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Updated draft 01.0

Priorities and needs: technologies for adaptation in agriculture, water resources and coastal zones; including experiences in stakeholder engagement and regulatory issues pertaining to the development, transfer and uptake of technologies in those sectors

Updated draft technical paper

Recommended action by the Adaptation Committee

The Adaptation Committee (AC), at its 21st meeting, will be invited to consider the updated draft technical paper on technologies for adaptation, along with possible next steps. It may wish to provide its feedback on the current draft, including guidance on completing the paper, and continue engaging with other interested stakeholders when refining and finalizing the paper ahead of AC22.

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1. Introduction

1. In its revised 2019-2021 workplan,[1] the Adaptation Committee (AC) agreed to prepare, in 2021, a technical paper on the application of technologies for an adaptation on a priority topic to be determined. It prepared a scoping note in the second half of 2020 to determine the topic; this scoping note was considered at AC18.[2]

2. Following AC18, the AC agreed on the topic of "Priorities and needs: technologies for adaptation in agriculture, water resources and coastal zones; including experiences in stakeholder engagement and regulatory issues pertaining to the development, transfer and uptake of technologies in those sectors" and further agreed to consider an annotated outline at its 19th meeting.[3]

3. At AC19, the AC agreed on the objective, scope and annotated outline of the technical paper, provided additional guidance on the outline, focus areas, and information sources for the paper, and requested the secretariat to seek inputs and feedback through the NAP Taskforce when preparing a first draft for consideration at AC20. The AC considered a first, work-in-progress draft at AC20; following this consideration, it requested the secretariat to continue developing the paper as indicated in that draft and provided additional feedback for integration into the second draft. As per usual practice, the AC welcomed inputs and feedback on the draft from observers and other interested stakeholders; this draft thus also incorporates inputs received from interested organizations and Parties during and since AC20.[4]

4. As a component of the AC's work on providing technical support and guidance to Parties on adaptation planning and implementation, including means of implementation, at the national and subnational level , this paper aims to provide an overview of planning and implementation of adaptation technologies in the areas of agriculture, water resources, and coastal zones. Chapter 2 discusses adaptation technologies in the agriculture, water resources, and coastal zones sectors in general terms, and describes the critical role of technology transfer in facilitating access to these technologies. Chapter 3 elucidates some of the priorities and needs for adaptation technologies in the agriculture, water resources, and coastal zones sectors identified as part of the adaptation planning process. Chapter 4 then examines the implementation of adaptation technologies in these sectors and more generally, as well as related good practices, gaps, needs, and challenges. Both chapters draw on the information communicated by Parties in their national adaptation plans (NAPs),[5] adaptation communications (ADCOMs),[6] technology needs assessments (TNAs), and nationally determined contributions (NDCs),[7] as well as documents from the Technology and Financial Mechanisms under the UNFCCC, along with academic and grey literatures. Chapter 5 looks at cross-cutting issues, including innovative approaches and technologies, regulatory issues, and stakeholder engagement. The concluding chapter offers general reflections on the preceding chapters, summarizes additional good practices, challenges, needs, and gaps, and outlines potential next steps for consideration by the AC.

2. Background

2.1. Technologies for adaptation

5. At the broadest level, technology may be defined as "a piece of equipment, technique, practical knowledge or skills for performing a particular technology" (IPCC, 2000). Adaptation technologies may be more narrowly defined as "the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impacts of climate change."[8] Adaptation technologies are commonly subdivided into three categories: hardware, software, and orgware (Christiansen, Olhoff, and Trærup, 2011). Hardware encompasses tangible "hard" technologies such as infrastructure or equipment,

[1] https://unfccc.int/sites/default/files/resource/ac_workplan_post_ac17_web.pdf
[2] https://unfccc.int/sites/default/files/resource/ac18_8b_technologies.pdf
[3] https://unfccc.int/sites/default/files/resource/ac19_8b_technologies.pdf
[4] This includes written inputs received from the Climate Technology Centre and Network, the Green Climate Fund secretariat, and the Government of Australia.
[5] See https://www4.unfccc.int/sites/NAPC/News/Pages/national_adaptation_plans.aspx
[6] See https://unfccc.int/topics/adaptation-and-resilience/workstreams/adaptation-communications
[7] See https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx
[8] FCCC/SBSTA/2005/8, para 17.

including climate resilient crops. Software, by contrast, refers to knowledge, skills and general capacity that underlies the use of technologies. Finally, orgware includes the institutional arrangements, coordination mechanisms, and policy and regulatory frameworks that exist where a given technology will be used and facilitate the use of the technology. These overarching categories cover a wide range of sub-categories that are important features of the adaptation technology landscape, including nature-based solutions and ecosystem-based adaptation, as well as indigenous and traditional knowledge and technologies.

6. Many adaptation technologies have existed and been deployed for many generations, such as building houses on stilts to cope with flooding or irrigating crops to cope with erratic precipitation. These also include technologies and practices developed by indigenous communities around the world, which have been forged in and tailored to climatic variability and extremes. At the same time, the rapid development of new and innovative technologies provides opportunities to apply new practices and techniques in the service of adaptation, and in some cases to improve upon the existing techniques by making them more efficient or environmentally sustainable.

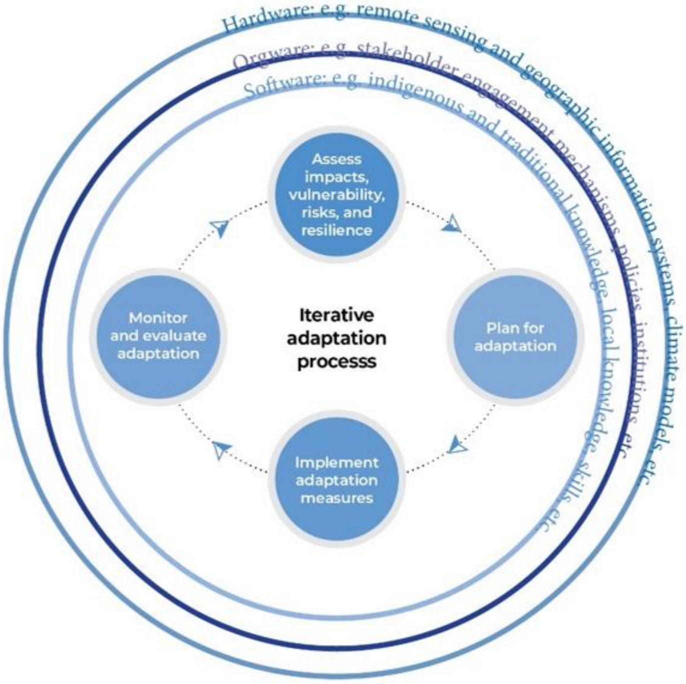
7. Despite this long history and expanding landscape of adaptation technologies, there are still urgent and growing technology-related needs that must be met in order for these technologies to fulfil their potential in reducing vulnerability, bolstering resilience, and enhancing adaptive capacity. To help meet these needs and enhance climate technology development and transfer, including for adaptation, a Technology Mechanism was established under the UNFCCC process in 2010. It consists of a policy arm (the Technology Executive Committee or TEC) and an implementation arm (the Climate Technology Centre and Network or CTCN). Five years later, in the Paris Agreement, Parties outlined a shared "long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions"[9] and, "noting the importance of technology for the implementation of mitigation and adaptation actions under [the] Agreement and recognizing existing technology deployment and dissemination efforts, [committed to] strengthen cooperative action on technology development and transfer."[10]

8. According to the *Fourth synthesis of technology needs identified by Parties not included in Annex I to the Convention* (hereafter referred to as the *Fourth synthesis of technology needs*), the most commonly prioritized sectors for adaptation technology needs are agriculture (87 per cent of Parties), water resources (79 per cent of Parties) and infrastructure and settlements, including coastal zones (33 per cent of Parties).[11] The prevalence of adaptation-related needs, including technology development and transfer needs, in these sectors was further substantiated by the UNFCCC Standing Committee on Finance's *First report on the determination of the needs of developing country Parties related to implementing the Convention and the Paris Agreement* (Standing Committee on Finance, 2021). Specifically, the report found that agriculture and water are the two leading sectors in which adaptation-related needs were identified by developing country Parties, with coastal zone management representing the sector with the fourth highest amount of needs. This testifies to the critical importance of adaptation technologies in these sectors and the enduring needs of countries to access and implement such technologies to build resilience to the worsening impacts of climate change.

9. Across these sectors, and in pursuit of adaptation more generally, hardware, software, and orgware can be applied at all stages of the iterative adaptation process. While there are some technologies that may be most suited to one of the stages – for example, hard technologies such as water efficient irrigation or breakwaters are clearly deployed while implementing adaptation measures – there are also technologies that are useful throughout the process. See Figure 1.

[9] Article 10, para. 1 of the Paris Agreement.
[10] Article 10, para. 2 of the Paris Agreement.
[11] FCCC/SBI/2020/INF.1, para. 61.

Figure 1. Examples of technology in the iterative process



Source: Adapted from Adaptation Committee, 2019.

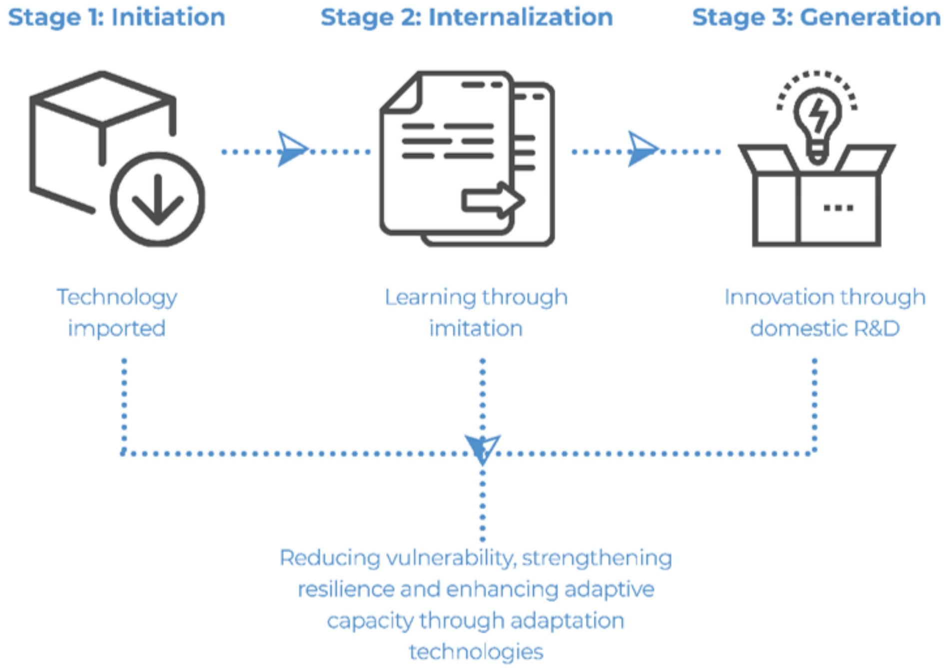
2.2. Technology transfer

10. Technology transfer, as defined by the IPCC (2018), is the "exchange of knowledge, hardware and associated software, money and good among stakeholders, which leads to the spread of technology for adaptation or mitigation" and "encompasses both diffusion of technologies and technological cooperation across and within countries." Technology transfer has been recognized as integral to climate action under the UNFCCC since its inception, with the Convention stipulating that developed countries "shall…provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of implementing measures that are covered by paragraph 1 of [Article 4],"[12] which included commitments to "[c]ooperate in preparing for adaptation to the impacts of climate change," and, particularly relevant to this technical paper, to "develop and elaborate appropriate and integrated plans for coastal zone management, water resources and agriculture." [13] As highlighted in paragraph **Error! Reference source not found.**, Article 10 of the Paris Agreement reiterated the importance of technology transfer to improve climate resilience and implement adaptation actions.

11. For developing countries, the process of technology transfer can involve progressively climbing through three stages (see Figure 2 below). First, an initiation stage during which technology is imported; an internalization stage, during which domestic firms learn through imitation; and, finally, a generation stage, where local firms and institutions undertake their own research and development to innovate (UNCTAD, 2007; Khor, 2012). This process thus "may involve the purchase and acquisition of equipment; the know-how to use, maintain and repair it; the ability to make it through 'emulation' or reverse engineering; to adapt it to local conditions; and eventually to design and manufacture original products" (Khor, 2012).

[12] Article 4, para. 3 of the Convention.
[13] Article 4, para. 1(e) of the Convention.

Figure 2. Stages of technology transfer



Sources: Based on UNCTAD, 2007; Khor, 2012.

12. The UNFCCC's Technology Mechanism plays an important role in facilitating and accelerating technology transfer to support the implementation of the Convention and the Paris Agreement. Examples are included throughout this paper, including the information on and examples of CTCN support highlighted in Chapter 3 below. Moreover, the Financial Mechanism also supports technology transfer, both through directly funding projects that aim at achieving technology transfer in a particular country or region and by supporting broader initiatives that aim to scale up adaptation technology transfer globally. An example of this latter approach is the Climate Resilience and Adaptation Finance and Technology Transfer Facility (CRAFT), funded in part by the GEF Special Climate Change Fund[14] and the GCF.[15] The CRAFT is a private equity fund that includes both concessional and commercial equity, as well as a complementary technical assistance facility that supports developing countries to apply adaptation technologies drawn from CRAFT's portfolio of companies.[16]

13. It is clear, however, that there is still significant scope for scaling up technology transfer for adaptation. Examining patent data from 1995-2015, Dechezleprêtre et al. (2020) found low rates of adaptation innovations transferred across borders relative to mitigation and non-climate domains, and particularly low diffusion in the areas of agriculture and coastal and river protection. What's more, 85 per cent of transfers of patented adaptation inventions occur between a small group of high-income countries plus China, and there "is virtually no transfer of patented knowledge to low-income countries" (Dechezleprêtre et al., 2020). This implies that those countries that currently are among the most vulnerable to climate change, and therefore in greatest need of technologies for adaptation, have particularly low access to technological innovations for advancing their adaptation action.

