TWN Climate Change Series 8

Technology Transfer to Support Just Transitions Towards Sustainable Development in Developing Countries

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CONTENTS

Executive Summary

THIS paper discusses the importance of technology transfer from developed to developing countries as a key means of implementation for effective climate action and sustainable development. It highlights the challenges and enablers for technology development and transfer identified by developing countries in their technology needs assessments (TNAs) and nationally determined contributions (NDCs) under the United Nations Framework Convention on Climate Change (UNFCCC).

The main challenges for technology development and transfer identified by developing countries in their TNAs and NDCs include:

- Economic and financial barriers, such as lack of access to financial resources, high initial costs of technologies, difficulties in obtaining loans, and uncertainties regarding returns on investment.

- Policy, legal, and regulatory gaps, including insufficient legal and regulatory frameworks, and the need for improved, strengthened, and streamlined domestic policy frameworks to facilitate the development and transfer of technologies.

- Technical capacity constraints, such as system limitations, insufficient expertise, inadequate standards, codes, and certification.

These challenges hinder the successful implementation of technologies and require multifaceted actions to ensure that all barriers to technology development and transfer are addressed effectively.

In summary, the key enablers highlighted are addressing economic/financial challenges, creating enabling policy/regulatory environments, building human and institutional capacities, and bridging the gap between policy, finance and technology. Overcoming economic and financial challenges is central to achieving technology development and transfer. Economic and financial challenges are not the only challenges, however, so efforts to realize technology transfer should target multiple challenges. Governments have a major role to play in creating enabling environments by establishing and enforcing appropriate regulatory and institutional frameworks.

A combination of market stimulation and human capacity development is key to further stimulating the transition to improved enabling environment conditions for technology development and transfer. Support to strengthen institutional and scientific capacities, especially in least developed countries (LDCs), is critical to creating the long-term enabling environments required for technology development and transfer. Education and training to assist developing countries in making early-stage decisions on financing, matching technology priorities with funding sources, and bridging the policy and finance communities is essential.

The paper then discusses various channels and initiatives for promoting technology transfer to developing countries. These channels and initiatives aim to address the barriers to technology transfer and promote the flow of climate-relevant technologies to developing countries. Some of these include:

- Establishing voluntary patent pools and technology banks to provide access to patented climate-relevant technologies for developing countries.

- Creating a new multilateral fund to support climate-relevant technology transfer.

- Enhancing intellectual property rights (IPR) flexibilities and avoiding intellectual property protection commitments in trade agreements that are stricter than those in the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).

- Regional cooperation and resource pooling among developing countries to build technical and financial capacities for technology transfer.

The paper highlights several key reasons why it is important to adopt a comprehensive approach involving both national action and international cooperation to address the technology gap between developed and developing countries. The diversity of national circumstances among developing countries in terms of their development priorities, capabilities, and constraints would dictate against a one-size-fits-all approach and prioritize the importance of national approaches that allow them to tailor solutions to their specific needs and conditions. At the same time, the technology gap is a global challenge that requires coordinated international response. International cooperation is essential to facilitate access to technologies, financing, and capacity building. Endogenous technology development in developing countries is essential as well; while technology transfer from developed to developing countries is crucial, it is also important to promote the development of domestic technologies in developing countries. This gives them greater autonomy and adaptability.

An integrated and coherent policy approach combining national action and international cooperation allows aligning technology development policies with countries' climate and sustainable development commitments. International cooperation is key to mobilizing the financial and technical resources needed to bridge the technology gap, which is difficult to achieve through national efforts alone. In summary, addressing the technology gap comprehensively, through both national action and international cooperation, is fundamental to achieving sustainable and inclusive development in developing countries. The paper emphasizes the need for this multi-pronged approach to effectively bridge the technology divide.

1 Introduction

THE achievement of sustainable development by 2030 is under threat. The multiplicity and interlinkages of global economic, social, political, and environmental challenges, including climate change, are undermining the hard-won development gains of the past and crippling progress towards the achievement of the Sustainable Development Goals (SDGs) by 2030. These challenges include:

- **Global economic uncertainty** – The policy uncertainties arising from continued global economic weakness and low growth patterns,[1] particularly among developing countries and some major developed-country economies, should be discussed and addressed holistically by United Nations system agencies, particularly in terms of how the concentric and assorted impacts of the 2008–2009 global financial crisis, the COVID-19 pandemic, a global trade slowdown, an emergent debt crisis, increasing global and national income inequality, increasing socio-economic losses and damages arising from climate change, biodiversity loss, and pollution should be treated in order to systemically address continued underdevelopment and poverty in developing countries and enable their socio-economic and climate resilience.

- **Technology change and impact** – The 21st century has seen rapid technological change, with automation, the digital revolution, and the advent of artificial intelligence rapidly driving significant changes in employment, production, consumption, trade, transfers, and innovation and knowledge control. These give rise to issues of future technological dominance, ownership and control, access, regulation of technology, the role of intellectual property rights and their impact on innovation and sharing of innovation benefits, privacy issues and control of big

data and the Internet, and the innovation, control and use of technologies (such as renewable energy and carbon capture technologies) that would be needed to address the multidimensional planetary crisis.[2]

- **Demographic change** – In November 2022, the world's population reached 8 billion, with UN projections suggesting that the global population would grow to 8.5 billion in 2030, 9.7 billion in 2050 and 10.4 billion in 2100. Recent demographic trends are harbingers of future challenges to achieving the SDGs. For example, countries experiencing rapid population growth, most of which are in sub-Saharan Africa, must provide schooling and health care to growing numbers of children, and ensure quality education and employment opportunities to increasing numbers of youth. Countries where population growth has slowed or stopped must prepare for an increasing proportion of older persons and, in some cases, decreasing population size.[3]

- **Climate change** – Global mean temperature in 2022 was estimated to be 1.15 ± 0.13°C above the 1850–1900 average. The nine years from 2015 to 2023 have been among the eight warmest years on record, with 2023 being the warmest year on record.[4] Changes to the global climate are undermining the global ability to achieve sustainable development.[5] In terms of multilateral policy, domestic political changes in major economies as well as geopolitical tensions may weaken international cooperation on climate change under the United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement, further exacerbating the socio-economic and ecosystem impacts of climate change, increasing losses and damages arising from such impacts, increasing the push to put in place potentially unilateral climate change response measures as well as to undertake economic and energy diversification, and heightening potential competition and rivalry over the innovation and control of energy technology and other technological responses to climate change.

- **Natural resource availability and access** – Biodiversity is declining at an unprecedented rate, and the pressures driving this decline are intensifying. None of the Aichi Biodiversity Targets will be fully met, in turn threatening the achievement of the SDGs and undermining efforts to address climate change.[6] Freshwater withdrawal from streams, lakes,

aquifers and human-made reservoirs (so-called "blue water" sources) has increased strongly during the last century and is still increasing in most parts of the world. Globally, water use is expected to grow by roughly 1% per year over the next 30 years, driven by increasing demand in the industry and energy sectors as well as by municipal and domestic uses, mainly as a function of industrial development and improving water and sanitation service coverage, in combination with population growth, economic development and shifting consumption patterns. An estimated four billion people live in areas that suffer from severe physical water scarcity for at least one month per year.[7] Global forest cover has been shrinking, with the rate of deforestation declining but still at 10 million ha. per year in 2015–2020. Some 47 million ha. of primary forest was lost between 2000 and 2020.[8] Assessed marine fishery stocks confirm that marine fishery resources have continued to decline. The fraction of fishery stocks within biologically sustainable levels decreased from 90% in 1974 to 64.6% in 2019, with maximally sustainably fished stocks at 57.3% and underfished stocks at 7.2%.[9]

In the face of these multiple challenges, the most difficult choices are in developing countries. They confront the challenge of having to pursue sustainable economic development, including generating economic opportunities for their populations, while keeping emissions and resource consumption within sustainable ecological boundaries. At the same time, many developing countries are in a position of structural and institutional weakness when it comes to pursuing their right to development and mobilizing domestic resources. Such weakness arises from their relatively disadvantaged positions in globalized economic and financial systems, the economic and social impacts of past crises (including the 2008 global financial crisis and the COVID-19 pandemic), ongoing global economic fragility and weakness, the losses and damages arising from the adverse effects of climate change and from global environmental degradation, multilateral and plurilateral treaties that restrict their developmental policy space (such as free trade agreements and bilateral and regional investment agreements that contain obligations that are more restrictive than those in World Trade Organization (WTO) agreements), and the emergent fracturing of the multilateral system of cooperation in various areas (trade, climate change, finance, investment, security). Developing countries have to meet the challenge of achieving inclusive and sustainable economic development, contributing to climate

change mitigation, and adapting to rising global temperatures, changing precipitation patterns and more extreme weather events, while at the same time being among those that are particularly vulnerable and often the least prepared to adapt to climate change.[10]

To eliminate poverty and achieve their right to development, they need diversified, more productive, and sustainable economies to create jobs and provide improved standards of living. Doing so will require, among other things, improving access to energy for their people and their economies. If they continue to rely largely on current fossil-fuel-based energy technologies, global greenhouse gas (GHG) emissions from fossil fuel use will continue to rise. Developing countries that rely on fossil-fuelled technologies risk getting locked into unsustainable production patterns and may have to face very high costs of switching to low-carbon technologies in the future, as the urgency of climate adaptation increases.

Past technological revolutions, especially since the Industrial Revolution that was largely powered by fossil fuels, have brought about immense advancements in the development conditions of countries and their peoples but have done so unevenly and in ways that have accelerated climate change. Developing countries need not, however, follow the historical pathways of fossil-fuelled technology and economic development followed by today's developed countries (which resulted in developed countries being historically responsible for approximately 70% of cumulative anthropogenic GHG emissions in the atmosphere that have led to today's climate crisis). [11] However, most future emissions are expected to come from developing countries (although their per capita emissions will generally continue to remain lower than those of developed countries), particularly if they continue to rely on fossil fuels and associated technologies for their energy needs and economic development.[12]

To hold global warming to between 1.5°C and 2.0°C as stipulated in Article 2.1(a) of the Paris Agreement as a means of achieving the objective of the UNFCCC,[13] Parties have agreed to aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse

gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.[14]

Doing so means that the global energy sector must undertake a rapid and systemic transformation towards low-carbon pathways, including energy conservation and efficiency, shifting away from fossil fuels to renewable energy, and the widespread deployment and mass-scale transfer of low-carbon technologies from developed to developing countries. Most of the necessary emissions reductions can be achieved by deploying and expanding the use of existing, commercially proven low-carbon technologies globally in four major sectors – energy, industry, transportation, and construction – to narrow the emission gap by almost two-thirds, while stopping deforestation.[15] In addition, climate adaptation technologies are also needed by developing countries to put their economies on climate-change-adapted pathways; technologies will be needed as well to address the losses and damages that will occur as a result of the adverse effects of climate change that have exceeded adaptation limits.

Developing countries thus need access to climate-action-relevant technologies to move towards a sustainable development pathway and enhance climate change action ambition. The central role of technology transfer to developing countries as well as their development of endogenous technology was recognized in the 1992 Rio Summit, as well as in its related conventions including the UNFCCC. Technology transfer is to be undertaken as part of international cooperation, and a proactive role of public policy at national and international levels is required to enable developing countries' access to technology. Under the UNFCCC, in recognition that GHG emissions from developing countries will continue to grow as their economies grow even as developed countries are committed to reducing their emissions, technology transfer is part of a broader policy package for international cooperation (along with climate finance and adaptation support) under which developed countries, following the principle of common but differentiated responsibilities, are committed to providing support to help developing countries undertake climate actions (mitigation and adaptation).[16]

Technology transfer could provide developing countries with the opportunity to leapfrog and effect structural transformation and economic diversification away from fossil-fuelled economic growth into sustainable development

pathways using low-carbon mitigation technologies, adaptation technologies, and loss-and-damage technologies that are appropriate for their specific economic and ecological conditions.[17] Doing so would enable developing countries to avoid long-term fossil-fuelled technology lock-in and provide opportunities for diversifying economic activity into sectors for which there would be new and expanding markets (such as those which require compliance with high environmental standards or meet consumer preferences for environmentally sustainable goods and services).[18]

Given that most technologies that developing countries import, absorb or adapt are privately owned,[19] and most climate-relevant technologies are currently developed and produced in developed countries,[20] the direction and enhanced efforts for technology transfer will have to be from developed to developing countries,[21] paying particular attention to ensuring that manifestations of private ownership of such technologies (e.g., in the form of patents or other intellectual property) and other trade-related rules do not hamper such transfers.[22] Technology transfer among developing countries through South-South cooperation could also play an important complementary role but has remained limited.[23] Deploying climate-relevant technologies from developed countries to developing countries will not be easy but can be done.

