MANILA OBSERVATORY

ADAPTATION-CENTERED JUST TRANSITION PATHWAYS: A MAPPING OF OPTIONS FOR UNDERSTANDING JUST TRANSITION IN THE CONTEXT OF ADAPTATION

Submission to the UNFCCC SBSTA and SBI Chairs' Call for Submissions on the Views of Parties, observers, and other non-Party stakeholders on opportunities, best practices, actionable solutions, challenges, and barriers relevant to the topic of the third dialogue under the United Arab Emirates Just Transition Work Programme pursuant to Decision 3/CMA.5, para. 9

Topic: "Approaches to enhancing adaptation and climate resilience in the context of just transitions"

2 June 2025

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Organization Profile: The Manila Observatory ("**MO**") is a scientific research institution with expertise in climate and disaster science. Aside from its scientific laboratories, it also has a climate policy research center, which aim is to provide legal and policy support on matters relating to climate change.

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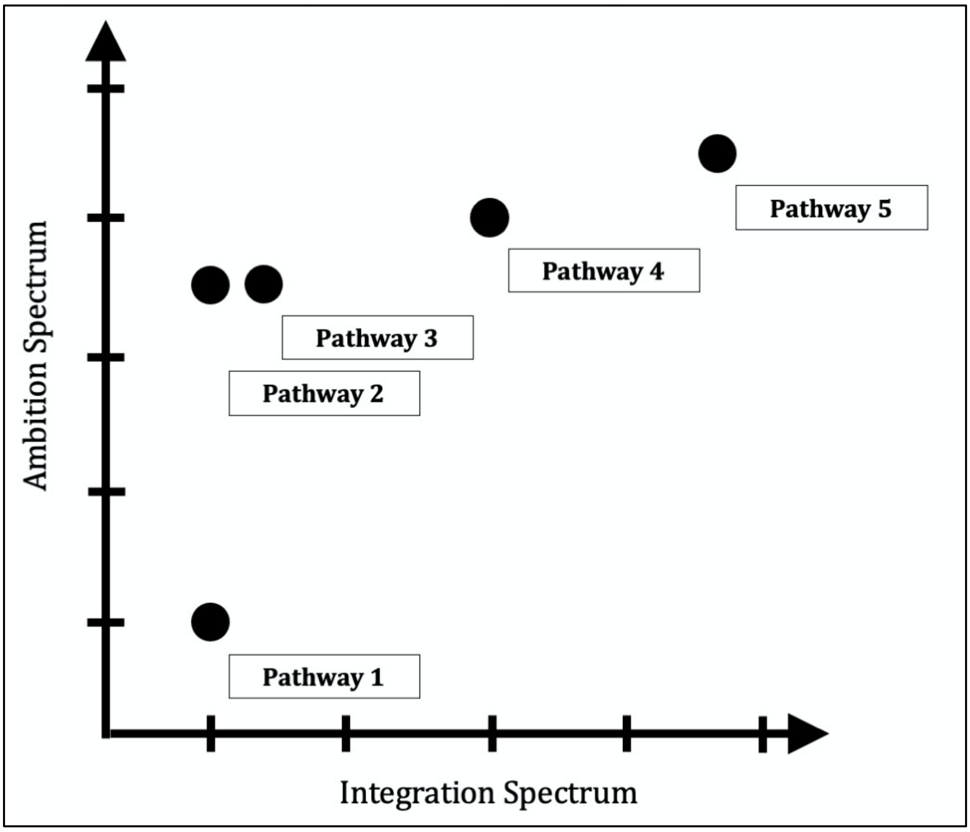
Background of Submission: Building on its broader work on Just Transition, the Manila Observatory engages in international, regional, national, and local work advancing just transition with special consideration for climate-vulnerable developing country context, where climate action is usually centered on adaptation and climate resilience. MO recognizes that there are various ways by which the dynamics between adaptation and just transition may be understood; some more foundational than others, yet all towards achieving "[a]pproaches to enhancing adaptation and climate resilience at the national and international level[.]"[1]

With due consideration of the premise that *just transition is a driver of ambitious climate action*, "**adaptation-centered just transition pathways**" are mapped along a **spectrum of ambition**, ranging from less ambitious to more ambitious; and a **spectrum of integration**, ranging from less integrated to more integrated.[2] For the purposes of this submission, *ambition* refers to achieving the goals of the Paris Agreement outlined in Article 2, paragraph 1, in the context of Article 2, paragraph 2,[3] whether through mitigation options[4] or adaptation options[5] without attempt to establish any form of hierarchy between the two. Further, *integration* refers to a holistic pursuit of both mitigation and adaptation aspects. The five (5) pathways are mapped in Figure 1.

