dietary changes and reduced food waste, are highly embedded in modes of behaviour that are influenced by the immediate environment (e.g., household, farm), the indirect environment (e.g., community) and macro-environmental factors (e.g., political, financial and economic contexts). Achieving zero-food waste could reduce the demands for land (SDG 15), water use (SDG 6) and chemical fertilisers (SDG 9), leading to GHG emissions reductions (SDG 13) by encouraging sustainable consumption and production practices (SDG 12).

17.3.3.2 Water-Energy-Food-Nexus

This section addresses the links between water, energy and food in the context of sustainable development and the associated synergies and trade-offs, with links to related chapters. The focus outline includes scoping and the relationship with the SDGs, general climate-change impacts on global water resources, energy-system impacts and the relationship to renewables, enabling strategies, trade-offs and cross-sectoral implications (see also Chapter 12), nexus-management tools and strategies, and a box with examples from India and South Africa.

The continually increasing pressures on natural resources, such as land and water, due to the rising demands from increases in populations and living standards, which also require more energy, emphasises the need to integrate sustainable planning and exploitation (Bleischwitz et al., 2018). The water-energy-food nexus is the epicentre of these challenges, which are of global relevance and are the focus of policies and planning at all levels and sectors of the global society. The nexus between water, energy and food (WEFN) (C. Zhang et al., 2018) is closely linked in a complex manner and needs careful attention and deciphering across spatio-temporal scales, sectors and interests to balance proper management and trade-offs and to pursue sustainable development (Biggs et al., 2015; Dai et al., 2018; Hamiche et al., 2016). The WEFN touches upon the majority of the UN's SDGs, such as 2, 6-7 and 11-15 (Bleischwitz et al., 2018), and deals with basic commodities, thus guaranteeing the basic livelihoods of the global population.

The task of gaining an improved understanding of WEFN processes across disciplines such as the natural sciences, economics, 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 also covers land (Ringler et al., 2013) and climate (Brouwer et al., 2018; Sušnik et al., 2018) and can be further assessed in the light of the economic, ecological, social and SDG aspects (Fan et al., 2019). Specifically, SDGs 2 (food), 6 (water), (7) energy, 11 (cities) and 12 (production and consumption) are considered essential to the WEFN (Bleischwitz et al., 2018). The nexus approach was introduced in the early 2010s, when it was argued that advantages could be gained by a nexus mind-set with regard to cross-sectoral and human–nature dependencies and taking externalities into account (Hoff, 2011). Hence, within the nexus obvious trade-offs exist with competing interests, such as water availability versus food production.

Climate change is projected to impact on the distribution, magnitude and variability of global water resources. A yearly increases in precipitation of 7% globally 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 by 2050 due to the industrial and domestic demand for water. Already four billion people 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, placing 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) and Koutroulis et al., (2019).

An obvious consequence of the impact of climate change on future hydro-climatic patterns is the fact that the energy system is projected to experience vast impacts through climate change (Fricko et al., 2016; M. T.H. van Vliet et al., 2016; Michelle T. H. van Vliet et al., 2016), see also chapter 6. 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 generation, which relies mainly on water cooling (Larsen and Drews, 2019; Pan et al., 2018), and water is also used for pollution and dust control, cleaning etc. (Larsen et al., 2019). Currently, 98% of electricity generation relies on thermoelectric power (81%) and hydropower (17%) (M. T.H. van Vliet et al., 2016). Of these thermoelectric sources, the vast majority employ substantial amounts of water for cooling purposes, although there is a tendency towards the implementation of more hybrid or dry forms of cooling (Larsen et al., 2019).

The renewable energy conversion technologies that are currently dominant globally and are projected to remain so are less vulnerable to water deficiencies than fossil-based technologies, since no cooling is used. These include, e.g., wind, solar PV and wave energy. Some less dominant renewable-energy technologies do use water for cooling, such as geothermal energy and solar CSP, if wet cooling is employed. Despite the general detachment from water resources, wind and solar PV, for example, are highly dependent on climate-change patterns, including variability depending on future energy-storage capacities and on/off-grid solutions (Schlott et al., 2018). Furthermore, regardless of whether they are based on renewables or not, climate change will affect energy usage across sectors, such as heating and cooling in the building stock. The energy systems in question need to be able to handle variations and extremes in demand (Larsen et al., 2020).

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 (M. T.H. van Vliet et al., 2016); see also Chapter 6. Alongside the global increase in hydropower potential, the global mean water-discharge cooling capacity, which also relates to water temperatures, experiences a decrease of 4.5% to 15% across scenarios. In very general and global terms, when combined these changes support the shift towards sources of renewable energy, including hydropower, in the energy mix. When it comes 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 the 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 40% today. Similarly, Craig et al., (2018) show 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 light of the projected nature of the future climate.

In the ongoing transition towards renewable sources of energy (see also Chapters 3, 4 and 6), 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 scaled up. Of these, hydropower, wind and solar energy are the key energy sources currently and in the near future, making up 2.5% and 1.8% of the total global primary energy supply in 2017 respectively (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 the supply of water, while at the same time being an essential counter-component to seasonality and climatological variation, as well as to current and future demand curves and diurnal variations, as 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, have been shown to enhance energy production during droughts (Gjorgiev and Sansavini, 2018). The significant influence of variation in the planning of renewable energy for the 21st century 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 temperature (Michelle T. H. van Vliet et al., 2016), 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 of CCS technologies in the effort to reach the GHG mitigation targets (Budinis et al., 2018) alongside higher water usage (Byers et al., 2015).

The extraction, distribution and wastewater processes of anthropogenic water-management systems similarly use vast amounts of energy, making the proper management of water essential to reduce energy usage and GHG emissions (Nair et al., 2014); see also Chapter 11. 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; Gao et al., 2019). all of which have the 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 demand for food and comestibles in regions that experience constant or intermittent supplies, transportation is needed, which in itself requires suitable 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 on 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 hydroclimate 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 on a continental scale in the US Great Plains, highlighting the influence of irrigation in mitigating reductions in crop yields (J. Zhang et al., 2018). 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 context 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 a virtual WEFN that includes water embodied within products that 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.

Within the WEFN, the implementation of policies to achieve low stabilisation targets is strongly linked to sustainable development within the water sector with regard to water management and water conservation, indicating that additional coherence in policies affecting the water, energy and food sectors (among others) will be critical in achieving the SDGs (Rasul, 2016) (see also Chapter 7). Subsidised fertilisers, 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 the demand for water resources outstrips sustainable supplies for at least part of the year. Irrigated agriculture is already using 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).

It has been argued that applying an integrated approach to water-energy-climate-food resource management and policy-making is highly beneficial to properly addressing the co-benefits and trade-offs (Brouwer et al., 2018; Howells et al., 2013), accommodating the SDGs (Rasul, 2016) and in general assessing enabling strategies towards improved resource efficiency (Dai et al., 2018). For an integrated approach to analysing the WEFN, a number of modelling approaches, tools and frameworks have been proposed (Brouwer et al., 2018; de Strasser et al., 2016; Gao et al., 2019; Larsen and Drews, 2019; Smajgl et al., 2016), often involving multi-objective calibration. Such tools enable decision-makers to evaluate the optimal water-allocation and energy-saving solutions for the specific geography in question. As an example, Scott et al., (2011) found the higher transportability of electricity, compared to water, pivotal in water-energy adaptation solutions in USA, while arguing for the additional coordination of water and energy policies as a key instrument in balancing the trade-offs.

Common to all these integrated efforts is the challenge involved in making comparisons across studies due to the combined complexities of 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 (C. Zhang et al., 2018). The lack of proper WEFN data-accessibility and quality has been highlighted by D'Odorico et al., (2018) and Larsen et al., (2019). Furthermore, gaps have been identified between theory and end-user applications in the lack of any 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 provide greater insights into all these aspects. Holistic frameworks have been put forward to facilitate methods of WEFN management by focusing on, for example, the geographical complexities with regard to transboundary challenges within hydrological catchments (de Strasser et al., 2016), aligning policy incentives (Rasul, 2016), and making synergies and trade-offs in relation to WEFN SDG targets (Fader et al., 2018) etc. The role of all levels of government in optimal WEFN management is also highlighted in Kurian (2017), especially with regard to shaping the behaviour of individuals. Furthermore, Kurian (2017) highlights the challenges involved in science and policy communicating with one another and in the provision of optimal instruments and guidelines. Engaging non-experts and end-users in scientific processes is seen as essential to capturing previous failures and successes and to ensure that understanding of the challenges is updated to help shape research questions.

Coordination of water use across different sectors and deltas are important factors in sustainable water management. Examples of instruments and policies that support this from India and Sub-Saharan Africa in relation to the groundwater crisis are given below. India is the world's largest user of groundwater for irrigation, which covers more than half of the total irrigated agricultural area, is responsible for 70% of food production and supports more than 50% of the population (700 million people) (see also Chapter 7). However, excessive extraction of groundwater is depleting aquifers across the country, and declines in the water table 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 subsidised, 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 stabilise 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.

Sub-Saharan Africa has an undeveloped potential for groundwater exploitation, despite the general perception of a global groundwater crisis, this being due to the absence of services to support groundwater development (Cobbing, 2020). It is estimated that most Sub-Saharan countries in Africa utilise less than 5% of their national sustainable yields (Cobbing and Hiller, 2019). The initial tool for driving sustainable groundwater exploitation is a change in the narrative of a lack of resources in order to stimulate increased agricultural production and increased fulfilment of the SDGs (Cobbing, 2020). Quantitative measures of actual groundwater vulnerability based on multiple indicators have been calculated by, for example, van Rooyen et al. (2020), showing that 20.4% of South Africa's current water resources are highly vulnerable and projected to increase fifty years into the future. Despite the positive perspectives regarding Sub-Saharan groundwater resources, the 2015-2017 water crisis in South Africa, including in Cape Town, clearly predicts vulnerability to climate variability (Carvalho Resende et al., 2019), which is predicted to increase. Serving as inspiration for the future mitigation of water depletion, Olivier and Xu (2019) suggest governance tools to improve the diversification of water sources and the management of existing supplies. An overview of synergies and trade-offs between mitigation options related to WEFN and the SDGs, based on the authors' assessment, is given in (Table 17.2).

Table 17.2 Overview of synergies and trade-offs between examples of WEFN mitigation options and food, water, energy access, life on land, and economic impacts

	Mitigation	Food	Water	Energy	Economy	Life on Land	Remarks
Increased hydropower dams	+	+/-	+/-	+	+	-	Could create land-use conflicts
Increased biomass power	+	-	+/-	+/-	+/-	+/-	Could create land-use conflicts
Increased solar power	+	+	+	+	+/-	+/-	Could be costly and only facilitate low supply in off-grid systems
Increased wind power	+	+	+	+	+/-	+/-	Could be costly and only facilitate low supply in off-grid systems
Improved access to electricity	+	+	+	+	+/-	+	Efficiency improvements and increased income generation could be facilitated

Improved water resource management	+	+	+	**n.a**	+	+	Resource savings could be made
Improved assess to water	+	+	+	**n.a**	+	**n.a.**	Time savings could be a benefit, and potentially also irrigation in dry areas

Dark blue signifies that synergies are expected, light blue that both synergies and trade-offs could be expected, and brown/red that trade-offs can be expected. Grey is used to indicate that the measure is not applicable based on the studies.

The overview provided in Table 17.2 shows that in many cases WEFN options can have positive synergies between mitigation and food, water and energy access, and that these can also create positive impacts in terms of the benefits to low-income groups with poor access today. However, there could also be conflicts over land use in relation to the increased use of hydropower dams and bioenergy.

17.3.3.3 Industry

Industrial transformation is a core component in achieving sustainable development. Across all industrial sectors, the development and deployment of innovative technologies, business models and policy approaches at scale will be essential in accelerating progress with meeting both the economic and social development goals, as well as low emissions. In this section we assess the synergies and trade-offs between mitigation options and the SDGs, with a specific focus on asking whether economic growth and employment creation can work jointly with climate actions and other SDGs in least developed and developing countries. Examples of synergies and trade-offs are provided based on the conclusions of Chapter 9 on the building sector and Chapter 11 on industry. The potential for greening industry is discussed in relation to Eco industrial parks, including examples from Ethiopia, China, South Africa and Ghana.

Chapter 11 concludes that achieving net-zero emissions from the industrial sector are possible. It will require the provision of electricity free from greenhouse gas (GHG) emissions, including from other energy carriers, increased electrification, low carbon feedstocks, and a combination of energy efficiency, reduced demand for materials, a more circular economy, electrification, and carbon capture, use and storage (CCUS).

Chapter 11 of this report has mapped the potential co-benefits of mitigation options in industry in relation to five categories of such options: material efficiency and reduction in demand for materials, circular economy and industrial waste, carbon capture utilisation and storage, energy efficiency, and electrification and fuel switching (Chapter 11, Figure 11.15). In particular, the first two categories of options are assessed as having several co-benefits for the SDGs, including SDGs 3, 5, 7, 8, 9 11, 12, and 15. Some studies also point out the potential trade-offs in respect of employment and the costs of cleaner production processes. The other options primarily impact on climate actions, decent work and employment, and industry as such.

Okereke et al. (2019) offer important generic conclusions on green industrialisation and the transition based on a study of socio-technical transition in the context of Ethiopia. The importance of drivers for change in terms of clear policy goals and government support for green growth and climate policies, as well as support from a strong culture of innovation, is emphasised. The study also identifies key barriers in relation to stakeholder interactions, the availability of resources, and the ongoing tension between ambitions for high economic growth and climate change. 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 conclude that instruments like low-cost finance for innovation and support to sustainable practices effectively promote green innovation.

Luken et al. (2019) have assessed the drivers, barriers and enablers for green industry in Sub-Saharan Africa, concluding that major barriers exist related to material and input costs, as well as product requirements in foreign markets, and that as a result there are trade-offs between economic and environmental performance. Studies of ten countries are reviewed, and although they suffer from limited information, they conclude similarly that further progress is hindered by poor access to finance and weak government regulation. Greenberg and Rogerson (2014) similarly conclude that that the greening of industry in South Africa is lagging behind, despite its high priority in government planning and among international partners due to economic barriers and weak governance.

Ghana has launched a "One District One Factory" (1D1F) initiative, aimed at establishing at least one factory or enterprise in each of Ghana's 216 districts as a means of creating economic growth poles to accelerate the development of these 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 industrialised economy driven primarily by the private sector (Yaw 2018). The programme is expected to facilitate the creation of between 7,000 and 15,000 jobs per district and between 1.5 million and 3.2 million jobs nationwide by the end of 2020 (Ohene-Kanadur, 2019).

Mensah et al. (2020) have studied the relationship between economic growth and environmental quality in the Ghana One District One Factory programme, with a focus on the impacts of foreign investments. They conclude that the programme has been very successful in creating economic growth, exports, and employment, but also that the environmental impacts have been negative; it therefore recommends imposing environmental regulations on foreign investments. Similar conclusions have been drawn by Solarin et al. (2017) concluding that foreign investors have faced a pollution heaven in Ghana.

Eco-industrial parks have been used as a key option to create synergies between industries, including competitiveness, growth, jobs, and environmental improvements. Chapter 11 points to the benefits of industrial parks in relation to overall reductions in both virgin materials and final wastes, implying significant reductions in industrial GHG emissions. Due to these advantages, eco-industrial parks have been actively promoted, especially in East Asian countries such as China, Japan and South Korea, where national indicators and governance exist (Geng et al. 2019; Geng and Hengxin 2009).

Zeng et al. (2020) have assessed the role of eco-industrial parks in China's green transformation for 33 development zones in relation to contributions to GDP, industrial value added, exports, water and energy consumption, CO_2 levels, and sulphur emissions. It was concluded that industrial parks have played a very important role in China's industrialisation, and that this structure has supported the decoupling of economic growth, energy- and water consumption from the environmental impacts. However, improved environmental performance would require better access to finance and a higher priority by management.

Industrial parks have been promoted in Ethiopia by the government and UNIDO based on the expectation that they could help to boost the economy (UNIDO, 2018). One of the success stories is an industrial park in Hawassa, a nation-level textile and garment industrial park with a "zero emission commitment" based on renewable energy and energy-efficient technologies. However, the concept of the industrial park, including feasible policies and institutional arrangements, is new to Ethiopia's regulatory processes, and this has created for management, knowledge, and governance, hindering their fast implementation.

A number of business associations have developed strategies for sustainable development and climate change, including cooperate social responsibility (CSR). 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, eliminating child labour and climate change (Lamb et al. 2017). Leventon et al. (2015) evaluated the role of mining industries in

Zambia in supporting climate-compatible development and concluded 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.

Table 17.3 provides an overview of the synergies and trade-offs between climate-change mitigation options and the key SDG impacts, based on the authors' assessment.

Table 17.3 Overview of synergies and trade-offs between examples of industrial mitigation options and food, water, energy access, and economic impacts.

	Mitigation	Food	Water	Energy	Poverty/ Economy	Remarks
Efficiency and demand reduction	+	+	+	+	+	Could reduce costs
Circular economy and waste management	+	+	+	+	+	Could reduce costs and several pollutants
Carbon capture and storage	+				-	Costly new technology
Electrification and renewable energy	+	+/-	+/-	+	+/-	Increased reliability of services
Industrial parks	+	+	+	+	+	Requires complex governance and management

Dark blue signifies that synergies are expected, light blue that both synergies and trade-offs could be expected, and brown/red that trade-offs can be expected. Grey is used to indicate that the measure is not applicable based on the studies.

Based on Table 17.3, it can be concluded that most of the mitigation options in industry considered in this section could have synergies with the SDGs, but also that some of the renewable-energy options could indicate some trade-offs in relation to land use, with implications for food- and water security and costs. Carbon capture and storage could also be costly.

17.3.3.4 Cities, Infrastructure and Transportation

With 80% of the global population expected to be urban by 2050, cities will shape development paths for the foreseeable future (United Nations, 2018). The challenge for many policymakers is to construct development paths that make cities clean, prosperous and liveable while mitigating climate change and building resilience to heatwaves, flooding and other climate risks. The IPCC 1.5 report sees achieving these objectives as feasible: cities could potentially realise significant climate and sustainable-development benefits from shifting development paths (Wiktorowicz et al., 2018). The section assesses the synergies and trade-offs between meeting the SDGs and climate-change mitigation, as well as providing a general overview of mitigation options in cities and of enabling factors, including city networks and plans for jointly addressing the SDGs and climate-change mitigation.

Chapter 8 concludes that urban areas potentially offer several joint benefits between mitigation and the SDGs, and that since AR5, evidence of the co-benefits of urban mitigation continues to grow. In developing countries, a co-benefits approach that frames climate objectives alongside other development benefits are increasingly being seen as an important concept justifying and driving climate-change actions in developing countries (Patterson et al. 2017; Seto et al. 2014).

Evidence for the co-benefits of urban mitigation measures on human health has increased significantly since the IPCC AR5, especially through the use of health-impact assessments in cities like Geneva, where energy savings and cleaner energy-supply structures based on measures for urban planning, heating and transport have reduced CO_2, NO_x and PM10 emissions and increased the opportunities for physical activity for the prevention of cardiovascular diseases.

There is increasing evidence that climate-mitigation measures can lower health risks that are related to energy poverty, especially in vulnerable groups, such as the elderly (Monforti-Ferrario et al. 2018). Moreover, the use of urban forestry and green infrastructure as both a climate mitigation and adaptation measure can reduce heat stress (Kim 2017; Privitera and La Rosa 2018) while removing air pollutants to improve air quality (Scholz et al. 2018; De la Sota et al. 2019) and enhancing well-being, including contributions to local development and possible reductions of inequalities (Lwasa et al. 2015). Other studies evidence the potential to reduce premature mortality by up to 7,000 in 53 towns and cities with 93,000 net new jobs and lower global climate costs, as well as lower personal energy costs based on roadmaps for renewable energy transformations (Dollinger and Jose 2019).

The co-benefits of energy-saving measures described by 146 signatories of a city climate network due to improved air quality have been quantified as 6,596 avoided premature deaths (with a 95% confidence interval of 4,356 to 8,572 avoided premature deaths) and 68,476 years of life saved (with a 95% confidence interval of 45,403 and 89,358 years of life saved) (Monforti-Ferrario et al. 2018). Better air quality further reinforces the health co-benefits of climate-mitigation measures based on walking and bicycling, since the evidence suggests that increased physical activity in urban outdoor settings with low levels of black carbon improves lung function (Laeremans et al. 2018).Chapter 9 shows that mitigation actions in buildings have multiple co-benefits resulting in substantial social and economic value beyond their direct impact on reducing energy consumption and GHG emissions, thus contributing to the achievement of almost all the United Nation's SDGs. Most studies agree that the value of these multiple benefits is greater than the value of the energy savings, while their quantification and inclusion in decision-making processes will strengthen the adoption of ambitious reduction targets and improve coordination across policy areas.

There are several examples of cities that have developed plans for jointly meeting the SDGs and mitigation, which demonstrates the feasibility of meeting these objectives jointly. Quito, Ecuador, a city with large carbon footprints (Go Explorer, 2019) and climate vulnerabilities, has adopted low-carbon plans that aim to achieve the climate goals while introducing net-zero energy buildings and reducing water stress (Ordonez et al., 2019; Marcotullio et al., 2018). Several cities in China, Indonesia, and Japan have invested in green city initiatives by means of green infrastructural investments in cities, which is claimed to be a form of smart investment. Through this type of investment, economic growth and greenhouse gas (GHG) emission reductions can be achieved in cities (Jupesta and Wakiyama, 2016). Multi-level governance arrangements, public-private cooperation, and robust urban-data platforms are among the factors enabling the pursuit of these objectives within countries (Corfee-Morlot, J., et al 2009; Gordon 2015; Creutzig et al., 2019, Yarime 2017).

In addition to the mostly domestic enablers listed previously, some cities have also benefited from working with international networks. The Global Covenant of Mayors for Climate and Energy (Energy 2019), the World Mayors Council on Climate Change (2019), ICLEI (2019), C40 (2019), and UNDRR (2019) have provided targeted support, disseminated information and tools, and sponsored campaigns (Race to Zero) to motivate cities to embrace climate and sustainability objectives. Despite this support, it should be stressed that most cities are in the early stages of climate planning (Climate-ADAPT, 2019; D. Reckien et al., 2014; D. Reckien et al., 2018). Further, in some cases city policymakers may fail to highlight the synergies and trade-offs between climate and sustainable development or rebrand GHG-intensive practices as 'sustainable' in relevant plans (Tozer 2018). Six priorities are highlighted within the focus on mitigation and adapting urban climate change: increasing the number of observations, understanding climate interactions, studying informal settlements, harnessing disruptive technologies, supporting the transformation, and recognising the context of global sustainability (Creutzig et al. 2019).

With regard to city networks, Chapter 8 concluded that the importance of urban-scale policies for sustainability has increasingly been recognised by international organisations and national and regional governments. For example, in 2015, more than 150 national leaders adopted the UN's 2030 Sustainable Development Agenda, including stand-alone SDG 11, to "make cities and human settlements inclusive, safe, resilient and sustainable" (United Nations 2015, p. 14). The following year, 170 countries agreed to the UN New Urban Agenda (NUA, a central part of which is recognising the importance of national urban policies (NUPs) as a key to achieving national economic, social, and environmental goals (United Nations 2015, 2017). Similarly, the Sendai Framework for Disaster Risk Reduction identifies the need to focus on unplanned and rapid urbanisation to reduce exposure and vulnerability to the risks of disasters (UNISDR 2015).

For many cities, a key to reorienting development paths will be investing in sustainable, low-carbon infrastructure. Because infrastructure has a long lifetime and influences everything from lifestyle choices to consumption patterns, decisions over an estimated USD 90 trillion of infrastructure investment (from now to 2030) will be critical in order to avoid becoming locked into unsustainable paths (The New Climate Economy 2016). This is particularly true in developing countries, where demands for new buildings, roads, energy, and waste management systems are already surging. To some extent, policies that accelerate building renovation rates, including voluntary programmes (Van der Heijden, 2018), can support transitions down more sustainable paths (Kuramochi et al., 2018). Factoring climate and sustainable development considerations into policy tools that facilitate quantitative emission performance standard (EPS) and the inclusion of climate and sustainable development benefits and risks in infrastructure assessments or risk-adjusted returns on investments in development banks could also prove useful (Rydge, 2015). Strong policy signals from the UNFCCC and from national climate policies and strategies (including NDCs) could facilitate the uptake of the relevant policies and the use of these tools.

Infrastructural investments will also have wide-ranging implications for sustainable, low-carbon urban development, namely transport and mobility. To some extent, decision-making frameworks such as Avoid-Shift-Improve could help make these patterns low carbon and sustainable (Dalkmann and Brannigan 2007; Wittneben et al. 2009). Mixed land-use planning and compact cities can not only help avoid emissions or shift travellers into cleaner modes (Cervero 2009chu), they can also improve air quality, reduce commuting times, enhance energy security, and improve connectivity (Choksi et al. 2014; Zusman et al. 2012).