Done correctly and appropriately, taking into account national circumstances and consistently with national development priorities, transfer of climate-relevant technologies (for mitigation, adaptation, and loss and damage) can help meet both climate change and sustainable development goals, improving lives and livelihoods, and enabling developing countries to become producers and exporters of climate-relevant technologies in their turn. To be effective, technology transfer has to include not only the physical hardware (e.g., solar panels and wind turbines) but also the technical know-how and capabilities necessary to understand, operate, and maintain new technologies, as well as institutional and policy arrangements that facilitate technological uptake and encourage local innovation. And to be sustainable, it requires the capabilities to deploy, operate, maintain, adapt, improve, and reproduce the transferred technology, and, ultimately, the capacity to invent new technologies.[24]

Technological uptake and innovation is strongly influenced by a country's ability to access, adopt, and diffuse technological knowledge generated abroad, implying that international technology transfer becomes a critical determinant for reducing the technological, knowledge and capacity gaps, as well as income and wealth gaps between developed and developing countries.[25] Hence, effective and sustainable technology transfers help create a win-win outcome for both the technology providers and recipients.[26] Technological innovation also does not have any "one size fits all" approach due to the diversity of countries' national circumstances and innovation needs.[27]

Technology transfer to developing countries is a key means to support the implementation of their nationally determined contributions (NDCs) under the Paris Agreement and for achieving sustainable development.[28] For example, the NDCs of 13 of 17 Latin American countries and 11 of 16 Caribbean countries express interest in receiving technology transfers, with most countries citing their developing status and minimal contribution to climate change and requesting financial and technological assistance from the international community to help them meet some or all of their emissions reduction goals.[29] A review of the 190 NDCs submitted prior to the 21st session of the Conference of the Parties to the UNFCCC (COP 21) in Paris in 2015 found that nearly 140 developing countries highlighted the importance of climate technologies and almost 50% of all developing countries specifically referred to the importance of technological innovation or research and development for achieving their climate objectives.[30]

To support developing countries' efforts to achieve sustainable development in a climate-constrained world, the most appropriate technologies for climate change monitoring, mitigation and adaptation hence need to be made available to developing countries. This should be under conditions that are cost-effective or more favourable than commercial conditions and come with the corresponding policy, technical assistance, and financial support package needed to make it easy for developing countries to undertake their own technology research and development and to innovate and adapt transferred technologies according to their development and climate change needs and priorities.

2 Technology Transfer Enablers and Challenges

THE transfer of climate-relevant technologies to developing countries is critical to promoting both sustainable development and effective climate action. However, the actual uptake of available climate-relevant technologies in developing countries is often observed to be low.[31]

Despite agreed treaty texts and soft law instruments mandating technology transfer from developed countries to developing countries as a key means of implementation for effective climate change action,[32] governments continue to be at odds over whether these transfers are mandatory, how to make these transfers happen and what technology transfers should be about – all too often, developed countries have not complied with these treaty mandates. As a study has noted, "Technology exporting countries and most global business – multinational firms and international business associations – advocate for a market-based model based on voluntary transfers of technology on terms agreed upon between providers and recipients. Developing and least developed countries – which see technology transfer as a process through which they can create local capabilities to absorb, adapt, replicate and develop their own technologies – promote hybrid mechanisms involving market, hybrid and non-market approaches, including compulsory licensing or mandatory technology transfers."[33]

The UNFCCC's Expert Group on Technology Transfer (EGTT) observed in 2014, in a survey of climate-related international collaborative activities relating to technology development and transfer, that "a number of large gaps" exist: "First, most existing initiatives are focused on enabling frameworks and facilitating deployment. Second, mitigation technologies (and within that, energy technologies) dominate; there is relatively limited

focus on adaptation. Third, most of the collaborations between developed and developing countries are targeted at or take place with the major developing economies … One particular observation relating to technologies for both mitigation and adaptation is that, while there are many international collaborative initiatives around technologies to address climate change, many of these involve processes for identifying needs and facilitating the sharing of knowledge and experiences rather than actually undertaking collaborative R&D [research and development]. Another relevant finding of the EGTT is the limited number of collaborative R&D initiatives in which least developed countries participate."[34]

Hence, while countries have generally agreed on the importance of technology as a key enabler for sustainable development and poverty eradication, the technology gap between developed and developing and between advanced developing countries and least developed countries continues to widen,[35] with the countries that are best placed to move to the technology innovation frontier being those with higher levels of skill and stronger manufacturing industries – i.e., mostly the developed countries.[36] This applies in particular to technologies with smaller carbon footprints, with the UN development agency UNCTAD warning that "economic inequalities risk growing as developed countries reap most of the benefits of green technologies."[37] This has been observed by the Intergovernmental Panel on Climate Change (IPCC) particularly in the context of renewable energy technologies with the rise of a "green global division of labour" in which there are some countries specializing in investments in R&D, manufacturing or deployment of renewables while others focus on the manufacture of hardware.[38] Technologies that are highly capital-intensive and labour-saving will be efficient only in countries where costs of capital are low and costs of labour are high (such as in developed countries) while technologies which require a large volume of skilled labour will be more competitive in a country where skilled labour is abundant (and hence cheap) than where it is scarce (such as in developing countries), resulting in a technological divide.[39]

According to UNCTAD, effective technology transfer depends on many factors, including the geographical position of origin and destination markets, market size and competitiveness, commercial prospects, the level of development of human capacities and skills, governance, and infrastructure.[40]

Direct government allocations to support an enabling environment for climate technologies are generally lower in developing countries than in high-income countries, and there is a strong positive correlation between governmental expenditures for research and development in climate technologies and rising income levels. This is consistent with the general concentration of technological development in a small number of (mostly developed) countries, making technology transfer critical to reducing the technological gaps between developed and developing countries.[41]

These issues need to be addressed to avoid technology dependency and additional vulnerabilities. As the IPCC noted, developing countries often have relatively limited technology innovation capabilities, which requires them to access technologies from developed countries with stronger innovation systems, which then, in many cases, requires innovation adaptation for the local context, needs and uses and to create new markets and business models that are required for successful deployment. This can lead to dependencies on foreign knowledge and providers, negative impacts in terms of higher costs, balance-of-payments constraints, and vulnerability to external shocks.[42]

A 2020 World Bank study highlighted five key challenges that make it difficult for developing countries to innovate, develop, produce, deploy, and trade in low-carbon and other climate-relevant technologies: (1) developing countries are at a disadvantage vis-à-vis developed countries in view of the latter having deeper stocks of the inputs needed for producing and trading such technologies; (2) developing countries vary widely in their starting points in terms of capacity to innovate, produce, trade, attract investment, and deploy such technologies, with some being better placed than others; (3) many developing countries tend to have existing institutional and policy regimes that do not favour investments in such technologies or which lock in carbon-intensive development pathways; (4) there are existing multiple market failures that militate against such technologies, such as the lack of effective carbon pricing; and (5) governmental policy inconsistency or variability.[43]

Developing countries face several obstacles to technology transfer, and "leapfrogging" towards low-carbon and other relevant climate technologies faces important challenges.[44] These include financial and economic (such as

cost and price) and legal and regulatory (such as standards and policies) barriers,[45] gaps in the adaptive and absorptive capacity to build the required technological capabilities,[46] implementation gaps with respect to compliance with existing technology transfer commitments under international law,[47] institutional constraints,[48] and ensuring policy coherence in both design and implementation to ensure that there is an integrated approach to structural transformation which supports climate adaptation and employment generation.[49]

The cost of and access to finance are often major challenges with respect to the deployment and transfer of climate technologies in developing countries. These are often capital-intensive and require mobilization of large upfront financing for investment life cycles that often span several decades and which could ultimately render them unaffordable for a developing country. There can also be differences in financing costs for a given technology even where the price or investment volume is identical in developed and developing countries, with such differences resulting in a significant cost differential and higher total costs for developing countries compared with developed countries. As a UN Environment Programme (UNEP) study has noted, "for renewable energy projects, for instance, the cost of capital in developing countries is significantly higher than in industrialized countries. This can severely constrain the deployment of technologies, even if they provide in principle the least-cost option for achieving mitigation or adaptation outcomes."[50] The World Intellectual Property Organization (WIPO) notes that access to adaptation technologies is not equal.[51]

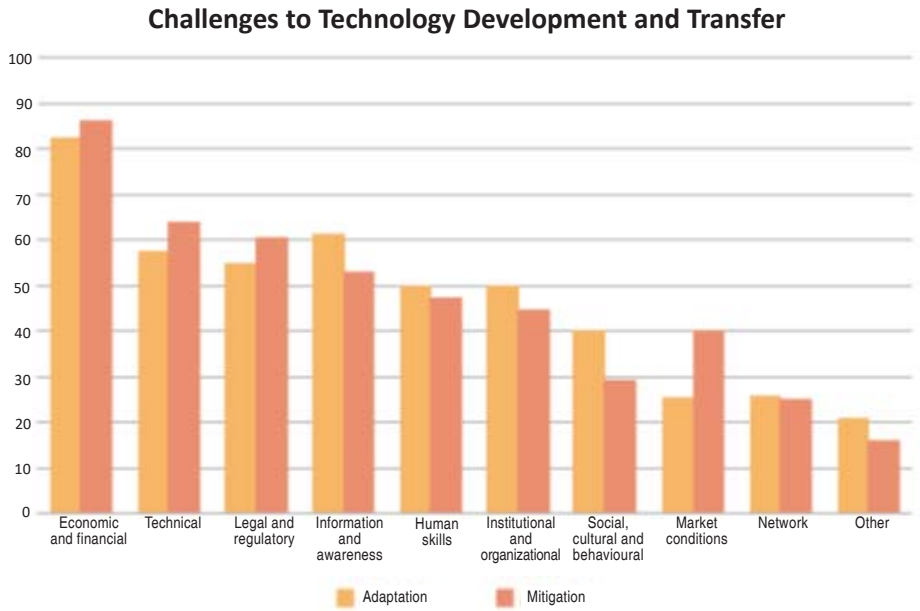
Furthermore, given that most climate technologies are patented, owned and produced by private sector firms whose primary motivation is to generate revenue from their products, the direction of investment would tend to be towards the development of products and solutions for the consumers of countries with "significant buying power" (i.e., developed countries) rather than poorer developing countries and their consumers.[52] In many cases, such products and solutions are often inappropriate or else need some level of adaptation to be able to fit developing-country circumstances.

In the technology needs assessments (TNAs) undertaken by more than 100 developing countries under the UNFCCC, developing countries reported the following:

	Most Commonly Reported Challenges to Technology Transfer	Most Commonly Reported Enablers of Technology Transfer
Mitigation	Economic, financial – lack of or inadequate access to financial resources, high initial cost of technologies, difficulties in obtaining loans, uncertainties regarding returns on investment and a general lack of financial resources Policy, legal and regulatory – insufficient legal and regulatory framework, need for improved, strengthened and streamlined domestic policy frameworks to facilitate the development and transfer of technologies Technical – system constraints, insufficient expertise and inadequate standards, codes and certification	Provision or expansion of financial incentives for the implementation and use of a given technology
Adaptation	Economic and financial – lack of or inadequate access to financial resources Policy, legal and regulatory – insufficient legal and regulatory framework, need for improved, strengthened and streamlined domestic policy frameworks to facilitate the development and transfer of technologies Institutional and organizational capacity Human skills	Increasing the financial resources available for adaptation technologies by introducing or increasing the allocation for such technologies in national budgets or by identifying and creating financial schemes, funds, mechanisms or policies

Sources: Author's tabulation, from UNFCCC, Fourth synthesis of technology needs identified by Parties not included in Annex I to the Convention: Report by the secretariat (FCCC/SBI/2020/INF.1, 3 April 2020), paras. 12-15, at https://unfccc.int/sites/default/files/resource/sbi2020_inf.01.pdf; UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer (2022), paras. 47-50, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf; see also Nils Meyer-Ohlendorf and Christiane Gerstetter, Trade and Climate Change: Triggers or Barriers for Climate Friendly Technology Transfer and Development? (FES Dialogue on Globalization Occasional Paper No. 41, February 2009), pp. 22-23, at https://library.fes.de/pdf-files/iez/global/06119.pdf

According to the UNFCCC's Technology Executive Committee (TEC), the range of challenges to technology development and transfer reported by developing countries in their TNAs includes: economic and financial, legal and regulatory, technical, information and awareness, market conditions, network development, institutional and organizational, human skills, social, cultural and behavioural, and others.