Subsequently, to provide examples for each of the pathways (except for Pathway 1), reference is made to the "**Cross Chapter Box FEASIB I Feasibility Assessment of Adaptation Options: An Update of the SR1.5**" located in Chapter 18. Climate Resilient Development Pathways of IPCC Working Group II's contribution to the Assessment Report 6,[6] and its Supplementary Material.[7] More particularly, Section 4 presents synergies and trade-offs of (a) adaptation options for mitigation and (b) mitigation options for adaptation from which the examples of the pathways are derived. These expand on the findings of Chapter 4. Strengthening and implementing global response of IPCC's Special Report on Global Warming of 1.5°.[8]

With the growing discourse on just transition and the recognition that *what consists* just transition is still debated—and even contested, this mapping provides options on what could be framed as just transition in the context of adaptation, depending on the actors who wield such concept. More particularly, this can also be used by actors as a guiding tool for accountability in the concept's use.

Figure 1. Mapping of adaptation-centered just transition pathways.



Note: Addressing the social considerations arising from climate action, whether mitigation options or adaptation options, is required in all pathways.

1. Adaptation efforts pathway

Climate adaptation efforts refer to interventions that respond to a particular or selected, rather than fundamental, adaptation needs of a targeted segment of the population. These are usually seen through one-time initiatives and reflective of fragmented climate action. Nonetheless, these still enhance climate resilience of the targeted segment.

In planning and implementing such climate adaptation efforts, there are various social considerations (not exclusive to climate vulnerability) manifesting in either risks or benefits, [9] or both, that affect the target segment. In some instances, such efforts also have externalities that affect peoples and communities besides the target segment.

A just transition could be said to exist **if climate adaptation efforts are planned and implemented with policies or mechanisms that address social considerations arising from such efforts.**

This pathway is on the lower ends of both *ambition* and *integration* spectrums.

Examples[10]

Climate Hazards	Adaptation Options
Floods	• Development and introduction of flood-resistant crop varieties • Developing environmental and climate change awareness programs • Planting of traditional tree and root crops to minimize soil erosion • Developing and rehabilitating the flood protection dykes
Droughts	• Scaling up climate smart agriculture through drought tolerant crop varieties and new agricultural techniques such as low to zero tillage, multi-cropping, hydroponics, and fertigation • Increasing the use of mobile pumping stations and permanent stations and efficient small-scale irrigation techniques • Increase of desalination capacity
Sea level rise	• Construction of dykes, coastal embankments, and sea wall for protection of coastal zones • Enforcement of buffer zones for coastal areas and mangrove areas • Mangrove rehabilitation and plantation • Use of water purification measures
Storms	• Development and implementation of early warning systems and localized forecasting • Construction of storm shelters and storm surge protection and other hurricane-resistant infrastructure • Climate-proofing vulnerable homes by providing access to an innovative, low-interest revolving loan program

2. **Adaptation, yet mitigation-neutral, systems transformations pathway**

Climate adaptation-anchored systems transformations refer to widescale changes in societal systems, which reimagine or restructure the current system into one that maximizes climate resilience. Compared to climate adaptation efforts, this pathway casts a wider net by addressing the adaptation needs of multiple communities or of national and sub-national governments. However, mitigation is not a priority consideration for this pathway.

Similar to the above-mentioned, in planning and implementing such climate adaptation-anchored systems transformations, there are various social considerations that may arise. Since systems transformations are more fundamental than adaptation efforts, the risks and benefits are also expected to be more pronounced.

A just transition could be said to exist **if *climate adaptation*-anchored systems transformations are planned and implemented with policies or mechanisms that address social considerations arising from such systems transformations.**

This pathway is on the middle-to-higher end of spectrum of *ambition*, while on the lower end of spectrum of *integration*.

Examples (See Annex 1 for Explanations)

System Transitions	Adaptation Options
Land and ecosystem	Coastal defence and hardening
Over-arching adaptation options	Population health and health systems
	Livelihood diversification
	Risk spreading and sharing

3. **Mitigation, yet adaptation-neutral, systems transformations pathway**

Climate mitigation-anchored systems transformations refer to widescale changes in societal systems, which reimagine or restructure the current highly-emitting system into a low-carbon one. Similar to the previous pathway (2), this pathway cast a wider net by driving systemic greenhouse gas (GHG) emissions reduction in the system or sector sought to be transformed. However, adaptation is not a priority consideration for this pathway. In this pathway, only the social considerations arising from the systems transformations are addressed, and not the adaptation needs.

A just transition could be said to exist **if *climate mitigation*-anchored systems transformations, which neither regress nor enhance climate resilience, are planned and implemented with policies or mechanisms that address social considerations arising from such systems transformations.**

This pathway is on the middle-to-higher end of spectrum of *ambition*, while on the lower end of spectrum of *integration*.