Chapter 10 of this report concludes that transport systems are also socio-economic systems and not just technological ones and that there are a range of systemic factors that are developing into potentially important factors for change: urban forms that minimise dependence on automobile; behaviour change programs that emphasise shared values and economies; smart technologies that enable better options for transit and active transport, as well as integrated approaches to using autonomous vehicles; new ways of enabling electric recharge systems to fit into electricity grids so as to balance grids and reduce anxieties about the range of electric vehicles; and new concepts for the future economy, such as the circular economy, dematerialisation, the shared economy and decoupling, which are beginning to reduce GHG emissions from transport.

Policy tools that can help recognise these climate and other co-benefits will also help to make transport planning sustainable and low carbon. At the same time, policy signals from international and national policymakers can help mobilise investments for improved land-use planning and make public transport more attractive, especially for city and subnational officials. Another major shift coming under the ‘I’ in the ‘ASI’ framework, involves the transition to electrification. Additional advances in battery technology and engine performance appear poised to accelerate the transition to electrification (IEA, 2019; Crabtree 2019). Electric vehicles can deliver significant reductions in greenhouse gases (GHGs) and air pollution, provided the electricity needed to operate the cars comes from renewable resources. Forward-looking companies such as Tesla, which are seeking to increase the market for electric vehicles, have made recent efforts targeting China. Governments from Norway to South Korea have used a combination of increasingly stringent regulations (fuel-economy standards) and pricing policies (tax incentives for purchases). These could be coupled with some of the policy signals mentioned previously to accelerate the transition to electrification.

Table 17.4 provides an overview of the synergies and trade-offs between climate-change mitigation options and key SDG impacts based on the authors' assessment. As shown in Table 4 the mitigation options for cities, infrastructure, and transportation are assessed as having many synergies between mitigation and energy, and water access. There are, however, a number of trade-offs in relation to the economic impacts, due to the high costs.

Table 17.4 The mitigation options for cities, infrastructure, and transportation are assessed as having many synergies between mitigation and energy, and water access

Cities, Infrastructure and Transportation Options	Mitigation Impacts	Food	Water	Energy	Mobility	Economic	Remarks
Urban waste management	+	+	+	+	n.a	-	The cost for waste disposal might occur and burden to citizen
Urban data sharing	+	n.a.	n.a	n.a	n.a	-	Data sharing will be useful for better design and planning on mitigation actions
Urban water management	+	n.a	+	n.a	n.a	-	The water treatment for recycling and reusing
Innovative building design	+	n.a	+	+	n.a	-	The upfront cost for green building might be high and return of investment would take several years
Retrofitting old building	+	n.a	-	-	n.a	+	New buildings might increase GHG emissions from cements etc, retrofitting will decrease GHG emissions
Using lightweight building materials (timber and bamboo) and green corridors to reduce the heat	+	n.a	+	+	n.a	-	The low carbon building will reduce GHG emission significantly from building sector
Low carbon transportation	+	n.a	n.a	+	+	-	Shifting from fossil fuels based into renewable energy (e.g.: biofuel, battery) could decrease GHG emissions
Transport sharing application	+	n.a	n.a	+	+	+	This online platform could improve air quality and social inclusion and reduced congestion
More charging stations for electric vehicle	+	n.a	n.a	+	+	+	The more number of charging stations will enabling more passengers shifting from fossil fuel based

							vehicle into electric vehicle

Dark blue signifies that synergies are expected, light blue that both synergies and trade-offs could be expected, and brown/red that trade-offs can be expected. Grey is used to indicate that the measure is not applicable based on the studies.

17.3.3.5 Mitigation-adaptation relations

The section will consider the links between mitigation and adaptation options in the context of sustainable development and the associated synergies and trade-offs. Cross-cutting conclusions will be drawn based on Chapter 3, the sectoral chapters of this report and WGII Chapter 18: Climate-resilient development pathways, before highlighting specific issues related to enabling. The focus will be on the following sectors.

- agriculture, food and land use.
- water-energy-food.
- industry and the circular economy.
- Urban areas.

WG II Chapter 18 addresses the mitigation-adaptation relationship in the context of climate-resilient development pathways. Adaptation and mitigation are discussed in the context of underlying development choices and sustainable development, the conclusion being that coherent and integrated policy-planning is needed. Chapter 4, Section 4.4.2, similarly assesses development pathways and the specific links between mitigation and adaptation and concludes that there can be co-benefits, and trade-offs, where mitigation implies maladaptation. However, adaptation can also be a prerequisite for mitigation. It is therefore concluded that making development pathways more sustainable can build the capacity for both mitigation and adaptation.

Climate actions, including climate-change mitigation and adaptation, are highly scale-dependent, and solutions are very context-specific. Especially in developing countries, a strong link exists between sustainable development, vulnerability and climate risks, as limited economic, social and institutional resources often result in low adaptive capacities and high vulnerability. Similarly, the limitations in resources also constitute key elements weakening the capacity for climate-change mitigation (Jakob et al., 2014)). The change to climate-resilient societies requires 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 to take place if synergies between mitigation and adaptation are 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 decarbonisation simultaneously involves social change (WG II, SOD Chapter 18).

As discussed in WG II, Chapter 18 Section 18.4.2.2, there are synergies and trade-offs between adaptation and sustainable development, as well as between mitigation and sustainable development. Furthermore, links between mitigation and adaptation options are identified, such as expected changes in energy demand due to climate change interacting with energy-system development and mitigation options, changes to agricultural production practices to manage the risks of potential changes in weather patterns affecting land-based emissions and mitigation strategies, or mitigation strategies that place additional demands on resources and markets. This increases the pressures on, and costs of adaptation or ecosystem restoration linked to carbon sequestration and the benefits in terms of the resilience of natural and managed ecosystems, but also could constrain mitigation options and increase costs. Chapter 3 of this report similarly concludes that the connectedness and coherence of actions to mitigate climate change could support the conservation and adaptation of ecosystems and meet wider sustainable development goals.

Options to reduce agricultural demand (e.g., dietary change, reducing food waste) can have co-benefits for adaptation through reductions in the demand for land and water (SRCCL Chapter 6). For example, Grubler et al. (2018) show that stringent climate-mitigation pathways without reliance on BECCS can be achieved through a fundamental transformation of the service sectors, significantly reducing the demands for energy and food.

Agriculture, food and land-use is the sector where most climate policy options can simultaneously generate impacts on mitigation, adaptation and the SDGs. Bryan et al., (2013) identified a range of synergies and trade-offs across adaptation, mitigation and the SDGs given the diversity of 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, as well as increase income generation from farming. However, other improvements to agricultural management in Kenya, for example, soil water conservation, could only provide benefits across all three domains in some specific sub-regions.

Conservation agriculture can yield mitigation co-benefits through improved fertiliser use or the efficient use of machinery and fossil fuels (Cui et al. 2019; Harvey et al. 2014; Pradhan et al. 2018a) and can help build adaptive capacity (Pradhan et al. 2018a; Tyszczuk and Smith 2018). Climate-smart agriculture (CSA) ties mitigation to adaptation through its three pillars of increased productivity, mitigation and adaptation (Lipper et al. 2014), although managing trade-offs among the three pillars requires care (Thornton et al. 2017; Soussana et al. 2019). Sustainable intensification also complements CSA (Campbell et al. 2014).

Agroforestry can sustain or increase food production in some systems and can increase farmers' resilience to climate change (Hummelbrunner and Jones, 2013). Some sustainable agricultural practices have trade-offs, and their implementation can have negative effects on adaptation or other ecosystem services. Agricultural practices can supply both mitigation and adaptation on the ground, but yields may be lower, and the interconnections within the global agricultural system may lead to deforestation elsewhere (Erb et al. 2016). Implementation of sustainable agriculture can increase or decrease yields, depending on context (Pretty et al. 2006) (Chapter 4).

Land-based mitigation and adaptation will not only help in reducing greenhouse gas emissions in the AFOLU sector, but also help augment the sector's role as a carbon sink by increasing forest and tree cover through afforestation and agroforestry activities and other nature-based solutions. This is because land acts as a natural carbon sink, with carbon stored in both the soil and above-ground biomass (forests and plants) (Chapter 7; Keramidas et al. 2018). If managed and regulated appropriately, the land use, land-use change and forestry (LULUCF) sector could become carbon-neutral as early as 2020–2030, being a key sector for emissions reductions beyond 2025 (Keramidas et al. 2018). However, the large-scale deployment of intensive bioenergy plantations, including monocultures, replacing natural forests and subsistence farmlands are likely to have negative impacts on biodiversity and can threaten food and water security, as well as local livelihoods, including by intensifying social conflicts (Díaz et al. 2019).

Based on a literature review, Berry et al. (2015) identified water-saving and irrigation techniques in agriculture as attractive adaptation options with positive synergies with mitigation in increasing soil carbon, reducing energy consumption, and reducing CH4 emissions from intermittent rice-paddy irrigation. These measures could, however, reduce water flows in rivers and adversely affect wetlands and biodiversity. The study also concluded that afforestation could reduce peak water flows and implies increased carbon sequestration, but trade-offs could emerge in relation to the increased demand for water.

Fast-growing tree monocultures or biofuel crops may enhance carbon stocks but reduce downstream water availability and the availability of agricultural land (Harvey et al. 2014). Similarly, in some dry environments, agroforestry can increase competition with crops and pastureland, decreasing productivity and reducing the yield of catchment water (Schrobback et al. 2011); (Chapter 7).

Hydro-power dams are among the low-cost mitigation options if only the cost of constructing the plant is taken into account, but they could have serious trade-offs in relation to key sustainable-development aspects, since in respect of water and land availability dams can have negative effects on ecosystems and livelihoods, thereby implying increased vulnerabilities. Section 17.4.3.2 on the water-energy-food nexus includes examples of trade-offs between the benefits of producing electricity from hydro-power dams and the trade-offs with ecosystem services and land-use for agriculture and livelihoods.
There are several potentially strong links between climate-change adaptation in industry and climate-change adaptation. Various supply chains can be affected by climate change, energy supply and water supply, and other resources can be disrupted by climate events. Adaptation measures can influence GHG emissions in their turn and thus mitigation because of the demand for basic materials, for example, as well as by influencing outdoor environments and labour productivity (Chapter 11).

Implementing adaptation options in industry can also imply increasing the demand for packing materials such as plastics and for access to refrigeration. These options are among the adaptation options that are dependent on temperature and storage possibilities, as well as being major sources of GHG emissions.

An increasing number of cities are becoming involved in voluntary actions and networks aimed at the development of integrated plans for sustainable development and climate-change mitigation and adaptation, including cities in both high- and low-income countries in the world. Grafakos et al., (2019) and Sanchez Rodriguez et al., (2018) concluded that cities are an obvious place for the development of plans that can capture several synergies between sustainable development and climate-resilient pathways. Kim and Grafakos (2019) and Landauer et al. (2019) similarly concluded that cities are an obvious platform for the development of integrated planning efforts because of the scale of policies and actions, which could potentially 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, concluding that the integration of climate-change mitigation and adaption plans was very weak in about half the cities and that the limited donor finance was a main barrier. The authors also mention barriers in relation to governance and the weak or lack of legal frameworks. The integration of SDGs with adaptation could help increase the willingness of politicians to implement climate actions, as well as providing stronger arguments for investing the required resources (Sanchez Rodriguez et al., 2018).

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

There are several links between mitigation and adaptation options in the building sector, as pointed out in Chapter 9, Section 9.7. Adaptation can increase energy consumption and associated GHG emissions (Kalvelage et al., 2013; Campagnolo and Davide et al., 2019), for example, in relation to the demand for energy to meet indoor thermal comfort requirements in a future warmer climate (de Wilde and Coley, 2012; Li and Bou-Zeid 2013;Clarke et al., 2018). Mitigation alternatives through passive approaches may increase the resilience to the impacts of climate change on thermal comfort and could reduce cooling needs (Wan et al. 2012b; Andrić et al. 2019). However, climate change may reduce their effectiveness (Ürge-Vorsatz et al., 2014).

Mitigation and the co-benefits of adaptation in urban areas in relation to air quality, health, green jobs, and equity was dealt with in Chapter 8, Section 8.2, where it was concluded that most mitigation options will have positive impacts on adaptation, with the exception of compact cities, with trade-offs between mitigation and adaptation. This is because decreasing urban sprawl can increase the risks of flooding and heat stress. Detailed mapping between mitigation and adaptation in urban areas shows that there are many, very close interactions between the two policy domains and that coordinated governance across sectors is therefore called for.

Rebuilding and refurbishment after climate hazards can increase energy consumption and GHG emissions in the construction and building materials sectors, as could making the existing building stock more climate resilient (Hallegatte 2009; de Wilde and Coley 2012; Pyke et al. 2012b). Climate changes such as extreme high temperatures, intense rainfall leading to flooding, more intense winds and/or storms, and sea level rises (SLRs) can seriously impact transport infrastructure, and the operations and mobility of road, rail, shipping and aviation; Chapter 10 documents the impacts on subsectors within transportation. At the same time, these sectors are major targets for GHG mitigation options, and many countries are currently examining what to do in terms of combined mitigation-adaptation efforts, using the need to mitigate climate change through transport-related GHG emissions reductions and pollutants as the basis for adaptation action (Thornbush et al., 2013; Wang et al., 2020). For example, urban sprawl indirectly affects climate processes, increasing emissions and vulnerability, which worsens the ability to adapt (Congedo and Munafò, 2014; Macchi and Tiepolo, 2014). Hence greater use of rail by passengers and freight will reduce the pressures on the roads, while having less urban sprawl will reduce the impacts on new infrastructure, often in more vulnerable areas (IPCC, 2019; Newman, Beatley, and Boyer, 2017).

Despite many links between mitigation and adaptation options, including synergies and trade-offs, Chapter 13 concludes that there are few frameworks for integrated policy implementation. One review of climate legislation in Europe found that a lack of coordination between mitigation and adaptation, implementation varying according to different national circumstances (Nachmany et al. 2015).

In developing and least developed countries, there are many examples of climate policies in the NDCs that have been drawn up in the context of sustainable development and cover both mitigation and adaptation (Beg et al., 2002; Duguma et al., 2014); also Chapter 13. However, there are many barriers to joint policy implementation. Despite the emphasis on both mitigation and adaptation policies, there is very limited literature on how to design and implement integrated policies (Di Gregorio et al. 2017; Shaw et al. 2014). For example, the links within the water, energy and food nexus require coordination among sectoral institutions and capacity-building in innovative frameworks linking science, practice and policy at multiple levels (Shaw et al. 2014; Cook and Chu 2018; Nakano et al. 2017).

Another challenge is the fact that limited financial, technical and human resources exist for implementing joint A&M (Kedia 2016; Bellinson and Chu 2019; Antwi-Agyei et al. 2018; David and Venkatachalam 2019; Satterthwaite 2017). Several studies have stressed that the lack of finance for integrating policy implementation between sustainable development and climate-change mitigation and adaptation may constitute barriers to the implementation of adaptation projects to protect least developed countries with many vulnerabilities.

Locatelli et al., (2016) come to similar conclusions regarding finance based on interviews with multilateral development banks, green funds, and government organisations in respect of the agricultural and forestry sectors. International climate finance has been totally dominated by mitigation projects. Those who were interviewed were asked about their willingness to change this balance and to commit more resources to projects that address both climate-change mitigation and adaptation. More than two-thirds of those interviewed, however, raised concerns that integrated projects could be too complicated and that a greater alignment of financial models across different policy domains could entail greater financial risks. Another barrier mentioned in respect of finance was that mitigation projects were primarily aimed at GHG emissions reductions, while adaptation projects had more national benefits and were also more suitable for community development and promoting equity and fairness.

Table 17.5 provides an overview of how the options assessed in this section impact on mitigation, adaptation, food, water, energy, and poverty-alleviation, based on a qualitative assessment by the authors.

Table 17.5 Overview of synergies and trade-offs between examples of mitigation-adaptation options and food, water, energy access, and economic impacts

Adaptation-Mitigation Option	Mitigation Impact	Adaptation Impact	Food	Water	Energy	Poverty
Agriculture, food land-use						
Improved management of soil fertility and livestock feeding	+	+	+	+/-	n.a	+
Conservation agriculture, smart systems	+	+	+	+	+	+
Agroforestry	+	+	+/-	+/-	+/-	+/-
Afforestation/efficient agriculture	+	+	+/-	+/-	+/-	+/-
Large-scale bioenergy plantations	+	-	-	+/-	+	+/-
Dietary changes and services	+	+	+/-	+/-	+	+/-
Water-energy-food						
Irrigation	+	+	+	-	+/-	+
Fast-growing monocultures	+	+/-	-	-	+/-	+/-
Hydropower	+	-	-	-	+	+
Industry						
Efficient construction processes and material use	+	+	+	+	+	+
Plastics protection of food, recycling	+	+	+	-	+	

Notes: The assessment is based on reports from sectoral chapters 6, 7, 9, 10, and 11. Dark blue signifies that synergies are expected, light blue that both synergies and trade-offs could be expected, and brown/red that trade-offs can be expected. Grey is used to indicate that the measure is not applicable based on the studies.

As shown in Table 17.5, there are several examples of options in the agriculture, food and land-use sectors, which, despite having positive impacts on both mitigation and adaptation, have both negative and positive impacts on access to food and water and poverty alleviation. These are particularly advanced production methods, like agroforestry and large-scale bioenergy plantations. The same is the case for the water-energy-food nexus, where fast-growing monocultures and hydropower plants can compromise access to food and water, as well as poverty alleviation. The options for industry and urban areas have few negative impacts, with the exception of adaptation in energy-intensive industries, which could increase energy consumption and thus emissions, as well as urban sprawl. That could imply increased emissions from transportation, as well as impacting on different income segments both positively and negatively.

17.3.3.6 Cross-sectoral digitalisation

In this section the potential role of digitalisation as a facilitator of a fast transition to sustainable development and low emission pathways is assessed based on sectoral examples. The contributions of digital technology could contribute to efficiency improvements, cross-sectoral coordination, including new IT services, and decreasing resource use, implying several synergies with the SDGs, as well as trade-offs, for example, in relation to reduced employment, increasing energy demand and the increasing demand for services, possibly increasing GHG emissions.

The cost of new services provided by digitalisation can also be high. Altogether this implies that any assessment of the contribution of digitalisation to supporting the SDGs and low-carbon pathways will only be able to provide very context-specific results.

Digital technologies could potentially disrupt production processes in nearly every sector of the economy. However, as an emerging area experiencing rapid penetration of many sectors, there could be a window of opportunity for integrating sustainable development and low emission pathways. TWI2050 (2020) concludes that the digital revolution is characterised by many innovative technologies, which can both create synergies and trade-offs with the SDG's (TWI2020, 2020).

WBSD (2019) has assessed the potential of communication technologies (ICT) to contribute to the transition to a global low-carbon economy in the energy, transportation, building, industry, and other sectors (Energy, 2019). The potential is estimated to be around 15% CO_2-equivalent emissions 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, efficient engines for transport, smart logistics and smart energy systems.

The TWI2050, 2019 report assessed both the positive and negative impacts of digitalisation in the context of sustainable development. It found that efficiency improvements, reduced resource-consumption and new services can support the SDGs, but also that there were challenges, including in respect of equality, facing the least developed and developing countries because of their low access to technologies. The necessary preconditions for successful digital transformation include prosperity, social inclusion, environmental sustainability and good governance of sustainability transitions. Negative impacts could include the loss of jobs, rising levels of inequality, and the replacement of labour by capital. Another negative impact of digitalisation could be the rebound effects, where easier access to services could increase demand and with it GHG emissions. Digitalisation in the manufacturing sector could also provide a comparative advantage to developed countries due to the falling importance of labour costs, while the barriers to emerging economies seeking to enter global markets could accordingly be increased.

In respect of governance, Balasubramaniam (2020) points out that the creation of synergies between sustainable development and low-emission urbanisation based on digitalisation could face barriers in the form of inadequate knowledge of structures and value creation through ecosystems that would need to be addressed through smart digitalising, requiring organisational measures to support transformation processes.

Urban areas are one of the main arenas for new digital solutions due to rapid urbanisation rates and high concentrations of settlements, businesses and supply systems, offering great potential for large-scale digital systems. The emergence of smart cities has supported the uptake of smart integrated energy, transportation, water and waste management systems, while synergies have been created in terms of more flexible and efficient systems. In its 2018 Policy and Action document, the Japanese Business Federation (Keidanren) launched Society 5.0, which include plans for smart city development (Keidanren Japanese Business Federation 2018). 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 also aims to offer high-standard medical and educational 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.

Chapter 6 of this report on "Energy Systems" points out that there are many smart energy options with the potential to support sustainable development by facilitating the integration of high shares of fluctuating renewable energy in electricity systems, potentially storing energy in EV batteries or fuel cells, and applying load shifting by varying prices over time. It is concluded that very large efficiency gains are expected to emerge from digitalisation in the energy sector (Figure 6.18).

Chapter 9 Section 9.9.2 concludes that improved energy efficiency and falling costs in the building sector, which could result from digitalisation, could have rebound effects, where energy consumption and comfort levels are both increased. Increasing GHG emissions could be the result, but if low-income consumers are given faster access to affordable energy, this could agree with the SDGs, making it desirable to integrate policies targeting mitigation.

Section 10.2 discusses how the sharing economy, which, for example, could be facilitated by ICT platforms, could influence both mitigation and the SDGs. On the one hand, sharing has the potential to save transport emissions, especially if EVs are supplied with decarbonised grid electricity. However, an increase in transport emissions could be the result if increasing demand and higher comfort levels are facilitated, for example, by making access to EVs relatively easy compared with mass transit. Another possible trade-off is that the supply of transport services would be limited to the elderly and other user groups.

Green innovation in agriculture is another emerging area in which digitalisation is making huge progress. From the perspective of water provision, weather data can be used to predict rain amounts so that farmers can better manage the application of farm chemicals to minimise polluting aquifers and surface water systems used for drinking water. Meanwhile, smart meters, onsite and remote sensors, and satellite data connected to mobile devices allow real-time monitoring of crop-water and optimal irrigation requirements. On the supply side, remote tele-control systems and efficient irrigation technologies enable farmers to control and optimise the quantity and timing of water applications, while minimising the energy-consumption trade-offs of pressurised irrigation in both rural and urban agricultural contexts (Germer et al., 2011; Ruiz-Garcia et al., 2009).

Technology-driven precision agriculture, which combines geomorphology, satellite imagery, global positioning, and smart sensors, enables enormous increases in efficiency and productivity. Taken together, these technologies provide farmers with a decision-support system in real time for the whole farm. Arguably, the world could feed the projected rise in population without radical changes to current agricultural practices if food waste can be minimised or eliminated. Digital technologies will contribute to minimising these losses through increased efficiencies in supply chains, better shipping and transit systems, and improved refrigeration. The following table (Table 17.6) provides an overview of the impact of the digitalisation options discussed in this section on mitigation and key aspects related to the SDGs based on the authors' assessment.

Table 17.6 The impacts of digitalisation options on mitigation and aspects of the SDGs, including food, water, energy, mobility, and the economic impacts.

Digitalisation Option	Mitigation Impact	Food	Water	Energy	Mobility	Poverty/ Economy	Remarks
High shares of fluctuating renewable energy	+	+	+	+	+	+/-	The renewable potential is increased, but with potentially high costs
Time-flexible demand management	+	+	+	+	+	+/-	Consumers could pay a high price at times when they prefer to consume
Integrated energy and transport systems with storage based on	+	n.a	n.a	n.a	+/-	+/-	Driving could be increased due to the decreasing costs of EVs

charging electric vehicles							
ICT transportation platforms for car sharing	+/-	n.a	n.a	n.a	+/-	+	Driving could be increased due to the low-cost availability of EVs
Platform for information exchange on sharing economy	+/-	+/-	+/-	+/-	+/-	+/-	Sharing could be increased, but old and inefficient technologies could be given extended lifetimes
Smart buildings	+	n.a	n.a	n.a	n.a	+/-	Efficiency improvements, but the rebound effect could increase demand
Smart agricultural irrigation	+	+	+	+/-	n.a	+	Decreasing water demand due to optimal location and timing
Nexus management	+	+	+	+	+	+	Pressure on land resources could come from bioenergy crops, but digitalisation supports integrated management

Notes: The assessment is based on reports from the sectoral chapters 6, 7, 9, 10, and 11. Dark blue implies that synergies are expected, light blue that both synergies and trade-offs could be expected, and brown/red that trade-offs can be expected. Grey is used to indicate that the measure is not applicable based on the studies.

As illustrated in Table 17.6, in most cases the digitalisation options may have both positive synergistic impacts on mitigation and the SDGs and some negative trade-offs. Energy-sector options are assessed primarily as having synergies, while some digitalisation options in transport could increase the demand for emission-intensive modes of transport. Digital platforms for the sharing economy could have both positive and negative impacts depending on the goods and services that are actually exchanged. The options assessed for agriculture and the energy-water-food nexus could help manage resources more efficiently across sectors, which could create synergies.