14. Indeed, Parties highlight various challenges and needs related to technology transfer in their national reports, underscoring the need to enhance technology transfer in order to implement their adaptation plans and commitments. More specifically, some outline enduring needs for the transfer of specific adaptation technologies in the water, agriculture, and coastal zones sectors, including those technologies listed in

[14] See https://www.thegef.org/newsroom/press-releases/gef-joins-forces-partners-promote-new-fund-resilience-poorest-countries
[15] See https://www.greenclimate.fund/project/fp181
[16] See https://www.ndf.int/what-we-finance/projects/project-database/climate-resilience-and-adaptation-finance-and-technology-transfer-facility-craft-c114.html

sections 2.1 to 2.3 above. To help address these challenges and needs, Parties in some cases outline various steps they have taken or will take, such as organizing national technology transfer events and programmes, establishing and supporting systems of innovation, establishing international cooperation initiatives. At least one Party also established a new institution to facilitate technology transfer in relation to climate change and other challenges (see Box 1).

Box 1: Nigeria's national Office for Technology Acquisition and Promotion

Like many other countries, Nigeria has identified a range of barriers to the successful transfer of technologies to support climate change action. These include bureaucratic barriers, low awareness of available technologies, poor understanding of the innovation process, and, most critically, tariffs and intellectual property rights.

In order to overcome these barriers and support the technology transfer process in service of climate action and other national objectives, Nigeria established the National Office for Technology Acquisition and Promotion (NOTAP). It expects that NOTAP will become the main vehicle for efficient and effective technology transfer for adaptation and mitigation, including in order to deliver on the commitments outlined in the country's NDC.

NOTAP has already achieved the following:

- Developing technology transfer agreements;
- Creating awareness on intellectual property rights;
- Creating a Patent Information and Documentation Centre;
- Establishing 39 Intellectual Property Technology Transfer Offices in Universities, Polytechnics and Research institutions, which strengthen linkages between research institutions and industry; develop a robust intellectual property right portfolio through patenting, copyright, and technology licensing; support the development of a patent culture; and advancing a formal system of incentives and rewards that encourage individual researchers to get involved in related partnerships.

Source: Federal Government of Nigeria, 2021.

15. Moreover, while technology transfer is often seen primarily as a process through which technologies from developed countries are transferred to developing countries, transfer among developing countries through South-South cooperation can also yield significant benefits. Mechanisms for this type of technology transfer include capacity-building initiatives like training and study tours and bottom-up participatory approaches such as community consultations and peer-to-peer learning; the latter in particular can help make local solutions and indigenous technologies for accessible, adaptable and affordable(TEC, 2017). At least in the water and agriculture sectors, however, the potential for South-South adaptation technology transfer "remains largely untapped" (TEC, 2017). Challenges include inadequate legal and regulatory frameworks, limited organizational and technical capacities, and inadequate access to financial resources. The TEC identified that, among other things, scaling up and fully taking advantage of South-South and triangular[17] cooperation requires a systematic approach, such as developing South-South/triangular cooperation strategies and embedding these into national development planning.

3. Priorities and needs in adaptation technologies in agriculture, water resources and coastal zones

16. Adaptation planning is a key mechanism through which national governments – as well as governments at other levels and non-state actors – identify technology-related needs and priorities. These

[17] That is, cooperation where donor countries and multilateral organizations facilitate South-South initiatives by providing support such as training, funding, and more. See https://www.unsouthsouth.org/about/about-sstc/#:~:text=Triangular%20cooperation%20is%20collaboration%20in,as%20other%20forms%20of%20support.

needs and priorities are often communicated through national adaptation plans, as well as other documents submitted under the UNFCCC. Examining NAPs, NDCs, ADCOMs, and national communications[18], complemented by information drawn from the *Fourth synthesis of technology needs*, this section details some of the needs identified in relation to the three areas of focus.

3.1. Agriculture

17. In 2014, the IPCC concluded that "[a]ll aspects of food security are potentially affected by climate change, including food access, utilization and price stability" (IPCC, 2014). To tackle the challenge of climate change and fulfil the promise of the Paris Agreement while simultaneously eradicating hunger, and achieving the Sustainable Development Goals more broadly, "will require a profound transformation of food and agriculture systems worldwide" (FAO, 2016). Adaptation technologies will inevitably play a vital role in this transformation. In the agriculture sector, common adaptation technologies include seasonal forecasts, which support planning decisions and early warning; water efficient irrigation, which helps farmers cope with drought and variable rainfall patterns; resilient crop varieties, which boost food security by enhancing resistance to water- and heat-stress, salinity, pests and other factors; and farmer-led sustainable agriculture practices, which help ensure farmer ownership, the sustainability of agricultural techniques and their suitability to their context (TEC, 2014a).

18. Most adaptation technologies prioritized by Parties in their TNAs in the agriculture sector relate to sprinkler and drip irrigation (prioritized by 37 per cent of Parties) and biotechnologies, such as those related to crop improvement, new varieties, and drought-resistant, salient-tolerant and short-maturing varieties (together prioritized by over 50 per cent of Parties).[19] Other commonly prioritized technologies relate to conservation agriculture and land-use planning, agroforestry, rainwater harvesting, storage techniques for grains and seeds, and integrated soil nutrient management.

19. In their various national reports, many countries include explicit mention of technologies for agriculture, highlighting their related priorities and needs for facing adverse climate change-related impacts, as well as taking advantage of any resulting opportunities. The level of detail included in these documents however, varies, with some providing generic statements on the need to develop and implement technologies in the agriculture sector – such as promoting and improving the use of appropriate technologies for crop production for vulnerable farmers – whereas others outline specific technologies and their envisioned use.

20. Among the most common type of hard agricultural technologies mentioned include biotechnologies such as genetically improved crop varieties that are drought resistant, saline tolerant or otherwise adapted (e.g. short cycle seeds). The prevalence of this type of measure testifies to the important role envisioned for drought-tolerant and otherwise improved crop varieties and climate-resilient livestock species. Also common are measures to improve the efficiency of adaptation measures in the agriculture sector, including energy efficiency (e.g. through using solar pumps and wind power) and water efficiency, (e.g. efficient irrigation technologies, rainwater harvesting, and other technologies that can reduce the water footprint of the agriculture sector, such as. including micro-irrigation and smart hydroponic systems). Some Parties also prioritized technologies specific to particular climate change-related hazards. These include technologies to protect crops against floods and heavy rains such as perimeter dikes and breakwaters; against high winds and sandstorms, such as living hedges or shelterbelts; and against plant and animal heat stress, through shade, cooling, and breeding technologies.

21. Other types of hardware prioritized in the agriculture sector include various technologies related to soil, including for the management and reduction of soil erosion and desertification; the recovery of agricultural soils degraded by salinization, including bioremediation processes and plant cover management; soil and water conservation, including mulching, cover cropping, zero tillage, crop rotation, and agroforestry; and tackling nutrient leaching and soil compaction. Still other measures included enhancing pest infestation warning services and post-harvest crop preservation technologies (e.g. infrastructure for effective grain and seed storage).

[18] Note: further information from national communications will be included in future drafts.
[19] FCCC/SBI/2020/INF.1, para. 79.

22. Some Parties highlighted plans to promote digital agriculture. Related measures proposed encompass technologies for information and data gathering and analysis, such as modelling and climate-risk mapping, as well as information and communications technologies to improve access to information and technologies in the agriculture sector. Improving animal breeding technologies through artificial intelligence, and conservation and precision agriculture were also highlighted.

23. Parties also underscored the need to develop new adaptive technologies in the agriculture sector, including new products, processes, and services, noting that existing technologies were not created considering the impacts of climate change. One specific example is developing soil management technologies that are suited to atoll conditions. Another example is developing and testing technologies for controlled environment agricultural production – such as cold frames and polytunnels with plastic and polycarbonate - which provide benefits such as protecting crops from adverse weather or extending growing seasons. It is anticipated that such new technologies, in addition to bolstering the resilience of crops and agricultural systems, may also generate higher crop yields and reduce the greenhouse gas emissions resulting from agricultural practices. Indeed, prioritizing measures that offer benefits across these areas was highlighted as a marker of an especially successful adaptation strategy.

24. Related to this, research on agricultural technology and innovation, including for soil management, resilient crop variety identification and climate-smart agriculture, featured as part of some Parties' plans for enhancing adaptation in the sector. Specific technologies to assist with research and assessment in the agricultural sector were also cited, including GIS mapping and crop modelling technologies, and weather stations to facilitate tailored climate services for farmers.

25. Some countries also referenced orgware-related needs to enhance the uptake of adaptation technologies in the agriculture sector, such as promoting market-based instruments for the adoption of new irrigation technologies, providing agricultural input subsidies and incentives, improving farmers' access to credit for procuring adaptation technologies and equipment or creating a system for using (dis)incentives to support agriculture enterprises that incorporate climate change considerations into their operations. Other orgware measures included improving support services for climate resilient crop production, establishing agricultural institutions to research drought resistant varieties, promoting the provision of improved extension services for farmers, and more. including programmes for knowledge development, extension services, and enhancing research and policy to support food security.

26. Capacity-building (i.e. software-related) objectives were also included, such as training agricultural technicians in climate-smart agriculture techniques, including the use of drought resistant crops; establishing climate-smart agriculture demonstration sites to showcase different technologies and techniques; creating farmer field school programs to enable peer-learning on climate-smart agricultural practices and technologies; or improving diagnostic facilities to deal with crop and livestock pests and diseases.

3.2. Water resources

27. According to the IPCC, increasing greenhouse gas concentrations significantly increase the freshwater-related risks of climate change; throughout the 21st century, it is expected that the fraction of the global population affected by major river floods and the fraction experiencing water scarcity will increase (IPCC, 2014). Moreover, it is expected that raw water quality will decrease as a result of climate change, which will also pose risks to drinking water quality as a result of various interacting factors, including increased temperature; increased sediment, nutrient, and pollutant loadings from heavy rainfall; increased pollutant concentration during droughts; and disruption of treatment facilities during floods. There is a wide range of technologies that can help adapt to these changes; common examples include boreholes and tube wells, which help enhance water efficiency and access to safe drinking water by extracting water from subsurface and groundwater levels; rainwater harvesting, which supplements water supply and increases efficiency through rainwater collection from rooftops and other catchments; desalination, which is the process of removing sodium chloride and other dissolved constituents to purify water; and various types of orgware, such as water management fora, which convene stakeholders to discuss options and develop related plans for the water resources sector (TEC, 2014b).

28. Parties place a high priority on applying adaptation technologies in the water resources sector in order to reduce their vulnerability and increase their resilience to these risks. In their TNAs, Parties most

commonly prioritized adaptation technologies in the water sector relate to rainwater harvesting (54 percent of Parties) and water storage and catchment (35 per cent of Parties).[20] Parties also prioritized technologies related to small reservoirs and dams, integrated river basin management, desalinization, water supply systems, and watershed management.

29. Countries frequently referenced adaptation technologies for the water resources sector in their national reports. Some measures prioritized adapting and ensuring the adequacy of water-related infrastructural technologies, including rain gauge stations, stormwater systems, drainage infrastructure, infiltration galleries, boreholes, dams, reservoirs, canals, aqueducts and modern wells, hand and solar pumps, leak detection and control technologies, and, more generally, developing water infrastructures for vulnerable people. Some Parties also referenced plans to build new water resources infrastructure, including accumulation lakes. In some cases, it was emphasized that the construction of new water infrastructure, as well as upgrades, repairs, and relocations of existing infrastructure, must be undertaken with a view to withstanding projected climate risks and meeting the future needs of all community members. This focus on infrastructure is apt, given that "the value of water to society is underpinned by hydraulic infrastructure" that store or move water and thereby deliver both economic and social benefits (UN Water and UNESCO, 2021).

30. Information and analytical technologies were also prioritized to support adaptation in the water sector. These include computer models - such as integrated hydrological models and climate forecasting models - weather radars, and sensors, technologies for monitoring water flow and sediment loads in priority basins, as well as data management platforms. Other prioritized technologies include those that can support water harvesting and water retention, facilitate water reclamation and reuse, treat and safely store household drinking water – including treatment through environmentally sustainable methods like reverse osmosis – reduce consumption, reduce surface evaporation from water bodies, and generally enhance water resource efficiency. Technologies for water desalination, including desalination plants, were also prioritized in various national reports for purposes such as increasing the amount of potable water in vulnerable areas.

31. Still other measures target specific demographics: using appropriate technologies to alleviate drinking water access issues for women in the dry season, or supporting urban areas vulnerable to climate change-related water shortages, through the installation of water-saving sanitary products such as low water consumption toilets, showers and urinals, water saving taps, flow reducers, and other devices. Parties also made general references to promoting and introducing technologies in the water sector, including for water work development and rehabilitation.

32. Some of the water-related technologies and technological measures prioritized are also intended to contribute to adaptation in the agriculture sector, testifying to the inherent linkages between adaptation in the two sectors including with respect to technologies for adaptation. Agriculture accounts for around 69 per cent of water withdrawals globally as a result of irrigation, as well as water for livestock and aquaculture (UN Water and UNESCO, 2021). The related technologies prioritized include, for example, implementing water storage infrastructure to ensure surface water availability for agricultural use in dry seasons and more generally constructing climate resilient water supply and storage infrastructure for crops and livestock production, promoting water conservation technologies and practices (e.g. mulching) in agricultural production systems, promoting rainwater maintenance, improving farm drainage infrastructure, and identifying the most appropriate, modern, and efficient irrigation technologies to improve efficiency and reduce water demand. This latter measure also encompasses improving irrigation systems in a broader sense for sustainable water conservation purposes, through practices such as hydro-zoning – i.e. grouping plants with similar water requirements – and biodiverse planting. Measures prioritizing water-related technologies for adaptation measures in other sectors were also highlighted, including technologies for promoting water reclamation and re-use in the tourism and industry sectors.