Examples (See Annex 1 for Explanations)

System Transitions	Mitigation Options
Land and ecosystem	Reduce overconsumption
Urban system	Digitalization
	Electromobility
	Fuel efficiency in transport
Energy system	Carbon dioxide capture and storage
Industrial system	Carbon dioxide capture and utilization
	Electrification and fuel switching
	Industrial energy efficiency
	Materials efficiency and demand management

4. **Mitigation, and adaptation-conscious, systems transformations pathway**

Compared to the previous pathway (3) that does not particularly improve climate resilience, this pathway pursues climate mitigation-anchored systems transformations that also has an intent of enhancing climate resilience. While it is short of an integrated approach, this pathway is sensitive to the climate adaptation needs of communities that will be affected by the mitigation-anchored systems transformations by ensuring that these needs are likewise addressed. In this pathway, both the social considerations arising from the systems transformations and the adaptation needs are addressed.

A just transition could be said to exist **if *climate mitigation*-anchored systems transformations, which enhance climate resilience, are planned and implemented with policies or mechanisms that address social considerations arising from such systems transformations.**

This pathway is on the middle-to-higher end of spectrum of *ambition*, while on the middle-to-higher end of spectrum of *integration*.

Examples (See Annex 1 for Explanations)

System Transitions	Mitigation Options
Land and ecosystem	Healthy balanced diets, rich in plant-based food (less animal-based); and reduced food waste

Energy system	Bioenergy and bioenergy with carbon capture and storage (BECCS)

5. **Integrated mitigation and adaptation systems transformations pathway**

Integrated climate mitigation and climate adaptation systems transformations refer to widescale changes in societal systems, which reimagine or restructure the current highly-emitting system into a low-carbon one *and simultaneously* into one that maximizes climate resilience. Compared to the previous pathway (4), this pathway considers a simultaneous systems transformation in both mitigation and adaptation aspects. In this pathway, both the social considerations arising from the systems transformations and the adaptation needs are addressed.

While the benefits (i.e., emissions reduction and enhanced climate resilience) of such an integrated approach are promising, the risks that may arise from such an integrated fundamental transformation may also pose danger to affected sectors and communities.

A just transition could be said to exist **if integrated *climate mitigation* and *climate adaptation* systems transformations are planned and implemented with policies or mechanisms that address social considerations arising from such systems transformations.**

This pathway is on the higher ends of both spectrums of *ambition* and of *integration*.

Examples (See Annex 1 for Explanations)

System Transitions	Adaptation Options
Land, ocean, and ecosystem	Sustainable forest management and conservation, reforestation and afforestation
	Biodiversity management and ecosystem connectivity
	Improved cropland management
	Sustainable acquaculture and fisheries
	Integrated coastal zone management
	Agro-forestry
Urban and infrastructure systems	Green infrastructure and ecosystem services
	Sustainable land use and urban planning

Energy systems	Resilient power infrastructures
	Reliable power systems
Over-arching adaptation options	Disaster risk management

System Transitions	**Mitigation Options**
Land and ecosystem	Protect and avoid conversion of forests and other ecosystems
	Reforestation and restoration of other ecosystems
	Sustainable management of forests and other ecosystems
Urban and infrastructure systems	Urban land use and spatial planning
	Urban nature-based solutions

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[1] UNFCCC. (2023). *United Arab Emirates just transition work programme*, 3/CMA.5, para. 2 (d).

[2] Adopted from Just Transition Research Collaborative. (2018). *Mapping Just Transition(s) to a Low-Carbon World*; La Viña, A.G.M. and Gamboa, J.R. (2022). Which Social Justice?: Situating the Philippine Legal Concept of Social Justice Within Just Transition Research Collaborative's Analytical Framework. *Journal of Global South Studies*, 39 (2), 402-430.

[3] UNFCCC. (2022). *Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its fourth session, held in Sharm el-Sheikh from 6 to 20 November 2022*, 1/CMA.4, para. 52.

[4] *See* Grubb, M., C. Okereke, J. Arima, V. Bosetti, Y. Chen, J. Edmonds, S. Gupta, A. Köberle, S. Kverndokk, A. Malik, L. Sulistiawati. (2022). Introduction and Framing. *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.003. "The ultimate goal of mitigation is to preserve a biosphere which can sustain human civilisation and the complex of ecosystem services which surround and support it. This means reducing anthropogenic GHG emissions towards net zero to limit the warming, with global goals agreed in the Paris Agreement. Effective mitigation strategies require an understanding of mechanisms that underpin release of emissions, and the technical, policy and societal options for influencing these."

[5] *See* Ara Begum, R., R. Lempert, E. Ali, T.A. Benjaminsen, T. Bernauer, W. Cramer, X. Cui, K. Mach, G. Nagy, N.C. Stenseth, R. Sukumar, and P. Wester. (2022). Point of Departure and Key Concepts. *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 121–196, doi:10.1017/9781009325844.003. "The

goals of climate change adaptation, as a broad concept, are to reduce risk and vulnerability to climate change, strengthen resilience, enhance well-being and the capacity to anticipate, and respond successfully to change."