Source: UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer (2022), Figure 6, p. 19, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

The TEC observed that there are differences with respect to how these challenges to technology development and transfer are reported by small island developing States (SIDS), least developed countries (LDCs) and other developing countries:

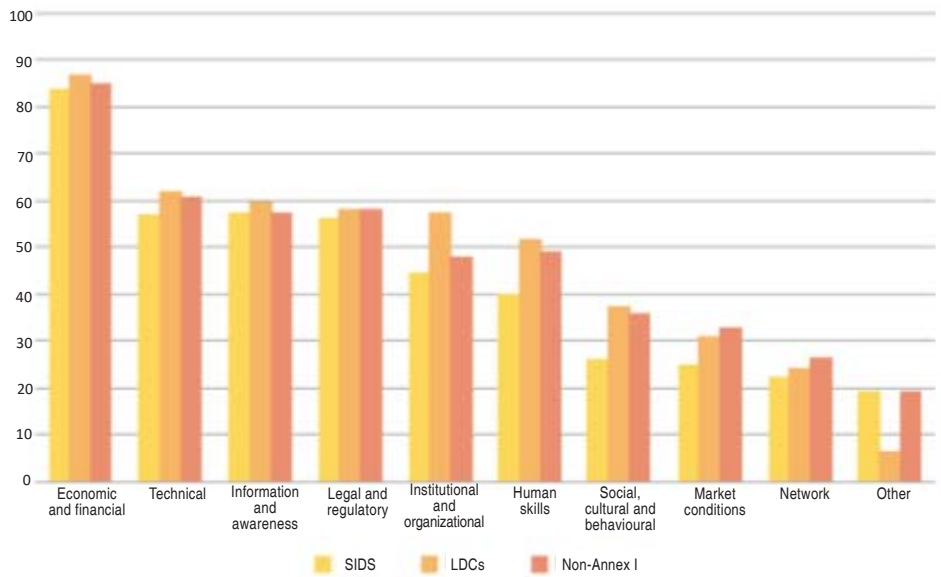
- SIDS report most challenges to be in the economic and financial (83%), information and awareness (57%) and technical (56%) categories. SIDS report fewer challenges per technology than do LDCs and non-Annex I Parties.

- LDCs report the majority of the challenges in the economic and financial (87%), technical (61%) and information and awareness (59%) categories.

- Other non-Annex I countries (i.e., other developing countries that are not SIDS or LDCs) report the majority of challenges in the economic and financial (84%), technical (61%), legal and regulatory (58%) and information and awareness (58%) categories. They also report more challenges related to market conditions and network development, compared with SIDS and LDCs.

- Across all of these developing-country groups, economic and financial challenges stand out as the most important category.[53]

Distribution of challenges identified by SIDS, LDCs and non-Annex I Parties



Source: UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer (2022), Figure 7, p. 20, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf
Note: SIDS – small island developing States; LDCs – least developed countries; non-Annex I – UNFCCC Parties not included in Annex I of the Convention (i.e., developing countries)

The reported challenges to technology development and transfer also vary across regions, according to the TEC:

- In the Africa region, the most frequently identified challenges are economic and financial (85%), technical (58%), legal and regulatory (52%) and information and awareness (52%).

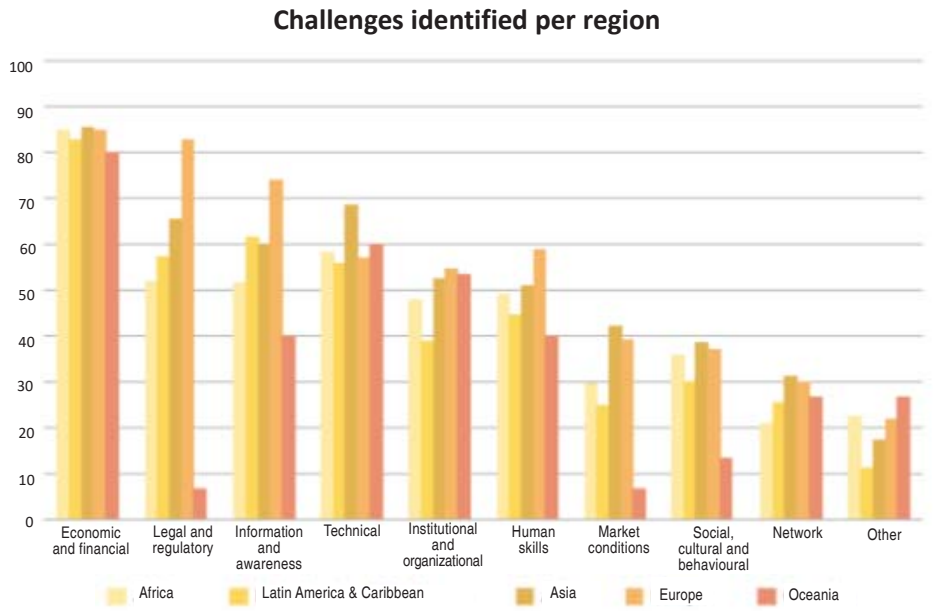
- In the Latin America and Caribbean region, economic and financial (83%) challenges are also predominant, followed by information and awareness (61%), legal and regulatory (57%) and technical (56%) challenges.

- In the Asia region, economic and financial (85%) challenges predominate over technical (68%), legal and regulatory (65%), and information and awareness (60%) challenges.

- In the Europe region, legal and regulatory (83%) challenges are almost as important as economic and financial (85%) challenges and are followed by information and awareness (74%) challenges.

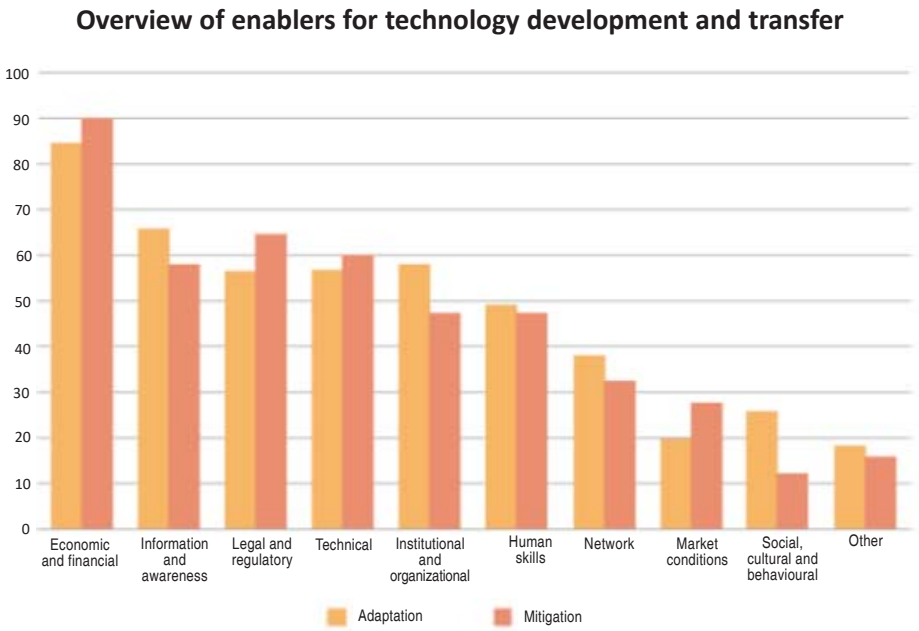
- In the Oceania region, economic and financial (80%), technical (60%) and institutional and organizational (53%) challenges are the three most commonly identified categories.

- Across regions, economic and financial, technical, and legal and regulatory challenges are frequently reported. In all regions, the Parties have identified economic and financial challenges as the most common challenges to technology development and transfer. In three of the five regions, technical challenges are the second most frequently identified challenges. Legal and regulatory challenges are the second most commonly reported challenges in one of the five regions, and the third most common in another three regions.[54]



Source: UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer Identified in Technology Needs Assessments, Nationally Determined Contributions, and Technical Assistance provided by the Climate Technology Centre and Network (March 2022), Figure 8, p. 21, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

Developing countries also reported, according to the TEC, on the enablers for technology development and transfer for mitigation and adaptation. Economic and financial, information and awareness, legal and regulatory, and technical enablers were the most frequently reported.



Source: UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer Identified in Technology Needs Assessments, Nationally Determined Contributions, and Technical Assistance provided by the Climate Technology Centre and Network (March 2022), Figure 1, p. 13, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

The regional breakdown for reporting of these enablers, according to the TEC, is as follows:

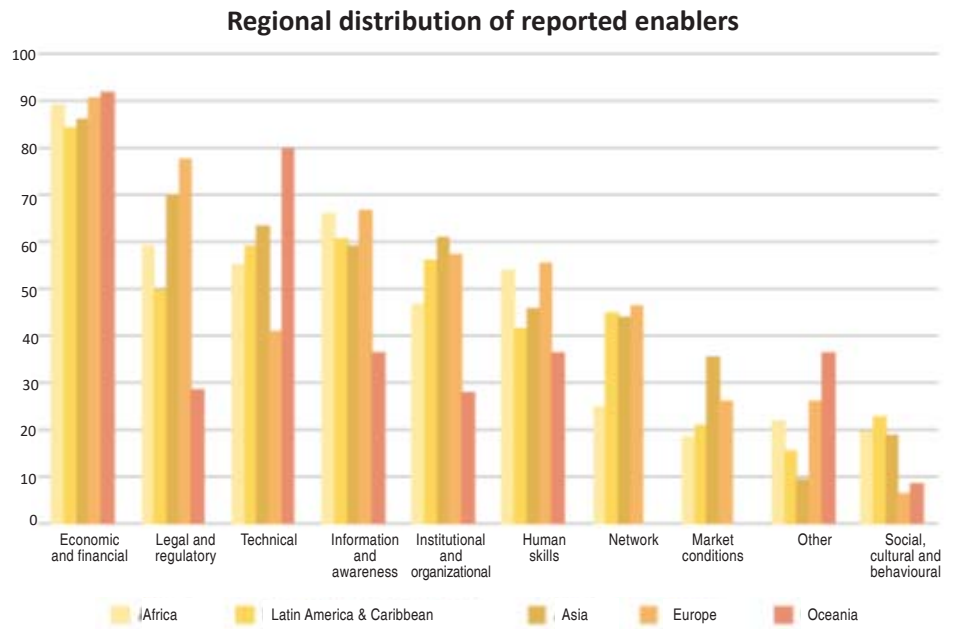
- In the Africa region, the most frequently identified enablers are economic and financial (89%), followed by information and awareness (66%), legal and regulatory (59%), and technical (55%).

- In Latin America and the Caribbean, economic and financial (85%) enablers are also predominant and are followed by information and awareness (61%), technical (59%) and institutional and organizational (56%).

- In the Asia region, economic and financial enablers (86%) predominate over legal and regulatory (70%) and technical (63%) enablers, which are closely followed by institutional and organizational capacities (61%).

- In Europe, economic and financial (91%) enablers are dominant as well. They are followed by legal and regulatory (78%) and information and awareness (67%).

- In Oceania, economic and financial enablers are reported for 92% of the technologies. For 80% of the technologies, enablers in the technical category are reported as being necessary. No enablers in the categories of market conditions and network enablers were identified in Oceania.[55]



Source: UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer Identified in Technology Needs Assessments, Nationally Determined Contributions, and Technical Assistance provided by the Climate Technology Centre and Network (March 2022), Figure 3, p. 15, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

From its analysis of TNAs, the TEC suggested the following findings with respect to enabling effective technology development and transfer to developing countries:

- Overcoming economic and financial challenges is central to achieving technology development and transfer.