33. Parties also highlighted orgware-related measures to help facilitate and coordinate the deployment of hardware and software in the water resources sector. Examples include establishing planning committees focused on watershed-based land use, developing integrated watershed management plans or national guidance for freshwater resources management, establishing a centre for early warning systems and technology to forecast future climate change impacts on water resources, strengthening institutions that can help boost water resources capacity, improving cooperation in transboundary water management, and

[20] FCCC/SBI/2020/INF.1, para. 80.

exploring policies such as price caps to ensure the affordability and adoption of prioritized technologies. Orgware to bolster private sector engagement in water resources management was also referenced, such as pursuing innovative public-private partnerships for water desalination and irrigation.

34. Efforts to bolster software in the water sector were also prioritized, such as conducting public awareness campaigns on the benefits of low flow technologies and other water conservation systems under current and future climatic conditions.

3.3. Coastal zones

35. As a result of climate change and associated sea level rise, coastal and low-lying areas are increasingly faced with submergence, coastal flooding, coastal erosion and other adverse impacts (IPCC, 2014). Small island States and some low-lying developing countries are expected to bear the brunt of these impacts, and in some cases will be confronted with damages and adaptation costs amounting to several percentage points of GDP. Technologies to adapt to these changes – and to avert, minimize, and address related loss and damage in coastal zones – include those that support risk assessments, those that advance risk retention, and those that facilitate recovery and rehabilitation (WIM Executive Committee and TEC, 2020). Included in the risk assessment category are ocean and coastal observation technologies, geospatial technology, numerical simulation models, stakeholder engagement mechanisms, institutions, and more. Meanwhile, the risk retention category encompasses technologies that directly manage risks, such as structural and engineered measures (e.g. seawalls, dykes, sand nourishment, tetrapods, etc.), organizational and financial planning, regulatory and legal measures, contingency planning, nature-based solutions, and more. Finally, the category of recovery and rehabilitation features technologies like mangrove restoration, data collection platforms, resilience-building assessment frameworks, and partnerships and mechanisms to support local communities in the aftermath of disasters.

36. In their TNAs, Parties' most prioritized adaptation technologies in relation to infrastructure and settlements, including coastal zones, were hard and soft measures related to coastal protection.[21] Specifically, these prioritized technologies related to wetland restoration and disaster prevention, such as early warning systems, as well as seawalls, mapping and surveying technologies, and beach reclamation.

37. Parties, in their national reports, prioritized similar technologies and measures, including coastal hardware such as detached breakwaters, drainage mechanisms, groins, seawalls, and revetments, and other coastal protection barriers, as well as relocating and rebuilding endangered structures, and generally promoting resilient coastal infrastructure to protect communities and infrastructure against sea level rise. In some cases, these barriers were envisioned as nature-based or hybrid solutions or plans to integrate ecosystem-based adaptation considerations into the construction of structures such as seawalls and riverbanks, including mangrove planting, were outlined. Mangrove-related measures are especially common, with Parties highlighting integrated mangrove ecosystem management, mangrove restoration, and mangrove conservation, as well as supporting measures such as establishing mangrove ecosystem health surveillance, monitoring and analysis tools.

38. Hard measures to improve the condition of beaches were also prioritized, including beach nourishment and reclamation, as well as the provision of laboratories and equipment to collect and analyse related data. Plans to establish coastal information systems were also featured. Parties further prioritized measures that could help facilitate the application of hard coastal adaptation technologies, such as building tools for modelling climate risks in coastal areas and devising solutions.

39. Risk assessment measures featured include, among other things, various orgware-related measures, such as establishing accurate sea level rise forecasting systems, updating vulnerability and risk maps for coastal areas, boosting climate resilient investments in shoreline protection, including built infrastructure, and providing open access information and communications networks for relevant sectors and actors. Other measures include developing port development plans and coastal zone policies, strategies, and management plans – including integrated coastal zone management – and managing a fund for the recovery of mangroves, coral reefs and other coastal marine ecosystems.

[21] FCCC/SBI/2020/INF.1, para. 81.

40. Parties also highlighted software related actions, including bolstering communication, education and public awareness on the importance of coastal ecosystem protection for natural disaster impact reduction; establishing institutional structures to strengthen the research, management and monitoring of coastal marine ecosystems and species, and their vulnerability to climate change; preparing guidance to support local authorities in interpreting related policies; and supporting nationwide research on coastal vulnerability and management; researching the role of mangrove forests and coastal dikes/drainage systems to protect against flooding and storm surges; and, in general, capacity-building efforts to support the deployment of adaptation activities.

4. Uptake of adaptation technologies in implementing adaptation actions in agriculture, water resources and coastal zones

41. It is thus clear that countries have widespread enduring needs and associated priorities for adaptation technologies in the water resources and agriculture sectors, as well as in coastal zones, and that these needs and priorities are well documented in their national planning and communications documents. It is also clear that needs must be met, priorities must be acted upon, and technologies must be applied in order to realize the envisioned progress towards building resilience to the impacts of climate change. The extent to which this transition between planning and prioritization to implementation is taking place, however, is more difficult to assess. According to the 2020 UNEP Adaptation Gap Report, close to 400 projects with adaptation as a primary aim have been financed by the UNFCCC climate funds since 2006 and these projects most frequently addressed the agriculture and water sectors (UNEP, 2021). While this represents a degree of progress, the report concluded that "[f]urther scaling up of the levels of implementation is needed to avoid falling behind with managing climate risks, particularly in developing countries."

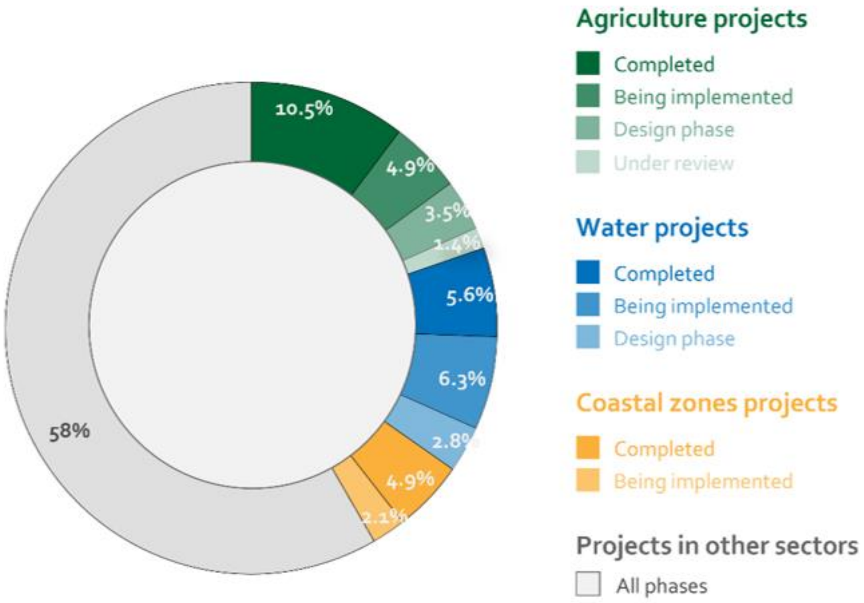
42. This chapter aims at a general discussion of the implementation of technologies for adaptation in agriculture, water resources, and coastal zones, rather than a comprehensive overview of the state of technology implementation in these sectors. It features sections on stakeholder engagement, regulatory issues, and innovative approaches given the importance of these factors in enabling the development and deployment of adaptation technologies in these sectors and beyond. Finally, each subchapter features a brief discussion of challenges, gaps, needs, and good practices – as well as a general subchapter devoted to these topics – in order to draw attention to some of the barriers that continue to complicate the path towards deployment of adaptation technologies, as well as some of the steps that can help alleviate those barriers.

43. Incorporating throughout the chapter are examples of indigenous technologies and practices that exemplify adaptation in the three focus sectors. This includes showcasing cases from what is known as the Lo-TEK movement; this movement "investigates lesser-known local technologies, traditional ecological knowledge (TEK), indigenous cultural practices and mythologies passed down as songs or stories" (Watson, 2020). Lo-TEK illuminates "design by radical indigenism," which "imagines a movement that rebuilds an understanding of indigenous philosophies in relation to design to generate sustainable and climate resilient infrastructures." It pushes back against the notion that indigenous practices are primitive as compared with modern technologies, and instead demonstrates their ingenuity and sophistication in working with complex ecosystems to enable survival in the face of extreme conditions.

44. Moreover, considering the central role of the CTCN in promoting the transfer of environmentally sound technologies for adaptation to meet the needs and priorities of developing countries, the below sections on agriculture, water, and coastal zones begin with a snapshot of CTCN activities aiming at accelerating technology deployment in each of these areas. Figure 3 below provides an overview of how these activities fit into its broader portfolio of technical assistance in the area of adaptation, for which there are, as at 7 March 2022, 143 projects listed on its website.[22]

[22] See https://www.ctc-n.org/technical-assistance/data?f%5B0%5D=ta_page_objective_facets%3A14912

Figure 3. CTCN Technical Assistance for Adaptation in the Agriculture, Water and Coastal Zones sectors



Source: https://www.ctc-n.org/technical-assistance/data?f%5B0%5D=ta_page_objective_facets%3A14912

* Percentages are of the 143 adaptation-related technical assistance projects listed on the CTCN website as at 7 March 2022. This count includes those projects listed jointly under mitigation and adaptation. Agriculture projects counted include those listed in both the "agriculture" and the "agriculture and forestry" categories on the CTCN database.

4.1. Agriculture

45. As at 7 March 2022, the CTCN lists 29 technical assistance projects in 24 countries focusing on adaptation in the agriculture or agriculture and forestry sectors, of which five are in the design phase, another seven are being implemented, two are under review, and the remaining fifteen have been completed.[23] These projects are aligned with several of the priorities and needs for the agriculture described by Parties and summarized in section 3.1 above. For example, the CTCN is supporting Mongolia to enhance the capacity and knowledge of herding communities on climate-resilient livestock farming,[24] and Sri Lanka to address the low level of adaptation technology adoption – including technologies such as soil and moisture conservation practices, cover cropping, and more – by coconut growers.[25] Completed projects have helped, among others, Belize to develop an integrated and comprehensive agroforestry policy,[26] and Benin to establish a sustainable system for collecting and disseminating agro-meteorological information.[27]

46. Around the world, indigenous peoples have pioneered and refined technologies for adaptation in the agriculture sector. A recent workshop held under the Koronivia joint work on agriculture pointed to indigenous agroecological food systems, which have been operating for centuries, as potential models for

[23] See https://www.ctc-n.org/technical-assistance/data?f%5B0%5D=ta_page_objective_facets%3A14912&f%5B1%5D=ta_page_sectors_facets%3A14957

[24] See https://www.ctc-n.org/technical-assistance/projects/enhancing-climate-resilience-and-economic-sustainability-livestock

[25] See https://www.ctc-n.org/technical-assistance/projects/technology-adaptation-program-farmers-minimize-impacts-climate-change

[26] See https://www.ctc-n.org/technical-assistance/projects/development-integrated-and-comprehensive-agroforestry-policy

[27] See https://www.ctc-n.org/technical-assistance/projects/establishment-sustainable-system-collection-and-dissemination-agro

sustainable food systems.[28] In Honduras, for example, indigenous peoples in the village of Guarita practice the Quexungal farming method, wherein crops are planted under trees whose roots anchor the soil (IFAD, 2016). See Box 2 for an additional example of indigenous agricultural technology.

Box 2: Lo-TEK Agricultural Technology: Waru Waru Agricultural Terraces of the Inca, Peru

In the Lake Titicaca basin in Peru, which sits at an altitude of four thousand meters, farming conditions are difficult due to the fluctuating environmental extremes, which range from severe drought to flood to frost. Developed around 1800 BCE, and later evolved, the waru waru agricultural terraces are raised beds for cultivating crops surrounded by canals for irrigation and fish farming.

The raised beds vary significantly in size and shape depending on the topography, but elevated fields are built above peak floodwaters to protect crops and seeds from being washed away. At the same time, the water captured in the channels irrigates and fertilizes the crops ahead of the dry season. Moreover, the waru waru systems serve a thermoregulation function, helping moderate the impact of extreme temperatures brought on by the high altitudes and protect crops from frost damage. Absorbing the sun's heat during the day, the canal waters then radiate it into the soil in the beds at night, thereby extending the growing season and creating habitat for new species.

After being largely abandoned due to factors associated with colonization and the introduction of new – mostly unsustainable and ineffective – agricultural techniques, some local communities and indigenous peoples are revisiting the practice to help sustain expanding populations. Factors such as modern plow farming, urbanization, and road building threaten the use of this technology, however. There are also range of additional barriers and challenges preventing its more widespread adoption despite its clear benefits, such as the drastic changes to the social, political, and economic environment since the waru waru were initially in use along with issues such as competing land tenure or labor demands.

Source: Watson, 2020.

47. The GCF's draft sectoral guide[29] on Agriculture & Food Security (GCF, 2021) presents critical needs and priorities within the agriculture sector the GCF aims to address. These include: 1) integrated agricultural development planning and capacities; 2) investment in innovative farming practices, agricultural technologies, and business models; 3) access to affordable finance for farmers and local agri-businesses; 4) public and private finance to invest in commercially viable climate-resilient projects and programs; 5 knowledge and access to information; 6) awareness of low-emissions agricultural practices, use of modern ICT tools and techniques; and 7) cultural and behavioural barriers.

48. The guide identifies non-exhaustive examples of interventions conducive to addressing the adaptation needs, including technologies in relation to improved and climate-resilient crop varieties and livestock breeds; innovative adaptation practices and technologies; improving natural resource management; agroecological approaches; water resource management; integrated pest management; integrated soil management; agricultural system diversification; agroforestry; diversifying crops and livestock and introducing improved or locally developed varieties; crop rotation; intercropping; mixed cropping and other variations based on agroecology; climate proofed irrigation systems; use of renewable energy for irrigation integration of woody species and cover crops for integrated water management at watershed level; climate information and early warning systems; digital technology investments; big data analytics; weather index insurance programs; digital and mobile technologies; among others.