[6] Schipper, E.L.F., A. Revi, B.L. Preston, E.R. Carr, S.H. Eriksen, L.R. Fernandez-Carril, B. Glavovic, N.J.M. Hilmi, D. Ley, R. Mukerji, M.S. Muylaert de Araujo, R. Perez, S.K. Rose, and P.K. Singh. (2022). Climate Resilient Development Pathways. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2655-2807, doi:10.1017/9781009325844.027.

[7] Schipper, E.L.F., A. Revi, B.L. Preston, E.R. Carr, S.H. Eriksen, L.R. Fernandez-Carril, B. Glavovic, N.J.M. Hilmi, D. Ley, R. Mukerji, M.S. Muylaert de Araujo, R. Perez, S.K. Rose, and P.K. Singh. (2022) Climate-Resilient Development Pathways Supplementary Material. *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Available from https://www.ipcc.ch/report/ar6/wg2/.

[8] de Coninck, H., A. Revi, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, J. Ford, S. Fuss, J.-C. Hourcade, D. Ley, R. Mechler, P. Newman, A. Revokatova, S. Schultz, L. Steg, and T. Sugiyama. (2018). Strengthening and Implementing the Global Response. *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, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 313-444, doi:10.1017/9781009157940.006.

[9] For instance, social considerations include "[j]ob creation, improvements in job quality and incomes, access to clean affordable energy through the development of low-carbon economic activities, new markets, economic diversification, cost savings for companies and consumers through increased energy and resource efficiency, better air quality and related health benefits" as benefits or opportunities, while "[n]egative socio-economic impacts, including job and income loss, geographical imbalances between job loss and job creation, job quality deterioration, lack of necessary skills in the workforce to sustain the transition, risks of inequitable effects for vulnerable groups, and pressures on land and other resources particularly affecting communities or indigenous people" as risks or challenges. *See* International Labour Organization and LSE Grantham Research Institute for Climate Change and the Environment. (2022). *Just Transition Finance Tool for banking and investing activities.*

[10] Adaptation Committee. (2020). *Synthesis report on how developing countries are addressing hazards, focusing on relevant lessons learned and good practices.*

Annex 1. Explanations for Examples of Pathways 2-4 from Schipper, E.L.F. (2022). *Climate-Resilient Development Pathways Supplementary Material.*

2. Adaptation, yet mitigation-neutral, systems transformations pathway

System Transitions	Adaptation Options	Explanation
Land and ecosystem	Coastal defence and hardening	*(medium, high confidence)* Hard-engineering infrastructures can affect ecosystem function and services (Antunes do Carmo, 2018; Hamin et al., 2018). *(weak, low confidence)* Building and protecting hard-engineering infrastructures may affect the demand for basic materials (e.g., steel and cement), which are carbon-intensive (Hamin et al., 2018). We have not found any estimates of the potential demand (WGIII Section 11.4.4).
Over-arching adaptation options	Population health and health systems	*(strong, high confidence)* Heat management strategies, including tree planting and other green infrastructure, cool roofing and paving, and a reduction in waste heat emissions from buildings and vehicles can lessen the health risk of rising temperatures, as well as lessen greenhouse gas emissions (Stone et al., 2019). *(strong, high confidence)* Groundwater-source heat pumps (GWSHP) are considered environmentally friendly and economically wise to use for heating and cooling buildings, and consequently have great potential to moderate greenhouse gas emissions (Osman and Sevinc, 2019). *(medium, medium confidence)* Use of indoor air conditioning can be an effective strategy to reduce heat exposure, stress and illness. However, this is associated with large energy consumption and may increase GHG emissions (Davide et al., 2019; Viguie et al., 2020), in turn worsening air quality and human health impacts (Abel et al., 2018).
	Livelihood diversification	*(strong, high confidence)* Sustainable livelihood diversification (promoted by local and global frameworks such as REDD+) that are equitable and pro-poor yield substantial co-benefits spanning adaptation, mitigation and sustainable development (e.g., coffee agro-forestry systems in West Africa, Tschora and Cherubini, 2020; in India, Guillemot et al., 2018; mixed outcomes of forest carbon projects in India, Aggarwal and Brockington, 2020). *(medium, high confidence)* Sustained evaluation and orientation to reform are however needed to ensure equal distribution of carbon revenues in land-based sustainable livelihood diversification but also meet local livelihood needs and ensure pro-poor benefit sharing (Atela et al., 2015; Asfaw et al., 2019; Shrestha and Dhakal, 2019). *(medium, medium confidence)* However, not all livelihood diversification options are pro-climate, particularly precarious mass risk hedging strategies across the rural–urban continuum in informal economies of southern geographies (Satterthwaite et al., 2018).