- Economic and financial challenges are not listed as the only challenges for any of the prioritized technologies, which indicates that the successful implementation of technologies must be achieved by doing more than overcoming just economic and financial challenges.

- Efforts to realize technology development and transfer should not target economic and financial challenges as a single cause. Instead, multifaceted actions are recommended to ensure that all challenges that hinder successful development and transfer are targeted.

- Governments have a major role to play in creating enabling environments to address the challenges to technology development and transfer by establishing and enforcing the appropriate regulatory and institutional frameworks.

- To further stimulate the transition to improved enabling environment conditions for technology development and transfer, a combination of market stimulation and human capacity development is identified as key by developing country Parties.

- Support to programmes designed to strengthen institutional and scientific capacities, with regard to technology development and transfer, of developing country Parties, in particular LDCs, is reported as critical to creating the long-term enabling environments required for technology development and transfer within these countries.

- There is a need for education and training to assist countries in making early-stage decisions on financing, match countries' planned technology priorities with funding sources, and in general establish an essential bridge between the policy and finance communities.[56]

3 Technology Transfer Commitments and Initiatives

INTERNATIONAL cooperation arrangements agreed to by States have often been marked by a recognition that developing countries would generally require some level of differentiated treatment and support. This recognition is reflected, for example, in the principle of common but differentiated responsibilities in the UNFCCC and its Paris Agreement and in the principle of special and differential treatment in the context of the WTO.

These principles are reflected in operational terms through having developed countries assume treaty obligations that commit them to providing developing countries with support to enable the latter to implement their own respective treaty obligations fully, such support usually being finance and technology transfer. For example, technology transfer was one of the two key "means of implementation" in Agenda 21 adopted in 1992, the other being financial resources.[57] Under the 2030 Agenda adopted in 2015, access to technology is a key element in the various Sustainable Development Goals,[58] with technology transfer also being a key area of partnership for SDG implementation.[59]

Developing and transferring technologies from developed countries to support developing countries' national actions on climate change is a core element of the multilateral climate regime under the UNFCCC and its related legal instruments – the Kyoto Protocol and the Paris Agreement. Articles 4.1(c), 4.3, 4.5, and 4.7 of the Convention[60] and Article 10[61] of the Paris Agreement establish common but differentiated commitments on Parties with respect to technology transfer.

Over the years, an elaborate architecture of institutions and mechanism has been created under the UNFCCC to promote technology transfer. In 2010 the COP established the Technology Mechanism with the objective of accelerating and enhancing climate technology development and transfer. It consists of two complementary bodies that work together – the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). Article 10.4 of the Paris Agreement established the Technology Framework to provide guidance to the work of the Technology Mechanism in promoting and facilitating enhanced action on technology development and transfer in order to support the implementation of the Agreement. Technology needs assessments and the preparation of technology action plans have been key activities relating to technology transfer undertaken by UNFCCC Parties since 2001.[62]

Other international agencies such as the World Bank, WTO, WIPO, UNCTAD, UNIDO, UN Technology Bank for LDCs, UNEP, and UNOSSC also have activities or programmes relating to the acquisition, use and learning from technologies that span from the public domain to the current scientific frontiers.[63]

4 Technology Transfer Priorities

THE Intergovernmental Panel on Climate Change defines technology transfer as "a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions … It comprises the process of learning to understand, utilize and replicate the technology, including the capacity to choose it and adapt it to local conditions and integrate it with indigenous technologies."[64] Hence, a central aspect of technology transfer is to support the building of local capacity to innovate and manufacture technologies which can be diffused into the local economy.[65]

In this context, technology transfer does not imply merely the transfer of hardware to the developing countries. It also includes the transfer of know-how and the right to use and further develop, innovate and adapt these technologies to fit developing-country needs and circumstances so as to also support the development of endogenous technologies and skills in developing countries. This implies that the actual transfer of technology would include:

- The transfer of physical assets, such as plants, machinery, and equipment.

- The assignment, sale and licensing of all forms of industrial property, except for trademarks, service marks and trade names when they are not part of technology transfer transactions.

- The provision of human skills, know-how and technical expertise in the form of feasibility studies, plans, diagrams, models, instructions, guides,

formulae, basic or detailed engineering designs, specifications and equipment for training, process know-how, organization and operating methods, quality control, knowledge of market characteristics, services involving technical advisory and managerial personnel, and personnel training.

- The provision of technological knowledge necessary for the installation, operation and functioning of plant and equipment, and turnkey projects, choice of technology, engineering design and plant construction.

- The provision of technological knowledge necessary to acquire, install and use machinery, equipment, intermediate goods and/or raw materials which have been acquired by purchase, lease or other means.

- The provision of technological contents of industrial and technical cooperation arrangements.[66]

Furthermore, as UNCTAD notes, if developing countries are to capture the economic gains associated with new technologies, it is not just scientific or technical skill that is needed but also the necessary policies, regulations, and infrastructure.[67]

Many developing countries have made their NDCs under the Paris Agreement conditional on receiving climate finance, technology transfer, and capacity-building support. However, a study has found that many low-carbon technology transfer initiatives focus on transferring multiple kinds of technologies to countries that are facing electricity access and governance challenges, and do not all address the key capacity-building components of knowledge transfer, and developing countries with "poor" intellectual property right (IPR) protections have fewer initiatives on average.[68]

Developing countries often face the challenge of identifying the most suitable technology that they need to address and respond to specific sustainable development or climate action priorities as there may often be a wide variety of alternative technologies and multiple sources of technologies. The determination of suitability will need to be context-specific given that developing countries will have widely varying national and subnational

circumstances, conditions, and climate change impacts that need to be responded to; otherwise, the technologies that may be acquired might end up being ineffective.[69]

Developing countries will have to ensure that their long-term sustainable development prospects are made more climate-resilient by putting in place needed adaptation and sustainable development and economic diversification policies and strategies in a manner that is socially and economically equitable. To do this, developing countries would have to ask what technologies would be needed for them to viably diversify to other economic sectors at the speed and scale needed considering national circumstances and priorities while at the same time effecting a just transition process. This would imply looking at, inter alia:

- The energy access and energy infrastructure transformation to clean/ renewable energy possibilities for developing countries, in light of their sustainable development objectives;

- The technological and financing (including investment) needs for such transformation and ensuring that a just transition takes place, particularly in developing countries concerning their workforce and their marginalized and vulnerable populations, and ensuring that social and economic conditions for their populations remain stable or are improved and that national development objectives will be achieved;

- Identification of the economic diversification and transition sectors that could be developed in the economies of those developing countries that are likely to be adversely affected by emission-reduction-focused response measures of other countries – particularly in light of current economic contexts and existing sectoral dependencies and the need to avoid non-solutions (such as bio-energy carbon capture and storage, carbon trade markets, and geoengineering) – or by initiatives to halt further expansion of fossil fuel production;

- Identification of key equity considerations from a developing-country context in terms of the extent of diversification, financing requirements, technology requirements, social impacts, economic impacts, and transition costs, and other considerations associated with ensuring that

there is a just transition in countries from today's fossil-fuel-dependent economies (whether in terms of export or import dependence or energy dependence) to ones that are more climate-resilient and adapted;

- Identification of international cooperation arrangements under the UNFCCC and its Paris Agreement that need to be enhanced or scaled up to better address equity, economic diversification, just transition for the workforce and other marginalized sectors, and the impact of response measures (including in climate finance, technology transfer, adaptation financing, and loss-and-damage financing).[70]

Over the years, developing countries have been able to determine what technologies they need to be able to shift their economies onto low-carbon sustainable development pathways and undertake national climate change actions. This has been done through, in many cases, national development planning cycles, technology needs assessment processes (such as those under the UNFCCC), or the development of technology action plans as part of their national climate action. At the same time, many international organizations and researchers have also identified a wide range of technologies that would be needed in developing countries to be able to effectively undertake mitigation and adaptation actions.

Technologies that are relevant to shifting to low-carbon development pathways and undertaking climate action (including mitigation and adaptation) have been variously termed low-carbon technology products, green technologies, environmentally sound technologies, environmentally preferable technologies, and climate technologies. In general, these would include technologies such as renewable energy equipment, non-fossil-fuelled vehicles (such as electric vehicles) and transportation technologies or systems, energy-efficient equipment, designs and technologies, environmental monitoring equipment, and climate adaptation technologies (such as climate-adapted seed varieties, early warning systems, adaptation infrastructure).[71]

As noted above, different developing countries will have different technology transfer requirements depending on their national circumstances. For example, economies that depend on fossil fuel imports will need to move towards renewable energy sources that allow for greater energy autonomy and self-sufficiency, while those countries with great renewable energy capacity

potential would have significant scope for progress in shifting to renewables.[72] Fossil-fuel-export-dependent developing countries, such as those in the Persian Gulf, could prioritize technology transfers that support economic diversification away from their fossil fuel extractive industries into existing non-fossil-fuel sectors within their respective economies (such as banking in Bahrain; logistics, seaports and trade in Dubai; the trade sector in Kuwait; and fisheries in Oman), and into new sectors with high growth potential such as aviation (airports, airlines, and air transport servicing and logistics), education, tourism and hospitality (such as conference and experiential tourism), finance, real estate, logistics and business services or, within manufacturing, high-technology-content products produced using low- or no-emissions production methods.[73]

Developing countries tend to prioritize climate-relevant technologies that are already at a mature or near mature stage, showing that "the key barrier to take up is access to the technology itself and technology adoption capacity."[74] This is consistent with other analysis showing that for developing countries that need to catch up or undertake more rapid climate action, the more mature technologies would be simpler and more affordable options since they demand less research and development.[75] For those developing countries that have the capacity to do so, there are also green frontier technologies that could be considered, although in this case, the innovation field is generally dominated by developed countries and China.[76]

The TNAs undertaken by many developing countries in the context of the UNFCCC are very revealing in terms of their priorities with respect to climate mitigation and adaptation technologies for which they are seeking technology transfer support. Ninety-two percent of the developing countries that undertook TNAs clearly stated that their national development priorities were considered in the TNA process, categorizing these priorities as environmental, social or economic. The commonly identified environmental development priorities were the reduction of environmental risks, environmentally sustainable development, efficient water management, and reduced air pollution. Among the most commonly identified social development priorities were reducing poverty and creating wealth and ensuring food security. The economic development priorities that were commonly identified included the development of infrastructure, enhanced energy security, increasing employment levels and enhancing general economic growth.[77] The TNAs

support countries' NDCs by providing a "bottom-up technology realism" to a country's NDC planning; top-down processes of NDC planning based on a national target and corresponding policies and measures "could forget what is realistic, by favouring 'state of the art' technologies" that might be less feasible for scaled-up implementation within a country context.[78]

The TNAs of developing countries highlighted the sectors and the technologies within each sector that they prioritized for purposes of climate mitigation and adaptation. For mitigation, almost all prioritized the energy sector, with the most prioritized subsectors of the energy sector being energy industries and transport. For adaptation, agriculture and water were the most prioritized sectors, followed by infrastructure and settlements.[79] Below is a summary of the mitigation and adaptation technologies prioritized by developing countries in their TNAs:

TNA Prioritized Mitigation Technologies	TNA Prioritized Adaptation Technologies
Parties identified more than 950 technology options in their preliminary lists (or long lists) of technologies within their prioritized mitigation sectors or subsectors. More than 350 technology options were prioritized by Parties. Within the energy sector (the most prioritized mitigation sector), the majority of the technologies prioritized for the energy industries subsector were related to electricity generation. Solar PV and hydroelectricity generation technologies were the most prioritized. Many of the prioritized technologies in the energy industries subsector were renewable energy technologies. In terms of scale of application, a minority of the prioritized technologies for electricity generation were small-scale technologies (i.e., for home application or not generally grid-connected). Most of the technologies within that category were for medium- or large-scale application (i.e., grid-connected plants). For the transport subsector of the energy sector, 39% of the Parties prioritized	Parties identified more than 1,000 technology options in their preliminary lists (or long lists) of technologies within their prioritized adaptation sectors. More than 400 technology options were prioritized. The technology needs identified in relation to adaptation comprised hard technologies, such as dikes and floodwalls, sprinkler and drip irrigation systems, and drought-resistant crop varieties, and soft technologies, such as the establishment of water user associations and the roll-out of knowledge transfer and awareness campaigns. Some of the Parties also prioritized indigenous technologies that could be used to assist national adaptation to changing weather conditions, such as traditional housing designs, bunds, levees, dikes and mangrove plantations. In that regard, the needs identified were generally related to the deployment and diffusion of the technologies and the further improvement of their design and quality through research and development. Within the agriculture sector (the most commonly prioritized adaptation sector), most of the technologies prioritized were related to