17.3.3.7 Cross sectoral overview of synergies and trade-offs between climate change mitigation and the SDGs

Based on the conclusions of the sectoral chapters of this report, Table 17.7 provides an overview of the synergies and trade-offs between sectoral mitigation options and the SDGs.

1 **Table 17.7 Trade-offs and synergies between sectoral mitigation options and the SDGs**

Sector/System	Mitigation option	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
Energy systems	Solar Energy	+	+/-	+	n.a	+	+	+	+	+	+	+/-	+/-	+	n.a	n.a	n.a	+
	Wind energy	+	+/-	+	n.a	+	+	+	+	+	+	+/-	+/-	+	-	n.a	na	+
	Hydroelectric power	-	+/-	+/-	n.a	n.a	+	+	+/-	n.a	n.a	n.a	n.a	+	+	+	n.a	n.a
	Nuclear	+/-	n.a	+/-	n.a	n.a	-	+/-	+/-	-	-	n.a	+	n.a	n.a	+/-	n.a	n.a
	Carbon Dioxide Capture, Utilization, & Storage	-	n.a	+	n.a	n.a	-	+/-	+	+	n.a	n.a	+/-	+	n.a	n.a	n.a	+/-
	Bioenergy	+/-	-	+/-	n.a	n.a	-	+	+	+	+	+	+	n.a	n.a	n.a	n.a	+
	Fossil fuel phaseout	+	n.a	+	n.a	n.a	n.a	+	+/-	+	+	+	+/-	+	+	+/-	n.a	+
	Geothermal	+	n.a	+/-	n.a	n.a	+/-	+	n.a	n.a	n.a	+	+/-	+	n.a	-	n.a	n.a
	Energy storage for low-carbon grids	+/-	n.a	n.a	n.a	n.a	n.a	+	n.a	n.a	n.a	+	-	n.a	n.a	-	n.a	+
	Demand side mitigation	+	+/-	+	n.a	n.a	+	+	n.a	+	n.a	+	+	n.a	n.a	n.a	n.a	+.
	System integration	+/-	n.a	n.a	n.a	n.a	n.a	+	n.a	n.a	n.a	+	+/-	n.a	n.a	n.a	n.a	n.a
Agriculture, Forestry & Land use	Healthy balanced diets, rich in plant-based food (less animal-based)	+/-	+	+	n.a	n.a	+	+	n.a	+/-	n.a	n.a	+	+	+	+	n.a	n.a
	Reduce non-CO2 emissions from agriculture	+/-	+	+	n.a	n.a	+	n.a	+/-	+/-	n.a	n.a	+	+	+	+	n.a	n.a
	Restore forests and other ecosystems	+	-	+	n.a	n.a	+	n.a	-	n.a	n.a	+	n.a	+	+	+	n.a	n.a
	Enhance carbon in agricultural systems	+	+	+/-	n.a	n.a	+	n.a	+	n.a	n.a	n.a	+/-	+	+	+	n.a	n.a
	Protect and avoid conversion of forests and other ecosystems	+/-	-	+	n.a	n.a	+	n.a	+	n.a	n.a	+/-	n.a	+	+	+	-	n.a
	Sustainably manage forests and other ecosystems	+	+/-	+	n.a	n.a	+	+/-	+	+	n.a	+/-	n.a	+	+	+	n.a	n.a
	Bioenergy and BECCS	+/-	-	+/-	n.a	n.a	+/-	+	+/-	+	n.a	n.a	+/-	+/-	+/-	+/-	n.a	n.a
Buildings	Envelope improvement	+/-	+	+/-	+	n.a	+	+	+/-	+/-	+/-	+	+	+	n.a	n.a	+	+
	Heating, ventilation and air conditioning (HVAC)	+/-	+	+	n.a	n.a	+	+	+/-	-	+/-	+	+	+	n.a	n.a	n.a	n.a
	Efficient Appliances	+/-	+	+	+	+	+	+	+/-	-	+/-	n.a	+/-	+	n.a	+	n.a	n.a
	Change in construction methods and materials	+/-	n.a	+/-	n.a	n.a	n.a	+	+/-	+/-	+/-	+	+	+	n.a	+	+/-	n.a
	Active and passive management and operation	+	+	+	n.a	n.a	+	+	+/-	+/-	+	+	+	+	n.a	n.a	n.a	n.a
	Digitalization	+	+	+	+	n.a	+	+	+/-	+	+	+	+	+	n.a	n.a	n.a	n.a
	Flexible comfort requirements	+	+	+	n.a	n.a	+	+	+/-	+/-	+	+	+	+	n.a	n.a	+	n.a
	Circular and shared economy	n.a	n.a	+	n.a	n.a	+	+	+	+	n.a	+	+	+	n.a	+	n.a	n.a
	Renewable energy production	+/-	+/-	+	+	+	+/-	+	+/-	+/-	+/-	+	+	+	n.a	+	+	+
Transport	Fuel efficiency	n.a	n.a	+	n.a	n.a	+	+	+	+	n.a	+	+	+	n.a	n.a	n.a	n.a
	Electromobility	n.a	n.a	+	n.a	+	+	+	+	+	n.a	n.a	n.a	+	n.a	n.a	n.a	n.a
	Heavy vehicle transition fuels	n.a	n.a	+	n.a	n.a	n.a	+	+	+	n.a	n.a	n.a	+	n.a	n.a	n.a	n.a
	Demand reductions	n.a	n.a	+	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	+	n.a	n.a	n.a	n.a
Industry	Energy efficiency	n.a	n.a	n.a	n.a	n.a	n.a	+	+	+	n.a	n.a	n.a	+	n.a	n.a	n.a	n.a
	Materials efficiency and Demand management	n.a	n.a	n.a	n.a	n.a	+	n.a	+/-	+	n.a	n.a	+	+	n.a	n.a	n.a	n.a
	Circular economy	n.a	n.a	+	n.a	n.a	+	+	+	n.a	n.a	+	+	n.a	n.a	+	n.a	n.a
	Electrification fuel switching	+	+	+	n.a	+	n.a	+	n.a	n.a	n.a	n.a	n.a	+	n.a	n.a	n.a	n.a
	CCU	n.a	n.a	n.a	n.a	n.a	n.a	+	+	+	n.a	n.a	n.a	+	n.a	n.a	n.a	n.a
	CCS	n.a	n.a	+	n.a	n.a	n.a	+	+	+	n.a	n.a	n.a	+	n.a	n.a	n.a	n.a
Cross sectional	Direct air capture	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
	Enhanced weathering	+	+	+	n.a	n.a	+	n.a	+	n.a	n.a	n.a	+	+	+	+	n.a	n.a
	Reduce overconsumption	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a

Notes: The assessment is based on reports from the sectoral chapters 6, 7, 9, 10, and 11. Dark blue implies that synergies are expected, light blue that both synergies and trade-offs could be expected, and brown/red that trade-offs can be expected. Grey is used to indicate that the measure is not applicable for the particular SDG based on the studies.

The sectoral overview provided in Table 17.7 shows that for most sectors there are many synergies between mitigation and the SDGs, for example, in relation to SDG 7 (affordable and clean energy). Some SDGs, including SDG 2 (zero hunger) and SDG 6 (clean water and sanitation) face several trade-offs in relation to mitigation in the energy sector and AFOLU, which reflects conflicts over land-use between bioenergy production and other land-uses. Trade-offs can also be identified in relation to SDG 9, industry, innovation and infrastructure for the building and energy sector. In many cases places there may be both synergies and trade-offs between sectoral mitigation options and the SDGs, reflecting the fact that such impacts may emerge jointly and also that the impacts are context-specific and can vary from place to place. It is important to recognise that this assessment critically depends on the number of mitigation options and studies assessed in the sectoral chapters.

17.4 Key barriers and enablers of the transition: synthesising results

This section provides a deep and broad synthesis of theory (Section 17.2) and evidence (Section 17.3) in order to identify the conditions that either enable or inhibit 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 marked departures from business as usual typically involve several factors, ranging from technological innovations to shifts in markets, and from policies and governance arrangements to changes in belief systems and market forces. All this comes together in a co-evolutionary process that unfolds at globally, internationally and locally over several decades (Hansen and Nygaard 2014; Rogge et al. 2017). While transitions necessarily follow context-specific trajectories, more general lessons can be drawn by comparing the empirical details with both the system level and narrower explanations for change.

Sections 17.2 and 17.3 show that transitions often face 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 in order 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, achieving a transition requires breaking locked-in high-carbon technological trajectories, path dependencies and resistance to change from the industries and actors that benefit from the current system (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 (e.g., technologies and innovations that support the integration between food, water and energy goals). Such effects may still happen 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, the same conditions that may serve to impede a transition (i.e., organisational structure, behaviour, technological lock-in) can also be 'flipped' so as to enable it (Burch, 2010; Lee et al., 2017), while the framing of policies relevant to the 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 will involve a process of social learning. However, it is also important to note that strong shocks to these systems, including accelerated 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 conditions appear to be individual and collective action, including leadership and education; financial, material and technical driver that foster innovation; supportive policy and governance dynamics at multiple levels that permit both agility and coherence; measures to recognise and address the challenges to equality 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 the barriers to and enablers of an accelerated transition to sustainable development pathways.

17.4.1 Behavioural and lifestyle changes

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 that shape behaviour, and of the dynamics of social movements and education. Individual action suggests aggregated but uncoordinated actions taken by individuals, whereas collection action involves coordination, a process of governance that may ensure more efficient, equitable, and effective outcomes. Indeed, individual action is necessary but insufficient to deliver transformative mitigation and must be coupled with collective action to accelerate the transition to sustainable development (Dugast et al., 2019). Actors with conflicting interests will compete to frame mitigation technologies that either "build or erode" the legitimacy of the technology, contested framing sites that can occur between incumbent and emerging actors or between actors in new but competing spaces (Rosenbloom et al., 2018). 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 (Lam et al., 2020; Horcea-Milcu et al., 2020).

17.4.1.1 Social movements and education

Sustainable development and deep decarbonisation 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 "Fridays 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 scholars like Schein, Lewin or Senge) that inspired a so-called "massive 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. Likewise, experiential tools, simulations, and role-playing games have been shown to increase knowledge of the causes and consequences of climate change, the sense of urgency around action, and the desire to pursue further learning (Ahamer, 2013; Eisnack and Reckien, 2013; Hallinger et al, 2020; Rooney-Varga et al, 2020).

The results from this research community reveal how experiential learning takes place and how it encourages bonding between people, society and nature. 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 involves 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) as ways of 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 businesses and technologies (see e.g., Lessem, 2018; Ferguson and Lovell, 2014).

A related line of inquiry involves education for sustainable development (ESD). This builds on the UNESCO programme on ESD for 2030 and involves core values like peace culture, valuing cultural diversity and living the global citizenship. One of the core insights from research on ESC is lifelong education continuing outside the classroom, a lifelong learning process that involves sustained actions by all ages and social segments (e.g., Hume and Barry, 2015) and achieving collaboration (Münger and Riemer, 2012). Some authors have pointed to good levels of communication either 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 toward the knowledge production that underpins awareness-raising (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., 2018a).

17.4.1.2 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 modes of public transport. This is made all the more challenging because car-manufacturing "incumbents" utilise information campaigns directed at the public, pursue lobbying and consulting with policy-makers, and set technical standards that privilege the status quo 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) systems failed in part due to an arguably top-down approach that had limited public support. It may nonetheless 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 (decentralising) energy generation, creating local engagement with sustainability, supporting green infrastructure to reduce costs, re-claiming local land, transforming industrial infrastructure, and creating examples of sustainable living (McMeekin et al. 2019).

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.).

17.4.2 Technological and social innovation

Individuals and organisations, 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 (SEs), for instance, are described as those who participate in the development of an innovation while simultaneously being rooted in the incumbent energy-intensive system. SE actors who have developed longer term relationships, both formal and informal, with the 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. Such clusters can put pressure on incumbent technologies and rules to 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 the alternative energy sector as both producers and suppliers (who often follow the lead of producers). Producers are responding to perceptions of larger-scale changes in the energy landscape (e.g., 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 forms of technology and enables transfers of knowledge and resources to be introduced within this developing niche (Steen and Weaver 2017). Many large, well-established firms are pursuing sustainability agendas and 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).

Experiments with the transition open up 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 for public education and engagement (Rosenbloom et al, 2018).

Material barriers and spatial dynamics are other critical obstacles to innovation: often infrastructure and built environments change more slowly than policies and institutions due to the inherently long lifespans 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 suburbanisation (Birch, 2016).

17.4.3 Financial systems and economic instruments

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 within 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). Carbon-pricing is an important instrument that helps to avoid the market failures that have hindered low-carbon investments. However, there may be some limitations in using carbon-pricing alone where market failures hinder low-carbon investments (Campiglio, 2016; Svobodova et al. 2020) 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. One of the root causes of the failure of traditional financial systems is the undervaluation of natural capital and unsettled property right issues that are associated with it. The exclusion of proper rents for scarcities or for global and local externalities, including climate change, can undermine 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 discourage project planning and bank-lending programmes (Bolton et al. 2016). The EU's previous actions regarding the "shareholder maximisation norm" and non-binding measures have created path dependencies, limiting the EU's flexibility in creating sustainable financial legislation. However, the Sustainable Finance Initiative and the Single Market may prove to be "policy hotspots" in encouraging sustainable finance (Ahlstom, 2019). Taking advantage of these hotspots may be crucial in overcoming path dependencies and setting new ones in motion.

One possible positive turn in this regard is the acceleration in investing in the environment (impact and ESG) globally: for instance, there is evidence that some institutional investors are divesting from coal, potentially auguring well for the future. The encouragement of governance and policy reforms that could facilitate 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 a transition lift and injects momentum into it. 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 non-monetary goods and services if large numbers of stakeholders want to invest in these areas (Chiengkul, 2018). However, thus far the movement may be attracting attention because it has not grappled with the underlying structures of the international political economy.

17.4.4 Institutional capacities and multi-level governance

Ultimately, the adoption of coordinated, multi-sectoral policies targeting new and rapidly developed innovations can help national economies take advantage of widespread decarbonisation. Industrial policies that focus on building domestic supply chains and capacities can help states prepare for the influx of renewable (Zenghelis, 2019) and carbon-negative (or carbon capture and storage) technologies (Quarton and Samsatli, 2020). Policies that govern green finance need to improve their guidance and regulation of investment to prevent asymmetries of information and balance ecological and financial goals better (Zhou et al. 2016).

Complicating matters further is the likelihood that pulling together different projects may require complementary changes to policies and institutions. For example, in Argentina decentralised renewable energy is in an advanced stage of development, but giving consumer electricity subsidies handicaps supporters of renewable energy, as they have to 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).

Sustainability transition policies place high demands on the public sector, while 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 has 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, like 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, recognising that there is no 'one size fits all' but only carefully crafted institutional reforms (Kern 2011).

However, introducing these reforms may not be purely a technical exercise. Political, economic and other overarching power relations can lock in structures, making it difficult to integrate the climate and development agendas. For example, the distinct lack of integration and movement on the energy transition in Australia has developed historically from the country's politico-economic situation, including the polarisation 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 regarding supply and affordability (Warren et al. 2016). Furthermore, the pre-existing institutional context (or capacity) may either enable or inhibit accelerated transitions to sustainability. For instance, the status-quo orientation of leaders (including decision-makers' disciplinary backgrounds, world views and risk perceptions) (Willis, 2018), as well as the organisational culture and management paradigms within which they operate, affect the ambition and speed of mitigation policy outcomes (Rickards et al., 2014).

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 destabilising transitions to sustainable development (Falcone and Sica 2015). This suggests that the state can play a key role in destabilising incumbent energy regimes, a role which is significantly strengthened when it has public support (Arranz 2017; Avelino et al. 2016). However, regime outsiders have also played a role in destabilising 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 transitions (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 financial 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 its initiator and enabler, the electricity transition 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, emphasising the need for collaboration as well as top-down policy-making (Lee et al. 2019).

Ultimately, complementary policies that simultaneously address the multiple jurisdictions and dimensions of a carbon-intensive energy system are more likely to succeed (Burch 2010). In addition, a realistic exit strategy for incumbents is required, as are interventions (or a lackof them) 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 approaches to governance and a tendency to incrementalism remain dominant (Hölscher et al., 2019). Institutions and organisations must play a key role in prioritising climate change across all sectors and scales, while thorough mainstreaming that prioritises the climate is needed in order to destabilise the influence of entrenched interests and put pressure on existing norms, rules and practices (ibid.).

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

17.4.5 Equity in a just transition

Energy justice, although increasingly being emphasised (Pellegrini-Masini et al., 2020), has been under-represented in the literature on sustainability and in debates on energy transitions. Energy justice includes affordability, sustainability, equity (accessibility for current and future households) and respect (ensuring that innovations do not impose further burdens on particular groups) (Fuso Nerini et al., 2019). Furthermore, it raises that prospect that a just transition will be enabled by wealthy industrialised countries making more rapid progress towards net negative emissions, thus allowing more time for developing and emerging economies to improve health, well-being and prosperity (van den Berg et al., 2020). Looking at climate change from a justice perspective means placing 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 decarbonised world. Neglecting issues of justice risks a backlash against climate action generally, particularly from those who stand to lose from such actions (Patterson et al., 2018). 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 (Ehnert et al. 2018; Breukers et al. 2017).

Renewable energy transitions in rural, impoverished locations can simultaneously reinforce and disrupt local power structures and inequities. Policy interventions to help 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 extension 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 changes 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 in which they will grow later (Ornetzeder and Rohracher 2013).

Intersectional theory can shine a light on the hidden costs of resource extraction (as well as renewable energy development – see, for instance, Chatalova and Balmann, 2017), which go beyond environmental or health risks to include the socio-cultural impacts on both communities adjacent to these sites and those who work in them (Daum et al., 2018). Indeed, development decisions often do not appropriately integrate the burdens and risks placed on marginalised groups, like indigenous peoples, while risk assessments tend to reinforce existing power imbalances by failing to differentiate between how benefits and risks might impact on certain groups (Kojola, 2019; Healy et al., 2019).

17.4.6 Holistic planning and the 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 (Rasul 2016). Greater policy coherence among the three sectors is critical to moving to a sustainable and efficient use of resources. The nexus approach –a systems-based methodology that focuses attention on the many ways that natural resources are deeply interwoven and mutually interdependent – can strengthen coordination and help to avoid maladaptive pathways (Cremades et al., 2019). A major shift is required 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 (Rasul, 2016). However, currently the application and implementation of nexus approaches are in their infancy. Liu et al., (2018) have suggested the need for a systematic procedure and provided 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 policymaking and governance in the integrated implementation of the SDGs.

In respect of processes, Seyfang and Haxeltine (2012) found a lack of realistic and achievable expectations among both members (internally) and the wider public (externally), which hampers movement development and growth. This 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, conceptualise and foster experiments in how socio-technical innovations for sustainability develop, are diffused and are scaled up (Miller et al. 2014).

Various strategies and processes have been explored that might facilitate the translation of barriers into enablers, thus accelerating a transition to sustainable development. Common themes include frequent monitoring and system evaluation to reveal the barriers in the first place, the collaborative co-creation and envisioning of pathways toward sustainable development, ambitious goal-setting, strategic tackling of sources of path dependence or inertia, iterative evaluations of progress, adaptive management, and building in opportunities for agile course-correction at multiple levels of governance (Burch et al., 2014; Halbe et al., 2015). Given the political infeasibility of stable, long-term climate policies, the better choice may be to embrace uncertainty in specific policies but entrench the low-carbon transition as the overarching 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.

Decarbonisation 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 the 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 harmonised, 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 now have an opportunity to reset their development trajectories by focusing on those 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 choose an alternative pathway by deciding to monetise carbon capital and diversifying away from the high-carbon aspects of risk. Countries rich in hydrocarbons can diversify their energy mix and maximise their renewable energy potential. For instance, Namibia, a net importer of electricity, is seeking to reduce its current dependence 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 to achieve low-carbon transitions can be built (Shaw et al. 2014; Holscher et al. 2019; Burch 2010), especially where centralised energy structures and national governance and politics are posing deep-rooted challenges to 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 locally, regionally and nationally sustainable development pathways requires creative methods and participatory processes. These may include powerful visualisations that make the implications of climate change (and decarbonisation) clear locally (Sheppard et al. 2011; Shaw et al. 2014), other visual aids or “progress wheels” that effectively communicate the relevant contexts (Glaas et al. 2018), storytelling and mapping, and both analogue and digital games.

Frequently Asked Questions

FAQ 17.1 Will decarbonisation efforts slow or accelerate sustainable development transitions?

Sustainable development offers a comprehensive pathway to achieving ambitious climate change mitigation goals. Sustainable development requires the pursuit of synergies and the avoidance of trade-offs between the economic, social and environmental dimensions of development, and can thus provide pathways that accelerate progress towards ambitious climate change mitigation goals. Factoring in equity and distributional effects will be particularly important in the pursuit of sustainable policies and partnerships and accelerating the transition to sustainable development. Using climate change as a key conduit can only work if synergies across sectors are exploited, and if policy implementation is supported by national and international partnerships.

The speed, quality, depth and scale of the transition will depend on the developmental starting point, explicit goals as well as the enabling environment – individual behaviour, mindsets, beliefs and actions, social cohesion, governance, policies, institutions, social and technological innovations etc. The integration of both climate change mitigation and adaptation policies in sustainable development is also essential in the establishment of fair and robust transformation pathways.

FAQ 17.2 What role do considerations of justice and inclusivity play in the transition towards sustainable development?

Negative economic and social impacts in some regions as a consequence of ambitious climate change mitigation policies could emerge if these are not aligned with key sustainable development aspirations such as those represented by the SDG's no poverty, energy-, water-, and food access etc, which could in turn, slow down the transition process. Nonetheless, many climate change mitigation policies could generate incomes, new jobs, and other benefits. Capturing these benefits could require that specific policies and investments are targeted directly towards including all parts of society in the new activities and industries created by the climate change mitigation policies, and that activities, which are reduced as part of transitions to low carbon including industries and geographical areas are seeing new opportunities. Poor understanding of how governance at multiple levels can meet these transition challenges may fail to make significant progress in relation to national policies and a global climate agreement and may therefore support or weaken the climate architecture, thus constituting a limiting factor.

FAQ 17.3 How critical are the roles of institutions in accelerating the transition and what can governance enable?

Institutions are critical in accelerating the transition towards sustainable development. Institutions can help to shape climate change response strategies both in terms of adaptation and mitigation. Local institutions are custodians of critical adaptation services ranging from mobilisation of resources, skills development and capacity building as well as dissemination of critical strategies. Transitions towards sustainable development are mediated by actors within a given institution, the governance mechanisms they use as implementing tools and the political coalitions they form to enable action. Patterns of production and consumption have implications for a low carbon development and many of these patterns can act as barriers or opportunities towards sustainable development. Trade policies, international economic issues and international financial flows can positively support the speed and scale of the transition or they can negatively impact on policies that may inhibit the process.

Nonetheless, contextual factors are a fundamental part of the change process, and institutions and their governance systems provide pathways that can influence contextual realities on the ground. For instance, politically vested interests may lead powerful lobby groups or coalition networks to influence the direction of the transition or could put pressure on a given political elite through the imposition of regulatory standards, taxation, incentives, and policies that may speed or delay the transition process. Civil society institutions, for example, NGOs or research centres can constitute effective governance 'watch dogs' in the transition process, particularly when they exercise a challenge function and question government's action in the transition process related to sustainable development.

References

Abson, D. J., and Coauthors, 2017: Leverage points for sustainability transformation. *Ambio*, https://doi.org/10.1007/s13280-016-0800-y.

Adger, W, Barnett Jon, Brown Katrina, Marshall, O. N., 2013: Cultural Dimensions of climate change impacts and adaptation. *Clim. Chang.*, **3**, 112–117.

Ahamer, G., 2013: Game, Not Fight: Change Climate Change! *Simul. Gaming*, **44**, https://doi.org/10.1177/1046878112470541.

Ahlborg, H., 2017: Towards a conceptualization of power in energy transitions. *Environ. Innov. Soc. TRANSITIONS*, **25**, 122–141, https://doi.org/10.1016/j.eist.2017.01.004.

Ahlström, H., 2019: Policy hotspots for sustainability: Changes in the EU regulation of sustainable business and finance. *Sustain.*, https://doi.org/10.3390/su11020499.

Akimoto, K., and Coauthors, 2012: Consistent assessments of pathways toward sustainable development and climate stabilization. *Nat. Resour. Forum*, **36**, https://doi.org/10.1111/j.1477-8947.2012.01460.x.

al, N., L. Comolli, and D. Collste, 2020: Innovations for Sustainability Pathways to an efficient and sufficient post-pandemic future. https://doi.org/10.13140/RG.2.2.25368.62725.