		(weak, medium confidence) The extent of trade-offs with mitigation targets is understudied, however, qualitatively, the consensus is building around potential trade-offs between climate transitions, acute poverty and informal economy (Heine et al., 2019; Dorband et al., 2019).
	Risk spreading and sharing	*(strong, medium confidence)* Insurance policies sustain the reconstruction and repair of damaged property and/or infrastructure and the return to the 'status quo', which may increase GHG emissions from the production of concrete and other needed materials of industrial origin (Cannon et al., 2020; Collier and Cox, 2021). *(strong, high confidence)* Access to crop and weather-indexed insurance schemes can drive farmers to adopt more intensive agricultural practices and increase agricultural productivity (Jørgensen et al., 2020), potentially increasing emissions related with the use of nitrogen fertilizers, lack of action to control ammonia and potential land use changes (e.g., deforestation). Increased food production may also increase food imports and their related transport GHG emissions.

3. Mitigation, yet adaptation-neutral, systems transformations pathway

System Transitions	Mitigation Options	Explanation
Land and ecosystem	Reduce over-consumption	*(weak, high confidence)* Improved dietary health and other health benefits, can enhance food security and environmental protection (Bodirsky et al., 2020; WGIII Section 12.4; WGIII Section 7.4.5.1; WGIII Section 7.4.5.2).
Urban and infrastructure systems	Digitalization	*(weak, low confidence)* Digitalisation in buildings, water, energy and transport systems will result in more efficiency and less GHG emissions hence less energy use in the case of disruption to the energy supply (Rudram et al., 2016; Balogun et al., 2020).
	Electromobility	*(weak, low confidence)* Makes vehicles and public transport independent of fuel distribution systems and may allow for vehicles to be charged with solar or renewable energies when available, in addition it reduces the urban heat island effect and air pollution (Yamaguchi and Ihara, 2020).
	Fuel efficiency in transport	*(weak, low confidence)* Vehicles requiring less fuel per mileage would allow for transport of people or goods in the case of disruptions to the fuel distribution chain (Liimatainen et al., 2018).
Energy systems	Carbon dioxide capture and storage	*(weak, low confidence)* Diversification of livelihood for people in areas of geological sequestration; potential for just transition away from high polluting industry jobs (Buck et al., 2020) *(weak, low confidence)* Training for workers currently engaged in fossil fuel extraction to create a community of practice on carbon management (Buck et al., 2020).
Industrial systems	Carbon dioxide	*(weak, medium confidence)* A key strategy to avoid GHG emissions throughout the lifecycle of chemicals is to use biomass feedstock,

	capture and utilization	including CCU with biogenic carbon dioxide (WGIII Section 11.4.1.3). If used to produce synthetic hydrocarbons and alcohols, these can be used by existing long-lived energy and feedstock infrastructure, transport and storage, which can compensate for seasonal supply fluctuations and contribute to enhancing energy security (WGIII Section 11.3.6). ***(weak, low confidence)*** CCU pathways can offer entry points for local diversification, see also CCS and enhanced weathering (EW) (Buck et al., 2020).
	Electrification and fuel switching	***(weak, high confidence)*** Electrification is a key option to decarbonize primary materials production and it can be done in ways so that demand is flexible (e.g., with electrolysis and hydrogen storage) and thus support the balancing of electricity grids (WGIII Section 11.3.5).
	Industrial energy efficiency	***(weak, medium confidence)*** Energy efficiency reduces the pressure on energy supplies and, if combined with demand flexibility, increases resilience of industrial production and the electricity system (WGIII Sections 11.3.4, 11.3.5).
	Materials efficiency and demand management	***(weak, low confidence)*** Reduced demand for basic materials (e.g., cement, steel, wood) means less pressure on primary resources and may in that way have synergies with adaptation, but we have no evidence of a clear link. There are mainly co-benefits with other SDGs (WGIII Section 11.5.3.1).

4. Mitigation, and adaptation-conscious, systems transformations pathway

System Transitions	Mitigation Options	Explanation
Land and ecosystem	Healthy balanced diets, rich in plant-based food (less animal-based); and reduced food waste	***(strong, high confidence)*** Reduces pressure on forests, protecting biodiversity; decreases production intensity and use of inputs; improves population health and enhances health benefits, prevents malnutrition by providing access to food (Bodirsky et al., 2020; WGIII Section 12.4; WGIII Section 7.4.5.1; WGIII Section 7.4.5.2). ***(weak, low confidence)*** Reducing food waste may enhance access to food, reduce food prices and—if combined with measures to improve distributional inequity and counter rebound effects—lead to more equal access to food (WGIII Section 7.4.5.1; WGIII Section 7.4.5.2; WGIII Section 12.4.4). ***(weak, high confidence)*** Reduction of food waste decreases use of inputs, pressure on (crop)land and reduces food costs. Solutions such as smart packaging can reduce food waste avoiding potential food safety risks (WGIII Section 7.4.5.1; WGIII Section 7.4.5.2; WGIII Section 12.4.3.5). ***(strong, medium confidence)*** Mostly a measure for the affluent society; a possible decrease in the price might lead to a rebound effect; shift to unsustainable fisheries may occur; reduced farmers' incomes when transition is not done in the right manner or without support (WGIII Section 7.4.5.1; WGIII Section 7.4.5.2).