TNA Prioritized Mitigation Technologies	TNA Prioritized Adaptation Technologies
technologies relating to modal shift, such as mass rapid transit road or rail systems, and 37% prioritized energy-saving technologies, including vehicle technology improvements. From the overview of prioritized technologies for transport, Parties mostly prioritized soft technologies, aimed at instituting behavioural change in relation to transportation and improvement of infrastructure. For the agriculture, forestry and other land use sector, prioritized technologies for mitigation in the forestry subsector were quite diverse, covering a wide range of categories. These primarily included forest conservation technologies, such as the protection of forest areas, promotion of sustainable forest management and general improvement of forest management. Sink enhancement (afforestation or reforestation) and forest rehabilitation and restoration techniques were also among the prioritized technologies. Technologies prioritized for the agriculture subsector of the agriculture, forestry and other land use sector included mainly new or alternative agricultural practices, such as organic farming; classic, mini or no tillage; fertilizer dosing; and irrigation techniques.	sprinkler and drip irrigation (prioritized by 37% of Parties), as well as biotechnologies, including technologies related to crop improvement, new varieties and drought-resistant, salient-tolerant and short-maturing varieties (together prioritized by more than 50% of Parties). Conservation agriculture and land-use planning was prioritized by 21% of Parties undertaking TNAs for adaptation. In the water sector, Parties prioritized technologies relating to rainwater harvesting (54% of the Parties) and water storage and catchment (35%). Within the infrastructure and settlements sector (including coastal zones), most of the prioritized technologies were related to coastal protection, including both hard and soft measures. The most commonly prioritized technologies related to wetland restoration and natural disaster prevention, such as early warning systems. Others included seawalls, mapping and surveying, and beach reclamation.

Source: UNFCCC, Fourth synthesis of technology needs identified by Parties not included in Annex I to the Convention: Report by the secretariat (FCCC/SBI/2020/INF.1, 3 April 2020), paras. 67-81, at https://unfccc.int/sites/default/files/resource/sbi2020_inf.01.pdf

In terms of regional distribution of technology transfer priorities, analysis of TNAs from countries in Africa, Asia-Pacific, and Latin America and the Caribbean commissioned by some UN agencies and the Global Environment Facility (GEF) highlights both similarities and differences among these regions, as summarized in the table below:

	Mitigation	Adaptation
Africa	Solar energy technologies are by far the most commonly prioritized technologies in respect of mitigation, representing 22% of the overall mitigation technologies prioritized by African countries, and accounting for 33% of overall energy-related technologies. The range of solar technologies is broad, and choices vary greatly from one country to another. Several countries identified large-scale and more complex solar technologies. In the land use and forestry sector, technologies related to forest management, reforestation and forest conservation were given a high priority, while in the waste management sector mechanical-biological waste treatment, along with waste recycling and composting, constituted first-choice technologies.	Ninety-four percent of African countries have prioritized agriculture and water as their key sectors for adaptation when assessing their technology needs. This is particularly because of the continent's very high dependency on agriculture. Increases in temperature and rainfall reduction associated with climate change will reduce agricultural production and increase the demand for more land and water to compensate for climate stresses. The coastal zones sector has been prioritized by 29% of countries, alongside land use, land-use change, and forestry (LULUCF & forestry) (19%). For the agricultural sector, countries have prioritized technologies for the management and diversification of crops, the development of new crop varieties, drip irrigation, soil management and food conservation. The diversification of crops and the introduction of new crop varieties constitute effective measures with which to build a resilient agriculture sector. In the water sector, water storage and harvesting, water management and water catchment are the most prioritized technologies. Finally, coastal zone management and restoration, climate monitoring and forecasting, and hard coastal protection are the most prioritized technologies for coastal zone adaptation.

	Mitigation	Adaptation
Asia-Pacific	Through the TNA process, all participating countries in the Asia-Pacific region have so far identified the energy sector as a key priority for their mitigation actions. Generally prioritizing two mitigation sectors, 41% of the region's countries have also prioritized the transport sector, and 23% the waste management sector. In the energy sector, countries have prioritized technologies related to solar energy, such as solar minigrids, solar irrigation pumps, solar lanterns and solar water-heating technologies.	Generally focusing on two adaptation sectors each, 90% of countries in the Asia-Pacific region prioritized the agriculture sector, 86% prioritized the water sector, and 33% prioritized the coastal zones sector. Climate-change-induced natural disasters such as tsunamis, typhoons and cyclones are also increasing in the region, and 19% of its countries identified natural disasters as a priority sector. In the agriculture sector, countries often identify technologies for the development of salt-, pest- and drought-tolerant crop varieties, drip irrigation systems, precision farming and windbreaker rehabilitation.
Latin America and the Caribbean	In their TNAs, 88% of Latin American and Caribbean countries prioritized energy as a mitigation sector, 53% transport and 24% agriculture. In the energy sector, countries are predominantly prioritizing technologies for energy-efficient buildings and lighting systems, bioenergy and solar energy.	Generally focusing on two adaptation sectors each, countries in the region have most frequently prioritized water (89%), agriculture (67%) and coastal zones (39%) as key adaptation sectors. In the water sector, countries' technology priorities include rainwater harvesting, storm-water reclamation and reuse, water mapping and modelling, and water-quality monitoring. In the agricultural sector, the priority is on technologies for irrigation and farming systems, such as drip irrigation, micro-sprinklers, soil nutrition, soil conservation and the introduction of climate-resilient crops.

Sources: Lea Jehl Le Manceau et al. (eds.), Technology Needs Assessment Regional: Technology Brief – Africa (2020), pp. 3-5, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNA_key_doc/2f7c0abccd674d41a183f347655f0b68/db28bf347c694b43ad27da5a93b01304.pdf; Lea Jehl Le Manceau et al. (eds.), Technology Needs Assessment Regional: Technology Brief – Asia Pacific (2020), pp. 4-5, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNA_key_doc/e247e8710df74cb7b394981905ad8806/292029a852fd48909fc9874a00959a1c.pdf; Lea Jehl Le Manceau et al. (eds.), Technology Needs Assessment Regional: Technology Brief – Latin America and the Caribbean (2020), pp. 3-4, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNA_key_doc/c88e74e06c88435cb3ff3c4ef9ba0fd5/3d92bd20f4aa4dc1a70c1d91bacddfc9.pdf

UN analysis suggests that technologies originating from developing countries are likely to be more suitable and cost-effective for other developing countries because of similar geoclimatic, cultural or socioeconomic conditions.[80] While technology transfer as envisioned under the UNFCCC, Agenda 21 and other instruments is primarily seen as a North-South flow due in large part to the dominance of developed countries in terms of technology innovation, development, production, and trade, South-South cooperation and triangular cooperation modalities for climate technologies are also taking place in and between all geographical regions and cover all priority areas outlined in developing countries' NDCs and national adaptation plans (NAPs), with the following thematic areas being the most promising for technology cooperation via these channels: agriculture, disaster risk reduction, renewable energy and energy efficiency, forestry, transport, water resources and waste management.[81]

A significant body of work has also been produced through the UNFCCC's technology institutions as well as other organizations such as WIPO that looks at the range of technologies that have been developed and which could be made the subject of technology transfers. These include technologies for adaptation in the water sector;[82] technologies for adaptation in the agriculture sector;[83] technologies relating to waste-to-energy and low-emission housing;[84] technologies for off-grid and decentralized energy solutions for smart energy and water use in the agrifood chain;[85] technology solutions to support the energy efficiency of vehicles and other modes of transport to support low-carbon transportation;[86] and renewable energy and energy efficiency technologies.[87]

A key outcome of the TNA process is the technology action plan (TAP) – a country's plan for the uptake and diffusion of prioritized technologies that will contribute to the country's social, environmental and economic development and climate change mitigation and adaptation. Developing countries are currently seeking support for around 640 TAPs and 440 project ideas that they prepared between 2009 and 2018.[88] Support needs range from financial resources for a given technology and the strengthening of institutions and human resources for technology research and development to capacity-building and the establishment of information and awareness-raising programmes.[89]

In their NDCs, many developing countries identified certain types of technology that they intend to use for implementing adaptation and mitigation actions, most frequently related to the energy, agriculture, water and waste sectors. Their identified technology needs were mainly of a cross-cutting nature addressing both adaptation and mitigation, followed by those focused on mitigation or adaptation.[90] The most frequently identified technologies in NDCs were related to the energy sector (e.g., enhancing use of renewable energy and clean hydrogen, and decarbonizing power systems and boosting their storage capacity), followed by agricultural technologies (e.g., climate-smart agriculture and smart irrigation technologies) and technologies related to water and waste management (e.g., waste-to-energy technologies and circular economy practices), and there is a growing focus on digital technologies for improving monitoring and data and information systems, including for forecasting and early warning systems, and on ecosystem-based technologies and practices, in particular across the agrifood system.[91]

Additionally, in a World Resources Institute survey of 50 long-term climate strategies so far submitted by countries to the UNFCCC under the Paris Agreement, "47 mention some plans for inclusion of natural or technological carbon removal, with 18 calling out specific technological carbon removal approaches, and four more considering the use of technological carbon removal."[92] Furthermore, analysis from the Clean Air Task Force from a review of 42 NDCs finds that both developed and many middle-income developing countries plan to use three broad types of advanced low-emission energy and climate technologies – carbon management (including carbon capture, utilization, and storage and direct air capture climate technologies); zero-carbon fuels (hydrogen and ammonia) produced using low-carbon methods; and nuclear energy (including advanced nuclear energy) – to meet their climate goals under the Paris Agreement.[93] As the study notes, some of the countries indicate they require international support to make use of the technologies and the interest in the different technologies reflects each country's past experiences, current energy use and potential, and climate and development goals – e.g., they already have experience in the technology, or they may be seeking to exploit growth opportunities.[94]

5 Technology Transfer and Trade Linkages

TECHNOLOGY transfer can be undertaken through many channels, with many paths and no single solution, with international trade in climate-relevant technologies being one of the main channels. While one challenge is to promote a greater level of technology flow from North to South through these channels, an equally important challenge is building the domestic capabilities in developing countries to adapt, use, and innovate on these technologies and eventually create endogenous ones.[95]

International trade

The impact of international trade on global GHG emissions can be both positive and negative, with such impact resulting from the interplay of the emissions released during the production and transportation of the traded goods and services, the emissions reduced as a result of increased availability of and access to climate-relevant goods and services, the adaptation impact of using such goods and services, as well as, among others, the sector and countries involved and the energy sources, production methods and modes of transport.[96]

Trade and trade policy can be a part of the policy toolbox to support climate action, just transitions, and moving the global economy to a low-carbon economy and sustainable development pathway. This is recognized in the 2030 Agenda; the IPCC has noted that trade-related measures can be among the policies and instruments that can incentivize mitigation actions; and the WTO Agreement's preamble itself recognizes sustainable development and the protection of the environment as an overarching objective.[97] Article 3.5 of the UNFCCC states that "the Parties should cooperate to promote a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties, particularly developing country Parties, thus enabling them better to address the problems of climate change. Measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade."

Greenhouse gas emissions in traded goods and services account for around a quarter of global carbon emissions, indicating that trade policy, in particular international trade rules, can play an important, albeit not primary, role in supporting climate change action.[98] However, international trade rules are shaped at the WTO, although regional and bilateral trade agreements also play key roles in governing trade flows.[99] Multilateral rules on climate change action are shaped in the UNFCCC and its Paris Agreement. The policy and practical intersection of these two international policy regimes and their consistency and coherence has been the subject of much policy and academic research and analysis.