Alexandratos, N., and J. Bruinsma, 2012: *World Agriculture Towards 2030/2050: The 2012 Revision.* FAO Rome,.

Alston, M., 2014: Gender mainstreaming and climate change. *Womens. Stud. Int. Forum*, **47**, 287–294, https://doi.org/10.1016/j.wsif.2013.01.016.

Altieri, K. E., H. Trollip, T. Caetano, A. Hughes, B. Merven, and H. Winkler, 2016: Achieving development and mitigation objectives through a decarbonization development pathway in South Africa. *Clim. Policy*, **16**, https://doi.org/10.1080/14693062.2016.1150250.

Amanuma, N., and Coauthors, 2018: *Governance for Integrated Solutions to Sustainable Development and Climate Change: From Linking Issues to Aligning Interests*. E. ZUSMAN and N. AMANUMA, Eds. IGES,.

Andrianto, A., H. Komarudin, and P. Pacheco, 2019: Expansion of oil palm plantations in Indonesia's frontier: Problems of Externalities and the Future of Local and Indigenous Communities. *Land*, **8**, https://doi.org/10.3390/land8040056.

Andries, H. F., M. G. J. den Elzen, A. Admiraal, M. Roelfsema, D. E. H. J. Gernaat, and D. P. van Vuuren, 2017: Global and regional abatement costs of Nationally Determined Contributions (NDCs) and of enhanced action to levels well below 2°C and 1.5°C. *Environ. Sci. Policy*, **71**, 30–40, https://doi.org/https://doi.org/10.1016/j.envsci.2017.02.008.

Ansari, D., and F. Holz, 2020: Between stranded assets and green transformation: Fossil-fuel-producing developing countries towards 2055. *World Dev.*, **130**, https://doi.org/10.1016/j.worlddev.2020.104947.

Antwi-Agyei, P., A. J. Dougill, T. P. Agyekum, and L. C. Stringer, 2018: Alignment between nationally determined contributions and the sustainable development goals for West Africa. *Clim. Policy*, **18**, 1296–1312, https://doi.org/10.1080/14693062.2018.1431199.

Arnell, N. W., and B. Lloyd-Hughes, 2014: The global-scale impacts of climate change on water resources and flooding under new climate and socio-economic scenarios. *Clim. Change*, **122**, https://doi.org/10.1007/s10584-013-0948-4.

Arranz, A. M., 2017: Lessons from the past for sustainability transitions? A meta-analysis of socio-technical studies. *Glob. Environ. Chang. POLICY Dimens.*, **44**, 125–143, https://doi.org/10.1016/j.gloenvcha.2017.03.007.

Arrow, K., and Coauthors, 2004: Are we consuming too much? *J. Econ. Perspect.*, 147–172, https://doi.org/10.1257/0895330042162377.

Ashford, N., and C. (1985 Ayers, 1985: Using Regulation to change the market for innovation. *Harvar Environ. Law Rev*, **9**, 416–419.

Ashford, N. A., and R. P. Hall, 2011: *Technology, globalization, and sustainable development: Transforming the industrial state*. Yale University Press, 1–720 pp.

——, and ——, 2018: Achieving Global Climate and Environmental Goals by Governmental Regulatory Targeting. *Ecol. Econ.*, **152**, 246–259,

https://doi.org/10.1016/j.ecolecon.2018.06.002.
van Asselt, H., 2014: *The fragmentation of global climate governance: Consequences and management of regime interactions*. Edward Elgar Publishing Ltd., 1–335 pp.
Austin, K. G., A. Schwantes, Y. Gu, and P. S. Kasibhatla, 2019: What causes deforestation in Indonesia? *Environ. Res. Lett.*, https://doi.org/10.1088/1748-9326/aaf6db.
Avelino, F., J. Grin, B. Pel, and S. Jhagroe, 2016: The politics of sustainability transitions. *J. Environ. POLICY Plan.*, **18**, 557–567, https://doi.org/10.1080/1523908X.2016.1216782.
Averchenkova, A., S. Bassi, K. J. Benes, F. Green, A. Lagarde, I. Neuweg, and G. Zachmann, 2016: Climate policy in China, the European Union and the United States: Main drivers and prospects for the future Policy brief In collaboration with.
Bachus, K., and F. Vanswijgenhoven, 2018: The use of regulatory taxation as a policy instrument for sustainability transitions: old wine in new bottles or unexplored potential? *J. Environ. Plan. Manag.*, **61**, 1469–1486, https://doi.org/10.1080/09640568.2017.1358155.
Banks, S., 2007: The Heart and Soul of Transition—Creating a Low Carbon Future with Psychological and Spiritual Awareness. *Self Soc.*, **35**, 5–14, https://doi.org/10.1080/03060497.2007.11083972.
De Barbosa, L. S. N. S., D. Bogdanov, P. Vainikka, and C. Breyer, 2017: Hydro, wind and solar power as a base for a 100% renewable energy supply for South and Central America. *PLoS One*, https://doi.org/10.1371/journal.pone.0173820.
Barker, T., E. Alexandri, J. F. Mercure, Y. Ogawa, and H. Pollitt, 2016: GDP and employment effects of policies to close the 2020 emissions gap. *Clim. Policy*, **16**, https://doi.org/10.1080/14693062.2014.1003774.
Bataille, C., H. Waisman, M. Colombier, L. Segafredo, J. Williams, and F. Jotzo, 2016: The need for national deep decarbonization pathways for effective climate policy. *Clim. Policy*, **16**, S7–S26, https://doi.org/10.1080/14693062.2016.1173005.
Bauer, N., C. McGlade, J. Hilaire, and P. Ekins, 2018: Divestment prevails over the green paradox when anticipating strong future climate policies. *Nat. Clim. Chang.*, **8**, 130–134, https://doi.org/10.1038/s41558-017-0053-1.
Baumgärtner, S., M. A. Drupp, J. N. Meya, J. M. Munz, and M. F. Quaas, 2017: Income inequality and willingness to pay for environmental public goods. *J. Environ. Econ. Manage.*, **85**, 35–61, https://doi.org/10.1016/j.jeem.2017.04.005.
Le Bec, C., 2020: Coronavirus: Pandemic puts strain 30 major African oil and gas projects.
Beder, S., 2000: Costing the Earth: Equity, Sustainable Development and Environmental Economics. *New Zeal. J. Environ. Law*, **4**, 227–243.
Beg, N., 2002: Linkages between climate change and sustainable development. *Clim. Policy*, https://doi.org/10.1016/s1469-3062(02)00028-1.
Bellinson, R., and E. Chu, 2019: Learning pathways and the governance of innovations in urban climate change resilience and adaptation. *Environ. Policy Plan*, **21**, 76–89, https://doi.org/https://doi.org/10.1080/1523908X.2018.1493916.
van den Berg, N. J., and Coauthors, 2020: Implications of various effort-sharing approaches for national carbon budgets and emission pathways. *Clim. Change*, **162**, https://doi.org/10.1007/s10584-019-02368-y.
Berkhout, F., G. Verbong, A. J. Wieczorek, R. Raven, L. Lebel, and X. Bai, 2010: Sustainability experiments in Asia: Innovations shaping alternative development pathways? *Environ. Sci. Policy*, **13**, https://doi.org/10.1016/j.envsci.2010.03.010.
Bernstein, S., and M. Hoffmann, 2018: The politics of decarbonization and the catalytic impact of subnational climate experiments. *Policy Sci.*, **51**, https://doi.org/10.1007/s11077-018-9314-8.
Berry, P, S. Brown, M. Chen, A. Kontogianni, O. Rowlands, G. Simpson, and M. Skourtos, 2015: Cross-sectoral interactions of adaptation and mitigation measures. *Clim. Chang.*, **128–393**, 381-, https://doi.org/https://doi.org/10.1007/s10584-014-1214-0.
Berry, P. M., S. Brown, M. Chen, A. Kontogianni, O. Rowlands, G. Simpson, and M. Skourtos, 2015: Cross-sectoral interactions of adaptation and mitigation measures. *Clim. Change*, **128**, 381–393, https://doi.org/10.1007/s10584-014-1214-0.
Betsill, M. M., and H. Bulkeley, 2006: Cities and the multilevel governance of global climate change. *Glob. Gov.*, **12**, 141–159, https://doi.org/10.1163/19426720-01202004.
Biermann, F., and Coauthors, 2012: Transforming governance and institutions for global sustainability:

Key insights from the Earth System Governance Project. *Curr. Opin. Environ. Sustain.*, **4**, 51–60, https://doi.org/10.1016/j.cosust.2012.01.014.

Biermann, F., N. Kanie, and R. E. Kim, 2017: Global governance by goal-setting: the novel approach of the UN Sustainable Development Goals. *Curr. Opin. Environ. Sustain.*, **26–27**, 26–31, https://doi.org/10.1016/j.cosust.2017.01.010.

Biggs, E. M., and Coauthors, 2015: Sustainable development and the water-energy-food nexus: A perspective on livelihoods. *Environ. Sci. Policy*, https://doi.org/10.1016/j.envsci.2015.08.002.

Birch, K., 2016: Materiality and sustainability transitions: integrating climate change in transport infrastructure in Ontario, Canada. *PROMETHEUS*, **34**, 191–206, https://doi.org/10.1080/08109028.2017.1331612.

Bleischwitz, R., and Coauthors, 2018: Resource nexus perspectives towards the United Nations Sustainable Development Goals. *Nat. Sustain.*, https://doi.org/10.1038/s41893-018-0173-2.

Bloomfield, H. C., D. J. Brayshaw, L. C. Shaffrey, P. J. Coker, and H. E. Thornton, 2016: Quantifying the increasing sensitivity of power systems to climate variability. *Environ. Res. Lett.*, https://doi.org/10.1088/1748-9326/11/12/124025.

BMU, 2018: *Conclusions of the Petersberg Climate Dialogue IX - BMU*.

Bolton, R., T. J. Foxon, and S. Hall, 2016: Energy transitions and uncertainty: Creating low carbon investment opportunities in the UK electricity sector. *Environ. Plan. C-GOVERNMENT POLICY*, **34**, 1387–1403, https://doi.org/10.1177/0263774X15619628.

Bowman, A. O'M. Portney, K. E. Berry, J. M., 2017: Multilevel Governance and City Sustainability Policies: Does It Exist? Does it Matter? *Paper delivered at the Local Governance and Sustainability Conference within Conference*, New Orleans, 1–118.

Bradbury, D., 2015: Internet of things How can privacy survive in the era of the internet of things? *Guard.*,.

Bradbury, H., S. Waddell, K. O' Brien, M. Apgar, B. Teehankee, and I. Fazey, 2019: A call to Action Research for Transformations: The times demand it. *Action Res.*, **17**, https://doi.org/10.1177/1476750319829633.

Breukers, S., R. M. Mourik, L. F. M. van Summeren, and G. P. J. Verbong, 2017: Institutional 'lock-out' towards local self-governance? Environmental justice and sustainable transformations in Dutch social housing neighbourhoods. *Energy Res. Soc. Sci.*, **23**, 148–158, https://doi.org/10.1016/j.erss.2016.10.007.

van den Brink, S., R. Kleijn, B. Sprecher, and A. Tukker, 2020: Identifying supply risks by mapping the cobalt supply chain. *Resour. Conserv. Recycl.*, **156**, https://doi.org/10.1016/j.resconrec.2020.104743.

Brodnik, C., and R. Brown, 2018: Strategies for developing transformative capacity in urban water management sectors: The case of Melbourne, Australia. *Technol. Forecast. Soc. Change*, **137**, 147–159, https://doi.org/10.1016/j.techfore.2018.07.037.

Broto, V. C., S. Glendinning, E. Dewberry, C. Walsh, and M. Powell, 2014: What can we learn about transitions for sustainability from infrastructure shocks? *Technol. Forecast. Soc. Change*, **84**, 186–196, https://doi.org/10.1016/j.techfore.2013.08.002.

Brouwer, F., G. Avgerinopoulos, D. Fazekas, C. Laspidou, J. F. Mercure, H. Pollitt, E. P. Ramos, and M. Howells, 2018: Energy modelling and the Nexus concept. *Energy Strateg. Rev.*, **19**, https://doi.org/10.1016/j.esr.2017.10.005.

Brown, O., A. Hammill, and R. McLeman, 2007: Climate change as the "new" security threat: Implications for Africa. *Int. Aff.*, **83**, 1141–1154, https://doi.org/10.1111/j.1468-2346.2007.00678.x.

Brown, P. T., W. Li, and S. P. Xie, 2015: Regions of significant influence on unforced global mean surface air temperature variability in climate models. *J. Geophys. Res.*, **120**, https://doi.org/10.1002/2014JD022576.

Bryan, E., C. Ringler, B. Okoba, J. Koo, M. Herrero, and S. Silvestri, 2013: Can agriculture support climate change adaptation, greenhouse gas mitigation and rural livelihoods? insights from Kenya. *Clim. Chang.*, **118**, 151–165, https://doi.org/https://doi.org/10.1007/s10584-012-0640-0.

Budinis, S., S. Krevor, N. Mac Dowell, N. Brandon, and A. Hawkes, 2018: An assessment of CCS costs, barriers and potential. *Energy Strateg. Rev.*, **22**, 61–81, https://doi.org/10.1016/j.esr.2018.08.003.

Burch, S., 2010: Transforming barriers into enablers of action on climate change: Insights from three municipal case studies in British Columbia, Canada. *Glob. Environ. Chang.*, **20**, 287–297, https://doi.org/10.1016/j.gloenvcha.2009.11.009.
——, 2017: The governance of transformative change: Tracing the pathway of the sustainability transition in Vancouver, Canada. *Urban Sustain. Transitions*, 50–64, https://doi.org/10.4324/9781315228389.
——, and J. Robinson, 2007: A framework for explaining the links between capacity and action in response to global climate change. *Clim. Policy*, **7**, https://doi.org/10.1080/14693062.2007.9685658.
——, A. Shaw, A. Dale, and J. Robinson, 2014: Triggering transformative change: A development path approach to climate change response in communities. *Clim. Policy*, **14**, 467–487, https://doi.org/10.1080/14693062.2014.876342.
——, M. Andrachuk, D. Carey, N. Frantzeskaki, H. Schroeder, N. Mischkowski, and D. Loorbach, 2016: Governing and accelerating transformative entrepreneurship: exploring the potential for small business innovation on urban sustainability transitions. *Curr. Opin. Environ. Sustain.*, **22**, 26–32, https://doi.org/10.1016/j.cosust.2017.04.002.
——, C. Mitchell, M. Berbes-Blazquez, and J. Wandel, 2017: Tipping Toward Transformation: Progress, Patterns and Potential for Climate Change Adaptation in the Global South. *J. Extrem. Events*, **04**, 1750003, https://doi.org/10.1142/s2345737617500038.
Bulkeley, V. Castán Broto, and G. A. S. Edwards, 2015: *An Urban Politics of Climate Change: Experimentation and the Governing of Socio-Technical Transitions*. Routledge, 282 pp.
Byers, E., and Coauthors, 2018: Global exposure and vulnerability to multi-sector development and climate change hotspots. *Environ. Res. Lett.*, **13**, 55012, https://doi.org/10.1088/1748-9326/aabf45.
Byers, E. A., and Coauthors, 2015: Cooling water for Britain's future electricity supply. *Proc. Inst. Civ. Eng. Energy*, https://doi.org/10.1680/ener.14.00028.
C40, 2019: C40 Cities.
Campagnolo, L., and M. Davide, 2019: Can the Paris deal boost SDGs achievement? An assessment of climate mitigation co-benefits or side-effects on poverty and inequality. *World Dev.*, **122**, 96–109, https://doi.org/10.1016/j.worlddev.2019.05.015.
Campbell, B. M., P. Thornton, R. Zougmoré, P. van Asten, and L. Lipper, 2014: Sustainable intensification: What is its role in climate smart agriculture? *Curr. Opin. Environ. Sustain.*, **8**, https://doi.org/10.1016/j.cosust.2014.07.002.
Campiglio, E., 2016: Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecol. Econ.*, https://doi.org/10.1016/j.ecolecon.2015.03.020.
Canitez, F., 2019: Pathways to sustainable urban mobility in developing megacities: A socio-technical transition perspective. *Technol. Forecast. Soc. Change*, **141**, 319–329, https://doi.org/10.1016/j.techfore.2019.01.008.
Carvalho Resende, T., and Coauthors, 2019: Assessment of the impacts of climate variability on total water storage across Africa: implications for groundwater resources management. *Hydrogeol. J.*, **27**, https://doi.org/10.1007/s10040-018-1864-5.
Cervero, R., 2009: Public transport and sustainable urbanism: Global lessons. *Transit Oriented Development: Making it Happen*.
Chan, S., and P. Pauw, 2014: A global framework for climate action: orchestrating non-state and subnational initiatives for more effective global climate governance, Discussion Paper. 54.
Chang, R., J. Zuo, Z. Zhao, V. Soebarto, G. Zillante, and X. Gan, 2017: Approaches for Transitions Towards Sustainable Development: Status Quo and Challenges. *Sustain. Dev.*, **25**, 359–371, https://doi.org/10.1002/sd.1661.
Chatalova, L., and A. Balmann, 2017: The hidden costs of renewables promotion: The case of crop-based biogas. *J. Clean. Prod.*, **168**, https://doi.org/10.1016/j.jclepro.2017.09.031.
Chen, H., J. Sun, and X. Chen, 2014: Projection and uncertainty analysis of global precipitation-related extremes using CMIP5 models. *Int. J. Climatol.*, https://doi.org/10.1002/joc.3871.
Cherp, A., V. Vinichenko, J. Jewell, E. Brutschin, and B. Sovacool, 2018: Integrating techno-economic, socio-technical and political perspectives on national energy transitions: A meta-theoretical framework. *ENERGY Res. Soc. Sci.*, **37**, 175–190, https://doi.org/10.1016/j.erss.2017.09.015.

Chichilnisky, G., and G. Heal, 1998: Economic returns from the biosphere. *Nature*, https://doi.org/10.1038/35481.
Chimhowu, A. O., D. Hulme, and L. T. Munro, 2019: The 'New' national development planning and global development goals: Processes and partnerships. *World Dev.*, **120**, 76–89, https://doi.org/https://doi.org/10.1016/j.worlddev.2019.03.013.
Chirambo, D., 2018: Towards the achievement of SDG 7 in sub-Saharan Africa: Creating synergies between Power Africa, Sustainable Energy for All and climate finance in-order to achieve universal energy access before 2030. *Renew. Sustain. Energy Rev.*, **94**, 600–608, https://doi.org/https://doi.org/10.1016/j.rser.2018.06.025.
Chokshi, P., Shukla, P. R.; Pathak, M; Bhaskar, K., 2014: Green Energy and Sustainable Urban Transport Transition: A Co-benefits Assessment for Ahmedabad. *International Conference and Utility Exhibition 2014 on Green Energy for Sustainable Development (ICUE 2014)*.
Clark, R., J. Reed, and T. Sunderland, 2018: Bridging funding gaps for climate and sustainable development: Pitfalls, progress and potential of private finance. *Land use policy*, **71**, 335–346, https://doi.org/10.1016/j.landusepol.2017.12.013.
Clayton, T., and N. Radcliffe, 2018: *Sustainability: A Systems Approach*. 253 pp.
Cobbing, J., 2020: Groundwater and the discourse of shortage in Sub-Saharan AfricaLes eaux souterraines et le discours de pénurie en Afrique subsaharienneLas aguas subterráneas y el discurso de la escasez en el África subsahariana非洲撒哈拉以南地区的地下水和短缺论评As águas subterrâneas e o discurso da escassez na África Subsaariana. *Hydrogeol. J.*, **28**, https://doi.org/10.1007/s10040-020-02147-5.
——, and B. Hiller, 2019: Waking a sleeping giant: Realizing the potential of groundwater in Sub-Saharan Africa. *World Dev.*, **122**, https://doi.org/10.1016/j.worlddev.2019.06.024.
Cole, D. H., 2015: Advantages of a polycentric approach to climate change policy. *Nat. Clim. Chang.*, **5**, https://doi.org/10.1038/nclimate2490.
Campagnolo, L., and M. Davide, 2019: Can the Paris deal boost SDGs achievement? An assessment of climate mitigation co-benefits or side-effects on poverty and inequality. *World Dev.*, **122**, 96–109, doi:10.1016/j.worlddev.2019.05.015.
Conca, J., 2018: Blood Batteries - Cobalt And The Congo.
Corfee-Morlot, J., L. Kamal-Chaoui, M. G. Donovan, I. Cochran, A. Robert, and P.-J. Teasdale, 2009: Cities, Climate Change and Multilevel Governance. *OECD Environ. Work. Pap.*, 125.
Crabtree, G., 2019: The coming electric vehicle transformation. *Science (80-.).*, https://doi.org/10.1126/science.aax0704.
Craig, M. T., and Coauthors, 2018: A review of the potential impacts of climate change on bulk power system planning and operations in the United States. *Renew. Sustain. Energy Rev.*, https://doi.org/10.1016/j.rser.2018.09.022.
Cremades, R., and Coauthors, 2019: Ten principles to integrate the water-energy-land nexus with climate services for co-producing local and regional integrated assessments. *Sci. Total Environ.*, **693**, https://doi.org/10.1016/j.scitotenv.2019.133662.
Creutzig, F., and Coauthors, 2019: Upscaling urban data science for global climate solutions. *Glob. Sustain.*, **2E2**, https://doi.org/10.1017/sus.2018.16.
Cui, R. Y., and Coauthors, 2019: Quantifying operational lifetimes for coal power plants under the Paris goals. *Nat. Commun.*, **10**, https://doi.org/10.1038/s41467-019-12618-3.
Curtis, P. G., C. M. Slay, N. L. Harris, A. Tyukavina, and M. C. Hansen, 2018: Classifying drivers of global forest loss. *Science (80-.).*, **14**, 1108–1111, https://doi.org/10.1126/science.aau3445.
D'Odorico, P., and Coauthors, 2018: The Global Food-Energy-Water Nexus. *Rev. Geophys.*, https://doi.org/10.1029/2017RG000591.
Dafermos, Y., M. Nikolaidi, and G. Galanis, 2017: A stock-flow-fund ecological macroeconomic model. *Ecol. Econ.*, **131**, https://doi.org/10.1016/j.ecolecon.2016.08.013.
Dai, J., and Coauthors, 2018: Water-energy nexus: A review of methods and tools for macro-assessment. *Appl. Energy*, **210**, 393–408, https://doi.org/10.1016/j.apenergy.2017.08.243.
Dalziel, P., and C. Saunders, 2010: Equity and sustainable development. *Int. J. Bus. Glob.*, **5**, https://doi.org/10.1504/IJBG.2010.035027.
Dangelico, R. M., D. Pujari, and P. Pontrandolfo, 2016: Green product innovation in manufacturing