Energy systems	Bioenergy and bioenergy with carbon capture and storage (BECCS)	*(strong, medium confidence)* Enhanced productivity when done properly as part of ongoing agriculture and forestry; enhanced waste recycling; enhanced income for farmers and forest owners when bioenergy is derived from residues and low-quality wood; favours local employment; local energy that can compensate for fluctuations from wind and solar. Clear air quality improvement and reduced air pollution (Shyamsundar et al., 2019) and non-CO2 emissions (Garg et al., 2011), if counterfactual is to burn residues in the field. *(weak, medium confidence)* When designed properly, bioenergy plantations can serve as connectivity pathways between nature areas (WGIII Section 12.5). *(strong, medium confidence)* Modern bioenergy provides clean energy access (WGIII Section 12.5.2). *(strong, medium confidence)* Bioelectricity complements VREs and reservoir hydropower as a balancing power source thus helping to ensure grid stability and quality, and in situations where hydro is limited due to drought (Lehtveer and Fridahl, 2020). *(strong, high confidence)* Clear air quality improvement if counterfactual is to burn residues in the field (SDG 3) (Smith et al., 2019). *(strong, high confidence)* There are clear absolute limits to amounts of bioenergy feasible; if derived from very large (maldesigned) bioenergy plantations then many risks and trade-offs occur with biodiversity pressure and loss, competition for food, food–water security risks, soil degradation due to overuse of fertilizers (WGIII Section 7.4.4; WGIII Section 12.5). *(strong, medium confidence)* Poorly sited energy crops can reduce water availability for agriculture and settlements (WGIII Section 12.5.2).

5. Integrated mitigation and adaptation systems transformations pathway

System Transitions	Adaptation Options	Explanation
Land, ocean, and ecosystem	Sustainable forest management and conservation, reforestation and afforestation	*(strong, high confidence)* Forest-based adaptation strategies have positive impacts on mitigation, carbon sequestration, biodiversity and provision of wood for buildings and bioenergy (Nabuurs et al., 2017; Shrestha and Dhakal, 2019; Ontl et al., 2020). *(strong, high confidence)* Avoided deforestation, prevented forest degradation and pro-forestation strategies reduce emissions of carbon into the atmosphere, while forest restoration, afforestation options and locally adapted climate smart forestry (including provision of timber for building), remove carbon from the atmosphere (Nabuurs et al., 2017; Favero et al., 2020; Ontl et al., 2020; Ota et al., 2020). *(strong, high confidence)* These forest-based adaptation strategies have important climate change mitigation effects in all biomes (Chausson et al., 2020; Seddon et al., 2020a; Seddon et al., 2020b).

		(strong, medium confidence) Over reliance on forest-based adaptation strategies may lead to an increased susceptibility to other climate-related hazards, such as wildfires, which emit large amounts of carbon and other greenhouse gases (GHGs) into the atmosphere (Nunes et al., 2020). ***(weak, medium confidence)*** Forest restoration initiatives that promote fast-growing plantations of pulp and timber species such as Pinus and Eucalyptus, which are extremely flammable, exacerbate wildfire risk and ecosystem carbon loss, leading to increased GHG emissions (Fleischman et al., 2020). A proper management and choice of a variety of tree species can counteract this risk.
	Biodiversity management and ecosystem connectivity	***(strong, high confidence)*** Adaptation options incorporating a biodiversity management-based approach can positively impact forests' resilience and their long-term capacity as carbon sinks (Seddon et al., 2019; Chausson et al., 2020; Seddon et al., 2020a; Seddon et al., 2020b). ***(strong, medium confidence)*** Without adequate and locally adapted measures, including a biodiversity management-based approach, vegetation-based adaptation alternatives might result in mal-mitigation (Yousefpour et al., 2017).
	Improved cropland management	***(medium, medium confidence)*** Improved cropland management practices and technologies (e.g., tillage methods, water application, nutrient management) reduce GHG emissions significantly but depend on technology type and the stage of its adoption, e.g., direct rice seeding can reduce methane emissions while laser land levelling can reduce energy used for irrigation (Aryal et al., 2020, in South Asia). ***(strong, medium confidence)*** Combinations of improved cropland practices such as reduced or no tillage, nutrient management and residue recycling have a higher rate of soil organic carbon sequestration, of 427.9 kg ha–1yr–1 under rice–rice systems (Yadav et al., 2019 in North East India), while optimised nutrient management through organic farmyard manure and other micronutrients increases soil organic carbon in maize–mustard cropping systems by up to 9.7% (Sarkar et al., 2018 in North East India). ***(strong, medium confidence)*** Improved soil management practices increase soil organic carbon (SOC) stocks, e.g., in the North China Plain, such practices have increased SOC by 56–73% compared with initial stocks in the 1980s. Implementation of such practices in just 27% of China's cropland increased annual carbon sequestration amount in surface soils to 10.9 Tg Cyr–1, contributing an estimated 43% of total carbon sequestration in China's croplands (Han et al., 2018). ***(medium, medium confidence)*** Emerging cropland management practices such as minimal tillage, stubble retaining and nutrient management increase soil organic carbon stocks but the extent varies with site-specific conditions (Singh et al., 2018, global review). ***(strong, medium confidence)*** Integrated soil–crop system management can reduce GHG emissions by 19% and carbon footprint by 30%