International trade can be a key vector for the diffusion of climate-relevant technologies, increasing their availability, access and potential to be used by developing countries to undertake climate mitigation, adapt to the impacts of climate change and build resilience.[100] According to the IPCC, research indicates that trade can facilitate the entrance of new technologies, but the impact on innovation is less clear[101] – that is, it is not clear whether trade by itself can spur domestic innovation and the development of endogenous technologies as a result although some analysis suggests that expanding the market size for climate technologies could spur innovation, foster competition and scale economies, and drive down costs.

Some countries have incorporated trade and trade policies within their Paris Agreement NDCs among the measures that can be used to reduce emissions, including through the adoption of climate technology action plans.[102]

Trade concentration and flows

WTO analysis suggests that liberalizing trade in energy-related environmental goods,[103] for example, could boost global exports by 5% (USD109 billion) by 2030, with the resulting increases in energy efficiency and renewable energy uptake estimated to reduce net global carbon emissions by 0.6% as well as generating millions of new jobs in the clean energy and related sectors by 2030. The WTO also points out that liberalized trade can facilitate the development and deployment of goods and services essential to help to adapt to climate change, although it is careful to note that trade and trade policy are “not a panacea to adapt to the highly disruptive consequences of climate

change." [104] There continue to be barriers (such as tariff and non-tariff measures) to trade in environmental goods and services, while these barriers tend to be lower in carbon-intensive industries than in clean industries.[105] Furthermore, for developing countries, there are also concerns about the potential discriminatory impact of climate- or sustainability-related labelling or certification requirements or regulations on goods that they export to developed countries arising from lack of capacity to comply with such requirements.[106]

In 2017, the global market for trade in climate-relevant technologies goods and services reached USD1.12 trillion.[107] Trade in such goods reached USD1.9 trillion in 2022, with electric and hybrid vehicles, non-plastic packaging and wind turbines performing especially well; UNCTAD projects that the global market for electric cars, solar and wind energy, green hydrogen and a dozen other green technologies will reach USD2.1 trillion by 2030.[108]

Source: UNCTAD, Global Trade Update (March 2023), at https://unctad.org/system/files/official-document/ditcinf2023d1_en.pdf

While trade in climate-relevant low-carbon technologies has increased more than global trade over the past three decades, developed countries continue to account for most of both exports and imports of such technologies (although China has become the world's largest single country importer and exporter of these technologies).[109]

In 1990–2015, 80% of all low-carbon technological inventions were concentrated in developed countries, with Japan, the United States and Germany leading the way.[110] Exports of climate- or sustainable-development-relevant technologies and knowledge remain concentrated in developed countries, which accounted for 72.8% of total exports in such technologies by value in 2016; upper-middle-income developing countries accounted for a quarter of such exports, and lower-middle-income and low-income developing countries combined accounted for just 2% of exports in 2016 (1.9% and 0.1% respectively).[111] Of this trade in 2016, North-South trade accounted for around a quarter while South-South trade accounted for 9%; South-North trade has also grown (but mostly from China and Mexico) from just 5.2% of global exports of such goods in 1992 to 18.1% by 2016.[112]

Between 2018 and 2021, total exports of green technologies from developed countries jumped from around USD60 billion to over USD156 billion, while in the same period, exports from developing countries rose from USD57 billion to only about USD75 billion (resulting in developing countries' share of global exports of such technologies falling from over 48% to under 33%).[113] In 2020, trade in such technologies accounted for 5% of global trade, with developed countries having the largest export share (69.82%), followed by middle-income developing countries (30.16%) and low-income developing countries (0.02%).[114]

These figures highlight what UNCTAD has noted with respect to such trade patterns – "developed economies are seizing most of the opportunities, leaving developing economies further behind."[115] Developed countries are largely remaining ahead of and dominating the curve (particularly with respect to so-called "frontier technologies", including climate-relevant technologies) while developing countries in Latin America, the Caribbean and sub-Saharan Africa are the least ready to harness such technologies and hence more at risk of missing technological opportunities (several Asian countries such as India and some in Southeast Asia are in a better position).[116]

Tariffs and non-tariff measures

Such trade flows are shaped in many ways by tariff and non-tariff measures. The reduction or elimination of tariff and non-tariff barriers to environmental goods and services trade was made the subject of multilateral negotiations in the WTO from 2001 as part of the Doha Round.[117] These multilateral negotiations came to a standstill without concluding in 2011; a subsequent attempt launched in 2014 by 18 WTO members to craft a plurilateral Environmental Goods Agreement likewise collapsed in late 2016 – since then, no actual negotiations on the liberalization of tariff and non-tariff barriers to such goods have taken place either multilaterally or on a plurilateral basis in the WTO.[118]

The policy rationale for launching such negotiations was that trade liberalization of such goods and services would make them more available and affordable by expanding markets, thus promoting environmental sustainability. However, tariffs on many climate-relevant environmental technologies are generally already low, averaging below 2% in 2016; developed countries have low tariff rates of below 1% (averaging 0.5%) while such rates tend to be higher in developing countries (averaging 5–6% and sometimes going above 10–20%).[119] With such low tariffs, especially in developed countries, there is little improved market access to be achieved through such negotiations – there are empirical studies that confirm the limited gains from tariff liberalization of such goods.[120]

Such gains (from increased exports) would accrue primarily to developed countries which are the main producers and exporters of such technologies, thereby exacerbating existing trade imbalances between developed and developing countries with respect to such technologies and providing few, if any, gains to developing countries.[121] Aside from limited gains from trade, such tariff liberalization could lead to substantial tariff revenue losses for developing countries – for example, in 2019, tariff revenue collected on these goods by developing countries amounted to USD15 billion (using applied tariffs), which, if tariffs were to be reduced or eliminated, would be revenue lost to developing countries with negative implications on their fiscal space.[122] In any event, developing countries may always unilaterally reduce or eliminate their tariffs on environmental goods if they so wish.

The climate rationale (in terms of reduction of GHG emissions) for liberalizing such tariffs is also unclear. One study for example stated that measuring emission reductions directly attributable to such liberalization or scale-up of the use of such technologies would be difficult, yet went on to suggest that "the maximum possible emissions reductions from tariff cuts would be just under 1% of 2030 emissions levels" and that the scaling up of the use of renewable energy technologies that may result from such tariff liberalization "could have a maximum abatement potential of up to 6.5 gigatons of carbon dioxide equivalent (GtCO2e) per year by 2030."[123]

Non-tariff measures (NTMs) constitute more significant barriers to the international trade in climate-relevant technologies.[124] These include a broad array of trade control instruments such as licences, quotas, price control measures and finance measures as well as technical regulations covering product characteristics, production processes and import conditions related to environmental protection or sustainability. According to UNCTAD and the IPCC, NTMs have been widely adopted to limit global GHG emissions – such as through technical regulations on mitigation efforts in areas such as energy efficiency, consumer information (labelling), fuel standards and low-emission industrial materials – to incentivize trade partners to adopt domestic climate change mitigation measures, or to remove disincentives to climate action.[125]

Such NTMs tend to be imposed more by developed countries rather than developing countries, reflecting underlying regulatory requirements that can easily become barriers to trade that developing countries may have difficulties with.[126]

The disagreements between developed and developing countries with respect to the liberalization of trade in climate-relevant technologies that led to the stalling of the multilateral and plurilateral negotiations on environmental goods can be directly linked to the perceived imbalance as to who would be the prospective winners (developed countries) and losers (mostly developing countries) from such negotiations. Pushing to further liberalize already low tariff rates while not addressing and eliminating NTMs is seen as a clear market access agenda on the part of developed countries that would only benefit them, lead to tariff revenue losses in developing countries, intensify the technological divide between them, and result in non-commensurate

minimal (if at all) global environmental gains in the form of emission reductions.[127] Nevertheless, as pointed out above, developing countries may at any time unilaterally reduce their tariffs if they deem it appropriate to do so.

Should tariffs on climate-relevant technologies (such as energy-related environmental goods and environmentally preferable products) be reduced or eliminated globally and NTMs on these technologies also reduced, WTO analysis suggests that these would "reduce global CO2 emissions by 0.58% in 2030, relative to the baseline. About half of this reduction in emissions would be the result of tariff liberalization, while the other half could be attributed to the reduction of NTMs."[128]

While current trade patterns in climate-relevant technologies may be imbalanced in favour of developed countries due to tariff profiles and NTMs, many developing countries (largely in Asia) do also import, innovate, produce, and export such technologies. For developing countries, the key challenge is how to maximize and realize the technology innovation potential of such imports of traded climate-relevant technologies as may take place so that these effectively contribute to the development of endogenous technologies that can enhance climate action and support sustainable development.

Some studies have pointed out that improved access to climate-relevant technologies through trade measures such as tariff and NTM liberalization can support a switch to low-carbon, efficient, and environmentally sound production processes, adoption of cleaner technologies, innovation, and employment creation in renewable energy and climate-friendly sectors.[129]

Endogenous technology innovation and development as an outcome of international trade in climate-relevant technologies requires more than simply liberalizing tariffs or reducing NTMs, however. A full suite of complementary policies, regulatory framework, investment and finance flows are needed in order to bring about the desired technology transfer outcomes.

For example, there should be a clear policy signal of the government's intent to pursue a low-carbon sustainable development pathway (such as NDCs, national climate action plans, or long-term low-emission development strategies). The regulatory framework needed to implement this policy signal

should be put in place, with adequate human resources and financial resources. Capacity-building and support for endogenous research and development would also be essential, including in providing skills training for local scientists, experts and engineers to enhance their ability not only to operate new technologies efficiently but also to modify, adapt and improve upon imported technology and to innovate in the development of new designs, production processes and products.

In particular, attention should be paid to ensuring that national intellectual property systems are geared towards promoting and supporting endogenous learning and follow-on innovation with respect to imported and transferred technologies. In doing so, governments should exercise maximum policy flexibility with respect to the adoption and use of intellectual property (IP) standards, with the aim of "dynamic competition."[130]

Intellectual property rights

The role of intellectual property rights in promoting or impeding technology transfer, technological progress and innovation in countries at different levels of development is an important consideration.[131]

Climate-related technologies exhibit similar patterns as other technologies, particularly in terms of geographical concentration in developed countries and low levels of diffusion in developing countries.[132] A study of over 800,000 patents filed between 1990 and 2015 for climate-relevant mitigation technologies showed that the largest number of patented technologies is in the energy,[133] manufacturing, and transportation sectors (which also accounted for the largest share of innovations or inventions over the same period), while carbon capture and storage (CCS), a recent and more limited field, accounts for the fewest patented technologies. These innovations or inventions are concentrated in developed countries and China, which produced at least 80% of climate-relevant innovations, while lower-middle-income and low-income developing countries produced almost none during the same period.[134]

Similarly, patented adaptation technologies are concentrated in predominantly developed countries, with two-thirds of such technologies in 2010–2015 being in China, Germany, Japan, the Republic of Korea or the United States.[135]

Patenting in most adaptation technologies has not surged in the past two decades, however, unlike the significant increase in patenting in mitigation technologies.[136]

The fact that most patents for climate-relevant technologies are in developed countries has significant implications on technology transfer possibilities as the design and use of such technologies may not be directly responsive to the needs of developing countries.[137] Most of these patents are held by private sector companies in developed countries, giving them a significant competitive advantage relative to their developing-country counterparts.[138] Furthermore, most of the climate-related research that contributes to the development of climate-related technologies in one way or another is carried out in developed countries: an analysis found that "between 2000 and 2014, for the 93,584 publications on climate change, more than 85% of author affiliations were from OECD countries, less than 10% were from any country in the South, and only 1.1% were from low-income economies. This has the effect of narrowing research paradigms to the cultural settings and perspectives of the global North and of countries mainly in the West, while depriving the scientific community of considerable intellectual capital."[139]

International patent data show "negligible levels" of transfers of such technologies to low-income developing countries as almost three-quarters of all such transfers between 2010 and 2015 occurred between developed countries, around a quarter from developed to middle-income developing countries, 4% from middle-income developing countries to developed countries, 1% between middle-income developing countries, and almost no technology transfers took place to or from low-income developing countries.[140] Likewise, 85% of cross-border trade of adaptation-related patents took place in developed countries and China.[141]