firms: A sustainability-oriented dynamic capability perspective. *Bus. Strateg. Environ.*, **26**, 490–506.
Day, D. V., J. W. Fleenor, L. E. Atwater, R. E. Sturm, and R. A. McKee, 2014: Advances in leader and leadership development: A review of 25 years of research and theory. *Leadersh. Q.*, https://doi.org/10.1016/j.leaqua.2013.11.004.
Delina, L. L., and B. K. Sovacool, 2018: Of temporality and plurality: an epistemic and governance agenda for accelerating just transitions for energy access and sustainable development. *Curr. Opin. Environ. Sustain.*, **34**, https://doi.org/10.1016/j.cosust.2018.05.016.
Denton, F., and Coauthors, 2014: Climate-resilient pathways: adaptation, mitigation, and sustainable development. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1101–1131.
Derman, B. B., 2014: Climate governance, justice, and transnational civil society. *Clim. Policy*, **14**, 23–41, https://doi.org/10.1080/14693062.2014.849492.
Destouni, G., F. Jaramillo, and C. Prieto, 2013: Hydroclimatic shifts driven by human water use for food and energy production. *Nat. Clim. Chang.*, **3**, 213–217, https://doi.org/10.1038/nclimate1719.
Diallo, I., F. Giorgi, A. Deme, M. Tall, L. Mariotti, and A. T. Gaye, 2016: Projected changes of summer monsoon extremes and hydroclimatic regimes over West Africa for the twenty-first century. *Clim. Dyn.*, **47**, https://doi.org/10.1007/s00382-016-3052-4.
Díaz, S., J. Settele, and E. Brondizio, 2019: Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). *J. Rural Plan. Assoc.*, 36, https://doi.org/10.2750/arp.36.13.
Doll, C. N. H., and J. A. Puppim De Oliveira, 2017: *Urbanization and climate co-benefits: Implementation of win-win interventions in cities*. Taylor and Francis, 1–324 pp.
Dollinger, J., and S. Jose, 2019: Correction to: Agroforestry for soil health (Agroforestry Systems, (2018), 92, 2, (213-219), 10.1007/s10457-018-0223-9). *Agrofor. Syst.*, **93**, https://doi.org/10.1007/s10457-018-0227-5.
Dovie, D. B. K., 2019: Case for equity between Paris Climate agreement's Co-benefits and adaptation. *Sci. Total Environ.*, **656**, 732–739, https://doi.org/10.1016/j.scitotenv.2018.11.333.
Dowling, R., P. McGuirk, and S. Maalsen, 2018: Multiscalar governance of urban energy transitions in Australia: The cases of Sydney and Melbourne. *Energy Res. Soc. Sci.*, **44**, 260–267, https://doi.org/10.1016/j.erss.2018.05.027.
Drupp, M. A., J. N. Meya, S. Baumgärtner, and M. F. Quaas, 2018: Economic Inequality and the Value of Nature. *Ecol. Econ.*, **150**, 340–345, https://doi.org/10.1016/j.ecolecon.2018.03.029.
Dubash, N. K., 2020: Revisiting climate ambition: The case for prioritizing current action over future intent. *Wiley Interdiscip. Rev. Clim. Chang.*, **11**, https://doi.org/10.1002/wcc.622.
Dugast, J., S. Uslu, and P.-O. Weill, 2019: A Theory of Participation in OTC and Centralized Markets. *SSRN Electron. J.*, https://doi.org/10.2139/ssrn.3395607.
E3G, 2018: E3G Annual Review 2018. https://www.e3g.org/library_asset/e3g-annual-review-2018/.
Easterlin, R. A., L. A. McVey, M. Switek, O. Sawangfa, and J. S. Zweig, 2010: The happiness - Income paradox revisited. *Proc. Natl. Acad. Sci. U. S. A.*, **107**, https://doi.org/10.1073/pnas.1015962107.
EC, 2019: The twentieth ACM conference on Economics and Computation (ACM EC '19. http://www.sigecom.org/ec19/.
ECLAC, 2017: *Annual report on regional progress and challenges in relation to the 2030 Agenda for Sustainable Development in Latin America and the Caribbean*. 114 pp.
——, 2018: *Mechanisms to accelerate the implementation of the Sustainable Development Goals in the Caribbean*. 32 pp.
Edmondson, D. L., F. Kern, and K. S. Rogge, 2018: The co-evolution of policy mixes and socio-technical systems: Towards a conceptual framework of policy mix feedback in sustainability transitions. *Res. Policy*, https://doi.org/10.1016/j.respol.2018.03.010.
EESC, 2015: *Building the Europe We Want: Models for civil society involvement in the implementation of the Post-2015 agenda at the EU level*. 54 pp.
Ehnert, F., F. Kern, S. Borgström, L. Gorissen, S. Maschmeyer, and M. Egermann, 2018: Urban sustainability transitions in a context of multi-level governance: A comparison of four European

states. *Environ. Innov. Soc. Transitions*, **26**, 101–116, https://doi.org/10.1016/j.eist.2017.05.002.
EIA, 2019: Data & Statistics. tps://www.iea.org/data-and-statistics.
Eisenack, K., and D. Reckien, 2013: Climate Change and Simulation/Gaming. *Simul. Gaming*, **44**, https://doi.org/10.1177/1046878113490568.
Elder, M., and P. King, 2018: *Realising the Transformative Potential of the SDGs*. 188 pp. https://iges.or.jp/en/pub/realising-transformative-potential-sdgs/en.
——, and A. Bartalini, 2019: *Assessment of the G20 Countries' Concrete SDG Implementation Efforts: Policies and Budgets Reported in Their 2016-2018 Voluntary National Reviews*. 92 pp. https://iges.or.jp/en/pub/assessment-g20-countries'-concrete-sdg.
den Elzen, M., and Coauthors, 2019: Are the G20 economies making enough progress to meet their NDC targets? *Energy Policy*, **126**, 238–250, https://doi.org/10.1016/j.enpol.2018.11.027.
Energy, C. of M. for C. &, 2019: Cities and towns gathered around one shared ambition. https://energy-cities.eu/project/covenant-of-mayors-for-climate-energy/.
ETP, 2017: Energy Technology Perspectives 2017. https://www.iea.org/reports/energy-technology-perspectives-2017.
Fader, M., C. Cranmer, R. Lawford, and J. Engel-Cox, 2018: Toward an understanding of synergies and trade-offs between water, energy, and food SDG targets. *Front. Environ. Sci.*, **6**, https://doi.org/10.3389/fenvs.2018.00112.
Falcone, P. M., and E. Sica, 2015: HOW MUCH DOES ECONOMIC CRISIS AFFECT SUSTAINABILITY TRANSITIONS? A SOCIAL NETWORK ANALYSIS OF THE ITALIAN BIOFUEL SECTOR. *Ekon. Reg. Reg.*, **1**, 264+, https://doi.org/10.17059/2015-1-23.
FAO, FAO Statistics, Annual population. 2019. http://www.fao.org/faostat/en/#data/OA (Accessed December 16, 2019).
Fastenrath, S., and B. Braun, 2018: Sustainability transition pathways in the building sector: Energy-efficient building in Freiburg (Germany). *Appl. Geogr.*, **90**, 339–349, https://doi.org/10.1016/j.apgeog.2016.09.004.
Favretto, N., A. J. Dougill, L. C. Stringer, S. Afionis, and C. H. Quinn, 2018: Links between climate change mitigation, adaptation and development in land policy and ecosystem restoration projects: lessons from South Africa. *Sustainability*, **10**.
Fazey, I., and Coauthors, 2018a: Community resilience for a 1.5 °C world. *Curr. Opin. Environ. Sustain.*, https://doi.org/10.1016/j.cosust.2017.12.006.
Fazey, I., and Coauthors, 2018b: Community resilience for a 1.5°C world. *Curr. Opin. Environ. Sustain.*, **31**, 30–40, https://doi.org/https://doi.org/10.1016/j.cosust.2017.12.006.
Ferguson, R. S., and S. T. Lovell, 2014: Permaculture for agroecology: Design, movement, practice, and worldview. A review. *Agron. Sustain. Dev.*, https://doi.org/10.1007/s13593-013-0181-6.
Fiack, D., and S. Kamieniecki, 2017: Stakeholder engagement in climate change policymaking in American cities. *J. Environ. Stud. Sci.*, **7**, https://doi.org/10.1007/s13412-014-0205-9.
Fishman, R., N. Devineni, and S. Raman, 2015: Can improved agricultural water use efficiency save India's groundwater? *Environ. Res. Lett.*, https://doi.org/10.1088/1748-9326/10/8/084022.
Fleurbaey, M., and Coauthors, 2014: Sustainable Development and Equity. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Folke, C., 2006: Resilience: The emergence of a perspective for social-ecological systems analyses. *Glob. Environ. Chang.*, https://doi.org/10.1016/j.gloenvcha.2006.04.002.
Fontana, G., and M. Sawyer, 2016: Towards post-Keynesian ecological macroeconomics. *Ecol. Econ.*, **121**, https://doi.org/10.1016/j.ecolecon.2015.03.017.
Forsyth, T., 2014: Climate justice is not just ice. *Geoforum*, **54**, 230–232, https://doi.org/10.1016/j.geoforum.2012.12.008.
Forzieri, G., A. Bianchi, F. B. e. Silva, M. A. Marin Herrera, A. Leblois, C. Lavalle, J. C. J. H. Aerts, and L. Feyen, 2018: Escalating impacts of climate extremes on critical infrastructures in Europe. *Glob. Environ. Chang.*, **48**, 97–107, https://doi.org/10.1016/j.gloenvcha.2017.11.007.
Frantzeskaki, N., D. Loorbach, and J. Meadowcroft, 2012: Governing societal transitions to sustainability. *Int. J. Sustain. Dev.*, https://doi.org/10.1504/IJSD.2012.044032.
Fricko, O., S. C. Parkinson, N. Johnson, M. Strubegger, M. T. Van Vliet, and K. Riahi, 2016: Energy

sector water use implications of a 2°C climate policy. *Environ. Res. Lett.*, https://doi.org/10.1088/1748-9326/11/3/034011.
Fuhr, H., T. Hickmann, and K. Kern, 2018: The role of cities in multi-level climate governance: local climate policies and the 1.5 °C target. *Curr. Opin. Environ. Sustain.*, **30**, https://doi.org/10.1016/j.cosust.2017.10.006.
Fujimori, S., T. Hasegawa, T. Masui, K. Takahashi, D. S. Herran, H. Dai, Y. Hijioka, and M. Kainuma, 2017: SSP3: AIM implementation of Shared Socioeconomic Pathways. *Glob. Environ. Chang.*, **42**, 268–283, https://doi.org/10.1016/j.gloenvcha.2016.06.009.
——, and Coauthors, 2019: A multi-model assessment of food security implications of climate change mitigation. *Nat. Sustain.*, **2**, 386–396, https://doi.org/10.1038/s41893-019-0286-2.
Fuseini, I., and J. Kemp, 2015: A review of spatial planning in Ghana's socio-economic development trajectory: A sustainable development perspective. *Land use policy*, **47**, 309–320, https://doi.org/https://doi.org/10.1016/j.landusepol.2015.04.020.
Fuso Nerini, F., and Coauthors, 2019: Connecting climate action with other Sustainable Development Goals. *Nat. Sustain.*, **2**, 674–680, https://doi.org/10.1038/s41893-019-0334-y.
Galli, A., G. Đurović, L. Hanscom, and J. Knežević, 2018: Think globally, act locally: Implementing the sustainable development goals in Montenegro. *Environ. Sci. Policy*, **84**, 159–169, https://doi.org/https://doi.org/10.1016/j.envsci.2018.03.012.
Gao, J., C. Li, P. Zhao, H. Zhang, G. Mao, and Y. Wang, 2019: Insights into water-energy cobenefits and trade-offs in water resource management. *J. Clean. Prod.*, **213**, https://doi.org/10.1016/j.jclepro.2018.12.126.
Gasbarro, F., E. Annunziata, F. Rizzi, and M. Frey, 2017: The Interplay Between Sustainable Entrepreneurs and Public Authorities: Evidence From Sustainable Energy Transitions. *Organ. Environ.*, **30**, 226–252, https://doi.org/10.1177/1086026616669211.
Gauer, P., D. Issler, K. Lied, K. Kristensen, and F. Sandersen, 2008: On snow avalanche flow regimes: Inferences from observations and measurements. *Proc. of the Intl. Snow Science Workshop ISSW '08, Whistler, B.C., Canada*.
Gauer, W., 2018: *Sumak Kawasy. Ossietzky*. http://www.ossietzky.net/20-2008&textfile=353.
Gaveau, D. L. A., D. Sheil, Husnayaen, M. A. Salim, S. Arjasakusuma, M. Ancrenaz, P. Pacheco, and E. Meijaard, 2016: Rapid conversions and avoided deforestation: Examining four decades of industrial plantation expansion in Borneo. *Sci. Rep.*, **6**, https://doi.org/10.1038/srep32017.
Geels, F. W., 2014: Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Cult. Soc.*, **31**, https://doi.org/10.1177/0263276414531627.
Geneletti, D., and L. Zardo, 2016: Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. *Land use policy*, **50**, 38–47, https://doi.org/https://doi.org/10.1016/j.landusepol.2015.09.003.
Geng, Y., and Z. Hengxin, 2009: Industrial park management in the Chinese environment. *J. Clean. Prod.*, **17**, https://doi.org/10.1016/j.jclepro.2009.03.009.
——, J. Sarkis, and R. Bleischwitz, 2019: How to globalize the circular economy. *Nature*, **565**, https://doi.org/10.1038/d41586-019-00017-z.
Germer, J., J. Sauerborn, F. Asch, J. de Boer, J. Schreiber, G. Weber, and J. Müller, 2011: Skyfarming an ecological innovation to enhance global food security. *J. fur Verbraucherschutz und Leb.*, **6**, https://doi.org/10.1007/s00003-011-0691-6.
GGKP, 2016: *National Strategy and Action Plan for Sustainable Consumption and Production in Jordan (2016-2025)*.
Gi, K., F. Sano, A. Hayashi, and K. Akimoto, 2019: A model-based analysis on energy systems transition for climate change mitigation and ambient particulate matter 2.5 concentration reduction. *Mitig. Adapt. Strateg. Glob. Chang.*, **24**, https://doi.org/10.1007/s11027-018-9806-z.
Gillard, R., A. Gouldson, J. Paavola, and J. Van Alstine, 2016: Transformational responses to climate change: Beyond a systems perspective of social change in mitigation and adaptation. *Wiley Interdiscip. Rev. Clim. Chang.*, https://doi.org/10.1002/wcc.384.
Gioacchino, G., 2019: You defend what you feel: 'Presencing' nature as 'experiential knowing.' *Action Res.*, https://doi.org/10.1177/1476750319829208.
Giorgi, F., F. Raffaele, and E. Coppola, 2019: The response of precipitation characteristics to global

warming from climate projections. *Earth Syst. Dyn.*, **10**, 73–89, https://doi.org/10.5194/esd-10-73-2019.
Gjorgiev, B., and G. Sansavini, 2018: Electrical power generation under policy constrained water-energy nexus. *Appl. Energy*, **210**, 568–579, https://doi.org/10.1016/j.apenergy.2017.09.011.
Glaas, E., M. Hjerpe, S. Storbjörk, T. S. Neset, A. Bohman, P. Muthumanickam, and J. Johansson, 2018: Developing transformative capacity through systematic assessments and visualization of urban climate transitions. *Ambio*, **48**, 515–528, https://doi.org/10.1007/s13280-018-1109-9.
Go Explorer, 2019: Go Explorer. *Quito Plan. Smaller CO2 Water Footprints*,. https://goexplorer.org/quito-planning-for-smaller-co2-and-water-footprints/.
Goldman-Schuyler, K., S. Skjei, J. Sanzgiri, and V. Koskela, 2017: "Moments of Waking Up": A Doorway to Mindfulness and Presence. *J. Manag. Inq.*, **26**, 86–100, https://doi.org/10.1177/1056492616665171.
Goldthau, A., and B. K. Sovacool, 2012: The uniqueness of the energy security, justice, and governance problem. *Energy Policy*, https://doi.org/10.1016/j.enpol.2011.10.042.
de Gooyert, V., E. Rouwette, H. van Kranenburg, E. Freeman, and H. van Breen, 2016: Sustainability transition dynamics: Towards overcoming policy resistance. *Technol. Forecast. Soc. Change*, **111**, 135–145, https://doi.org/10.1016/j.techfore.2016.06.019.
Göpfert, C., C. Wamsler, and W. Lang, 2019: A framework for the joint institutionalization of climate change mitigation and adaptation in city administrations. *Mitig. Adapt. Strateg. Glob. Chang.*, **24**, 1–21, https://doi.org/10.1007/s11027-018-9789-9.
Gordon, D. J., 2015: An uneasy equilibrium: The coordination of climate governance in federated systems. *Glob. Environ. Polit.*, **15**, 121–141, https://doi.org/10.1162/GLEP_a_00301.
Gorissen, L., F. Spira, E. Meynaerts, P. Valkering, and N. Frantzeskaki, 2018: Moving towards systemic change? Investigating acceleration dynamics of urban sustainability transitions in the Belgian City of Genk. *J. Clean. Prod.*, **173**, 171–185, https://doi.org/https://doi.org/10.1016/j.jclepro.2016.12.052.
Government of the Republic of Fiji, 2019: FIJI LOW EMISSION DEVELOPMENT STRATEGY 2018-2050.
Grafakos, S., K. Trigg, M. Landauer, L. Chelleri, and S. Dhakal, 2019: Analytical framework to evaluate the level of integration of climate adaptation and mitigation in cities. *Clim. Change*, **154**, 87–106, doi:10.1007/s10584-019-02394-w. http://link.springer.com/10.1007/s10584-019-02394-w (Accessed July 13, 2019).
Gramkow, C., and A. Anger-Kraavi, 2018: Could fiscal policies induce green innovation in developing countries? The case of Brazilian manufacturing sectors. *Clim. Policy*, **18**, 246–257, https://doi.org/10.1080/14693062.2016.1277683.
Grandin, J., H. Haarstad, K. Kjærås, and S. Bouzarovski, 2018: The politics of rapid urban transformation. *Curr. Opin. Environ. Sustain.*, **31**, 16–22, https://doi.org/https://doi.org/10.1016/j.cosust.2017.12.002.
Greenberg, D. A., and J. M. Rogerson, 2014: The greening of industrial property developments in South Africa. *Urbani Izziv*, **25**, https://doi.org/10.5379/urbani-izziv-en-2014-25-supplement-009.
Griggs, D., and Stafford-Smith, 2013: Sustainable development goals for people and planet. *Nature*, **495**, 305–307, https://doi.org/doi:10.1038/495305a.
Grinde, B., R. B. Nes, I. F. MacDonald, and D. S. Wilson, 2018: Quality of Life in Intentional Communities. *Soc. Indic. Res.*, https://doi.org/10.1007/s11205-017-1615-3.
Grubler, A., and Coauthors, 2018: A low energy demand scenario for meeting the 1.5 °c target and sustainable development goals without negative emission technologies. *Nat. Energy*, https://doi.org/10.1038/s41560-018-0172-6.
Guenther, E., T. Guenther, F. Schiemann, and G. Weber, 2016: Stakeholder Relevance for Reporting: Explanatory Factors of Carbon Disclosure. *Bus. Soc.*, https://doi.org/10.1177/0007650315575119.
Guillaume, T., Kotowska, M.M., Hertel, D. et al., 2018: Carbon costs and benefits of Indonesian rainforest conversion to plantations. *Nat Commun*, **9**, 11, https://doi.org/https://doi.org/10.1038/s41467-018-04755-y.
Haddeland, I., and Coauthors, 2014: Global water resources affected by human interventions and climate change. *Proc. Natl. Acad. Sci. U. S. A.*, https://doi.org/10.1073/pnas.1222475110.
Haines, A., and K. Ebi, 2019: The Imperative for Climate Action to Protect Health. *N. Engl. J. Med.*,

380, 263–273, https://doi.org/10.1056/nejmra1807873.
Hakansson, I., 2018: The socio-spatial politics of urban sustainability transitions: Grassroots initiatives in gentrifying Peckham. *Environ. Innov. Soc. TRANSITIONS*, **29**, 34–46, https://doi.org/10.1016/j.eist.2017.10.003.
Halbe, J., C. Pahl-Wostl, M. A. Lange, and C. Velonis, 2015: Governance of transitions towards sustainable development – the water–energy–food nexus in Cyprus. *Water Int.*, **40**, https://doi.org/10.1080/02508060.2015.1070328.
Haley, B., 2017: Designing the public sector to promote sustainability transitions: Institutional principles and a case study of ARPA-E. *Environ. Innov. Soc. Transitions*, **25**, 107–121, https://doi.org/10.1016/j.eist.2017.01.002.
Hall, J. W., D. Grey, D. Garrick, F. Fung, C. Brown, S. J. Dadson, and C. W. Sadoff, 2014: Coping with the curse of freshwater variability. *Science (80-.).*, 80, https://doi.org/10.1126/science.1257890.
Hallegatte, S., and J. Rozenberg, 2017: Climate change through a poverty lens. *Nat. Clim. Chang.*, **7**, 250.
Hallinger, P., R. Wang, C. Chatpinyakoop, V. T. Nguyen, and U. P. Nguyen, 2020: A bibliometric review of research on simulations and serious games used in educating for sustainability, 1997–2019. *J. Clean. Prod.*, **256**, https://doi.org/10.1016/j.jclepro.2020.120358.
Hamiche, A. M., A. B. Stambouli, and S. Flazi, 2016: A review of the water-energy nexus. *Renew. Sustain. Energy Rev.*, https://doi.org/10.1016/j.rser.2016.07.020.
Hamman, P., 2019: Local governance of energy transition: sustainability, transactions and social ties. A case study in Northeast France. *Int. J. Sustain. Dev. World Ecol.*, **26**, 1–10, https://doi.org/10.1080/13504509.2018.1471012.
Hanasaki, N., and Coauthors, 2013: A global water scarcity assessment under Shared Socio-economic Pathways - Part 1: Water use. *Hydrol. Earth Syst. Sci.*, **17**, https://doi.org/10.5194/hess-17-2375-2013.
Hannis, M., and K. Rawles, 2013: Compensation or Bribery? Ethical Issues in Relation to Radwaste Host Communities. *Radioactivity in the Environment*, Vol. 19 of.
Hansen, U. E., and I. Nygaard, 2014: Sustainable energy transitions in emerging economies: The formation of a palm oil biomass waste-to-energy niche in Malaysia 1990-2011. *Energy Policy*, **66**, 666–676, https://doi.org/10.1016/j.enpol.2013.11.028.
Hanson, K. T., and T. M. S. Korbla P. Puplampu, 2018: *From Millennium Development Goals to Sustainable Development Goals Rethinking African Development*. Routledge 2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN, 180 pp.
Harry, S., and M. Morad, 2013: Sustainable development and climate change: Beyond mitigation and adaptation. *Local Econ.*, **28**, 358–368, https://doi.org/10.1177/0269094213476663.
Harvey, C. A., and Coauthors, 2014: Climate-Smart Landscapes: Opportunities and Challenges for Integrating Adaptation and Mitigation in Tropical Agriculture. *Conserv. Lett.*, doi:10.1111/conl.12066.
Hasegawa, T., and Coauthors, 2018: Risk of increased food insecurity under stringent global climate change mitigation policy. *Nat. Clim. Chang.*, **8**, https://doi.org/10.1038/s41558-018-0230-x.
——, P. Havlík, S. Frank, A. Palazzo, and H. Valin, 2019: Publisher Correction: Tackling food consumption inequality to fight hunger without pressuring the environment (Nature Sustainability, (2019), 2, 9, (826-833), 10.1038/s41893-019-0371-6). *Nat. Sustain.*, **2**, https://doi.org/10.1038/s41893-019-0439-3.
Hayashi, A., F. Sano, Y. Nakagami, and K. Akimoto, 2018: Changes in terrestrial water stress and contributions of major factors under temperature rise constraint scenarios. *Mitig. Adapt. Strateg. Glob. Chang.*, **23**, https://doi.org/10.1007/s11027-018-9780-5.
Haywood, L. K., N. Funke, M. Audouin, C. Musvoto, and A. Nahman, 2019: The Sustainable Development Goals in South Africa: Investigating the need for multi-stakeholder partnerships. *Dev. South. Afr.*, **36**, 555–569, https://doi.org/10.1080/0376835X.2018.1461611.
Healy, N., J. C. Stephens, and S. A. Malin, 2019: Embodied energy injustices: Unveiling and politicizing the transboundary harms of fossil fuel extractivism and fossil fuel supply chains. *Energy Res. Soc. Sci.*, **48**, 219–234, https://doi.org/10.1016/j.erss.2018.09.016.
Hedlund-de Witt, A., J. de Boer, and J. J. Boersema, 2014: Exploring inner and outer worlds: A

quantitative study of worldviews, environmental attitudes, and sustainable lifestyles. *J. Environ. Psychol.*, https://doi.org/10.1016/j.jenvp.2013.11.005.

van der Heijden, J., J. Patterson, S. Juhola, and M. Wolfram, 2019: Special section: advancing the role of cities in climate governance–promise, limits, politics. *J. Environ. Plan. Manag.*, **62**, 365–373, https://doi.org/10.1080/09640568.2018.1513832.

Van der Heijden, J., 2018a: The limits of voluntary programs for low-carbon buildings for staying under 1.5 °C. *Current Opinion in Environmental Sustainability*, 30,59-66.

——, 2018b: The limits of voluntary programs for low-carbon buildings for staying under 1.5 °C. *Curr. Opin. Environ. Sustain.*, 59–66, https://doi.org/10.1016/j.cosust.2018.03.006.

Hermwille, L., 2018: Making initiatives resonate: how can non-state initiatives advance national contributions under the UNFCCC? *Int. Environ. Agreements Polit. Law Econ.*, **18**, 447–466, https://doi.org/10.1007/s10784-018-9398-9.

Hess, D. J., 2014: Sustainability transitions: A political coalition perspective. *Res. Policy*, **43**, 278–283, https://doi.org/10.1016/j.respol.2013.10.008.

Hinkel, J., 2011: Indicators of vulnerability and adaptive capacity: towards a clarification of the science-policy interface. *Glob. Environ. Chang.*, **21**, 198–208.

Hjerpe, M., E. Glaas, and P. Fenton, 2017: The role of knowledge in climate transition and transformation literatures. *Curr. Opin. Environ. Sustain.*, **29**, 26–31, https://doi.org/https://doi.org/10.1016/j.cosust.2017.10.002.

Hoek, A., M. Shirin, Rob Raven, Eli Court, and Emily Byrne, "Towards environmentally sustainable food systems: decision-making factors in sustainable food production and consumption" - ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S2352550920314081 (Accessed December 21, 2020).

Hoffmann, M 2011: *Climate Governance at the Crossroads*. Oxford University Press,.

Hoff, H., 2011: Understanding the Nexus. *Backgr. Pap. Bonn2011 Conf. Water, Energy Food Secur. Nexus.*,.