[28] FCCC/SB/2021/3/Add.1, para. 10.

[29] Sectoral guides covering GCF result areas are technical documents that aim at providing evidence-based knowledge, best practices, and lessons learned to guide proposal development for the GCF. The guides also provide a comprehensive overview of what elements and scopes can be considered by the GCF to address the priorities and needs of developing countries. The sectoral guides are currently in different stages of development and public consultation. Therefore, information provided here based on these guides is still subject to change based on the further development and finalization of the documents.

49. As noted in its sectoral guide on agriculture, the GCF emphasizes the following four approaches when it comes to boosting paradigm-shifting investment:

a) Transformational planning and programming;

b) Catalyzing climate innovation;

c) Mobilization of finance at scale; and

d) Coalitions and knowledge to scale up success.

50. The guide further describes how these approaches could be integrated into GCF investment in the agriculture sector through three paradigm-shifting investment pathways, namely, promoting resilient agroecology; facilitating climate-informed advisory and risk management services; and reconfiguring food systems. In addition, all GCF investments should be aligned with the relevant GCF result areas: most vulnerable people and communities; health, food, and water security; and forest and land use.

51. The guide introduces several GCF projects and programmes, which demonstrate the GCF's support for the implementation of agriculture sector adaptation through technology, including the following:

a) In Pakistan, the Transforming the Indus Basin with Climate Resilient Agriculture and Water Management project is strengthening government capacity to leverage information and innovative technology to adapt to climate change impacts on agriculture and water management.[30] It is also aiming to enhance the climate resilience of the most vulnerable farmers through skills, knowledge, and technology improvements.

b) The Acumen Resilient Agriculture Fund aims at improving climate resilience to ensure long-term sustainable increases in agricultural productivity and incomes for smallholder farmers in several African countries.[31] The project is leveraging this approach by supporting innovative agri-business start-ups aiming to bolster smallholder farmers' climate resilience by providing aggregators, digital platforms, and innovative financial services to smallholders. The long-term vision of the project is moving climate change adaptation activities from grant dependence to long-term capital formation.

52. Similarly, the Adaptation Fund supports countries in addressing a variety of technology-related needs in the agriculture sector. Ongoing projects aim to, for example, improve agricultural productivity by deploying climate-smart agricultural practices and best available technologies to climate-proof production and post-harvest activities, such as solar based pumping systems and post-harvest processing equipment. At the intersection of the agriculture and water sectors, Adaptation Fund support is also being directed towards the piloting of new and innovative technologies, such as technologies that facilitate groundwater availability and use while running on self-generating renewable power, thereby increasing resilience to disruptions to the electrical grid due to extreme weather events and other factors. In addition to testing and deploying hard technologies, support to countries under the Adaptation Fund also helps address software-related needs and barriers in the agriculture sector, such as improving awareness of agricultural machinery and production technologies among women and youth, and orgware-related issues, such as institutional capacity-building and policy engagement.

53. The Adaptation Fund's project database lists, as at 10 March 2022, 19 projects in 18 countries that are categorized under agriculture. Three of these have been completed, 12 are being implemented, and four have had their proposals approved. Completed projects include:

a) The Enhancing the Adaptive Capacity and Increasing Resilience of Small-size Agriculture Producers of the Northeast of Argentina project focused on adaptation actions for family agricultural producers dealing with climate change impacts, particularly in relation to increasingly intense hydro-meteorological events.[32] It involved implementing soil moisture monitoring systems and developing early warning systems, along with training and capacity-building measures. Beneficiaries included indigenous peoples, who were included in the

[30] See https://www.greenclimate.fund/project/fp108
[31] See https://www.greenclimate.fund/project/fp078
[32] See https://www.adaptation-fund.org/projects-document-view/?URL=en/429561571868641505/54-2-2-DIPROSE-Project-Completion-Report-Non-definitive-version-ENG.pdf

deployment of technologies. Local knowledge was also taken into account, including when building dams.

b) In Madagascar, the Promoting Climate Resilience in the Rice Sector through Pilot Investments in Alaotra-Mangoro Region project.[33] It worked to, among other things, implement hard technologies related to crop modelling, resilient crop varieties, as well as water efficiency, management and conservation. It also included software-related measures, and orgware-related measures such as revitalizing producer's cooperatives and water user associations and recommending policy reforms.

54. Through its various funds, the Global Environment Facility also aids countries in planning and implementing technological interventions in support of climate-resilient agriculture. For example, this includes helping small island developing States identify climate-resilient hard technologies to improve soil management, advancing software in this area through the creation of farmer field schools, or catalysing supportive orgware, such as inclusive microinsurance targeted to small-holder farmers and small business owners.

55. Despite a long history of adaptation technologies being deployed in agriculture, and their widespread inclusion in adaptation plans and projects, the implementation of adaptation technologies in this sector can nonetheless be reactive and ad hoc in practice. Indeed, as worsening climate change impacts catch producers and firms off guard, adaptation measures used in the sector are sometimes temporary and arguably extreme measures that are far removed from the careful planning taking place at the national level. This underscores the need to scale up proactive adaptation technologies. See Box 3 for an example.

Box 3: Reactive adaptation technology deployment in the agriculture sector

Around the world, vineyards facing changing climatic conditions are increasingly turning to temporary and desperate technologies to save their crops. In Napa Valley, in the United States, the region's soil, temperature, and rainfall patterns used to be well suited to growing cabernet, chardonnay, zinfandel, and other varieties of grapes for wine production. Now, extreme heat is causing problems across the valley, from wildfire smoke penetrating the grapes and tainting the taste of grapes – and the resulting wine – to scorching temperatures roasting grapes on the vine. While the smoke taint is difficult to prevent or solve, some growers are turning to spraying sunscreen on their crops to keep them from burning, a strategy that produces mixed results. More expensive options include using shade cloth to cover the crops, or costlier still, to replant vines so that they sit parallel to the sun during the hottest part of the day.

Across the ocean, wine producers in Europe are struggling with late frosts that threaten to damage delicate spring buds. In April 2021, some vineyards in France and Italy surrounded their vines with "bucket-sized candles" to warm the air and protect their crop. This technology proved insufficient in some cases, with some regions losing 90% of their crop – an approximately €2 billion loss – to frost. In the face of these challenges, there are calls for producers to plant more diverse and resilient grape varieties. Nonetheless, the above examples demonstrate how some agricultural producers are being caught out by the adverse effects of climate change and are not yet implementing the costlier. but longer-term, adaptation measures that can better safeguard their operations in a changing climate.

Sources: (1) https://www.nytimes.com/2021/07/18/climate/napa-wine-heat-hot-weather.html (2) https://www.economist.com/europe/2021/07/15/climate-change-is-affecting-wine-flavours

4.2. Water resources

56. In its project database as at 7 March 2022, the CTCN outlines 21 projects in 20 countries focused on advancing adaptation technologies in the water sector.[34] Four of these projects are in the design phase, nine are being implemented, and the remaining eight have been completed. These projects are supporting

[33] See https://www.adaptation-fund.org/projects-document-view/?URL=en/963251627512647341/10-2020-AFB-5060-1111-2G49-madagascar.pdf

[34] See https://www.ctc-n.org/technical-assistance/data?f%5B0%5D=ta_page_objective_facets%3A14912&f%5B1%5D=ta_page_sectors_facets%3A7

countries in advancing on their technology needs and priorities in the water sector. This includes, for example, ongoing support to Tunisia to implement a smart water supply network, through technologies such as hydraulic modelling, smart metering, and more;[35] support to Cambodia to implement a low-cost, sustainable, and locally-suitable gravity-driven membrane technology to deliver safe drinking water supplies to rural communities;[36] and identifying and promoting feasible, efficient, and effective water recycling technologies for households in Namibia.[37] Completed projects have supported, among others, Grenada to improve its water supply management through a GIS-based monitoring and control system,[38] and Bangladesh to install saline water purification technologies at the household level.[39]

57. The GCF Water Security sectoral guide[40] will offer a snapshot of indicative priorities and needs that could be addressed by GCF investment in relevant technology innovation. For instance, the sectoral guide points to the following priorities to achieve a paradigm shift in addressing water security in the context of GCF investment through two pathways: 1) enhancing water conservation, water efficiency and water re-use through demand management and smart digital water management; and 2) strengthening integrated water resources management and water management through preserving and developing alternative water supplies, ecosystem-based management, circular economy resource recovery, and integrated water resources management. Some relevant technologies are highlighted in the guide in the context of these two pathways.

58. The guide further provides a list of cross-cutting water security issues that can be addressed in line with the GCF result areas, including the food, health and water security result areas. They include, among others, climate-smart agriculture; irrigation and efficient water-use; urban water supply resiliency; urban water treatment; urban sanitation including decentralized wastewater management; ecosystem-based management; forest management to preserve watersheds; solar panels in water channels/hydro-dams, generating power and reducing evaporation; early warning systems for flood and drought management; water use efficiency, including demand management; water conservation; circular economy; water efficiency technologies; rainwater harvesting, groundwater protection; and managed aquifer recharge; wastewater management; Climate Resilient Water, Sanitation and Hygiene programmes; efficient pumping, among others.

59. In addition, the guide identifies the following key barriers and enablers:

a) *Environmental:* the water sector often lacks adequate climate information to plan, develop, and manage water sustainably to ensure that environmental limits are not reached. There is often a lack of time and funds for policy and decision-makers to be familiar with the latest environmental technologies.

b) *Economic and financial:* water pricing is often insufficient to cover the maintenance cost and investments in new water management technologies. Rising operation and maintenance (O&M) costs and declining revenues resulting from inefficient water management, threaten funding sources for new infrastructures but open the opportunity for new technologies to reduce loses and cost.

c) *Cultural and social:* the water sector is perceived as less innovative, resulting in less research and development compared to other sectors. Investment decisions and the success of water security initiatives are influenced by social factors, which can inhibit project viability or the sustainability of outcomes.

[35] See https://www.ctc-n.org/technical-assistance/projects/smart-drinking-water-network-tunisia-first-phase-sousse-and-monastir
[36] See https://www.ctc-n.org/technical-assistance/projects/application-gravity-driven-membrane-gdm-technology-supplying
[37] See https://www.ctc-n.org/technical-assistance/projects/water-recycling-technologies-namibia
[38] See https://www.ctc-n.org/technical-assistance/projects/improvement-water-supply-management-grenada-through-gis-based
[39] See https://www.ctc-n.org/technical-assistance/projects/saline-water-purification-households-and-low-cost-durable-housing
[40] Currently being finalized.

d) *Institutional and regulatory:* institutions may be reluctant to support novel sustainable technologies over traditional hard engineering grey approaches. There may be a lack of political will to implement new technologies and a lack of capacity (financial or technical). In addition, new technologies often face higher regulatory and market costs as compared to existing technologies.

e) *Infrastructure and technical:* a lack of appropriate infrastructure can impede innovation, and current infrastructure may be unable to support alternative practices. For instance, new technologies may require complementary technologies that may not be available or are expensive or difficult to use.

60. The GCF water security sectoral guide refers to the following two pathways to make the GCF investment paradigm-shifting. The first pathway "Enhancing water conservation, water efficiency and water re-use," compels water demand management and competitive water use within the water-food energy nexus, by enhancing water efficiency and distributed water management, removing barriers for water re-use as an alternative water source. This includes a focus on demand management, specifically on water re-use and water efficiency. The second pathway "Strengthening integrated water resources management and water management" encompasses climate proofing of the water infrastructures promoting preservation of water at each step of the water cycle, by maximising technological, institutional, and financial innovation and supporting principles of a circular economy. Specifically, this includes the preservation of water resources, water supply including from new sources, and protection from water-related hazards.

61. In addition, the sectoral guide notes the vision for a paradigm shift in water security to secure water resilience and water services under conditions of increased climate change impacts. This can be achieved through integrated adaptative planning and policies that: (i) compel water demand management by enhancing water efficiency and removing barriers; and (ii) encompass climate proofing of water infrastructures, promoting the preservation of water at each step of the water cycle, by maximising innovation and supporting circular economy principles. Furthermore, that the GCF water sector portfolio is distributed between Integrated Water Resource Management, Water, Sanitation and Hygiene (WASH) and Integrated Flood and Drought Management. The guide highlights various projects, including:

a) In Kiribati, the South Tarawa Water Supply project aims to address affordability and willingness to pay for water services.[41] In particular, the project aims to increase the climate resilience of the water services through a seawater reverse osmosis desalination plant powered by a new solar photovoltaic installation.

b) In Palestine, the Water Banking and Adaptation of Agriculture to Climate Change in Northern Gaza project aims to develop an integrated low carbon water management scheme to reduce the impact of climate change and deliver additional amounts of water usable for sustaining agriculture and increasing the resilience of local populations in Gaza.[42] It will achieve this through the following three outcomes: reducing the vulnerability of Gaza's coastal aquifer and securing sustainability of access to domestic and agricultural water; promoting climate-resilient and water-efficient agriculture; and enhancing the institutional and operational capabilities for integrated and resilient water management.

62. In the water management sector, the Adaptation Fund is supporting countries to deploy adaptation technologies to boost their resilience. This includes helping tackle climate change-related challenges that are exacerbated by social pressures - such as an influx of displaced persons increasing pressure on water supply – through hard technologies including rainwater harvesting and waste water treatment and reuse, software-related measures like awareness raising and capacity-building to maintain and replicate such hardware, and orgware-related actions such as improving policies and regulations to further increase resilience. Such cases illustrate how adaptation technology needs are dynamic, and how countries must sometimes plan and deploy these technologies while navigating multiple overlapping crises.