Among developing countries, China is the primary outlier in terms of innovation and patenting in climate-relevant technologies, reflecting its prioritization of innovation in such technologies.[142] This is consistent with China's new economic development push to grow new strategic industries and become a global climate leader, making its new energy industries significant domestic economic drivers, particularly in the areas of solar panels, electric vehicles, and energy storage.[143]

Several forms of intellectual property are potentially relevant to climate change mitigation and adaptation initiatives: patents, trademarks, especially certification marks, trade secrets/know-how, plant variety rights, and the suppression of unfair competition. However, the climate change discussions touching on the IP system have principally concerned patents.[144] Companies that export technology and invest in foreign countries use patents to protect their intellectual property, making patents a proxy measure of technology transfer because they "give the right to commercially exploit the invention in the country where the patent is filed and because patentable technologies must be both novel to the local context and susceptible to industrial application."[145]

There continue to be academic and policy debates over the impact of patents on technology development and transfer, especially with respect to climate-relevant technologies. The evidence as to whether patents promote or hinder technology transfer continues to be contentious, with proponents on both sides of the debate. On one hand, some argue that stronger patent rights may trigger increased international trade flows as patent-sensitive industries and firms respond positively to the strengthening of patent rights among middle-income and large developing countries, and that patents do not prevent countries from taking measures to promote climate-related technology transfer (so long as the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) is complied with).[146] On the other hand, some argue that stronger patent rights can prevent endogenous innovation through reverse engineering and adaptive copying, can be expected to raise considerably the rents earned by international firms as patents become more valuable, obliging developing countries to pay more for the average inward protected technology, and would not result in technology transfer to developing countries, especially low-income developing countries.[147] Yet there are others that show that the picture will likely be mixed, depending on the circumstances in which the technology transfer and the patented technology interact.[148] In any event, one should also note that with respect to climate-relevant technologies, under Article 4.5 of the UNFCCC, technology transfer is a treaty commitment of developed countries that should be complied with regardless of the level of IPR protection existing in developing countries.

Developing countries have recently stressed the importance of having the WTO reinvigorate the discussions that have been taking place since 2002 on the relationship between trade and technology transfer. The African Group of countries in July 2023 called for the WTO's Working Group on Trade and Transfer of Technology (WGTTT) to undertake thematic discussions on the role of technology transfer, including with respect to pandemics, digital technologies, agricultural resilience, climate change, and e-commerce.[149] India in October 2023 proposed a roadmap for work to be undertaken by the WGTTT in relation to trade and technology transfer to address climate change.[150]

6 Technology Transfer and Finance

SUPPORTING technology transfer to developing countries in a way that enables them to undertake endogenous technology development requires: (1) addressing financial and capacity constraints that impact on technology absorption and innovation, and (2) having the policy space in which to do policy exploration to determine what technology transfer approaches would work best.

The UNFCCC and the Paris Agreement recognize the integral linkage between financing and effective technology transfer, with both instruments clearly indicating that developed countries' climate finance commitments include financing technology transfer.[151] Technology transfer rarely happens without financial support, which may take the shape of finance available to risk-takers and entrepreneurs or incentives provided by governments to improve access to technology.[152]

As noted previously in this paper, developing countries have indicated finance as both a key challenge and a key enabler of effective technology transfers. The finance requirements for the implementation of the technology action plans and project ideas developed by developing countries under the UNFCCC have been estimated by the UNFCCC. For the implementation of the technology action plans, a cumulative estimated budget of USD20.1 billion for mitigation and USD4.4 billion for adaptation is needed. For the implementation of technology project ideas, USD22.0 billion for mitigation and USD14.0 billion for adaptation would be needed.[153] Many developing countries provided quantitative estimates of their financial support needs in their NDCs.[154]

A UNEP study identified region-specific financing needs for technology transfer based on countries' technology action plans as follows:

	Mitigation	Adaptation
Africa (22 countries)	USD2.7 billion	USD2.4 billion
Asia-Pacific (16 countries)	USD5.3 billion	USD1.2 billion
Latin America and the Caribbean (14 countries)	USD0.1 billion	USD0.542 billion

Sources: Lea Jehl Le Manceau et al. (eds.), Technology Needs Assessment Regional: Technology Brief – Africa (2020), p. 6, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNA_key_doc/2f7c0abccd674d41a183f347655f0b68/db28bf347c694b43ad27da5a93b01304.pdf; Lea Jehl Le Manceau et al. (eds.), Technology Needs Assessment Regional: Technology Brief – Asia Pacific (2020), pp. 5-6, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNA_key_doc/e247e8710df74cb7b394981905ad8806/292029a852fd48909fc9874a00959a1c.pdf; Lea Jehl Le Manceau et al. (eds.), Technology Needs Assessment Regional: Technology Brief – Latin America and the Caribbean (2020), p. 5, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TNA_key_doc/c88e74e06c88435cb3ff3c4ef9ba0fd5/3d92bd20f4aa4dc1a70c1d91bacddfc9.pdf

The bulk of financing for climate-relevant technology transfer is provided and generated, and will still have to be obtained, by developing countries from their domestic financial systems and their enhanced access to global financial markets and capital pools. This implies that the ability of developing countries to develop and maintain financial space will be crucial for them to be able to finance the infrastructure investments and associated climate technologies that are required to achieve sustainable development.[155] However, while the primary responsibility for financing inward flows of technology to support their sustainable development process rests with the developing countries themselves, existing treaty commitments such as Articles 4.3, 4.5, and 4.7 of the UNFCCC and Articles 9.1 and 9.6 of the Paris Agreement establish obligations on developed countries to provide financing to help developing countries meet the "agreed incremental costs"[156] associated with such technology transfers that are needed to implement climate actions.

Determining how much financing has been provided or received to support technology transfers to developing countries under the UNFCCC, however, is difficult – there is no associated common reporting format or methodology, institutional capacity is often limited, and data and resources to track climate finance received are often lacking.[157]

According to their biennial reports under the UNFCCC, developed countries have more than doubled their number of technology development and transfer activities since 2012–2013, reporting a total of 391 activities relating to technological support provided to developing countries (compared with 303 activities reported in the third biennial report submitted in 2017 and 170 in the first biennial report submitted in 2013). The technological support provided covered both hardware (equipment) and software (know-how, methods, practices) in approximately equal amounts. More than half (56%) of the supported activities were mitigation technology activities. Support for adaptation technology activities made up around a quarter of all the supported activities (26%). The remaining activities related to technologies that cut across both mitigation and adaptation. Support for adaptation technology transfer activities mainly targeted the agriculture, cross-cutting and water sectors (including agricultural practices, such as seed or crop improvements, climate-smart and/or biological farming, or general food security improvements, general infrastructural development or research and development activities, disaster risk reduction, water supply systems, water desalination and water harvesting). Support for mitigation technology transfer efforts focused on the energy sector (about 63%), especially on renewable energy (such as implementation of either general renewable energy technology efforts or specific renewable energy technologies, such as solar, biomass, geothermal, wind and hydropower) and energy efficiency. In this context, the technology activities reported by developed countries in their fourth biennial reports were consistent with the prioritized technology needs identified by developing countries in their technology needs assessments.

Developing countries in the Asia-Pacific region continued to benefit most from the reported technology support, with almost half (46%) of all technology support focusing on the region, followed by Africa (23%) and Latin America and the Caribbean (13%). More than half (62%) of technology activities reported by developed countries went to activities in the least developed countries and small island developing States. The sources of funding for supporting implementation of technology activities were in most cases public, with the majority of activities being undertaken by public-private partnerships (63%).[158] However, it is not possible to calculate how much financing for technology transfer has been provided by developed countries due to the lack of data contained in their biennial reports under the UNFCCC.

Financing channels for technology transfer under the UNFCCC and Paris Agreement to developing countries vary. In their biennial reports under the UNFCCC, several developed countries highlighted that they had mainstreamed technology transfer activities in their bilateral development cooperation (official development assistance (ODA)) activities.[159] They are doing so through various development cooperation instruments, including direct support and financing, technical assistance and capacity-building financing, policy support financing, and catalyzing and mobilizing additional finance.[160]

UNEP has estimated that the amount of technology-related climate development finance has significantly increased between 2015 and 2019, from USD13.3 billion to USD28.6 billion, outpacing the growth rate in total climate-related development finance. Development cooperation support for mitigation-related technology transfer in the energy sector totalled USD8.9 billion a year in 2015–2019 or 53% of development finance for mitigation-related technology transfer. According to UNEP, the sectors that developed countries targeted the most for their ODA financing between 2015–2019 to support technology transfers were the energy sector (34%), transport and storage (28%), agriculture (12%), environmental protection (8%) and water supply and sanitation (5%). Most of this funding took the form of debt instruments (59%), followed by grants (40%) and equity investment (1%).[161]

In a separate analysis, UNCTAD reported that the technology sectors that attracted "green ODA" the most in 2020 were transport and storage, and agriculture, forestry, and fisheries. Of this, 51% was in the form of grants, and 45% in debt instruments. In terms of regional distribution, 41% went to Asia, and 25% to Africa. UNCTAD highlighted a concern over the use of debt instruments, which appeared to be highest in the lower-middle-income developing countries, at 75%, followed by upper-middle-income developing countries at 67%. Other low-income countries received ODA solely through grants, though in far lower amounts.[162]

Debt-based financing for technology transfer, as part of debt-based financing for mitigation and adaptation in developing countries, increases the debt burdens of the developing-country recipients. For example, in 2020, according to a study, USD48.6 billion, constituting 71% of developed countries' public

climate finance flows, was channelled through concessional and non-concessional loans for developing countries, while grants amounted to only USD17.9 billion (26%). The cost would be substantial for developing countries as the obligation to repay such climate-finance-sourced debt, when added on to other existing debt payment obligations, could severely restrict any remaining or available fiscal space to implement climate and other sustainable development measures.[163] Such pattern of debt-based climate financing is particularly concerning on ethical, climate justice, economic justice, and climate action sustainability grounds, given that many developing countries are at high risk of, or are already in, debt distress.[164] Furthermore, debt-based financing essentially implies that it will ultimately be the developing countries fully paying for their climate actions themselves, something that is not consistent with the intent of Article 4.3 of the UNFCCC and Article 9.1 and 9.6 of the Paris Agreement for developed countries to provide financial resources, including for technology transfer, to developing countries to help them meet the incremental costs of implementing climate actions under the UNFCCC and the Paris Agreement.

Aside from bilateral development cooperation, financing from developed countries to support technology transfers under the UNFCCC and the Paris Agreement to developing countries is also channelled through the multilateral operating entities of the UNFCCC and Paris Agreement's Financial Mechanism – the Global Environment Facility (GEF) and the Green Climate Fund (GCF).