Höhne, N., and Coauthors, 2017: The Paris Agreement: resolving the inconsistency between global goals and national contributions. *Clim. Policy*, **17**, https://doi.org/10.1080/14693062.2016.1218320.

Holling, C. S., 2001: Understanding the complexity of economic, ecological and social systems. *Ecosystems*, **4**, 390–405.

Holscher, K., N. Frantzeskaki, T. McPhearson, and D. Loorbach, 2019: Tales of transforming cities: Transformative climate governance capacities in New York City, US and Rotterdam, Netherlands. *J. Environ. Manage.*, **231**, 843–857, https://doi.org/10.1016/j.jenvman.2018.10.043.

Hölscher, K., J. M. Wittmayer, and D. Loorbach, 2018: Transition versus transformation: What's the difference? *Environ. Innov. Soc. Transitions*, **27**, 1–3, https://doi.org/https://doi.org/10.1016/j.eist.2017.10.007.

Hopkins, R., 2010: What can communities do? *The post carbon reader. Managing the 21st century sustainability crisis*, 442–454.

Horcea-Milcu, A. I., B. Martín-López, D. P. M. Lam, and D. J. Lang, 2020: Research pathways to foster transformation: Linking sustainability science and social-ecological systems research. *Ecol. Soc.*, **25**, https://doi.org/10.5751/ES-11332-250113.

Hummelbrunner, R., and H. Jones, *March 2013 shaping policy for development Background Note*. www.odi.org.uk.

Hourcade, J.-C., M. Jaccard, C. Bataille, and F. Ghersi, 2006: Hybrid Modeling: New Answers to Old Challenges Introduction to the Special Issue of The Energy Journal. *Energy J.*, https://doi.org/10.5547/issn0195-6574-ej-volsi2006-nosi2-1.

Howells, M., and Coauthors, 2013: Integrated analysis of climate change, land-use, energy and water strategies. *Nat. Clim. Chang.*, https://doi.org/10.1038/nclimate1789.

Hoyer, C., 2020: Accelerating Climate Action Beyond Company Gates. *Handbook of Climate Change Management: Research, Leadership, Transformation*, W. Leal Filho, J. Luetz, and D. Ayal, Eds., Springer International Publishing, 1–22.

Hsu, A., and Coauthors, 2019: A research roadmap for quantifying non-state and subnational climate mitigation action. *Nat. Clim. Chang.*, **9**, 11–17, https://doi.org/10.1038/s41558-018-0338-z.

Hulme, M., 2009: Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity . Cambridge, UK: Cambridge University Press. *Glob. Environ. Polit.*, https://doi.org/10.1162/glep.2010.10.1.160.
——, 2018: WIREs Climate Change 2018: An editorial essay. *Wiley Interdiscip. Rev. Clim. Chang.*, **9**, https://doi.org/10.1002/wcc.503.
Hume, T., and J. Barry, 2015: Environmental Education and Education for Sustainable Development. *International Encyclopedia of the Social & Behavioral Sciences: Second Edition*.
Hutchison, S., and J. Walton, 2015: An inquiry into the significance of first-person research for the creation of knowledge to reduce suffering and enhance human flourishing. In: Action Learning and Action Research Association (ALARA) World Congress.
Hüther, G., 2018: *Co-creativity and Community*. First edit. Vandenhoeck & Ruprecht, 184 pp.
Huxham, M., M. Anwar, and D. Nelson, 2019: *Understanding the impact of a low carbon transition on South Africa*. 114 pp. https://www.climatepolicyinitiative.org/wp-content/uploads/2019/03/CPI-Energy-Finance-Understanding-the-impact-of-a-low-carbon-transition-on-South-Africa-March-2019.pdf.
ICLEI, L. G. forSustainability, 2019: No Title. *Local Gov. Sustain.*,. https://www.iclei.org/.
IEA, 2015: International Energy Agency (IEA) - World Energy Outlook 2015. *Fr. Int. Energy Agency*,.
——, 2017: *World Energy Outlook 2017*. https://www.iea.org/reports/world-energy-outlook-2017.
International Energy Agency, 2020: World Energy Outlook 2020 - Event - IEA. *World Energy Outlook 2020 - Event - IEA*,.
International Energy Agency (IEA), 2019: World Energy Outlook 2019 – Analysis - IEA. *World Energy Outlook 2019*,.
Inventory, Cd. policy, 2018: *Climate policy database*. http://climatepolicydatabase.org/index.php/CDlinks_policy_inventory.
IPBES, 2019: *Global Assessment Report on Biodiversity and Ecosystem Services*. https://ipbes.net/global-assessment-report-biodiversity-ecosystem-services.
IPCC, 2007: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson,*. 214–219 pp.
——, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*.
——, 2014: *AR 5 Mitigation Policies*. C.U. Press., Ed.
——, 2018a: *Global Warming of 1.5 °C an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change*. http://www.ipcc.ch/report/sr15/.
——, 2018b: Special report, 1.5 temperature change.
____, AR6 1 Chapter 1, 4, 6, 7, 8, 9, 10, 12 and 13 (WGIII) 2020
____,AR6 Chapter 18 (WGII) 2020
Ives, C. D., R. Freeth, and J. Fischer, 2019: Inside-out sustainability: The neglect of inner worlds. *Ambio*, https://doi.org/10.1007/s13280-019-01187-w.
Iyer, G., and Coauthors, 2018: Implications of sustainable development considerations for comparability across nationally determined contributions. *Nat. Clim. Chang.*, https://doi.org/10.1038/s41558-017-0039-z.
Jakob, M., and J. Stecke, 2016: Implications of climate change mitigation for sustainable development. *Environ. Res. Lett.*, **11**, 104010.
Jakob, M., J. Steckel, S. Klasen, J. Lay, N. Grunewald, I. Martínez-Zarzoso, S. Renner, and O. Edenhofer, 2014: Feasible mitigation actions in developing countries. *Nat. Clim. Chang.*, **4**, 961–698, https://doi.org/https://doi.org/10.1038/nclimate2370.
Jenkins, K., B. K. Sovacool, and D. McCauley, 2018: Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change. *Energy Policy*, **117**, 66–74, https://doi.org/10.1016/j.enpol.2018.02.036.
Jones, C.A. and Levy, D. L., 2009: Business strategies and climate change. Changing climates in North American politics. *Business strategies and climate change. Changing climates in North American politics*, P.J. Pulver, S., Rabe, B.G. and Stoett, Ed., 219–240.

Jones, G. A., and K. J. Warner, 2016: The 21st century population-energy-climate nexus. *Energy Policy*, **93**, 2016–2212, https://doi.org/10.1016/j.enpol.2016.02.044.
Jupesta, Joni, Akimoto, Keigo, B. R., *How to Achieve carbon neutral in oil palm plantation? submitted to Journal Integrated Environmental Assessment and Management*.
Jupesta, J., A. Supriyanto, G. Martin, J. Piliang, S. Yang, A. Purnomo, A. Neville, and J. Caliman, Establishing Multi-Partnerships Environmental Governance in Indonesia: Case of Desa Makmur Perduli Api (Fire Free Village) Program. *Food security and land use change under conditions of climatic variability: A multidimensional perspective*, V.. Squire and M.K. Gaur, Eds., Springer Nature Publisher, p. 2020.
Jupesta, J., T. Wakiyama, and A. Abdullah, 2016: Introduction. *Low Carbon Urban Infrastructure Investment in Asian Cities*, Palgrave Macmillan.
Kainuma, M., P. R. Shukla, and K. Jiang, 2012: Framing and modeling of a low carbon society: An overview. *Energy Econ.*, https://doi.org/10.1016/j.eneco.2012.07.015.
Kalvelage, T., and Coauthors, 2013: Nitrogen cycling driven by organic matter export in the South Pacific oxygen minimum zone. *Nat. Geosci.*, **6**, https://doi.org/10.1038/ngeo1739.
Kanadur, O., 2019: DISTRICT INDUSTRIALISATION FOR JOBS &WEALTH CREATION.
Kanie, N., 2018: Governance with multilateral environmental agreements: A healthy or ill-equipped fragmentation? *Green Planet Blues: Critical Perspectives on Global Environmental Politics*.
Kanie, N., and F. Biermann, 2017: *Governing through Goals: Sustainable Development Goals as Governance Innovation*. MIT Press, Cambridge, MA, USA, 352 pp.
Kates, R., W. Travis, and T. Wilbanks, 2012: Transformational adaptation when incremental adaptations to climate change are insufficient. *Proc. Natl. Acad. Sci.*, **109**, https://doi.org/https://doi.org/10.1073/pnas.1115521109.
Kazhamiaka, F., C. Rosenberg, and S. Keshav, 2019: Tractable lithium-ion storage models for optimizing energy systems. *Energy Informatics*, **2**, https://doi.org/10.1186/s42162-019-0070-6.
Keck, M. E., and K. Sikkink, 1999: Transnational advocacy networks in international and regional politics. *Int. Soc. Sci. J.*, **51**, 89–101, https://doi.org/10.1111/1468-2451.00179.
Kefford, B. M., B. Ballinger, D. R. Schmeda-Lopez, C. Greig, and S. Smart, 2018: The early retirement challenge for fossil fuel power plants in deep decarbonisation scenarios. *Energy Policy*, https://doi.org/10.1016/j.enpol.2018.04.018.
Keidanren Japanese Business Federation, 2018: ANNUAL REPORT 2018.
Kemp, R., and B. Never, 2017: Green transition, industrial policy, and economic development. *Oxford Rev. Econ. Policy*, https://doi.org/10.1093/oxrep/grw037.
Keohane, R. O., and D. G. Victor, 2016: Cooperation and discord in global climate policy. *Nat. Clim. Chang.*, **6**, https://doi.org/10.1038/nclimate2937.
Keramidas, K., and Coauthors, 2018: *Global Energy and Climate Outlook 2018: Sectoral mitigation options towards a low-emissions economy - Global context to the EU strategy for long-term greenhouse gas emissions reduction*.
Kern, F., 2011: Ideas, institutions, and interests: Explaining policy divergence in fostering "system innovations" towards sustainability. *Environ. Plan. C Gov. Policy*, https://doi.org/10.1068/c1142.
——, and K. S. Rogge, 2016: The pace of governed energy transitions: Agency, international dynamics and the global Paris agreement accelerating decarbonisation processes? *Energy Res. Soc. Sci.*, **22**, https://doi.org/10.1016/j.erss.2016.08.016.
Kim Gowwoo, C. P., 2019: *Growth and Ecosystem Services of Urban Trees*. 142–163 pp.
Kim, H., and S. Grafakos, 2019: Which are the factors influencing the integration of mitigation and adaptation in climate change plans in Latin American cities? *Environ. Res. Lett.*, **14**, https://doi.org/https://doi.org/10.1088/1748-9326/ab2f4c.
Kim, J., G. Yoo, D. Kim, W. Ding, and H. Kang, 2017: Combined application of biochar and slow-release fertilizer reduces methane emission but enhances rice yield by different mechanisms. *Appl. Soil Ecol.*, **117–118**, https://doi.org/10.1016/j.apsoil.2017.05.006.
Kjellén, M., 2006: From Public Pipes to Private Hands : Water Access and Distribution in Dar es Salaam, Tanzania.
Koch, M., 2020: The state in the transformation to a sustainable postgrowth economy. *Env. Polit.*, **29**, https://doi.org/10.1080/09644016.2019.1684738.
Koehn, P. H., 2008: Underneath Kyoto: Emerging subnational government initiatives and incipient

issue-bundling opportunities in China and the United States. *Glob. Environ. Polit.*, **8**, 53–77, https://doi.org/10.1162/glep.2008.8.1.53.
Köhler, J., and Coauthors, 2019: An agenda for sustainability transitions research: State of the art and future directions. *Environ. Innov. Soc. Transitions*, **31**, 1–32, https://doi.org/10.1016/j.eist.2019.01.004.
Kojola, E., 2019: Indigeneity, gender and class in decision-making about risks from resource extraction. *Environ. Sociol.*, https://doi.org/10.1080/23251042.2018.1426090.
Kolk, A., D. Levy, and J. Pinkse, 2008: Corporate responses in an emerging climate regime: the institutionalization and commensuration of carbon disclosure. *Eur. Account. Rev.*, **17**, 719–745.
Kousksou, T., A. Allouhi, M. Belattar, A. Jamil, T. El Rhafiki, A. Arid, and Y. Zeraouli, 2015: Renewable energy potential and national policy directions for sustainable development in Morocco. *Renew. Sustain. Energy Rev.*, **47**, 46–57, https://doi.org/https://doi.org/10.1016/j.rser.2015.02.056.
Koutroulis, A. G., L. V. Papadimitriou, M. G. Grillakis, I. K. Tsanis, R. Warren, and R. A. Betts, 2019: Global water availability under high-end climate change: A vulnerability based assessment. *Glob. Planet. Change*, **175**, 447–461, https://doi.org/10.1016/j.gloplacha.2019.01.013.
Krause, U., 2013: Innovation: The new Big Push or the Post-Development alternative? *Development*, **56**, https://doi.org/10.1057/dev.2013.29.
Krey, V., and Coauthors, 2019: Looking under the hood: A comparison of techno-economic assumptions across national and global integrated assessment models. https://doi.org/10.1016/j.energy.2018.12.131.
Kummu, M., D. Gerten, J. Heinke, M. Konzmann, and O. Varis, 2014: Climate-driven interannual variability of water scarcity in food production potential: A global analysis. *Hydrol. Earth Syst. Sci.*, https://doi.org/10.5194/hess-18-447-2014.
Kurian, M., 2017: The water-energy-food nexus: Trade-offs, thresholds and transdisciplinary approaches to sustainable development. *Environ. Sci. Policy*, **68**, 97–106, https://doi.org/10.1016/j.envsci.2016.11.006.
De la Sota, C., V. J. Ruffato-Ferreira, L. Ruiz-García, and S. Alvarez, 2019: Urban green infrastructure as a strategy of climate change mitigation. A case study in northern Spain. *Urban For. Urban Green.*, **40**, https://doi.org/10.1016/j.ufug.2018.09.004.
Van De Laar, A., 2006: A Radical History of Development Studies: Individuals, Institutions and Ideologies edited by Uma Kothari. *Dev. Change*, **37**, https://doi.org/10.1111/j.1467-7660.2006.00516_2.x.
Laeremans, M., and Coauthors, 2018: Short-term effects of physical activity, air pollution and their interaction on the cardiovascular and respiratory system. *Environ. Int.*, **117**, https://doi.org/10.1016/j.envint.2018.04.040.
Lahn, Glada, Bradley, S., 2016: Left Stranded? Extractives-Led Growth in a Carbon-Constrained World. 40.
Lal, R., J. A. Delgado, P. M. Groffman, N. Millar, C. Dell, and A. Rotz, 2011: Management to mitigate and adapt to climate change. *J. Soil Water Conserv.*, **66**, 276–282, https://doi.org/10.2489/jswc.66.4.276.
Lam, D., B. Martín-López, A. Wiek, E. Bennett, N. Frantzeskaki, I. Horcea-Milcu, and D. Lang, 2020: Scaling the impact of sustainability initiatives: a typology of amplification processes. *Urban Transform.*, **2**, https://doi.org/10.1186/s42854-020-00007-9.
Lamb, S., J. Jennings, and P. Calain, 2017: The evolving role of CSR in international development: Evidence from Canadian extractive companies' involvement in community health initiatives in low-income countries. *Extr. Ind. Soc.*, https://doi.org/10.1016/j.exis.2017.05.011.
Landauer, M., S. Juhola, and M. Söderholm, 2015: Inter-relationships between adaptation and mitigation: a systematic literature review. *Clim. Change*, **131**, 505–517, https://doi.org/10.1007/s10584-015-1395-1.
Landauer, M., S. Juhola, and J. Klein, 2019: The role of scale in integrating climate change adaptation and mitigation in cities. *Cities. J. Environ. Plan. Manag*, 741–765.
Lange, E. A., 2018: Transforming Transformative Education Through Ontologies of Relationality. *J. Transform. Educ.*, **16**, 280–301, https://doi.org/10.1177/1541344618786452.
Larsen, M., S. Petrović, A. M. Radoszynski, R. Mckenna, and O. Balyk, 2020: Climate change impacts

on trends and extremes in future heating and cooling demands over Europe. *Energy Build.*, https://doi.org/10.1016/j.enbuild.2020.110397.
Larsen, M. A. D., and M. Drews, 2019: Water use in electricity generation for water-energy nexus analyses: The European case. *Sci. Total Environ.*, **651**, 2044–2058, https://doi.org/10.1016/j.scitotenv.2018.10.045.
Larsen, M. A. D., S. Petrovic, R. E. Engström, M. Drews, S. Liersch, K. B. Karlsson, and M. Howells, 2019: Challenges of data availability: Analysing the water-energy nexus in electricity generation. *Energy Strateg. Rev.*, **26**, https://doi.org/10.1016/j.esr.2019.100426.
Leclère, D., and Coauthors, 2020: Bending the curve of terrestrial biodiversity needs an integrated strategy. *Nature*, **585**, https://doi.org/10.1038/s41586-020-2705-y.
Lee, H., E. Y. Jung, and J. D. Lee, 2019: Public–private co-evolution and niche development by technology transfer: A case study of state-led electricity system transition in South Korea. *Energy Res. Soc. Sci.*, **49**, 103–113, https://doi.org/10.1016/j.erss.2018.11.001.
Lee, S.-Y., E. Zusman, and S. Lee, 2017: Tracing Sustainability Transitions in Seoul Governance: Enabling and Scaling Grassroots Innovations. *URBAN TRANSITIONS CONFERENCE*, Seto, K and Robinson, D and Virji, H and Kovacs, Z and Zhai, J and Sami, N and Pettit, C and Sridhar, KS, Ed., Vol. 198 of *Procedia Engineering*, 293–304.
Lele, S., and T. Jayaraman, 2011: *Equity in the context of sustainable development*.
Lemos, M., A. Agrawal, H. Eakin, D. Nelson, N. Engle, and O. Johns, 2013: Building Adaptive Capacity to Climate Change in Less Developed Countries. *Climate Science for Serving Society*, G. Asrar and J. Hurrell, Eds., Springer Netherlands, Dordrecht, 437–457.
Lessem, R., 2018: Mexico-U.S. immigration: Effects of wages and border enforcement. *Rev. Econ. Stud.*, https://doi.org/10.1093/restud/rdx078.
Leventon, J., J. C. Dyer, and J. D. Van Alstine, 2015: The private sector in climate governance: Opportunities for climate compatible development through multilevel industry-government engagement. *J. Clean. Prod.*, **102**, 316–323, https://doi.org/10.1016/j.jclepro.2015.04.125.
Lewis, S., 2016: *Positive Psychology and Change: How Leadership, Collaboration and Appreciative Inquiry Drive Transformational Results*.
Li, D., and E. Bou-Zeid, 2013: Synergistic interactions between urban heat islands and heat waves: The impact in cities is larger than the sum of its parts. *J. Appl. Meteorol. Climatol.*, **52**, https://doi.org/10.1175/JAMC-D-13-02.1.
Liang, J., Z. H. Sun, F. Li, and H. M. Cheng, 2016: Carbon materials for Li-S batteries: Functional evolution and performance improvement. *Energy Storage Mater.*, https://doi.org/10.1016/j.ensm.2015.09.007.
Lidskog, R., I. Elander, and A. Standring, 2020: COVID-19, the climate, and transformative change: Comparing the social anatomies of crises and their regulatory responses. *Sustain.*, **12**, https://doi.org/10.3390/SU12166337.
Lipper, L., and D. Zilberman, 2018: A Short History of the Evolution of the Climate Smart Agriculture Approach and Its Links to Climate Change and Sustainable Agriculture Debates. *Climate Smart Agriculture : Building Resilience to Climate Change*, L. Lipper, N. McCarthy, D. Zilberman, S. Asfaw, and G. Branca, Eds., Springer International Publishing, 13–30.
Lipper, L., and Coauthors, 2014: Climate-smart agriculture for food security. *Nat. Clim. Chang.*, **4**, 1068–1072, doi:10.1038/nclimate2437.
Liu, J., and Coauthors, 2018: Nexus approaches to global sustainable development. *Nat. Sustain.*, **1**, 466–476.
Liu, J., K. S. Bawa, T. P. Seager, G. Mao, D. Ding, J. S. H. Lee, and J. K. Swim, 2019: On knowledge generation and use for sustainability. *Nat. Sustain.*, **2**, 80–82, https://doi.org/10.1038/s41893-019-0229-y.
Liu, S. M., 2013: When food quality control in China meets mobile and wireless technology: Interactions, potentials and pitfalls. *ACM International Conference Proceeding Series*.
Lo, K., and V. Castán Broto, 2019: Co-benefits, contradictions, and multi-level governance of low-carbon experimentation: Leveraging solar energy for sustainable development in China. *Glob. Environ. Chang.*, **59**, https://doi.org/10.1016/j.gloenvcha.2019.101993.
Locatelli, B., C. Pavageau, E. Pramova, and M. Di Gregorio, 2015: Integrating climate change mitigation and adaptation in agriculture and forestry: Opportunities and trade-offs. *Wiley*

Interdiscip. Rev. Clim. Chang., **6**, 585–598, https://doi.org/10.1002/wcc.357.
Locatelli, B., G. Fedele, V. Fayolle, and A. Baglee, 2016: Synergies between adaptation and mitigation in climate change financ. *Clim. Chang. Strateg. Manag*, **8**, 112–128, https://doi.org/https://doi.org/10.1108/IJCCSM-07-2014-0088.
Lockhart, H., 2011: *Spirituality & Nature in the transformation to a more sustainable world: Perspectives of South African change agents*. https://www.sustainabilityinstitute.net/si-library/5466-spirituality-nature-in-the-transformation-to-a-more-sustainable-world-perspectives-of-south-african-change-agents.
Loorbach, D., 2010: Transition management for sustainable development: A prescriptive, complexity-based governance framework. *Governance*, **23**, https://doi.org/10.1111/j.1468-0491.2009.01471.x.
——, H. Shiroyama, J. M. Wittmayer, J. Fujino, and S. Mizuguchi, 2016: *Governance of Urban Sustainability Transitions - European and Asian Experiences*. 202 pp.
——, N. Frantzeskaki, and F. Avelino, 2017: Sustainability Transitions Research: Transforming Science and Practice for Societal Change. *ANNUAL REVIEW OF ENVIRONMENT AND RESOURCES, VOL 42*, Gadgil, A and Tomich, TP, Ed., Vol. 42 of *Annual Review of Environment and Resources*, 599–626.
Lucas, P., K. Ludwig, M. Kok, and S. Kruitwagen, 2016: *Sustainable Development Goals in the Netherlands: Building blocks for environmental policy for 2030*. 56 pp.
Luken, T., 2019: Easy does it: an innovative view on developing career identity and self-direction. *Career Dev. Int.*, **25**, https://doi.org/10.1108/CDI-05-2019-0110.
Macintyre, T., H. Lotz-Sisitka, A. Wals, C. Vogel, and V. Tassone, 2018: Towards transformative social learning on the path to 1.5 degrees. *Curr. Opin. Environ. Sustain.*, **31**, 80–87, https://doi.org/https://doi.org/10.1016/j.cosust.2017.12.003.
Madden, N. J., 2014: Green means stop: Veto players and their impact on climate-change policy outputs. *Env. Polit.*, **23**, https://doi.org/10.1080/09644016.2014.884301.
Månberger, A., and B. Stenqvist, 2018: Global metal flows in the renewable energy transition: Exploring the effects of substitutes, technological mix and development. *Energy Policy*, **119**, https://doi.org/10.1016/j.enpol.2018.04.056.
Manthiram, A., S. Chung, and C. Zu, 2015: Lithium – Sulfur Batteries : Progress and Prospects. 1980–2006, https://doi.org/10.1002/adma.201405115.
Marcotullio, P., J. Sarzynski, A. Sperling, J. Chavez, A. Estiri, M. Pathak, and R. Zimmerman, 2018: Energy transformation in cities. *Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network. Cambridge University Press*, C. Rosenzweig, W. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal, and A. Ibrahim, Eds., 443–490.
Markandya, A., J. Sampedro, S. J. Smith, R. Van Dingenen, C. Pizarro-Irizar, I. Arto, and M. González-Eguino, 2018: Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. *Lancet Planet. Heal.*, https://doi.org/10.1016/S2542-5196(18)30029-9.
Markard, J., R. Raven, and B. Truffer, 2012: Sustainability transitions: An emerging field of research and its prospects. *Res. Policy*, **41**, 955–967, https://doi.org/https://doi.org/10.1016/j.respol.2012.02.013.
Mathur, V. N., S. Afionis, J. Paavola, A. J. Dougill, and L. C. Stringer, 2014: Experiences of host communities with carbon market projects: towards multi-level climate justice. *Clim. Policy*, **14**, 42–62, https://doi.org/10.1080/14693062.2013.861728.
McCauley, D., and R. Heffron, 2018: Just transition: Integrating climate, energy and environmental justice. *Energy Policy*, **119**, https://doi.org/10.1016/j.enpol.2018.04.014.
McCauley, S. M., and J. C. Stephens, 2012: Green energy clusters and socio-technical transitions: Analysis of a sustainable energy cluster for regional economic development in Central Massachusetts, USA. *Sustain. Sci.*, **7**, 213–225, https://doi.org/10.1007/s11625-012-0164-6.
McCollum, D. L., and Coauthors, 2018: Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nat. Energy*, **3**, https://doi.org/10.1038/s41560-018-0179-z.
McElwee, P., and Coauthors, 2020: The impact of interventions in the global land and agri-food sectors on Nature's Contributions to People and the UN Sustainable Development Goals. *Glob. Chang. Biol.*, **26**, https://doi.org/10.1111/gcb.15219.