		compared with traditional practices (Wang et al., 2020, Yangtze River basin, China). ***(strong, high confidence)*** Integrated soil fertility management and conservation agriculture contribute to climate change mitigation by reducing SOC losses (Sommer et al., 2018, in Western Kenya; Shah and Wu, 2019, global review). ***(strong, medium confidence)*** Conservation agriculture has an estimated annual carbon sequestration benefit of 143 Tg C yr–1 (Gonzalez-Sanchez et al., 2019, in Africa). ***(weak, medium confidence)*** Improved cropland management practices aimed at increasing carbon sequestration in agriculture soils could lead to increased greenhouse gas emissions if the nitrogen inputs are not managed effectively. By 2060, around half of sites in Europe with carbon-mitigating agricultural practices could turn into a net source of greenhouse gases (Lugato et al., 2018). ***(weak, low confidence)*** The increase in soil organic carbon through climate-smart agriculture practices could be offset by increased nitrous oxide emissions within corn belt states in the USA (McNunn et al., 2020).
	Sustainable acquaculture and fisheries	***(strong, high confidence)*** Sustainable aquaculture can enhance carbon sequestration (Ahmed et al., 2018); (Otuoze et al., 2018; Turolla et al., 2020; Mustafa et al., 2021) and ecosystem restoration (Stentiford et al., 2020). ***(strong, high confidence)*** Reducing impacts of sustainable aquaculture can have important co-benefits such as maintaining large quantities of organic carbon (Ahmed et al., 2018, 'blue carbon'; see Section 3.4.4.12 of IPCC SR1.5) and carbon ('blue carbon'; see section 3.4.4.12 of IPCC SR1.5) from exposure to the atmosphere (Hoegh-Guldberg et al., 2018).
	Integrated coastal zone management	***(strong, high confidence)*** Implementation of nature-based solutions for coastal management can enhance and stabilise carbon sequestration capacity of the ecosystems (Propato et al., 2018; Morecroft et al., 2019; Morris et al., 2019; Donatti et al., 2020; Erftemeijer et al., 2020; Gómez Martín et al., 2020; Hanley et al., 2020; Jones et al., 2020; Krauss and Osland, 2020).
	Agro-forestry	***(strong, high confidence)*** Agro-forestry is generally found to have positive impacts on mitigation by improving carbon sequestration (Tschora and Cherubini, 2020). ***(weak, medium confidence)*** Thinning of natural forest canopy to establish agricultural crops such as cocoa or coffee seedlings retains more trees than in a monoculture plantation, but carbon stocks are diminished (Tschora and Cherubini, 2020). In addition, over reliance on vegetation-based adaptation strategies may lead to an increased susceptibility to wildfires, which release large amounts of carbon into the atmosphere (Nunes et al., 2020).