63. In its project database, as at 10 March 2022, the Adaptation Fund lists 17 projects under the water sector category. Of these, five have been completed, nine are under implementation, and three have had their proposal approved. Completed projects include:

[41] See https://www.greenclimate.fund/project/fp091
[42] See https://www.greenclimate.fund/project/fp119

a) The Developing Climate Resilient Flood and Flash Flood Management Practices to Protect Vulnerable Communities of Georgia project, which included designing a range of hard flood management technologies and practices such as bank terracing, vegetative buffers, and tree revetments.[43] It also included orgware elements – introducing a floodplain development policy – and software elements – training authorities charged with climate risk management on climate risk management planning and flood prevention.

b) The Addressing Climate Change Risks on Water Resources in Honduras: Increased Systemic Resilience and Reduced Vulnerability of the Urban Poor project enabled the installation of automatic hydrometeorological stations, piloting of low-cost water storage facilities and water pricing and risk transfer/insurance systems, updating of climate-related risk maps, and training on integrating climate adaptation data in decision-making.[44]

64. Over the years, the GEF has also helped address a wide range of water management related needs. For example, modifying the design of reservoirs and irrigation channels so that they take into account climate change impacts; improving rainwater harvesting facilities; bolstering the expertise and awareness of key institutions and stakeholders; integrating climate change risks into policies, plans, and programmes that govern integrated water resources management; and more.

65. Private enterprises are also developing and implementing innovative technologies in the water resources sector that meet some of the technological priorities and needs outlined by Parties in their plans, commitments and communications. See box 4 for an example.

Box 4: Producing drinking water through innovative water harvesting technology

SOURCE Global is a water harvesting technology company that builds solar-powered "hydropanels" that produce renewable drinking water for homes, schools, workplaces and communities by pulling moisture from the air. The company has installed thousands of these panels in around 50 countries, helping to create a reliable, resilient and affordable supply of clean drinking water.

On the island of Atauro in Timor-Leste, the small population relies on rainwater that is prone to contamination and is running out during long dry seasons, which are lengthening, partly as a result of climate change. Villagers – mostly women – must then walk long distances to reach remaining water sources. They also import single-use plastic water bottles or, as a last resort, relocate entirely until the end of the dry season, which leaves their rich marine life vulnerable to illegal plunder by outsiders. In 2018, 80 hydropanels were installed on Atauro, enabling the villagers to remain in their communities year-round and generating a clean drinking water supply that is reliable even in the face of lengthening dry seasons.

Similarly, in Maharashtra, India, students at Zilla Parishad Primary School Kolpimpri – located in a region prone to severe drought – students lacked access to safe drinking water. Hydropanels installed in the village created a source of clean, reliable drinking water that is resilient to droughts. This effort also supported the local government's initiative with the aim of transforming villages to align with the Sustainable Development Goals.

Sources: (1) https://www.aiib.org/en/news-events/media-center/blog/2021/Water-from-Air-Climate-Resilience-with-Lightsmith.html; (2) https://www.source.co/resources/case-studies/zilla-parishad-primary-school-kolpimpri/

66. Nature-based solutions are gaining traction in efforts to adapt to climate change, including in the water sector. These solutions – such as constructed wetlands – assist with stormwater and flood/drought risk management, facilitate water pollution control, and benefits across the water-food-energy nexus (i.e.

[43] See https://www.adaptation-fund.org/project/developing-climate-resilient-flood-and-flash-flood-management-practices-to-protect-vulnerable-communities-of-georgia/

[44] See https://www.adaptation-fund.org/project/addressing-climate-change-risks-on-water-resources-in-honduras-increased-systemic-resilience-and-reduced-vulnerability-of-the-urban-poor/

making water available for food and energy production) (Oral et al., 2020). Constructed wetlands in particular can also provide ancillary benefits, such as creating recreational areas or ecological niches in urban areas.

67. In their national reports to the UNFCCC, some Parties also provide examples of nature-based solutions for the water sector being implemented. This includes, for example, creating large urban green spaces to strengthen wetland ecosystem health and improve flood resilience and restoring peatlands to reduce downstream flood risk, filter water, and increase biodiversity. Oral et al. (2020) document a range of examples of nature-based solutions for urban water management being implemented in urban areas throughout Europe.

68. Indigenous peoples around the world have also long practiced a variety of techniques that work in concert with nature and their environments to manage water supply and quality, including in water stressed environments (IFAD, 2016). For example, indigenous peoples in South Asia have harvested rainwater for centuries by scooping earth to build embankments around farms to trap rainwater. The Amazigh people in Tunisia, meanwhile, use a system of dams and terraces to collect run-off water ("the jessour system") in order to cultivate various crops. See Box 5 for another example.

Box 5: Lo-TEK Water Technology: Qanat Underground Aqueducts, Iran

Originating around 500 BCE in what is present-day Iran, Qanat underground aqueducts "are meticulously designed tunnels and channels" that have long served to move direct water from mountain aquifers to agricultural areas and cities in low-lying areas. At its most basic, these systems consist of three components: a mother well, a series of vertical shafts, and a gently sloping horizontal channel.

Through precise engineering, the tunnel systems are dug under the slope of a mountain following a survey of the terrain to look for signs of seepage or water. After a site is deemed appropriate, specialist diggers construct a trial well, hauling out excavated materials to build a spoil crater surrounding the shaft. This crater stops the shaft from being contaminated by surface runoff and stilt. The first section of the qanat collects water from the aquifer, the central and longest portion delivers this water over great distances while reducing evaporation loss, and the mouth serves as a public foundation. Non-potable water is then used for irrigation, after being distributed through the village and arriving at the agricultural zone. Rather than continually extracting water, qanats release it back to its aquifer at the end.

Although this technology has stood the test of time and represents a sustainable method for securing water supplies in water-stressed areas, it is increasingly difficult to build new qanat systems or maintain existing ones due to factors such as the cost of construction, government fragmentation or isolation, and division of large landholdings into smaller ones. Instead, wells – which deplete aquifers and use power-intensive diesel pumps – are increasingly the favoured option. This is leading to "the loss of ecologically conscious water infrastructures, ancient knowledge, vernacular construction skills, and community frameworks, built around the sharing of natural resources." The technology still has potential, however, to be applied more widely in arid environments.

Source: Watson, 2020.

4.3. Coastal zones

69. Similar to the agriculture and water resources sectors, the CTCN is also providing support to developing countries in the area of adaptation technologies for coastal zones. As at 7 March 2022, it lists 10 projects across 19 countries,[45] of which three are being implemented and the remaining seven have been

[45] Two of the projects are regional: one includes eight countries while the other includes four.

completed.[46] The projects being implemented include support to Panama to develop a marine dynamics database for its coastal zones to assess impacts and vulnerability to sea level rise[47] and support to Kiribati, Marshall Islands, Palau, and the Solomon Islands to build capacity to address risks in coastal zones, with actions related to assembling and cataloguing coastal terrain and bathymetric data, producing terrain models, developing and interpreting wave inundation models, and more.[48] Completed projects have supported, for example, Argentina to update tools for studying coastal morphology and monitoring the effects of climate change in coastal zones[49] and Mauritius to sustainably manage and nourish its beaches[50] and to conduct a climate change vulnerability and adaptation study, including an action plan, for its Port.[51]

70. While the GCF currently has no sectoral guide dedicated to coastal zones, the GCF portfolio includes several projects and programmes that are financing adaptation actions in coastal zones. In these projects, the following issues are referred to as urgent needs and priorities that may be addressed through GCF financing: coastal adaptation needs due to slow onset events, including relative sea-level rise and the associated flooding arising from extreme weather events; coastal flooding and saline intrusion; changes in monsoon rainfall patterns and drought frequency; coral bleaching, sea-level rise reducing the area in which mangroves can thrive; damaged coastal ecosystems; increasingly intensive wave action on key infrastructure; reduction and growing scarcity in freshwater resources; beach erosion; among others.

71. The GCF investment in coastal areas supporting the uptake of adaptation technology continues to be guided by existing policies and investment frameworks. The following projects demonstrate how the GCF invests in the implementation of adaptation measures in coastal areas:

a) The Enhancing Climate Information and Knowledge Services for resilience in five island countries of the Pacific Ocean project was approved by the GCF Board in 2020. The project aims to support increasing climate-resilient sustainable development of 100,000 beneficiaries in the Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. In terms of investing in the uptake of various technologies, for example, the project will fund observation technologies for enhanced observations, modelling and forecasting. In addition, the project will complement and contribute incidentally to other ongoing technology transfer activities (data management software, use of software in generating forecasts, etc.) and capacity development through its work on climate forecasting capacity and application.

b) The Monrovia Metropolitan Climate Resilience Project envisages enhancing the resiliency of vulnerable coastal communities to climate-induced sea-level rise by constructing coastal defence structures, developing a coastal zone management plan, and supporting livelihood diversification. In the context of supporting relevant adaptation technology uptake, the project aims to support the procurement of an integrated real-time oceanographic monitoring system, among others.

72. Similarly, projects in the Adaptation Fund portfolio are addressing needs related to coastal zone management. These include strengthening the adaptive capacity of traditional fishermen dealing with climate change induced shifts in fish migration and circulation patterns, restoring coastal ecosystems, designing and developing supporting facilities to anticipate coastal flooding and tidal waves.

73. The Adaptation Fund lists 11 projects in nine countries as at 10 March 2022 that are categorized under the coastal management sector in its database. Of these, three have been completed, six are being implemented, and a further two have been approved. Completed projects include:

a) In Senegal, the Adaptation to Coastal Erosion in Vulnerable Areas project involved implementing physical adaptation measures, such as anti-salt dikes, seawalls, and underwater berms, alongside

[46] See https://www.ctc-n.org/technical-assistance/data?f%5B0%5D=ta_page_objective_facets%3A14912&f%5B1%5D=ta_page_sectors_facets%3A3

[47] See https://www.ctc-n.org/technical-assistance/projects/development-marine-dynamics-database-panamanian-coasts-assess

[48] See https://www.ctc-n.org/technical-assistance/projects/capacity-development-address-risks-coastal-zones

[49] See https://www.ctc-n.org/technical-assistance/projects/technologies-coastal-management-province-buenos-aires

[50] See https://www.ctc-n.org/technical-assistance/projects/identification-characterization-and-exploitation-potential-offshore

[51] See https://www.ctc-n.org/technical-assistance/projects/climate-change-vulnerability-and-adaptation-study-port-port-louis

training residents in adaptation measures and developing coastal zone management policies and regulations.[52]

b) The Implementation of Concrete Adaptation Measures to Reduce Vulnerability of Livelihood and Economy of Coastal Communities in Tanzania project included the construction of seawalls and groynes, the restoration of coastal mangroves, policy and planning measures, as well as various capacity building and training initiatives. Notably, the final evaluation report suggested that the delivery of hard adaptation measures was more effective than efforts related to capacity development, enhancing public engagement, and planning-policy linkages.[53]

74. Under the GEF, support for adaptation in coastal zones is also addressing various needs, such as coping with sea level rise and its impacts on food security and livelihood resilience, by funding actions like the demonstration of community-based adaptation options and the revision of coastal development policies and strategies; developing early warning systems for coastal flooding and other extreme events; or securing potable water for communities vulnerable to saline intrusion, such as rainwater harvesting and micro surface and ground water treatment facilities.

4.4. Good practices, gaps, needs, and challenges

4.4.1. Agriculture

75. Parties in their TNAs have identified various barriers to the development and transfer of prioritized technologies in the agriculture sector. One hundred per cent of Parties included in the *Fourth synthesis of technology needs* reported economic and financial barriers; these include a lack of or inadequate access to financial resources for the required technologies, high production costs, inappropriate financial incentives and disincentives, financial unviability, high transaction costs, and uncertain macro-economic and financial environments.[54] To address these barriers, Parties identified several enabling measures, including strengthening existing or establishing new financial mechanisms, policies, incentives, or subsidies; reviewing national policies to, for example, address price competitiveness; or create an allowance in the national budget for the prioritized technology, including for research and development activities.

76. The second most common type of barrier related to policy, legal and regulatory issues, with Parties frequently reporting insufficient legal and regulatory frameworks, insufficient enforcement, policy intermittency and uncertainty, a clash of interests between proponents of new and incumbent technologies, and red tape/bureaucracy. Options to address these barriers, as identified in TNAs, include establishing a comprehensive agriculture development policy, revising policy frameworks to, for example, improve access to and secure land, revise regulatory frameworks to include extension services and facilitate their recognition and prioritization, establish quality control systems, and facilitate accreditation and certification systems.

77. Other types of barriers cited in TNAs with respect to adaptation technologies in the agriculture sector include technical, information and awareness, human skills, market failure/imperfection, social, cultural and behavioural, and network failures. Enabling measures identified to address these and other barriers include organizing awareness campaigns, training farmers through field visits to demonstration plots, promoting and strengthening research and development programmes, and establishing coordination and communication channels and exchange of information among partners.

78. With respect to other national reports, in some cases, Parties had the technologies and capacities required for some of their outlined agricultural adaptation measures, whereas other measures required further capacity-building, including for water conservation, soil management, and zero-tillage practices, and additional technologies, including large-scale infrastructure such as grain storage silos. Specific and pressing research gaps and innovation needs pertaining to the agriculture sector were also cited, including related to:

[52] See https://www.adaptation-fund.org/project/adaptation-to-coastal-erosion-in-vulnerable-areas/

[53] https://www.adaptation-fund.org/projects-document-view/?URL=en/744291620254169611/22-4141-AFB2G48-2019-te-unep-gef-af-fsp-spcc-Adaptation-Tanzania.pdf

[54] FCCC/SBI/2020/INF/1, paras. 100-104.

a) Crop types and varieties: drought and heat tolerant, pest and disease resistant, early maturing, appropriate alternative types and varieties;

b) Water use efficiency, efficient irrigation systems, water harvesting;

c) Developing irrigation plans based on future water availability and needs.

d) Farming practices: soil moisture conservation, land management, crop rotation, forecast-based farming, precision agriculture;

e) Predicting shifts in agro-ecological zonation;

f) Applying conservation agriculture technologies and practices.

79. One good practice and opportunity in the area of agriculture is to focus on food systems (production, processing, transportation, and consumption) in a holistic and connected way, rather than on specific aspects of agricultural production more narrowly.[55] Such an approach can help prioritize adaptation technologies that not only reduce risk or increase production, but also provide corollary benefits such as improving health or reducing emissions. See Box 6 for an example of this approach.