McGlade, C., and P. Ekins, 2015: The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature*, https://doi.org/10.1038/nature14016.
McMeekin, A., F. W. Geels, and M. Hodson, 2019: Mapping the winds of whole system reconfiguration: Analysing low-carbon transformations across production, distribution and consumption in the UK electricity system (1990-2016). *Res. Policy*, **48**, 1216–1231, https://doi.org/10.1016/j.respol.2018.12.007.
Meadowcroft, J., 2011: Engaging with the politics of sustainability transitions. *Environ. Innov. Soc. Transitions*, **1**, 70–75, https://doi.org/10.1016/j.eist.2011.02.003.
Meckling, J., N. Kelsey, E. Biber, and J. Zysman, 2015: Winning coalitions for climate policy. *Science (80-.).*, 1170–1171, https://doi.org/10.1126/science.aab1336.
Meijaard, E., and Coauthors, 2020: The environmental impacts of palm oil in context. *Nat. Plants*, **6**, 1418–1426, https://doi.org/10.1038/s41477-020-00813-w.
Mendizabal, M., O. Heidrich, E. Feliu, G. García-Blanco, and A. Mendizabal, 2018: Stimulating urban transition and transformation to achieve sustainable and resilient cities. *Renew. Sustain. Energy Rev.*, **94**, 410–418, https://doi.org/https://doi.org/10.1016/j.rser.2018.06.003.
Mensah, C. N., L. Dauda, K. B. Boamah, and M. Salman, 2020: One district one factory policy of Ghana, a transition to a low-carbon habitable economy? *Environ. Dev. Sustain.*, https://doi.org/10.1007/s10668-020-00604-5.
Meyer, M., M. Hirschnitz-Garbers, and M. Distelkamp, 2018: Contemporary resource policy and decoupling trends-lessons learnt from integrated model-based assessments. *Sustain.*, **10**, https://doi.org/10.3390/su10061858.
Michaelowa, K., and A. Michaelowa, 2017: Transnational Climate Governance Initiatives: Designed for Effective Climate Change Mitigation? *Int. Interact.*, **43**, https://doi.org/10.1080/03050629.2017.1256110.
Miller, T., A. Wiek, D. Sarewitz, J. Robinson, L. Olsson, D. Kriebel, and D. A. Loorbach, 2014: The future of sustainability science: a solutions-oriented research agenda. *Sustain. Sci.*, **9**, 239–246.
Moe, E., 2014: Vested Interests, Energy Policy and Renewables in Japan, China, Norway and Denmark. *The Political Economy of Renewable Energy and Energy Security*, Palgrave Macmillan UK, 276–317.
Monforti-Ferrario, F., C. Astorga-Llorens, and E. Pisoni, 2019: *Policy pressures on air Anticipating unforeseen effects of EU policies on Air Quality*. 50 pp. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC118320/poa_s4p_final_online.pdf.
Montuori, A., and G. Donnelly, 2018: Transformative leadership. *Handbook of Personal and Organizational Transformation*.
Morgan, J., and D. Waskow, 2014: A new look at climate equity in the UNFCCC. *Clim. Policy*, **14**, 17–22, https://doi.org/10.1080/14693062.2014.848096.
Morin, E., 2016: *Seven complex lessons in education for the future. Early Years Educator*.
Moser, S. C., 2012: Adaptation, mitigation, and their disharmonious discontents: An essay. *Clim. Change*, **111**, 165–175, https://doi.org/10.1007/s10584-012-0398-4.
Munasinghe, M., 2007: The importance of social capital: Comparing the impacts of the 2004 Asian Tsunami on Sri Lanka, and Hurricane Katrina 2005 on New Orleans. *Ecol. Econ.*, **64**, https://doi.org/10.1016/j.ecolecon.2007.05.003.
Nachmany, M., and SetzerJoana, 2018: Global trends in climate change legislation and litigation: 2018 snapshot. *Grantham Res. Inst. Clim. Chang.*, 8.
Nair, S., B. George, H. M. Malano, M. Arora, and B. Nawarathna, 2014: Water-energy-greenhouse gas nexus of urban water systems: Review of concepts, state-of-art and methods. *Resour. Conserv. Recycl.*, https://doi.org/10.1016/j.resconrec.2014.05.007.
Nasiritousi, N., and K. Bäckstrand, 2019: International Climate Politics in the Post-Paris Era. *Nord. Econ. Policy Rev.*,.
NBS, 2018: The National BIM Report 2018. https://www.thenbs.com/knowledge/the-national-bim-report-2018.
Nefzaoui, A., H. Ketata, and M. El Mourid, 2012: Agricultural Technological and Institutional Innovations for Enhanced Adaptation to Environmental Change in North Africa.
Neuteleers, S., and B. Engelen, 2015: Talking money: How market-based valuation can undermine environmental protection. *Ecol. Econ.*, **117**, https://doi.org/10.1016/j.ecolecon.2014.06.022.

Newell, P., and M. Paterson, 2010: *Climate capitalism: Global warming and the transformation of the global economy*.
——, and D. Mulvaney, 2013: The political economy of the "just transition." *Geogr. J.*, **179**, https://doi.org/10.1111/geoj.12008.
——, and J. Phillips, 2016: Neoliberal energy transitions in the South: Kenyan experiences. *GEOFORUM*, **74**, 39–48, https://doi.org/10.1016/j.geoforum.2016.05.009.
Newell, R., A. Dale, and M. Roseland, 2018: Climate Action Co-benefits and Integrated Community Planning: Uncovering the Synergies and Trade-Offs. *Clim. Chang. Impacts Responses*, **10**, 1–23, https://doi.org/https://doi.org/10.18848/1835-7156/CGP/v10i04/1-23.
Ngwadla, X., 2014: An operational framework for equity in the 2015 Agreement. *Clim. Policy*, **14**, 8–16, https://doi.org/10.1080/14693062.2014.857199.
Nightingale, A. J., and Coauthors, 2020: Beyond Technical Fixes: climate solutions and the great derangement. *Clim. Dev.*, **12**, 343–352, https://doi.org/10.1080/17565529.2019.1624495.
Nordhaus, W. D., 2008: *A question of balance weighing the options on global warming policies*.
Novita, N., J. . Kauffman, K. Hergoaulc'h, D. Murdiyarso, D. . Tryanto, and J. Jupesta, 2020: Carbon Stocks from Peat Swamp Forest and Oil Palm Plantation in Central Kalimantan, Indonesia. *Climate Change Research, Policy and Actions in Indonesia: Science, Adaptation and Mitigation*, R. Djalante, J. Jupesta, and E. Aldrian, Eds., Springer Nature Publisher.
O'Brien, K., 2018: Is the 1.5°C target possible? Exploring the three spheres of transformation. *Curr. Opin. Environ. Sustain.*, **31**, 153–160, https://doi.org/10.1016/J.COSUST.2018.04.010.
O'Neil, K., and B. A. Boyce, 2018: Improving Teacher Effectiveness in Physical Education Teacher Education Through Field-Based Supervision. *Phys. Educ.*, **75**, https://doi.org/10.18666/tpe-2018-v75-i5-7739.
Obersteiner, M., and Coauthors, 2016: Assessing the land resource food price nexus of the Sustainable Development Goals. *Sci. Adv.*, **2**, https://doi.org/10.1126/sciadv.1501499.
OECD, 2016a: How stringent are environmental policies? Policy Perspectives. *OECD*,.
——, 2016b: *Better Policies for Sustainable Development 2016: A New Framework for Policy Coherence*. OECD Publishing, Paris, 295 pp.
——, 2018: *Policy Coherence for Sustainable Development 2018: Towards Sustainable and Resilient Societies*.
——, 2020: Editorial: Turning hope into reality. *OECD*, **2**.
Okereke, C., A. Coke, M. Geebreyesus, T. Ginbo, J. J. Wakeford, and Y. Mulugetta, 2019: Governing green industrialisation in Africa: Assessing key parameters for a sustainable socio-technical transition in the context of Ethiopia. *World Dev.*, **115**, https://doi.org/10.1016/j.worlddev.2018.11.019.
Olivier, D. W., and Y. Xu, 2019: Making effective use of groundwater to avoid another water supply crisis in Cape Town, South Africa. *Hydrogeol. J.*, **27**, https://doi.org/10.1007/s10040-018-1893-0.
Olsson, L., M. Opondo, P. Tschakert, A. Agrawal, S. H. Eriksen, S. Ma, L. N. Perch, and S. A. Zakieldeen, 2014: *Livelihoods and poverty. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 793–832 pp.
Ordoñez, E., D. Mora, and K. Gaudry, 2019: Roadmap Toward NZEBs in Quito. *IOP Conference Series: Materials Science and Engineering*, ,IOP.
Ornetzeder, M., and H. Rohracher, 2013: Of solar collectors, wind power, and car sharing: Comparing and understanding successful cases of grassroots innovations. *Glob. Environ. Chang.*, **23**, 856–867, https://doi.org/10.1016/j.gloenvcha.2012.12.007.
Oshiro, K., M. Kainuma, and T. Masui, 2016: Assessing decarbonization pathways and their implications for energy security policies in Japan. *Clim. Policy*, **16**, https://doi.org/10.1080/14693062.2016.1155042.
Ostrom, E., 2008: Polycentric Systems as One Approach for Solving Collective-Action Problems. *Clim. Chang. Sustain. Dev. New Challenges Poverty Reduct.*, https://doi.org/10.2139/ssrn.1304697.
Owen, R., G. Brennan, and F. Lyon, 2018: Enabling investment for the transition to a low carbon economy: government policy to finance early stage green innovation. *Curr. Opin. Environ.*

Sustain., **31**, 137–145, https://doi.org/10.1016/j.cosust.2018.03.004.
P. Puplampu, K., K. Hanson, and T. Shaw, 2017: 'From MDGs to SDGs: African Development Challenges and Prospects.'
Paech, N., 2017: Woher kommt der Wachstumszwang? *GAIA - Ecol. Perspect. Sci. Soc.*, **16**, https://doi.org/10.14512/gaia.16.4.13.
Pan, Y., and Coauthors, 2011: A large and persistent carbon sink in the world's forests. *Science (80-.).*, **333**, https://doi.org/10.1126/science.1201609.
Parra, D., L. Valverde, F. J. Pino, and M. K. Patel, 2019: A review on the role, cost and value of hydrogen energy systems for deep decarbonisation. *Renew. Sustain. Energy Rev.*, **101**, https://doi.org/10.1016/j.rser.2018.11.010.
Pradhan, B. B., R. M. Shrestha, A. Pandey, and B. Limmeechokchai, 2018b: Strategies to Achieve Net Zero Emissions in Nepal. *Carbon Manag.*, **9**, 533–548, doi:10.1080/17583004.2018.1536168.
Patterson, J., and Coauthors, 2017: Exploring the governance and politics of transformations towards sustainability. *Environ. Innov. Soc. Transitions*, **24**, 1–16, https://doi.org/10.1016/j.eist.2016.09.001.
Patterson, J. J., and Coauthors, 2018: Political feasibility of 1.5°C societal transformations: the role of social justice. *Curr. Opin. Environ. Sustain.*, **31**, 1–9, https://doi.org/10.1016/j.cosust.2017.11.002.
Pauw, W. P., P. Castro, J. Pickering, and S. Bhasin, 2020: Conditional nationally determined contributions in the Paris Agreement: foothold for equity or Achilles heel? *Clim. Policy*, **20**, 468–484, https://doi.org/10.1080/14693062.2019.1635874.
Pellegrini-Masini, G., A. Pirni, and S. Maran, 2020: Energy justice revisited: A critical review on the philosophical and political origins of equality. *Energy Res. Soc. Sci.*, **59**, https://doi.org/10.1016/j.erss.2019.101310.
Pelling, B., Bauler, Kemp, T, Wittmayer, R, Avelino J, F, Dorland, J., 2015: From research design to meta analysis guidelines.
Pelling, M., 2010: *Adaptation to climate change: From resilience to transformation*.
Pencheon, D., 2018: Developing a sustainable health care system: the United Kingdom experience. *Med. J. Aust.*, **208**, 284–285, https://doi.org/10.5694/mja17.01134.
Peszko, G., and Coauthors, 2020: *Diversification and Cooperation in a Decarbonizing World: Climate Strategies for Fossil Fuel-Dependent Countries*.
Peters, G. P., R. M. Andrew, J. G. Canadell, S. Fuss, R. B. Jackson, J. I. Korsbakken, C. Le Quéré, and N. Nakicenovic, 2017: Key indicators to track current progress and future ambition of the Paris Agreement. *Nat. Clim. Chang.*, **7**, 118–122, https://doi.org/10.1038/nclimate3202.
Pfaff, A., E. O. Sills, G. S. Amacher, M. J. Coren, K. Lawlor, and C. Streck, 2010: Policy Impacts on Deforestation: Lessons Learned from Past Experiences to Inform New Initiatives. *Ni R 10-02*,.
Piggot, G., M. Boyland, A. Down, and A. R. Torre, 2019: Realizing a just and equitable transition away from fossil fuels. *Stock. Environ. Inst.*,.
van der Ploeg, F., and A. Rezai, 2020: Stranded assets in the transition to a carbon-free economy. *Annu. Rev. Resour. Econ.*, **12**, https://doi.org/10.1146/annurev-resource-110519-040938.
Van Der Ploeg, F., 2011: Natural resources: Curse or blessing? *J. Econ. Lit.*, https://doi.org/10.1257/jel.49.2.366.
Pomeroy, E., and K. Oliver, 2018: Pushing the boundaries of self-directed learning: research findings from a study of u.lab participants in Scotland. *Int. J. Lifelong Educ.*, https://doi.org/10.1080/02601370.2018.1550447.
Poudel, S., 2014: Climate Smart Agriculture: A Development Alternative.
Power, C., 2016: Special Thematic Section on "Rethinking Prefigurative Politics": The Integrity of Process: Is Inner Transition Sufficient? *J. Soc. Polit. Psychol.*, **20**, 347–363.
Privitera, R., and D. La Rosa, 2017: ENHANCING CARBON SEQUESTRATION POTENTIAL OF URBAN GREEN SPACES THROUGH TRANSFER OF DEVELOPMENT RIGHTS STRATEGY. *Acta Geobalcanica*, **4**, https://doi.org/10.18509/agb.2018.02.
Prudhomme, R., A. De Palma, P. Dumas, R. Gonzalez, P. Leadley, H. Levrel, A. Purvis, and T. Brunelle, 2020: Combining mitigation strategies to increase co-benefits for biodiversity and food security. *Environ. Res. Lett.*, https://doi.org/10.1088/1748-9326/abb10a.
Quarton, C. J., and S. Samsatli, 2020: The value of hydrogen and carbon capture, storage and utilisation

in decarbonising energy: Insights from integrated value chain optimisation. *Appl. Energy*, **257**, https://doi.org/10.1016/j.apenergy.2019.113936.
Rabe, B. G., 2007: Beyond Kyoto: Climate change policy in multilevel governance systems. *Governance*, **20**, 423–444, https://doi.org/10.1111/j.1468-0491.2007.00365.x.
Rashid Sumaila, U., T. C. Tai, V. W. Y. Lam, W. W. L. Cheung, M. Bailey, A. M. Cisneros-Montemayor, O. L. Chen, and S. S. Gulati, 2019: Benefits of the Paris Agreement to ocean life, economies, and people. *Sci. Adv.*, **5**, 1–10, https://doi.org/10.1126/sciadv.aau3855.
Rasul, G., 2016: Managing the food, water and energy nexus for achieving the Sustainable Development Goals in South Asia. *Environ. Dev.*, **18**, 14–25.
Reckien, D., and Coauthors, 2014: Climate change response in Europe: What's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. *Clim. Change*, https://doi.org/10.1007/s10584-013-0989-8.
Reckien, D., and Coauthors, 2018: How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. *J. Clean. Prod.*, **191**, 207–219, https://doi.org/10.1016/j.jclepro.2018.03.220.
Reese, R., A. Levermann, T. Albrecht, H. Seroussi, and R. Winkelmann, 2020: The role of history and strength of the oceanic forcing in sea level projections from Antarctica with the Parallel Ice Sheet Model. *Cryosphere*, **14**, https://doi.org/10.5194/tc-14-3097-2020.
Rickards, L., J. Wiseman, and Y. Kashima, 2014: Barriers to effective climate change mitigation: The case of senior government and business decision makers. *Wiley Interdiscip. Rev. Clim. Chang.*, **5**, https://doi.org/10.1002/wcc.305.
Ringler, C., A. Bhaduri, and R. Lawford, 2013: The nexus across water, energy, land and food (WELF): Potential for improved resource use efficiency? *Curr. Opin. Environ. Sustain.*, https://doi.org/10.1016/j.cosust.2013.11.002.
Roberts, C., F. W. Geels, M. Lockwood, P. Newell, H. Schmitz, B. Turnheim, and A. Jordan, 2018: The politics of accelerating low-carbon transitions: Towards a new research agenda. *Energy Res. Soc. Sci.*, **44**, 304–311, https://doi.org/https://doi.org/10.1016/j.erss.2018.06.001.
Robinson, J., and R. J. Cole, 2015a: Theoretical underpinnings of regenerative sustainability. *Build. Res. Inf.*, **43**, 1333–143, https://doi.org/10.1080/09613218.2014.979082.
——, and ——, 2015b: Theoretical underpinnings of regenerative sustainability. *Build. Res. Inf.*, **43**, 133–143, https://doi.org/10.1080/09613218.2014.979082.
Rochmyaningsih, D., 2019: Making peace with oil palm. *Science*, **365**, 112–115, https://doi.org/10.1126/science.365.6449.112.
Rockström, J., and Coauthors, 2009: A safe operating space for humanity. *Nature*, **461**, 472.
Roelfsema, M., and Coauthors, 2020: Taking stock of national climate policies to evaluate implementation of the Paris Agreement. *Nat. Commun.*, **11**, 1–12, https://doi.org/10.1038/s41467-020-15414-6.
Rogelj, J., and Coauthors, 2016: Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature*, **534**, 631–639, https://doi.org/10.1038/nature18307.
Rogge, K. S., and P. Johnstone, 2017: Exploring the role of phase-out policies for low-carbon energy transitions: The case of the German Energiewende. *Energy Res. Soc. Sci.*, **33**, 128–137, https://doi.org/10.1016/j.erss.2017.10.004.
Roker, S., 2018: *Democratic Republic of Congo home to largest hard rock lithium resource*. https://www.globalminingreview.com/exploration-development/02082018/democratic-republic-of-congo-home-to-largest-hard-rock-lithium-resource/.
Romero-Lankao, P., S. Hughes, A. Rosas-Huerta, R. Borquez, and D. M. Gnatz, 2013: Institutional capacity for climate change responses: An examination of construction and pathways in Mexico City and Santiago. *Environ. Plan. C Gov. Policy*, **31**, 785–805, https://doi.org/10.1068/c12173.
——, D. M. Gnatz, O. Wilhelmi, and M. Hayden, 2016: Urban sustainability and resilience: From theory to practice. *Sustain.*, **8**, 1224, https://doi.org/10.3390/su8121224.
Rooney-Varga, J. N., F. Kapmeier, J. D. Sterman, A. P. Jones, M. Putko, and K. Rath, 2020: The Climate Action Simulation. *Simul. Gaming*, **51**, https://doi.org/10.1177/1046878119890643.
van Rooyen, J. D., A. P. Watson, and J. A. Miller, 2020: Combining quantity and quality controls to determine groundwater vulnerability to depletion and deterioration throughout South Africa. *Environ. Earth Sci.*, **79**, https://doi.org/10.1007/s12665-020-08998-1.

Roschnik, S., G. S. Martinez, M. Yglesias-Gonzalez, D. Pencheon, I. Tennison, and W. H. O. R. O. for Europe, 2017: Transitioning to environmentally sustainable health systems: the example of the NHS in England. *Public Heal. Panor.*, **03**, 229–236.
Rosenbloom, D., 2017: Pathways: An emerging concept for the theory and governance of low-carbon transitions. *Glob. Environ. Chang. POLICY Dimens.*, **43**, 37–50, https://doi.org/10.1016/j.gloenvcha.2016.12.011.
——, J. Meadowcroft, S. Sheppard, S. Burch, and S. Williams, 2018: Transition experiments: Opening up low-carbon transition pathways for Canada through innovation and learning. *Can. Public Policy*, **44**, 368–383, https://doi.org/10.3138/cpp.2018-020.
Rosendahl, K. E., and D. R. Rubiano, 2019: How Effective is Lithium Recycling as a Remedy for Resource Scarcity? *Environ. Resour. Econ.*, **74**, https://doi.org/10.1007/s10640-019-00356-5.
Rothausen, S. G. S. A., and D. Conway, 2011: Greenhouse-gas emissions from energy use in the water sector. *Nat. Clim. Chang.*, https://doi.org/10.1038/nclimate1147.
Roy, J., and Coauthors, 2018: Sustainable Development , Poverty Eradication and Reducing Inequalities. *Global Warming of 1.5 °C an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change*.
Rumpel, C., and Coauthors, 2019: The 4p1000 initiative: Opportunities, limitations and challenges for implementing soil organic carbon sequestration as a sustainable development strategy. *Ambio*, https://doi.org/10.1007/s13280-019-01165-2.
Rydge, J., M. Jacobs, and I. Granoff, 2015: *Ensuring New Infrastructure is Climate-Smart. Contributing paper for Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate*. http://newclimateeconomy.report/misc/working-papers/.
S, L., L. B, M. D, M. C, Q. M, and B. H, 2016: A match made in Paris: Adaptation-mitigation synergies in the land sector. *A match made Paris Adapt. Synerg. L. Sect.*, 1–4, https://doi.org/10.17528/cifor/006106.
Sachs, J., G. Schmidt-Traub, C. Kroll, G. Lafortune, and G. Fuller, 2019: *Sustainable Development Report 2019*. https://s3.amazonaws.com/sustainabledevelopment.report/2019/2019_sustainable_development_report.pdf.
Sanchez Rodriguez, R., D. Ürge-Vorsatz, and A. Barau, 2018: Sustainable Development Goals and climate change adaptation in cities. *Nat. Clim. Chang.*, **8**, 181–183, https://doi.org/https://doi.org/10.1038/s41558-018-0098-9.
Sandfort, J., and K. Quick, 2015: Building deliberative capacity to create public value: the practices and artifacts of the Art of Hosting. *Public Administration and Public Value*, J. Bryson, B. L, and B. Crosby, Eds., 39–52.
Sartor, O., 2018: Implementing coal transitions: Insights from case studies of major coal-consuming economies.
Scharmer, C, Kaufer, K., 2015: Awareness-Based Action Research: Catching Social Reality Creation in Flight. *The SAGE Handbook of Action Research*, H. Bradbury, Ed., SAGE Publications Ltd, 199–2010.
Scharmer, C., 2018: *The Essentials of Theory U: Core Principles and Applications - Otto Scharmer - Google Books*.
Schaube, P., W. Ortiz, and M. Recalde, 2018: Status and future dynamics of decentralised renewable energy niche building processes in Argentina. *Energy Res. Soc. Sci.*, **35**, 57–67, https://doi.org/10.1016/j.erss.2017.10.037.
Schlott, M., A. Kies, T. Brown, S. Schramm, and M. Greiner, 2018: The impact of climate change on a cost-optimal highly renewable European electricity network. *Appl. Energy*, **230**, https://doi.org/10.1016/j.apenergy.2018.09.084.
Schneidewind, U., and C. Von Wissel, 2015: Transformative Wissenschaft. Warum Wissenschaft neue Formen der Demokratisierung braucht. *Forum Wiss.*, **4**, 4–8.
Scholz, L., A. Ortiz Perez, B. Bierer, J. Wöllenstein, and S. Palzer, 2018: Gas sensors for climate research. *J. Sensors Sens. Syst.*, **7**, https://doi.org/10.5194/jsss-7-535-2018.
Schoneveld, G. C., D. Ekowati, A. Andrianto, and S. Van Der Haar, 2019: Modeling peat- and forestland conversion by oil palm smallholders in Indonesian Borneo. *Environ. Res. Lett.*, **14**,