Urban and infrastructure systems	Green infrastructure and ecosystem services	***(medium, high confidence)*** Urban forestry and agriculture has mitigation benefits through increased carbon uptake, e.g., in Lugo, Spain, urban forestry and farming collectively sequester 0.26 t C ha–1 yr–1 (De la Sota et al., 2019). ***(strong, medium confidence)*** Urban agriculture can reduce energy intensive food transportation, improve soil carbon sequestration capacity (if sustainable agricultural practices are used), and enable transitions towards low-carbon, plant-based diets (Artmann and Sartison, 2018; Grafakos et al., 2019). ***(weak, medium confidence)*** Green infrastructure options such as xeriscaping and water-sensitive urban design (permeable surfaces, bioswales, etc.) can sequester carbon and have cooling effects that indirectly lead to reduced energy consumption (Sharifi, 2021). ***(strong, medium confidence)*** The lack of consideration of the heat–water–vegetation nexus can increase heat and water stress (Afshari, 2017; Upreti et al., 2017; Zardo et al., 2017; Chen et al., 2019; Peng et al., 2020; Rahman et al., 2020). ***(weak, medium confidence)*** Mitigation policies towards urban greening can sometimes incentivise urban greening with low biodiversity value (e.g., afforestation with non-native monocultures) leading to maladaptive outcomes (Seddon et al., 2020a).
	Sustainable land use and urban planning	***(strong, high confidence)*** Land use and urban planning can be a tool for resilient cities, but also can lead to reduced emissions through incentivising high-density housing or investing in public transportation to replace private automobiles (Hughes, 2020). ***(strong, medium confidence)*** Climate-resilient urban buildings can also be built with low-carbon materials (Hughes, 2020). ***(weak, medium confidence)*** High-density cities can lead to fewer carbon emissions, but risks concentrating people and infrastructure in exposed locations (Hinkel et al., 2018).
Energy systems	Resilient power infrastructures	***(strong, high confidence)*** Strong synergies with mitigation goals as resilient infrastructure allows power generation systems to continue operations without disruptions (or minimal disruptions). This is especially important for renewable energy systems (Kennedy et al., 2013; O'Neill-Carrillo and Rivera-Quiñones, 2018). ***(strong, high confidence)*** In rural landscapes, resilient power infrastructure ensures electricity availability during emergencies and protects the communities from any malfunction of the infrastructure itself. (Ley, 2017; Bertheau and Blechinger, 2018; Mazur et al., 2019).
	Reliable power systems	***(strong, high confidence)*** Strong synergies with mitigation goals as reliable systems decrease the risk of disruptions and avoid the use of fossil fuels, in the cases where the main energy system is renewable energy, either centralised or decentralised (Ley, 2017; Sun et al., 2018; Lai et al., 2019; Mishra et al., 2020).

Over-arching adaptation options	Disaster risk management	***(strong, medium confidence)*** Incorporating environmental considerations into recovery decision making (Amin Hosseini et al., 2016), implementing disaster risk management plans and increasing ex ante resilience to disasters are important to reduce the extent of rebuilding following disasters, and the emissions associated with recovery. ***(weak, medium confidence)*** Post-disaster recovery can help rebuild in a more resilient way with less GHG emissions, or to 'build back better', particularly where immediate impact is substantial but not overwhelming (Guarnacci, 2012; Mochizuki and Chang, 2017). ***(weak, medium confidence)*** Effective disaster risk management may reduce the need for international transport of materials and other forms of aid, which can be emissions intensive (Abrahams, 2014). ***(weak, medium confidence)*** The urgency of recovery and the surge in demand for construction materials have been observed to promote unsustainable behaviours, including deforestation (Nazara and Resosudarmo, 2007; Ongpeng et al., 2019) or uncontrolled extraction of sand and gravel (Abrahams, 2014). ***(strong, high confidence)*** 'Building back better' requires capacity, time and mechanisms for balancing competing desires and perspectives that are not necessarily available after severe disasters, and may be challenged by both local and external influences in the rebuilding process (Abrahams, 2014; O'Hare et al., 2016; Paidakaki and Moulaert, 2017).

System Transitions	Mitigation Options	Explanation
Land and ecosystem	Protect and avoid conversion of forests and other ecosystems Reforestation and restoration of other ecosystems Sustainable management of forests and other ecosystems	***(strong, high confidence)*** Increased provision of ecosystem services and goods, such as improved regulation of microclimate, increased groundwater recharge and watershed protection, improved quality of air and water, reduced soil erosion, expansion of biomass coverage and improved habitat for wildlife and biodiversity (Buotte et al., 2020). ***(weak, medium confidence)*** May increase susceptibility to other climate-related hazards, such as fire (Nunes et al., 2020). ***(strong, medium confidence)*** Forest restoration-based mitigation could reduce the availability of productive agricultural land with potentially significant social and environmental consequences, including potential conflicts over land for agriculture, and rights and access of local people to forest resources when restoration initiatives are not duly planned nor funding has been secured, in addition to loss of biodiversity and other ecosystem functions, such as diminished water runoff as a result of upstream reforestation, (Bustamante et al., 2019).
Urban and infrastructure systems	Urban land use and spatial planning	***(strong, high confidence)*** Resilience towards extreme events. Avoiding buildings in areas at risk (for example from forest fires or flooding). Building new developments in areas with water supply and good and redundant communication networks (Hughes, 2020).

		(strong, high confidence) High-density cities reduce transportation and emissions from buildings (Hughes, 2020). ***(strong, high confidence)*** High-density cities can concentrate people and infrastructure in exposed locations, for example enhancing the heat islands effect (Hinkel et al., 2018).
	Urban nature-based solutions	***(strong, high confidence)*** Green and blue spaces can both aid decarbonisation and alleviate urban heat island effects, as well as potentially reduce floods impacts from storms (Alves et al., 2019). ***(strong, high confidence)*** Urban nature can potentially be inequitably distributed across social and economic groups, resulting in increased vulnerability, usually for ethnic minorities and low-income groups (Amorim Maia et al., 2020; Venter et al., 2020).