Box 6: FOOD 2030 Policy Framework in the European Union

FOOD 2030 is the EU research and innovation policy response to the Paris Agreement, the SDGs, and other recent international policy developments. It calls for a systemic approach to future-proofing nutrition and food systems so that they become sustainable, resilient, diverse, responsible, inclusive, and competitive over the long term. The FOOD 2030 framework aims to cover the entire food system, including food production, processing, packaging, logistics, distribution, healthy people (consumption), and waste streams. It has four priorities:

(1) Nutrition for sustainable and healthy diets;
(2) Climate-smart and environmentally sustainable food systems;
(3) Circular and resource efficient food systems; and
(4) Innovation and empowerment of communities.

Under the second priority, it aims at, for example, enabling precision agriculture technologies for small farmers to increase the efficiency of water use and the use of other inputs; improving soil health through improved management techniques, including an innovative technology that replaces natural humus in degraded soils while increasing crop yields and reducing water use and pollution; and more.

Sources: European Commission, 2017a; European Commission, 2017b.

4.4.2. Water resources

80. In their national reports, Parties outlined technology- and innovation-related weaknesses and knowledge gaps that could potentially undermine the feasibility of their planned adaptation measures in the water resources sector. This includes poor water resources management, lack of modern technologies, insufficient research on climate change impacts on water resources and, specifically, a lack of hydrometeorological information and climate change projections broken down by biome, a lack of economical methods for reducing surface water evaporation from large multipurpose reservoirs, and limited information on groundwater resources, wells and aquifers, including their quality, quantity, extraction and safe yield. Some capacity needs also relate to the construction and operation of specific water-related infrastructure such as desalination plants and large dams. To help address these gaps and weaknesses, Parties plan to, among other things, pursue and promote technology transfer and related capacity-building opportunities in accordance with the principles and frameworks under the UNFCCC.

[55] FCCC/SB/2021/3/Add.1, para. 10.

81. Opportunities and good practices in this area include mainstreaming adaptation into integrated water resources management (IWRM), which is "a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment."[56] While incorporating adaptation into IWRM may increase its implementation burden, a holistic approach is necessary to deal with the complex problems - such as those that lie at the intersection of climate change and water management – and success in both IWRM and adaptation shares some key elements, including public participation and information sharing (Giupponi and Gain, 2017). While IWRM itself is a form of orgware, it can provide the framework for identifying, applying, and monitoring the use of adaptation hardware in the water sector. Indeed, various parties highlight IWRM as part of their water sector adaptation plans, highlighting intentions to provide full support for IWRM or strengthen IWRM for a multi-layered development of national water resources infrastructure, while some mention progress already made in implementing IWRM.

4.4.3. Coastal zones

82. Gaps highlighted with respect to implementing measures for coastal zones in NAPs include lack of communication, data access, and up to date information and data on coastal characteristics, dynamics, and related behavioural patterns. Further gaps that impact the application of adaptation technologies in coastal zones include lack of policies, legislation, and restrictions limiting and controlling new construction in coastal areas. Parties also highlighted equipment and technology needs for implementing their prioritized coastal zone adaptation measures, including advanced technologies for pumping sand from the sea bed to support beach nourishment and reclamation, as well as equipment and laboratories to support data collection and analysis for assessing both the vulnerability of beaches the efficacy of related adaptation measures. In a related vein, there are also capacity and training needs to bolster the knowledge and skills required for implemented these advanced technologies for nourishment and reclamation, and for operating advanced data collection and analysis equipment.

83. Parties also cited related needs in their national reports, including technical expertise and financial support for mangrove restoration efforts and other coastal protection measures. Examples of good practices, drawn from a CTCN-supported project to develop a NAP for coastal zones in Uruguay, included: reducing uncertainty in identifying at risk zones by "combining high-resolution basic information with impact process models and a probabilistic approach;" following a gender-responsive approach to measure inequalities in control of and access to resources, as well as participation in related decision-making, in coastal zones; and ensuring long-term sustainability of climate modelling and vulnerability assessment technology through shared ownership platforms that involve governments at differently levels as well as academic and civil society stakeholders (TEC and CTCN, 2021).

5. Cross-cutting issues in the identification and uptake of adaptation technologies

5.1. Innovative technologies and approaches

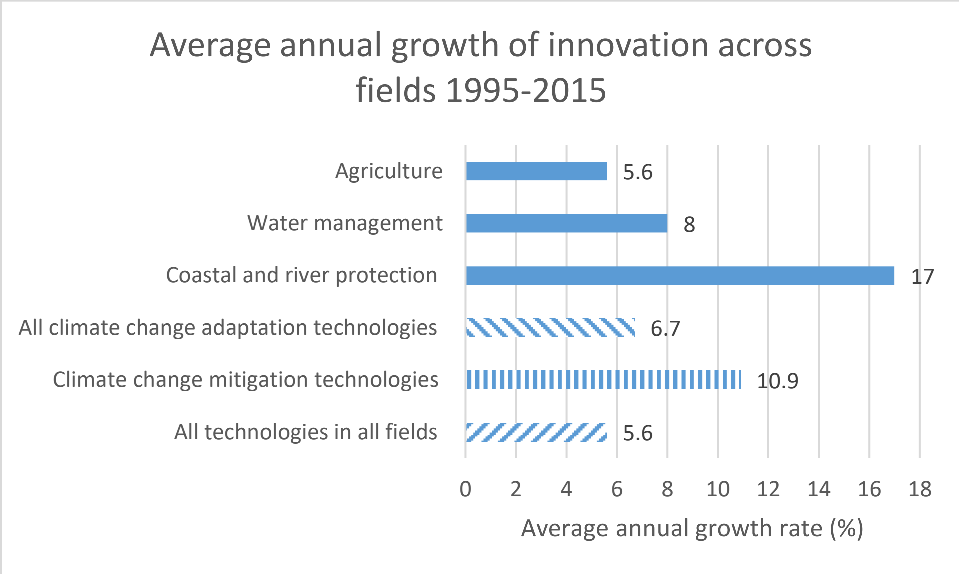
84. Innovation can be defined as "the process by which new ideas are developed to respond to societal, environmental, and economic needs" (UNFCCC, 2018). Although many adaptation measures can be implemented with existing technologies and management practices, technologies can nonetheless "expand the range of adaptation possibilities"(Mimura et al., 2014). Indeed, the Paris Agreement states that "[a]ccelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development."[57] Innovation can thus play an important role in meeting the adaptation-related goals of the Paris Agreement and achieving the Sustainable Development goals, given that the new products, services, businesses, behavioural change, and organizational models generated through innovation can scale and speed up climate action (UNFCCC, 2018).

[56] See https://www.gwp.org/en/GWP-CEE/about/why/what-is-iwrm/#:~:text=Integrated%20Water%20Resources%20Management%20(IWRM,vital%20ecosystems%20and%20the%20environment.

[57] Article10, para. 5 of the Paris Agreement.

85. One approach for measuring the level of technological innovation for adaptation is by assessing trends in patent filings over time. One such analysis of high-value patents (i.e. those filed in at least two patent offices) based on data from the World Patent Statistical Database found an annual growth rate of adaptation patents of 6.7 per cent between 1995 and 2015 (Dechezleprêtre et al., 2020). This is comparable to the growth rate in filed patents for all technologies across all fields (5.6 per cent), but significantly lower than that for climate change mitigation technologies (10.9 per cent). This figure does not represent a proportional rise in adaptation innovation, however, as it has remained relatively constant over time while the urgency of adaptation has only grown. What's more, more than one quarter of adaptation patents were for technologies categorized under both adaptation and mitigation. The growth rates for adaptation technologies also vary across sectors, with a very high rate in coastal and river protection, for example, but a rate below average for agricultural technologies (see figure 4).

Figure 4. Average annual growth of innocation across fields 1995-2015



Source: (Dechezleprêtre et al., 2020).

86. Beneath these figures lies a striking imbalance in both the generation of and access to innovations in climate change adaptation. The top ten countries generating high-value adaptation patents account for almost 80 per cent of the total, of which eight are developed countries and the remaining two are middle-income countries (Dechezleprêtre et al., 2020). While this concentration of adaptation innovation activity could be counterbalanced by international technology transfer, this does not appear to be occurring (see section 2.4 above). Instead, what emerges is an inverse correlation between climate change vulnerability and adaptation needs on the one hand, and diffusion of adaptation technologies on the other.

87. Frontier technologies – that is, technologies that are new, cutting-edge, innovative, and often disruptive – have significant potential to address climate change and help tackle other environmental challenges (ITU et al., 2020). These technologies continue to proliferate, and include artificial intelligence, digitalization and big data, 5G, the Internet of Things, and more. While these technologies may be a "double-edged sword" that sometimes "bring unintended consequence to the detriment of the environment and societies" (ITU et al., 2020), it is nonetheless worth exploring the potential application of these technologies to enhancing adaptive capacity, building resilience, and reducing vulnerability to the impacts of climate change. Indeed, technology choices and systems generally can both reduce and exacerbate climate risks depending on the timeframe and other circumstances (Mimura et al., 2014), and frontier technologies are no different in that respect.

88. Artificial intelligence, or AI, is a growing field "which combines computer science and robust datasets, to enable problem-solving" (IBM Cloud Education, 2020). Among its sub-fields are machine learning and deep learning, in which AI algorithms are used to build expert systems capable of making predictions or classifications based on data. Under the UN system, there are existing efforts to apply AI to reduce hydrological risk. For example, UNESCO's International Hydrological Programme, in partnership with the

Center for Hydrometeorology and Remote Sensing at the University of California, Irvine, developed the G-WADI PERSIANN-CCS[58] Geoserver, which uses remote sensing technologies in combination with AI to estimate real-time precipitation (ITU et al., 2020). It does so by using an adaptive neural network algorithm that combines information drawn from various satellites, with a cloud classification system algorithm that is optimized for observing extreme precipitation.[59] This tool helps inform emergency management and planning for droughts, floods, and other hydrological risks around the world. In Namibia, for example, the Namibian Drought Hydrological Services prepares daily bulletins for local communities containing up-to-date information on flood and drought conditions.

89. There are also private sector enterprises that are beginning to offer related services. For example, the company One Concern combines AI/machine learning with human-centric disaster science through probabilistic models that generate dynamic predictions. These predictions facilitate disaster preparedness, response, and mitigation.[60] The company is aiming to create “the world’s digital twin” by building a digital architecture mirroring the natural and built environments and the complex systems in which they’re embedded.[61] The models use data from various sources, including open source providers, private providers, and the individual clients that the company works with; the models learn, evolve, and scale as more data is fed into them. Their tools can, for example, generate block-by-block level impact predictions for specific events, which help to assess the likelihood of damage in multiple disaster scenarios. This, in turn, allows for improved identification of shelters and assessment of shelter locations post-disaster.

90. Cervest, another company, provides asset-level analysis that helps clients to anticipate and act on climate risks by combining machine learning, climate science, and scalable computing.[62] The company’s services are powered by earth science AI technologies, which fuse real-time data from global sensors with historic data and forecasts to shed light onto the past, present, and future. These services are suitable for various clients, including businesses, insurance companies, and governments.

91. These companies represent only two examples of a growing fields of start-ups that offer what they term climate intelligence services or resilience-as-a-service; their tools, which integrate frontier technologies, can be applied to advance adaptation action across a range of sectors and locations.

92. In the agriculture sector specifically, the practice of precision agriculture is also being advanced by AI technologies, and by start-ups providing related services. Precision agriculture, in contrast to conventional agricultural management, entails “the application of modern information technologies to provide, process, and analyse multisource data of high spatial and temporal resolution for decision making and operations in the management of crop production” (National Research Council, 1997). By using AI in the agriculture sector, farmers are able to improve their crop yields using fewer inputs, such as seeds, water, pesticides, and herbicides, as well as fewer emissions; such data-driven management can help grow more with less, and contribute to overcoming some of the challenges to the sector posed by climate change and population growth (Linaza et al., 2021). Despite this potential, the adoption of these technologies is not currently widespread due to lack of knowledge, among other factors. Indeed, the underlying algorithms can often “look like black box systems for farmers,” and their results can be difficult to understand (Linaza et al., 2021). In response, various start-ups are now providing AI-powered precision agriculture tools and insights tailored to farmers. Examples include Prospera,[63] which uses AI and machine learning to help farmers optimize factors from fertilization to pollination, and Ceres,[64] which focuses on irrigation, helping to detect problems like clogs and leaks, quantify various issues and their potential impact on yields, and improve systems by correcting overwatering and underwatering and optimizing system design and scheduling to terrain and soil conditions. What’s more, these firms strive to present the information in ways that enable decision-making by farmers; for example, Ceres’ services are designed to integrate with existing farm management software. While these new ventures and technological applications show great promise, it will

[58] The abbreviation stands for Global Network on Water and Development Information for Arid Lands (G-WADI) Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks - Cloud Classification System (PERSIANN-CCS).
[59] See https://gwadi.org/persiann-family-precipitation-estimation-products
[60] See https://oneconcern.com/en/platform/
[61] See https://oneconcern.com/en/technology/
[62] See https://cervest.earth/
[63] See https://www.prospera.ag/main
[64] See https://www.ceresimaging.net/

be important to consider how these products and services can be distributed to the people and places who stand to gain in order to fully realize their potential. Notably in the agriculture sector, this includes smallholder farmers, who often "lack access to inputs, technical advice, credit and other financial services" and therefore "are unable to access technologies that improve the resilience of crop systems to specific climate stressors and reduce yield gaps" (FAO, 2021).