https://doi.org/10.1088/1748-9326/aaf044.
Schrobback, P., D. Adamson, and J. Quiggin, 2011: Turning Water into Carbon: Carbon Sequestration and Water Flow in the Murray–Darling Basin. *Environ. Resour. Econ.*, **49**, 23–45, doi:10.1007/s10640-010-9422-1. http://link.springer.com/10.1007/s10640-010-9422-1 (Accessed July 13, 2019)
Schweizer-Ries, P., 2018: Sustainability Science and its contribution to IAPS: seeking for integrated sustainability. *IAPS Bull.*, **40**, 9–12.
Scobie, M., 2016: Policy coherence in climate governance in Caribbean Small Island Developing States. *Environ. Sci. Policy*, **58**, 16–28, https://doi.org/https://doi.org/10.1016/j.envsci.2015.12.008.
Scott, J., 2011: Social network analysis: developments, advances, and prospects. *Soc. Netw. Anal. Min.*, **1**, https://doi.org/10.1007/s13278-010-0012-6.
Seligman, M., and M. Csikszentmihalyi, 2014: Positive Psychology: An Introduction. *Flow and the Foundations of Positive Psychology*, M. Csikszentmihalyi, Ed., Dordrecht: Springer, 279–298.
Seyfang, G., and A. Smith, 2007: Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Env. Polit.*, **16**, 584–603, https://doi.org/10.1080/09644010701419121.
——, and A. Haxeltine, 2012: Growing grassroots innovations: Exploring the role of community-based initiatives in governing sustainable energy transitions. *Environ. Plan. C-POLITICS Sp.*, 381–400.
Sgouridis, S., M. Carbajales-Dale, D. Csala, M. Chiesa, and U. Bardi, 2019: Comparative net energy analysis of renewable electricity and carbon capture and storage. *Nat. Energy*, **4**, https://doi.org/10.1038/s41560-019-0365-7.
Shah, N., M. Wei, V. E. Letschert, and A. A. Phadke, 2015: *Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning*.
Sharifi, A., 2020: Co-benefits and synergies between urban climate change mitigation and adaptation measures: A literature review. *Sci. Total Environ.*, **750**, 141642, https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.141642.
Shaw, A., S. Burch, F. Kristensen, J. Robinson, and A. Dale, 2014: Accelerating the sustainability transition: Exploring synergies between adaptation and mitigation in British Columbian communities. *Glob. Environ. Chang.*, **25**, 41–51, https://doi.org/10.1016/j.gloenvcha.2014.01.002.
Shaw, D., and P. Roberts, 2017: *Regional Planning and Development in Europe*. Routledge,.
Shelley, G., 2019: Lithium Mining: Dirty Investment or Sustainable Business? *Investopedia*,.
Sheppard, S. R. J., A. Shaw, D. Flanders, S. Burch, A. Wiek, J. Carmichael, J. Robinson, and S. Cohen, 2011: Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. *Futures*, **43**, 400–412, https://doi.org/10.1016/j.futures.2011.01.009.
Shove, E., M. Pantzar, and M. Watson, 2014: The Dynamics of Social Practice. *The Dynamics of Social Practice: Everyday Life and How it Changes*.
Shukla, P. R., and V. Chaturvedi, 2012: Low carbon and clean energy scenarios for India: Analysis of targets approach. *Energy Econ.*, **34**, 487–495, https://doi.org/10.1016/j.eneco.2012.05.002.
Sindico, F., 2016: Paris, Climate Change, and Sustainable Development. *Clim. Law*, **6**.
Sklair, L., 2016: D'Alisa, G., Demaria, F. and Kallis. G. (eds) Degrowth: A Vocabulary for a New Era 2014 Routledge 220 pp. £24.99 (paperback). *Br. J. Sociol.*, **67**, 168–170, https://doi.org/10.1111/1468-4446.12181.
Smajgl, A., J. Ward, and L. Pluschke, 2016: The water-food-energy Nexus - Realising a new paradigm. *J. Hydrol.*, **533**, 533–540, https://doi.org/10.1016/j.jhydrol.2015.12.033.
Smink, M. M., M. P. Hekkert, and S. O. Negro, 2015: Keeping sustainable innovation on a leash? Exploring incumbents' institutional strategies. *Bus. Strateg. Environ.*, **24**, 86–101, https://doi.org/10.1002/bse.1808.
Smith, A., A. Stirling, and F. Berkhout, 2005: The governance of sustainable socio-technical transitions. *Res. Policy*, **34**, 1491–1510, https://doi.org/10.1016/j.respol.2005.07.005.
Smith, M. R., and S. S. Myers, 2018: Impact of anthropogenic CO2 emissions on global human nutrition. *Nat. Clim. Chang.*, **8**, 834–839, https://doi.org/10.1038/s41558-018-0253-3.
Smith, P., and Coauthors, 2020: Which practices co-deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification? *Glob. Chang. Biol.*, **26**,

https://doi.org/10.1111/gcb.14878.
Solarin, S. A., U. Al-Mulali, I. Musah, and I. Ozturk, 2017: Investigating the pollution haven hypothesis in Ghana: An empirical investigation. *Energy*, **124**, https://doi.org/10.1016/j.energy.2017.02.089.
Soussana, J.-F., and Coauthors, 2019: Matching policy and science_ Rationale for the {\textquoteleft}4 per 1000 - soils for food security and climate{\textquoteright} initiative. *Soil Tillage Res.*, **188**, 3–15.
Sovacool, B. K., 2018: Bamboo Beating Bandits: Conflict, Inequality, and Vulnerability in the Political Ecology of Climate Change Adaptation in Bangladesh. *World Dev.*, **102**, 183–194, https://doi.org/https://doi.org/10.1016/j.worlddev.2017.10.014.
Sovacool, B. K., M. Burke, L. Baker, C. K. Kotikalapudi, and H. Wlokas, 2017: New frontiers and conceptual frameworks for energy justice. *Energy Policy*, **105**, https://doi.org/10.1016/j.enpol.2017.03.005.
Spencer, T., and Coauthors, 2018: The 1.5°C target and coal sector transition: at the limits of societal feasibility. *Clim. Policy*, **18**, 335–351, https://doi.org/10.1080/14693062.2017.1386540.
Springmann, M., and Coauthors, 2018: Options for keeping the food system within environmental limits. *Nature*, **562**, 519–525, https://doi.org/10.1038/s41586-018-0594-0.
Srikanth, R., 2018: India's sustainable development goals – Glide path for India's power sector. *Energy Policy*, **123**, 325–336.
Steen, M., and T. Weaver, 2017: Incumbents' diversification and cross-sectorial energy industry dynamics. *Res. Policy*, **46**, 1071–1086, https://doi.org/10.1016/j.respol.2017.04.001.
Steenkamp, L. A., 2017: A review of policy options for clean electricity supply in South Africa. *2017 6th International Conference on Clean Electrical Power: Renewable Energy Resources Impact, ICCEP 2017*.
Steffen, W., and Coauthors, 2015: Planetary boundaries: Guiding human development on a changing planet. *Science (80-.).*, **347**, https://doi.org/10.1126/science.1259855.
Stevis, D., and R. Felli, 2020: Planetary just transition? How inclusive and how just? *Earth Syst. Gov.*, https://doi.org/10.1016/j.esg.2020.100065.
De Strasser, L., A. Lipponen, M. Howells, S. Stec, and C. Bréthaut, 2016: A methodology to assess thewater energy food ecosystems nexus in transboundary river basins. *Water (Switzerland)*, https://doi.org/10.3390/w8020059.
Sušnik, J., and Coauthors, 2018: Multi-stakeholder development of a serious game to explore the water-energy-food-land-climate nexus: The SIM4NEXUS approach. *Water (Switzerland)*, **10**, https://doi.org/10.3390/w10020139.
Svobodova, K., J. R. Owen, J. Harris, and S. Worden, 2020: Complexities and contradictions in the global energy transition: A re-evaluation of country-level factors and dependencies. *Appl. Energy*, **265**, https://doi.org/10.1016/j.apenergy.2020.114778.
——, ——, and ——, 2021: The global energy transition and place attachment in coal mining communities: Implications for heavily industrialized landscapes. *Energy Res. Soc. Sci.*, **71**, 101831, https://doi.org/10.1016/j.erss.2020.101831.
Swain, R. B., and A. Karimu, 2020: Renewable electricity and sustainable development goals in the EU. *World Dev.*, **125**, https://doi.org/10.1016/j.worlddev.2019.104693.
Swart, R., and F. Raes, 2007: Making integration of adaptation and mitigation work: Mainstreaming into sustainable development policies? *Clim. Policy*, **7**, 288–303, https://doi.org/10.1080/14693062.2007.9685657.
Sweeney, S., and J. Treat, 2018: *TRADE UNIONS AND JUST TRANSITION The Search for a Transformative Politics*. 52 pp. http://unionsforenergydemocracy.org/wp-content/uploads/2018/04/TUED-Working-Paper-11.pdf.
Sweileh, W. M., 2020: Bibliometric analysis of peer-reviewed literature on climate change and human health with an emphasis on infectious diseases. *Global. Health*, **16**, 1–17, https://doi.org/10.1186/s12992-020-00576-1.
Swilling, M. Annecke, E., 2010: Forthcoming . Just Transitions : Explorations of Sustainability in an Unfair World . Cape To. *Just transitions.*,.
The National People's Congress of the People's Republic of China, 2016: The 13th Five-Year Plan for Economic and Social Development of the People'S Republic of China. *Cent. Compil. Transl. Press*, https://doi.org/0012-1606(89)90322-9 [pii].

Thornton, T. F., and C. Comberti, 2017: Synergies and trade-offs between adaptation, mitigation and development. *Clim. Change*, **140**, 5–18, https://doi.org/10.1007/s10584-013-0884-3.
Till Bunsen, and Coauthors, 2019: Global EV Outlook 2019 to electric mobility. *OECD iea.org*,.
Tompkins, E. L., and W. Neil Adger, 2005: Defining response capacity to enhance climate change policy. *Environ. Sci. Policy*, **8**, 562–571, https://doi.org/10.1016/j.envsci.2005.06.012.
Tong, D., Q. Zhang, Y. Zheng, K. Caldeira, C. Shearer, C. Hong, Y. Qin, and S. J. Davis, 2019: Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target. *Nature*,
Thornton, T. F., and C. Comberti, 2017: Synergies and trade-offs between adaptation, mitigation and development. *Clim. Change*, **140**, 5–18, https://doi.org/10.1007/s10584-013-0884-3.
572, https://doi.org/10.1038/s41586-019-1364-3.

Townshend, T., S. Fankhauser, R. Aybar, M. Collins, T. Landesman, M. Nachmany, and C. Pavese, 2013: How national legislation can help to solve climate change. *Nat. Clim. Chang.*, **3**, 430–432, https://doi.org/10.1038/nclimate1894.
Tozer, L., 2018: Urban climate change and sustainability planning: an analysis of sustainability and climate change discourses in local government plans in Canada. *J. Environ. Plan. Manag.*, **61**, 176–194, https://doi.org/10.1080/09640568.2017.1297699.
Tumushabe, J. T., 2018: Climate Change, Food Security and Sustainable Development in Africa. *The Palgrave Handbook of African Politics, Governance and Development*, S.O. Oloruntoba and T. Falola, Eds., Palgrave Macmillan US, 853–868.
Turnheim, B., and B. Nykvist, 2019: Opening up the feasibility of sustainability transitions pathways (STPs): Representations, potentials, and conditions. *Res. Policy*, **48**, 775–788, https://doi.org/10.1016/j.respol.2018.12.002.
Turnheim B., P. Kivimaa, F. B., 2018: *Innovating Climate Governance*. Cambridge University Press,.
TWI2050 - The World in 2050, 2018: *Transformations to Achieve the Sustainable Development Goals - Report prepared by The World in 2050 initiative*. 157 pp.
Tyszczuk, R., and J. Smith, 2018: Culture and climate change scenarios: the role and potential of the arts and humanities in responding to the '1.5 degrees target.' *Curr. Opin. Environ. Sustain.*, **31**, 56–64, https://doi.org/https://doi.org/10.1016/j.cosust.2017.12.007.
U.N-INRA, 2019: *AFRICA'S DEVELOPMENT IN THE AGE OF STRANDED ASSETS*. 44 pp. https://inra.unu.edu/publications/articles/discussion-paper-africas-development-in-the-age-of-stranded-assets_2019.html.
U.N. Secretary-General, I. G. of S. appointed by the, 2019: *GLOBAL SUSTAINABLE DEVELOPMENT REPORT2019: THE FUTURE IS NOW SCIENCE FOR ACHIEVING SUSTAINABLE DEVELOPMENT*. 252 pp. https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf.
UICN, 2017: *INTERNATIONAL UNION FOR CONSERVATION OF NATURE*. 52 pp. https://portals.iucn.org/library/sites/library/files/documents/2018-007-En.pdf.
UN- UNDRR, 2019: UN Office for Disatser Risk Reduction, Sendai Framework. *Sendai Framew.*,. https://www.unisdr.org/.
UN, 2015: Summit Charts New Era of Sustainable Development. *United Nations Press release*.
UN Women, 2017: *Approaches by African Countries in the Implementation and Localization of SDGs*. 60 pp.
UNCTAD, 2020: COMMODITIES AT A GLANCE Special issue on strategic battery raw materials. 74.
UNDESA, 2016: *Voluntary National Reviews - Synthesis Report 2016*. 71 pp.
——, 2017: *Voluntary National Reviews - Synthesis Report 2017*. 78 pp.
——, 2018: *Voluntary National Reviews - Synthesis Report 2018*. 80 pp.
UNDP, UNEP, U. D. T. U. & W. R. I., 2020: *Implementing Nationally Determined Contributions (NDCs)*. 116 pp.
UNEP/SEI, 2020: *Production Gap Report 2020:The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C*. 76 pp. https://productiongap.org/wp-content/uploads/2020/12/PGR2020_FullRprt_web.pdf.
UNFCCC, 2015: *UNFCCC. Synthesis Report on the Aggregate Effect of the Intended Nationally Determined Contributions. Report No. FCCC/CP/2015/7.*

http://unfccc.int/resource/docs/2015/cop21/eng/07.pdf.
——, 2016: *Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015*.
UNFCCO, 2020: Petersberg Climate Dialogue Seeks Climate-Resilient Economic Recovery. *Petersb. Clim. Dialogue Seek. Clim. Econ. Recover.*,. https://unfccc.int/news/petersberg-climate-dialogue-seeks-climate-resilient-economic-recovery.
UNIDO, 2018: *INDUSTRIAL PARK DEVELOPMENT IN ETHIOPIA CASE STUDY REPORT*. https://www.unido.org/api/opentext/documents/download/10694802/unido-file-10694802.
United Nation, 2018: *Sustainable Development Goal 6: Synthesis Report on Water and Sanitation*.
United Nations Environment Programme, U. N., 2019: *Emissions Gap Report 2019*. 108 pp. https://www.unenvironment.org/resources/emissions-gap-report-2019.
United Nations General Assembly 2019, 2019: Resolution adopted by the General Assembly on 15 October 2019. 6.
United Nations Secretary General, 2020: Climate Ambition Summit. https://news.un.org/en/story/2020/12/1079862.
UPS, 2018: Blood Batteries – The Congo and The Cobalt. *UPS*,.
UToronto, 2016: *G20 Action Plan on the 2030 Agenda for Sustainable Development*.
Vandyck, T., K. Keramidas, B. Saveyn, A. Kitous, and Z. Vrontisi, 2016: A global stocktake of the Paris pledges: Implications for energy systems and economy. *Glob. Environ. Chang.*, **41**, 46–63, https://doi.org/10.1016/j.gloenvcha.2016.08.006.
——, ——, A. Kitous, J. V. Spadaro, R. Van Dingenen, M. Holland, and B. Saveyn, 2018: Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. *Nat. Commun.*, **9**, https://doi.org/10.1038/s41467-018-06885-9.
Veciana, S., and K. Ottmar, 2018: Inner conflict resolution and self-empowerment as contribution for personal sustainability on the case of intentional community practices. *Personal Sustainability: Exploring the Far Side of Sustainable Development*.
Veldkamp, T. I. E., Y. Wada, H. de Moel, M. Kummu, S. Eisner, J. C. J. H. Aerts, and P. J. Ward, 2015: Changing mechanism of global water scarcity events: Impacts of socioeconomic changes and inter-annual hydro-climatic variability. *Glob. Environ. Chang.*, **32**, 18–29, https://doi.org/10.1016/j.gloenvcha.2015.02.011.
van Vliet, M. T. H., L. P. H. van Beek, S. Eisner, M. Flörke, Y. Wada, and M. F. P. Bierkens, 2016: Multi-model assessment of global hydropower and cooling water discharge potential under climate change. *Glob. Environ. Chang.*, **40**, 156–179, https://doi.org/10.1016/j.gloenvcha.2016.07.007.
Van Vliet, M. T. H., J. Sheffield, D. Wiberg, and E. F. Wood, 2016: Impacts of recent drought and warm years on water resources and electricity supply worldwide. *Environ. Res. Lett.*, https://doi.org/10.1088/1748-9326/11/12/124021.
Wada, Y., and Coauthors, 2016: Modeling global water use for the 21st century: The Water Futures and Solutions (WFaS) initiative and its approaches. *Geosci. Model Dev.*, https://doi.org/10.5194/gmd-9-175-2016.
Waisman, H., and Coauthors, 2019: A pathway design framework for national low greenhouse gas emission development strategies. *Nat. Clim. Chang.*, **9**, 261–268, https://doi.org/10.1038/s41558-019-0442-8.
Walsh, Z., J. Böhme, and C. Wamsler, 2020: Towards a relational paradigm in sustainability research, practice, and education. *Ambio*, https://doi.org/10.1007/s13280-020-01322-y.
Wang, H., and W. Chen, 2019: Gaps between pre-2020 climate policies with NDC goals and long-term mitigation targets: Analyses on major regions. *Energy Procedia*, **158**, 3664–3669, https://doi.org/10.1016/j.egypro.2019.01.894.
Warren, B., P. Christoff, and D. Green, 2016: Australia's sustainable energy transition: The disjointed politics of decarbonisation. *Environ. Innov. Soc. Transitions*, **21**, 1–12, https://doi.org/10.1016/j.eist.2016.01.001.
WCED, 1987: *World Commission on Environment and Development. 1987. Our Common Future. Delhi: Oxford University Press*.
Weitzman, M. L., 2009: On modeling and interpreting the economics of catastrophic climate change. *Rev. Econ. Stat.*, **91**, https://doi.org/10.1162/rest.91.1.1.

Westley, F., and N. Antadze, 2010: Making a difference: Strategies for scaling social innovation for greater impact. *Innov. J.*, **15**.
Wheeler, T., and J. Von Braun, 2013: Climate Change Impacts on Global Food Security. **341**, 1–22.
White, D. J., K. Hubacek, K. Feng, L. Sun, and B. Meng, 2018: The Water-Energy-Food Nexus in East Asia: A tele-connected value chain analysis using inter-regional input-output analysis. *Appl. Energy*, **210**, 550–567, https://doi.org/10.1016/j.apenergy.2017.05.159.
Wiktorowicz, J., T. Babaeff, J. Breadsell, J. Byrne, J. Eggleston, and P. Newman, 2018: WGV: An Australian urban precinct case study to demonstrate the 1.5 °C agenda including multiple SDGs. *Urban Plan.*, **3**, 64–81, https://doi.org/10.17645/up.v3i2.1245.
de Wilde, P., and D. Coley, 2012: The implications of a changing climate for buildings. *Build. Environ.*, **55**, https://doi.org/10.1016/j.buildenv.2012.03.014.
Williams, S., and A. Doyon, 2020: The Energy Futures Lab: A case study of justice in energy transitions. *Environ. Innov. Soc. Transitions*, **37**, https://doi.org/10.1016/j.eist.2020.10.001.
Willis, R., 2018: How Members of Parliament understand and respond to climate changett. *Sociol. Rev.*, **66**, https://doi.org/10.1177/0038026117731658.
Wilson, C., H. Pettifor, E. Cassar, L. Kerr, and M. Wilson, 2019: The potential contribution of disruptive low-carbon innovations to 1.5 °C climate mitigation. *Energy Effic.*, https://doi.org/10.1007/s12053-018-9679-8.
Winkler, H., 2019: Putting equity into practice in the global stocktake under the Paris Agreement. *Clim. Policy*, **0**, 1–9, https://doi.org/10.1080/14693062.2019.1680337.
Winsemius, H. C., B. Jongman, T. I. E. Veldkamp, S. Hallegatte, M. Bangalore, and P. J. Ward, 2018: Disaster risk, climate change, and poverty: assessing the global exposure of poor people to floods and droughts. *Environ. Dev. Econ.*, **23**, 328–348, https://doi.org/DOI: 10.1017/S1355770X17000444.
Wittneben, B., D. Bongardt, H. Dalkmann, W. Sterk, and C. Baatz, 2009: Integrating sustainable transport measures into the clean development mechanism. *Transp. Rev.*, **29**, 91–113, https://doi.org/10.1080/01441640802133494.
Woiwode, C., 2016: Off the beaten tracks: The neglected significance of interiority for sustainable urban development. *Futures*, **84**, 82–97, https://doi.org/10.1016/j.futures.2016.10.002.
Woiwode, D., and N. Woiwode, 2019: Off the beaten tracks: The neglected significance of interiority for sustainable urban development. *Practical Spirituality and the Contemporary City: Awakening the Transformative Power for Sustainable Living*, A. Giri, Ed., Palgrave Mcmillan, 129–151.
WWAP, 2019: *WWAP (UNESCO World Water Assessment Program). 2019. The United Nations World Water Development Report 2019: Leaving No One Behind . Paris, UNESCO.*
Yang, F., and X. Zhang, 2018: Two faces of an eco-city? Sustainability transition and territorial rescaling of a new town in Zhuhai. *Land use policy*, **78**, 627–636, https://doi.org/10.1016/j.landusepol.2018.06.007.
Yarime, M., 2017: Facilitating data-intensive approaches to innovation for sustainability: opportunities and challenges in building smart cities. *Sustain. Sci.*, **12**, https://doi.org/10.1007/s11625-017-0498-1.
Yaw, N., 2018: ONE DISTRICT, ONE FACTORY OFFICIALLY TAKES OFF. *smartlinewestafrica*,.
Yin, W., L. Hu, S. C. Han, M. Zhang, and Y. Teng, 2019: Reconstructing Terrestrial Water Storage Variations from 1980 to 2015 in the Beishan Area of China. *Geofluids*, **2019**, https://doi.org/10.1155/2019/3874742.
Yohe, G. W., 2001: Mitigative capacity--The mirror image of adaptive capacity on the emissions side. *Clim. Change*, **49**, 247–262, https://doi.org/10.1016/0022-4405(70)90067-1.
Zeng, D. Z., L. Cheng, L. Shi, and W. Luetkenhorst, 2020: China's green transformation through eco-industrial parks. *World Dev.*, 105249, https://doi.org/10.1016/j.worlddev.2020.105249.
Zenghelis, D., 2019: Can we be green and grow?
Zhang, J., P. E. Campana, T. Yao, Y. Zhang, A. Lundblad, F. Melton, and J. Yan, 2018: The water-food-energy nexus optimization approach to combat agricultural drought: a case study in the United States. *Appl. Energy*, **227**, 449–464, https://doi.org/10.1016/j.apenergy.2017.07.036.
Zhang, R., R. Sutton, G. Danabasoglu, Y. O. Kwon, R. Marsh, S. G. Yeager, D. E. Amrhein, and C. M. Little, 2019: A Review of the Role of the Atlantic Meridional Overturning Circulation in Atlantic Multidecadal Variability and Associated Climate Impacts. *Rev. Geophys.*, **57**,

https://doi.org/10.1029/2019RG000644.
Zhao, X., S. Zhang, Y. Zou, and J. Yao, 2013: To what extent does wind power deployment affect vested interests? A case study of the Northeast China Grid. *Energy Policy*, **63**, https://doi.org/10.1016/j.enpol.2013.08.092.
Zhenmin, L., and P. Espinosa, 2019: Tackling climate change to accelerate sustainable development. *Nat. Clim. Chang.*, **9**, 494–496, https://doi.org/10.1038/s41558-019-0519-4.
Zhou, B., W. Li, K. W. Chan, Y. Cao, Y. Kuang, X. Liu, and X. Wang, 2016: Smart home energy management systems: Concept, configurations, and scheduling strategies. *Renew. Sustain. Energy Rev.*, **61**, 30–40, https://doi.org/10.1016/j.rser.2016.03.047.
Zuo, J., and Z. Y. Zhao, 2014: Green building research-current status and future agenda: A review. *Renew. Sustain. Energy Rev.*, **30**, 271–281, https://doi.org/10.1016/j.rser.2013.10.021.
Zusman, E., A. Srinivasan, and S. Dhakal, 2012: *Low carbon transport in Asia: Strategies for optimizing co-benefits*.
{Bibliography