93. Innovation is not limited to the development and deployment of new and disruptive "hard" technologies, but also encompasses changes in institutions and organizations, as well as new business models and services (OECD, World Bank, and UN Environment, 2018). Beyond innovations in individual technologies, systemic innovations are increasingly recognized as integral to addressing the challenge of climate change (EIT Climate-KIC, 2020). EIT Climate-KIC, a knowledge and innovation community (KIC) supported by the European Institute of Innovation and Technology, aims to catalyse such innovation through "deep demonstrations." These demonstrations are large-scale projects through which bespoke innovation portfolios are developed in order to catalyse systems change. Many of these deep demonstrations aim at facilitating mitigation and adaptation in the agriculture and land-use sector. For example, the "Friendly Fruit" project is aiming to transform agricultural practices in strawberry and apple cultivation through innovations "such as pest-resistant and high-performing fruit varieties better adapted to weather changes, mechanical weeding systems intended to decrease herbicide use, and subsoil smart-sensors which monitor water levels." The project seeks to systematise sustainable agricultural practices and strengthen agricultural supply chains facing challenges ranging from early and erratic crop flowering and lower fruit quality to new diseases and water supply issues. Another initiative – EIT Climate-KIC's Carbon Farming project – is deploying a systemic approach to increase soil carbon sequestration (SCS), a nature-based solution that offers both mitigation and adaptation benefits. On the adaptation side, the storage of carbon in the soil increases its organic matter, leading to increased water retention capacity and fertility, which in turn help crops better adjust to drought conditions. The project currently has components in France, Switzerland, the Netherlands, and Sweden.[65] For example, in France, corn farmers are being encouraged to grow cover crops like clover, which are grown primarily for the benefit of the soil and help suppress weeds, enhance fertility and quality, reduce erosion, promote biodiversity, and discourage pests and diseases. In addition to benefits such as improved yields and lower input costs from pesticide and fertilizer, farmers are also incentivized by a carbon premium of approximately €75 per tonne of carbon permanently fixed in the soil. Remote sensing technologies are also being deployed through the project to provide a simple evaluation of the SCS.

94. One important component of orgware that can support technological innovation is the national system of innovation, which encompasses the organizations, systems, and incentives in a given country that stimulate technology generation and adaptation (Nelson, 1993). Indeed, the importance of these systems – in particular for the water and agriculture sectors - has been recognized in some Parties' NAPs, wherein some prioritize supporting and establishing systems of innovation to promote adaptation technology and development transfer. The national system of innovation, in turn, is the foundation on which a country's entrepreneurial ecosystem rests; entrepreneurial ecosystems refer to "sets of actors, institutions, social networks, and cultural values that produce and sustain entrepreneurial activity" (Roundy, Bradshaw, and Brockman, 2018). Entrepreneurial ecosystems are important in supporting the various stages of technology development and entrepreneurship and the different actors that participate in entrepreneurial activities, including start-ups who develop new climate technologies and existing enterprises "who adopt and adapt climate technologies" (UNFCCC, 2018). Incubators and accelerators are increasingly important parts of these ecosystems that provide support to start-ups and can, in turn, help catalyse technology entrepreneurship for adaptation. The term "incubator" encapsulates a range of institutions and environments that support start-ups through services such as physical locations; business, marketing, information and technical services; financial support, and networking. Accelerators, by contrast, are institutions that provide short-term services such as mentoring, peer review, and skills transfer with the aim of speeding up the successful creation of ventures, generally seeking a shareholding percentage in return. There have been doubts raised about the capacity for accelerators to facilitate climate-related technology entrepreneurship – given, for example, the short time periods which are well suited to digital technologies but may be insufficient for hardware related start-ups, such as those producing drip irrigation systems (Racine, 2017), and that there are sometimes uncertain paths to commercialization in the climate

[65] See https://www.climate-kic.org/innovation-spotlight/carbon-farming-is-innovating-land-use/

technology space (Malek, Maine, and McCarthy, 2014) – but there are existing attempts to adapt the accelerator model to better serve climate entrepreneurship, including the World Bank's infoDev programme (UNFCCC, 2018).

95. It is estimated that about 70 incubators and accelerators worldwide – under two per cent of the total - focus on climate technology, with the majority of these located in Europe and North America[66] (UNFCCC, 2018). Many of these focus on mitigation technologies, though there are examples of incubators and accelerators supporting the development of adaptation technologies, including in the agriculture and water sectors. For example, the United Nations Development Organization global cleantech innovation programme has supported the development of Tarla.io Risk, a one-click service climate risk information service for farmers, by Turkish entrepreneurs. It helps farmers boost their yield and resulting profits by offering hyperlocal statistics and insights that enable climate-informed crop planting. Another example is the Kenya Climate Innovation Centre, which supports adaptation technology development especially in the agriculture and water sectors. It supported, for example, SwissQuest Water Supplies, a venture offering smart water metering solutions that increase water use efficiency through prepaid water meters equipped with water valve control functions and radio communication. Other adaptation technologies supported by the Centre in the water sector include filters, purifiers, and desalination units, while those supported in the agriculture sector relate to irrigation, fertilizers, land management, and more.

96. While it is thus important to set up the conditions to encourage and support innovation domestically, it is also critical to ensure that adaptation innovations in the agriculture, water resources, and coastal zone sectors and beyond are made widely available. Considering that "no single government has all the technological, scientific, financial and other resources needed" to adapt to climate change and more broadly address the climate crisis, "it is important that strong national policies for innovation are accompanied by effective international cooperation in the development and diffusion of innovations" (OECD, World Bank, and UN Environment, 2018). Developing and least developed countries in particular should be supported in both accessing innovative technologies for adaptation and bolstering their capacity to generate such innovations domestically. As discussed above, calls to facilitate and finance technology transfer and related support to developing countries in the service of climate action are at least as old as the UNFCCC regime itself; it is revealing that, more than a quarter of a century later, these calls only grow in urgency each year. Indeed, it is important to heed the warning of the IPCC that "[t]echnology-led, market-led or state-led transitions aimed at meeting Paris Agreement [objectives] and SDGs may fail without integrating dimensions of social justice and addressing the social and political exclusion that prevent the disadvantages from accessing such improvements and increasing their incomes" (IPCC, 2022).

5.2. Regulatory issues

97. Beyond stakeholder engagement, policies and regulations have an important role to play in facilitating the development and uptake of adaptation technologies. In their fifth assessment report, the IPCC concluded that strengthening policy and regulatory environments, alongside capacities to absorb, employ and improve technologies suited to local circumstances, may also influence the success of technology transfer (Mimura et al., 2014). Regulations encompass measures such as standards and obligations, zoning and spatial planning, disclosure obligation, building codes, and related rules (Nachmany, Byrnes, and Surminski, 2019). Policy, legal and regulatory barriers to the development and deployment of adaptation are widespread, however; these were cited by 98 per cent of Parties included in the *Fourth synthesis of technology needs*, with insufficient legal and regulatory frameworks listed as the most common type of barrier within this category (cited by 92 per cent of Parties).[67]

98. To overcome these barriers, as part of the orgware-related measures Parties highlight in their national documents, several reference plans to update or introduce regulatory measures to support their adaptation measures in relation to agriculture, water resources, and coastal zones. Related to coastal zones, plans to improve the regulatory framework to combat coastal erosion or develop and implement regulations, laws,

[66] This is one feature of the climate entrepreneurship landscape among many that make climate technology entrepreneurship more difficult for those in developing countries. Other challenges include more difficulty launching start-ups due to limited personal assets or assets from friends and family, and limited government-funded promotional programmes, and few early-stage or angel investors (Green Climate Fund, 2021).
[67] FCCC/SBI/2020/INF/1, paras. 96-97.

and policies that integrate climate change resilience into infrastructure planning and development have been highlighted by Parties; with respect to infrastructure, this includes developing design criteria to protect assets in flood risk areas, such as protecting mangrove forests and prohibiting coastal sand and shell ridge removal.

99. To support the implementation of nature-based solutions or integrated green-grey approaches, regulatory changes may be especially vital. Existing regulations and standards have largely been designed under the assumption that traditional grey infrastructures are the primary, or even only option, which may have generated regulatory environments that are biased towards these infrastructures and complicate the feasibility of deploying nature-based solutions. In the water sector, specific elements of regulatory and policy environments that should be evaluated include land-use regulations and zoning, permitting, safety and performance codes and standards, procurement policies, land rights, and environmental protection regulations (OECD, 2020). In the case of green-grey approaches for coastal zone adaptation technologies, enabling regulatory and policy environments must cut across various types and instruments of regulation, including "land-use regulations, marine planning and zoning, building codes, and engineering guidelines" (TEC et al., 2021). Related regulations should also be adaptable in order to help foster further innovation, because innovations that cannot be permitted, approved, or funded ultimately cannot deliver benefits.

100. An enabling policy environment more generally can support the creation and adoption of adaptation technologies. This includes both supply-side policies – which help boost the development and availability of new technologies - and demand-side policies – which help create a market pull for technological and other climate innovations. On the supply-side, governments can use policy tools to bolster research and development of adaptation technologies, including direct funding of the research and development process through loans and grants or tax credits and other fiscal incentives (OECD, World Bank, and UN Environment, 2018). Public research specifically can play a role in not only stimulating the creation of new technologies, but also investigating how to deliver systemic innovations by also investigating related socioeconomic and political factors that may influence, for example, behaviours underlying the acceptance and adoption of new technologies. For more on systemic innovation, see section 5.1 above.

101. It is also important that such enabling environments link implementation to policy and regulatory frameworks bidirectionally, such that regulations and policies not only steer implementation but also reflect the realities of implementation, including the viability of technologies in technical, economic, social, and institutional terms (TEC and CTCN, 2021).

102. Through its technical assistance, the CTCN has been working with countries to modify their regulatory environments in order to be more adaptation technology friendly. For example, in coordination with the World Agroforestry Centre, the CTCN supported Nepal's development of a National Agroforestry Policy. Through this project, an analyses of existing policies and laws revealed various regulations that deter the adoption of agroforestry practices, such as restrictive regulations on felling, transport, and marketing of tree species.[68] In other cases, it is the lack of legal and regulatory frameworks that is the core issue; for example, the CTCN is assisting with the establishment of an integrated coastal zone management plan in Liberia, where climate change-related impacts on coastal areas, along with human activities such as unregulated beach sand mining and construction on beaches, contribute to coastal erosion.[69]

5.2.1. Innovative approaches

103. Governments can consider modifying their public procurement policies and regulations to further support adaptation action and stimulate technological innovation in service of resilience building. The World Bank estimates that, in 2018, public procurement globally amounted to USD 11 trillion or 12 per cent of global GDP (Bosio and Djankov, 2020). This spending can be used to stimulate the development of climate technologies and boost demand for these technologies across sectors (Filer, 2021). Often discussed under the banner of "green public procurement," these efforts frequently focus on greenhouse gas mitigation but can also be directed toward adaptation-related outcomes, such as protecting soil or conserving water (Hasanbeigi, Becqué, and Springer, 2019). Policymakers can embed climate change

[68] See https://www.ctc-n.org/sites/www.ctc-n.org/files/learning-reports/2016000029_-_nepal_-_closure_report_icraf_.pdf
[69] See https://www.ctc-n.org/system/files/response_plans/20210211_Response%20Plan%20-%20Liberia_signed%20by%20CTCN%20and%20NDE.pdf

adaptation into expected standards for public procurement and, for example, building standards for new builds and refurbishments of buildings owned by the government; policymakers should also ensure that projects commissioned are designed to be climate resilient over their expected lifetime, which can be 50 years or more (Cambray et al., 2009).

5.3. Engagement of stakeholders

104. As with adaptation and climate action more broadly, stakeholder engagement is integral to the successful development and deployment of technologies for adaptation. Stakeholders have a right to participate in the decisions that will affect their lives, livelihoods, and overall futures; what's more, the implementation and maintenance of many adaptation measures, including technologies, will depend on local expertise and active involvement (UNFCCC, 2006). In this vein, the UNFCCC Technology Executive Committee (TEC) delivered a key message to COP 20 recommending that local stakeholders are both "involved and empowered" in relation to adaptation technologies, so that local solutions can be replicated and improved, and in order to "promote the sustainable application of technologies for adaptation."[70] The NAP Technical Guidelines recognize the vital importance of engaging a wide range of stakeholders in adaptation planning and implementation (LEG, 2012), which encompasses planning for and using adaptation technologies. Stakeholder engagement is also a common feature of the TNA process. Indeed, the Handbook for conducting TNAs underscores the role of stakeholders in the process, stating that successful stakeholder engagement can give rise to key benefits, potentially "lead[ing] to transfer of new knowledge, especially local knowledge, and insights on specific technology challenges and opportunities that might otherwise have been missed" (UNDP, 2010). Parties engage stakeholders in the TNA process through different approaches, including creating working groups, consulting experts, organizing meetings and workshops, and more.[71]

105. When it comes to the successful development and deployment of adaptation technologies, the term "stakeholders" encompasses a wide range of groups and organizations that often have different but complementary roles. Table 1 below provides an overview of some of these different stakeholder groups and examples of their respective roles. The table is for illustrative purposes and is non-exhaustive; other stakeholder groups may become involved, the groups and corresponding roles may intersect with one another, and the stakeholder groups listed may take on a variety of roles beyond what is listed below; for example, all stakeholders listed below could play a role in monitoring the implementation of adaptation technologies and providing feedback on the impacts and results of these technologies.

Table 1. The roles of different stakeholder groups in developing and deploying adaptation technologies in the agriculture, water, coastal zone sectors and beyond

Stakeholder group	Roles in adaptation technology development and deployment (non-exhaustive)
Communities	• Select and prioritize appropriate technologies • Deploy adaptation technologies
Research community (e.g. Universities, Research Institutes)	• Develop and tests new technologies
National governments	• Establish policies to support adaptation technologies • Facilitate an enabling environment for adaptation technologies
Local governments	• Support technology users • Assist with scaling-up small-scale or community-led technologies

[70] FCCC/SB/2014/3, para. 53(c)(v).
[71] FCCC/SBI/2020/INF.1, paras. 34-35.

Non-governmental/civil society organizations	• Research, implement, facilitate, monitor, evaluate, and finance adpatation technologies • Facilitate communication among multiple stakeholders • Promote appropriate technologies
Private sector actors (including startups and SMEs)	• Secure financial and non-financial resources • Develop adaptation technologies and provide related services • Capacity-building for technology implementation
International actors (e.g. multilateral development banks, international organizations)	• Provide financial resources • Increase connections among institutions and stakeholders • Promote technologies and supportive frameworks
Youth	• Assist with identifying priorities and options • Implement adaptation technologies
Women	• Identifying priorities and suitable options • Implementing adaptation technologies
Indigenous peoples	• Identifying priorities and suitable options • Implementing indigenous technologies

Sources: TEC, 2014*;* TEC, 2020; UNFCCC, 2021.

106. Some countries identify specific measures for engaging stakeholders in the research, exchange, or use of adaptation technologies. For example, in the agriculture sector, this includes undertaking climate change assessments, crop modelling, and GIS mapping in partnership with a diverse set of stakeholders and enhancing research collaborations with communities, farmers, disadvantaged groups, and research institutions to create communities of practice and knowledge networks that facilitate innovative and adaptive agriculture practices. It also includes undertaking intermediate steps to pave the way for future stakeholder engagement, such as developing viable business models for the private sector to support the development of technologies prioritized or the import of their required elements, or the establishment of competitive financial products and services that can scale up farmers' adoption of adaptation technologies.

107. Specific approaches for implementing adaptation measures and technologies may also provide inherent opportunities for engaging stakeholders. For example, community-based adaptation can help ensure that communities play a role in the adoption of adaptation technologies, which in turn can increase the sustainability and social acceptance of these technologies (UNFCCC, 2014). There are also examples specific to the sectors addressed in this paper. Integrated water resources management not only offers "a valuable and flexible framework for adapting" water resource use to the impacts of climate change, but also points to opportunities to involve communities, including women, "who are in the best position to choose forms of water-supply adaptation that can safeguard the ecosystems on which they depend for cropping, livestock, fisheries and forestry" (UNFCCC, 2006). Climate-smart agriculture, which is reflected in many of the adaptation plans and priorities communicated by Parties, has similarly been highlighted as an opportunity to promote coordinated, multi-stakeholder collaborations.

108. Policy changes can help improve stakeholder engagement in the use of technologies for adaptation. For example, one NAP recognizes that inclusive policies can play a role in enabling women to participate in agricultural activities by ensuring that men and women have the same opportunities and access to technology, technical assistance, extension services, and related training. It further highlights the necessity of taking into account the roles of men and women in the agricultural value chain and considers how public policy can promote the transformation of gender relations so that women can participate on equal footing.

109. Strategies and frameworks specific to certain types of stakeholders can also help generate fruitful engagement. When engaging the private sector, for example, governments can improve their partnerships by creating a dedicated framework for private sector engagement (TEC, 2020). This could include a communications strategy that makes clear how engagement in a particular project or programme contributes to broader goals, and what types of contributions are envisioned from partners.

110. In terms of good practices, stakeholder engagement should be approached as an opportunity to co-design adaptation technology solutions, projects, and programmes with various groups and organizations, rather than an invitation for stakeholders to rubber stamp the use of solutions decided upon elsewhere. This helps to increase the social acceptance of technology projects and programmes (TEC, 2020). This, in turn, may also enhance the long-term sustainability of implemented solutions, as well as their ultimate effectiveness in building resilience or reducing vulnerability to the impacts of climate change.

5.3.1. Innovative approaches

111. Beyond the traditional avenues for engaging stakeholders in the adaptation process, there are emerging innovative approaches for engagement in adaptation technology research, selection, deployment, and upscaling. Mobilizing technology champions – that is, stakeholders who advance a particular technology option at the national or sectoral level – is one such approach that is emerging through the TNA process (TEC, 2020). These champions can help accelerate the implementation of climate change technologies in developing country contexts by, for example, lobbying for a technology or incentives to support its uptake, or organizing events to showcase and promote technologies. Champions may emerge from the public, private, or non-profit sectors, or beyond, and can act based on business or personal interests, as well as in one's capacity as a representative of a stakeholder community or interest group (TEC, 2019). Winners of the Gender Just Climate Solutions Awards are prime examples of technology champions who, on top of contributing tangibly to adaptation efforts, also empower women and promote their democratic rights and participation. Launched by the UNFCCC Women and Gender Constituency in 2015, the awards have since honoured several initiatives that help build resilience in the three sectors on which this technical paper is focusing (Women Engage for a Common Future (WECF), 2020, 2021). See Box 7 for examples.

Box 7: Gender Just Climate Solutions award winners addressing agriculture, water, and coastal zones

Various award winners were recognized for work related to adaptation technologies for agriculture. In Zambia, the Green Living Moment project bolsters climate resilience by implementing community-owned, gender-responsive agroecological systems that prevent deforestation while also reducing the burden of domestic work for women. Some projects also lie at the intersection of agriculture and water. For example, the Community Agriculture and Environmental Protection Association Cameroon won an award for helping better the livelihoods of women warmers through new sustainable farming technologies and ensuring their equal access to land ownership. Through this initiative, at least 500 families were trained in enhancing soil quality, protecting water sources and developing sustainable cropping systems. Similarly, the GenderCC SA project, based in South Africa, empowered 2000 farmers in rural communities to use and maintain new technologies for farming and water harvesting, as well as for waste management and sustainable energy, delivering mitigation benefits as well.

Another winning project, based in Bangladesh, demonstrated the potential of women-led initiatives to safeguard drinking water in coastal areas, where increasing salinity complicated the task of fetching potable water. Groups of women introduced sustainable, participatory water governance systems to tackle these challenges, giving rise to transformative adaptation-related outcomes, including collecting rainwater during monsoons to create new drinking water sources, and properly storing rainwater through Pond Sand Filters to provide additional drinking water and reduce waterborne diseases.

Another winner, a project in India implementing the Bhungroo© storm water management technology, advances adaptation in relation to agriculture, water, and coastal zones. Specifically, the locally-developed technology filters, injects, and stores excess stormwater through pipes in subsoil layers, and ultimately helps protect crops from flooding during monsoon and ensures sufficient irrigation during dry periods. The technology is affordable, and reduces water salinity through a filtration system. Although initially targeted to male smallholders, female participation in the development of the technology began increasing and yielding better and more cost-effective results; women therefore became the target group for disseminating and localizing the technology in rural communities throughout India.

Sources:
(1) https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/GJCS_English_Final.pdf
(2) https://www.ctc-n.org/sites/www.ctc-n.org/files/resources/WECF%20Gender%20Just%20Climate%20Solutions%202021%20ENG.pdf
(3) https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/techandndc/c93353c94cfc4a1daa013f27ea92df2f/bdc9d4fab72f44c283a0f35fb72ecc8e.pdf

112. Another type of innovative approach to stakeholder engagement in the climate technology sphere consists of empowering stakeholders to adopt new technologies through community-level knowledge exchange, as opposed to simply presenting stakeholders with new technological solutions and expecting or insisting upon their uptake (TEC, 2020). The Plantwise programme led by the Centre for Agriculture and Bioscience International (CABI), an intergovernmental not-for-profit organization, offers an example of this approach in practice. Under the programme, CABI established plant clinics in Bangladesh where farmers could seek plant health advice and solutions. Various stakeholder interventions and capacity-building initiatives were also conducted. Instead of imposing new farming technologies and practices over traditional knowledge and methods, it follows a stakeholder-oriented approach where the decisions of which solutions to apply rests with the farmers.

113. These examples depart from mechanisms of stakeholder engagement that seek limited input from stakeholders at discrete portions of the adaptation process and instead embrace forms of engagement that recognize stakeholders as key players in the uptake of adaptation technologies. Box 8 highlights an additional innovative approach that similarly involves stakeholders more directly in the research and application of adaptation technologies.

Box 8: Stakeholder engagement through citizen science

Consultations, workshops, working groups and other similar stakeholder participation mechanisms are mainstays in adaptation action. There are, however, other options that can engage stakeholders in a much more hands-on way, which can be especially valuable for piloting and implementing adaptation technologies. Citizen science initiatives, for example, engage the public directly in scientific research. A project led by Bioversity, in collaboration with the International Center for Tropical Agriculture and regional and local partners in Central America, Kenya, Ethiopia, and India sought to scale out a „farmer citizen science“ approach to advance the adoption of climate-smart agriculture. This approach has farmers test and rank agricultural technologies – for example, crop varieties and management practices – characterize local conditions using cheap but reliable weather sensors and share related information via mobile phone. As a result, the farmer citizen science approach helped generate empirical and location-specific advice for farmers on climate-smart technologies and practices that can advance adaptation in the agriculture sector.

Sources:
(1) https://citizenscience.org/
(2) https://ccafs.cgiar.org/research/projects/citizen-science-approach-climate-adaptation

6. Conclusion and next steps

114. Technologies are a critical component of adapting to climate change. Adaptation technologies are in especially high demand in the agriculture and water sectors, as well as in coastal zones. This is evidenced by the variety and prevalence of priorities and needs for adaptation technologies in these areas, as documented in TNAs, NAPs, NDCs, and ADCOMs, as well as the continual pursuit of implementing these technologies around the world. While most Parties prioritize longstanding adaptation technologies in these sectors, there are increasingly innovative technologies and approaches that may offer new adaptation solutions and improve upon the related processes and institutions. Adaptation technologies are not, however, a panacea, and they must be embedded in comprehensive and iterative adaptation processes, and implemented alongside ambitious greenhouse gas mitigation, in order to mount an effective response to the climate crisis.

6.1. Additional good practices, gaps, needs, and challenges

115. While there is evidently widespread demand for adaptation technologies in the agriculture, water resources, and coastal zones sectors, there are enduring challenges, gaps, and needs that stand in the way of ensuring that current and future technologies fulfil their potential in driving forward adaptation action. According to the *Fourth synthesis of technology needs*, almost all Parties included in the analysis reported barriers to the development and transfer of prioritized adaptation technologies in the following areas: economic and financial (including lack of or inadequate access to financial resources as one of the main barriers); policy, legal and regulatory (including insufficient legal and regulatory frameworks as one of the main barriers); institutional and organizational capacity; and human skills.[72] It is no surprise, then, that the most commonly cited enabler of prioritized adaptation technologies was increasing the financial resources available for adaptation technologies; this could be achieved by, for example, introducing or increasing the allocation for such technologies in national budgets or identifying and creating financial schemes, funds, mechanisms or policies.[73]

116. There are also barriers specific to innovation that emerging and developing economies may face. This includes:

a) The fact that markets may undersupply innovation when firms do not capture all the benefits arising from their innovations,

b) That the demand for innovation may be tempered where households or firms do not have to pay for environmental costs or services,

c) Information asymmetries – potentially exacerbated by uncertain future policies – can limit financing by new market participants of ambitious or radical innovations; and

d) Trade barriers and low country capacity to adopt, adapt, and deploy new technologies can undermine the spread of new climate technologies internationally (OECD, World Bank, and UN Environment, 2018).

117. Further, there are various roadblocks in the process of transitioning from the research and development of adaptation technologies to their commercialization, including “poor understanding of adaptation markets, weak policy frameworks, and few suitable financial mechanisms that are able to effectively blend public and private finance, reduce investment risk and shorten the time needed for a return on investment” (UNFCCC, 2019). Challenges in the commercialization of adaptation technologies also inevitably affect the availability and upscaling of these technologies. The TNA process continues to be an important avenue for countries seeking to identify and meet their climate technology needs and overcome the associated challenges. Indeed, an important first step towards commercializing adaptation technologies is ensuring that TNAs and their associated technology action plans are completed and up to date. As part of the TNA process, countries identify barriers to the deployment and diffusion of prioritized technologies in the national context, as well as measures to overcome these barriers.[74] The process culminates in a technology action plan, which outlines specific actions and associated enabling activities, thereby paving the

[72] FCCC/SBI/2020/INF.1, para. 13.
[73] FCCC/SBI/2020/INF.1, para. 15.
[74] See https://www.ctc-n.org/technologies/technology-needs-assessments

way for various actors to work towards implementation of the prioritized technologies. More broadly, in addition to the TNA process, measures to develop legal, regulatory, and policy frameworks conducive to adaptation technology commercialization, as well as building partnerships with relevant industry associations, can also accelerate adaptation technology commercialization and deployment (UNFCCC, 2019).

118. Moreover, gaps and challenges related to the adoption and use of adaptation technologies can vary systematically by gender. Such disparities may arise in cases where, for example, women make significant contributions to agricultural production but have limited access to information and services and are marginalized in decisions related to agricultural technology adoption (Paudyal et al., 2019). Gender-responsive approaches to the promotion and dissemination of adaptation technologies can help to remedy gender-based gaps and inequalities. Components of gender-responsive approaches may include collecting gender-disaggregated data to inform policymaking and planning related to adaptation technologies, incorporating gender-based (indigenous) knowledge and skills in technology generation processes, and promoting gender sensitization and responsiveness among related service providers (e.g. climate-smart agriculture service providers) (Paudyal et al., 2019).

119. There are also, however, a range of good practices and opportunities, many of which have already been mentioned in the sections above. These include:

a) Taking a holistic approach to adaptation technologies that incorporates not only hardware, but also the software and orgware that can support the use of hardware and bolster resilience more broadly;

b) Similarly, working towards an enabling environment that is conducive to the application of adaptation technologies, including appropriate policy and regulatory environments;

c) Engaging a wide range of stakeholders in various capacities throughout the entire process of designing, identifying, developing, deploying, and evaluating adaptation technologies;

d) Ensuring that adaptation technologies are gender-responsive;

e) Viewing innovation broadly as encompassing sophisticated traditional and indigenous technologies and practices, as opposed to a narrow view focused on modern high-tech solutions;

6.2. Next steps

120. At AC21, the AC may wish to:

a) Provide its feedback on this updated draft of the technical paper;

b) Continue engaging with various stakeholders, as needed, to revise and finalize the paper;

c) Request the secretariat to publish the paper, when finalized and cleared by the AC, as a user-friendly publication;

d) Initiate exploring potential recommendations for consideration by the SBSTA, SBI, COP and/or CMA, as well as follow-up activities for the AC, if desired.

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