The GEF operates two funds dedicated to climate change – the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF). Both the SCCF and the LDCF have supported the transfer of climate-resilient technologies to developing countries in their project portfolios – in the period 2018–2022, 65 projects were approved totalling USD331.1 million which leveraged USD1.42 billion in co-financing.[165] The SCCF provides grants to developing countries to address, inter alia, limited access to climate-resilient technologies and infrastructure.[166] Under its 2022–2026 strategy, the SCCF has established a funding window to strengthen technology transfer, innovation, and private sector engagement in adaptation, with entry points including supporting technology transfer, innovation and deployment. Open to all developing countries, the SCCF's financial scenarios to support

technology transfer, innovation and private sector engagement range from USD103.5 million to USD198.5 million for 2022–2026, depending on donor funding.[167]

The GCF also supports and funds technology development and transfer, innovation, incubation and acceleration at different stages of the technology cycle, including funding readiness projects to support national innovation systems and support local technology production. As of September 2021, for example, the GCF approved funding for readiness support for 40 technology-related projects totalling USD19.4 million. An analysis of 173 projects in its project portfolio indicated that 65% of GCF projects have at least one technology component.[168]

Despite the bilateral and multilateral funding made available by developed countries to support technology transfer under the UNFCCC and the Paris Agreement as discussed above as well as the other technology-related initiatives within the UN system, it is clear that the quantum of such funding and the impact of such initiatives are insufficient. The need to scale up climate finance, including for technology transfer, has led to "an increasing focus on more catalytic use of scarce development finance resources, and an evolution of the operating models used by development banks and finance institutions."[169] In this vein, the TEC and CTCN, for example, have warned that insufficient funding continues to be a key challenge, that public funds are limited and therefore it is necessary to tap the private sector and encourage public-private partnerships.[170]

Examples of these partnerships include:

- The Climate Resilience and Adaptation Finance and Technology Transfer Facility (CRAFT), a commercial investment vehicle and growth equity fund focused on expanding the availability of technologies and solutions for climate adaptation and resilience. It will invest in 10–20 companies, located in both developed and developing countries, which have proven technologies and solutions for climate resilience and have demonstrated market demand and revenue. The fund, together with an accompanying technical assistance facility, will help companies – like weather analytics, catastrophe risk modelling services, and drought-resilient seed

companies, among others – expand into new sectors and geographic markets.[171]

- The European Bank for Reconstruction and Development's Finance and Technology Transfer Centre for Climate Change (FINTECC) programme helps companies implement climate technology, offering grants and technical support.[172]

- The Climate Investment Funds' Clean Technology Fund (CTF) seeks to enable clean energy transformation in developing countries by providing resources to scale up low-carbon technologies with significant potential for long-term greenhouse gas emissions savings. The fund supports a wide array of clean technologies across different areas, including renewable energy, energy efficiency (of buildings, agriculture, and industry), and clean transport.[173]

The TEC, in particular, has also noted that fully leveraging the potential of climate technologies will need innovation in other areas such as financing, social innovation (including new cooperative forms and business models), information sharing and policy mechanisms. On finance, the TEC noted that "venture capital and angel investors are growing alternative sources of funding for bringing climate technology prototypes to market. Green bonds are also beginning to provide significant financing for technological innovation, especially for large scale diffusion of mature technologies. Examples of social innovation include innovative pay-as-you-go models that are revolutionizing the use of pico-solar photovoltaic technologies in the developing world, especially in Africa and India. And new policy mechanisms such as feed-in tariffs or auctions are innovative ways to build markets and create demand."[174]

7 Entry Points for Enhanced International Cooperation on Technology Transfer

GREATER attention needs to be paid to endogenous technology development in developing countries in support of their economic diversification and just transition efforts to shift to low-carbon development pathways and improve climate change adaptation and resilience prospects. It is not about simply improving terms of trade for these technologies but using trade-related and other policy measures to support shifts in production and consumption patterns in developing countries.

The gap between developed and developing countries when it comes to the ability to develop, innovate, access, endogenously produce and deploy climate-relevant technologies is a key constraint adversely affecting collective progress in global efforts to achieve sustainable development and effective climate action. Existing treaty instruments such as the UNFCCC and its Paris Agreement, the TRIPS Agreement and the Convention on Biological Diversity (CBD), among others, and agreed multilateral arrangements such as the SDGs all recognize that such a gap needs to be addressed through a coherent and effective combination of national action and international cooperation to promote the transfer of technology from developed to developing countries, in the first place, and to encourage the development of endogenous technologies in the second place.

National action

In the area of national action, advancing these objectives will require a more strategic approach to technology-related policymaking in the context of the achievement of national sustainable development priorities and objectives. Structural transformation of the national economy, focused on technological and economic diversification into climate-adapted and environmentally

sustainable sectors appropriate to national conditions and reflective of the existing and projected impacts of climate change, would be the goal. Given the diversity of developing countries and their development conditions, some developing countries might wish and be able to undertake such structural transformation on a purely national basis; other developing countries might conclude that such structural transformation should be achieved through strengthening regional integration processes; yet other developing countries might find that international cooperation and integration into global value chains would be the primary vectors for structural transformation; and still others might find that such transformation will require all of these approaches to be undertaken whether sequentially or simultaneously.

The United Nations' recent reports looking at the implementation of the SDGs showed that the current complex of environmental crises facing the global community, including climate change, biodiversity loss, land degradation and pollution, and their underlying causes demonstrate the interdependency and interlinkages among the various dimensions of sustainability – from health, well-being, and social and economic prosperity to climate and ecosystems. To address the vulnerabilities exposed by the COVID-19 pandemic, governments and the international community should make structural transformations and develop common solutions guided by the SDGs. These include significantly strengthening social protection systems and public services (including health systems, education, water, sanitation and other basic services); increasing investments in science, technology and innovation; creating fiscal space in developing countries; taking a sustainable green economy approach and investing in clean energy and industry; and transitioning to sustainable food systems.[175] For example, UNCTAD has recommended that the trajectory of development for developing countries should be to build a diversified low-carbon economic system, powered by renewable energy sources and green technologies, where economic activities within and across sectors are interconnected through resource-efficient linkages and leading to diversification into high-productivity high-wage activities.[176]

A key first step at the national level to undertake such structural transformation and move either national or, in some cases, regional integration into more economically diverse and sustainable trajectories would be for governments to strengthen national capacities for analyzing new sectors and identifying

and acquiring the skills, infrastructure, and resources needed for the transformation. This will require an evaluation of the country's existing technological and productive capacities,[177] the availability of natural resources, how a transformed national or regional economy could fit into the global economy and global value chains, and the changes that need to be made to existing institutional frameworks and economic systems.[178] Successful structural transformations have generally relied on proactive government policies and effective regulations that would set the direction of travel towards sustainable development, investment signals into green economic sectors and research and development, development of the needed infrastructure and skills, and building the domestic (or regional) market demand for climate-relevant technologies.[179]

A key tool in this regard would be the employment of green industrial policy as an important part of the policy mix governments can use to foster economic diversification, direct the economy towards achieving environmental goals, and increase resilience to the impacts of response measures. Green industrial policy would include, inter alia, measures to encourage cleaner production in potentially impacted vulnerable sectors (e.g., promoting renewable energy as an input to the production of traded steel); redesigning existing export goods such that they have less climate impact in their end use (e.g., promoting a shift from internal combustion engine vehicles to electric vehicle production; promoting production of higher-efficiency white goods); phasing out of significant climate-damaging sectors (e.g., removal of subsidies to entrenched vulnerable sectors such as the fossil fuel industry); and supporting the development of entirely new low-carbon and climate-adapting sectors of economic activity (e.g., promoting the development of new clean energy technologies, transportation systems, or production methods).[180] Such green industrial policies are likely to gain more attention as part of the policy toolbox for countries to undertake economic diversification efforts and move towards a low-carbon development pathway.[181] Green industrial policies, however, could have trade-related implications mainly through the use of standards, labelling requirements and other regulatory measures relating to the industrial production of goods, focusing either on the energy performance of the goods themselves or on production or processing methods (PPMs).[182]

International cooperation

In most cases, developing countries' national actions to pursue sustainable development and climate-resilient adaptation pathways should be supported by international cooperation arrangements. This includes, especially, international cooperation for technology transfer. This need is reflected in the fact that within the United Nations system, there are several technology-related initiatives intended to support developing countries, including:

- The UN pursuant to the Addis Ababa Action Agenda (AAAA) established the Technology Facilitation Mechanism (TFM) to support the SDGs by encouraging the development, adaptation, dissemination, diffusion and transfer of environmentally sound technologies to developing countries. Its goal is to facilitate multi-stakeholder collaboration and partnerships through the sharing of information, experiences, best practices and policy advice among member States, civil society, the private sector, the scientific community, United Nations entities and other stakeholders. It does not, however, provide financing.[183]

- The UN Technology Bank for LDCs helps LDCs identify through technology needs assessments appropriate technologies that address development challenges and facilitate their transfer to LDCs by strengthening scientific and technical knowledge and capacities. It does not provide financing.[184]

- The Climate Technology Centre and Network, hosted by UNEP, is the implementation arm of the UNFCCC and Paris Agreement's Technology Mechanism and has the mandate to promote "the accelerated transfer of environmentally sound technologies for low carbon and climate resilient development at the request of developing countries" by providing technology solutions, capacity building and advice on policy, legal and regulatory frameworks using expertise from a global network of technology companies and institutions. It supports technology matchmaking, technical assistance, international collaboration, and capacity building.[185]

- WIPO has established WIPO GREEN, its online platform and database for technology exchange to support global climate efforts by connecting

providers and seekers of environmentally friendly technologies. Green technology inventors, entrepreneurs and companies can list their products in the WIPO GREEN database while those seeking eco-friendly technology solutions can use WIPO GREEN to publicize their needs and find potential providers. The database can also be used by potential investors interested in green technology arrangements by providing information about and access to technologies, providers, and seekers globally.[186]

- Through its Division on Technology and Logistics, UNCTAD helps countries strengthen their national innovation systems, build capacity for science, technology and innovation policymaking, and obtain information and advice on the use and role of appropriate investment and intellectual property frameworks. It also hosts the UN Network of Experts in Science, Technology and Innovation Policy and Practice and the UN Commission on Science and Technology for Development.[187]

- The UN Industrial Development Organization (UNIDO)'s Investment and Technology Promotion Office (ITPO) promotes selected sound, productive and environmentally friendly technologies and know-how of Japanese companies seeking partners overseas, through foreign direct investment (FDI), joint ventures, licensing of technology, etc., with emphasis on, among other things, energy and environment-related technologies and solutions which Japanese enterprises possess. When UNIDO ITPO receives delegates from developing and emerging countries, those technologies and companies are introduced to meet their requirements for technology transfer.[188]

In the WTO, Article 66.2 of the TRIPS Agreement requires developed countries to provide incentives for technology transfer to LDCs, with developed countries required to periodically submit reports on actions taken or planned to implement Article 66.2.[189] Such reports are made pursuant to the 19 February 2003 TRIPS Council decision[190] on the implementation of Article 66.2. The WTO also has a Working Group on Trade and Transfer of Technology established in 2001 to examine the issue of how technology transfers between developed and developing countries take place in practice and if specific measures might be taken within the WTO to encourage such transfer.[191]

The patchwork of bilateral and multilateral initiatives to support technology transfer is intended to address the fact that there continues to be a wide gap between developed and developing countries when it comes to technology innovation, development, production, trade, and use, especially in the climate change context. Developed countries, by and large, continue to dominate climate-relevant technology innovation, development, production and trade, as pointed out earlier in this paper. Some researchers have noted that the track record of such a patchwork approach has been mixed and that it would not be able to close the technology gap.[192]

There are various entry points for enhancing international cooperation on technology transfer that could be explored in this regard, including patent pools and technology banks, creating a new multilateral fund to support climate-relevant technology transfer, enhancing IPR flexibilities at the WTO, and not proposing or agreeing to provisions in free trade agreements (FTAs) and WTO accession that require countries to adopt IP standards and protections that are more stringent than those in the TRIPS Agreement, among other things.

Technology and patent pools

There have been previous suggestions for having a global voluntary patent pool[193] of patented climate-relevant technologies that can be accessed by developing countries or having developing countries pool their needs for such patented technologies together and negotiate collective access to such technologies with the patent holders.[194] Others have suggested that existing funding mechanisms such as the GCF[195] can be leveraged to acquire ownership and dissemination rights in patent-protected technologies to expedite technology transfer to poor countries through technology donations, aided by voluntary patent pool agreements, and that cooperative IPR arrangements such as cross-licensing, patent pooling, technology standards agreements, and other forms of technology sharing could have "the greatest, outsized positive impact in the poorest countries with least access to finance."[196] Developing countries could also mutually support each other in building their technical and financial capacities by pooling resources at the regional level to create Green Technology Banks, where identified patent-free green technologies and new technologies innovated through new South-South research partnerships can be made available as public goods.[197]

Technology transfer funds

In addition to existing funding flows from bilateral agencies and multilateral organizations such as the GCF and the GEF, there have also been suggestions for the establishment of a new multilateral fund dedicated to stimulating climate-relevant innovation and enhancing technology cooperation between countries. UNCTAD, for example, has proposed the establishment of a multilateral challenge fund funded by international organizations, donors and international philanthropy to "mobilize creative thinking and stimulate innovations that could respond to many global challenges. The next step would be to design a global green innovation competition. The criteria for assessing projects would be the extent to which they incorporate North-South and South-South STI [science, technology and innovation] cooperation for green innovation."[198] UNCTAD has also proposed the establishment of a new "Trade and Environment Fund", first suggested by some developing countries such as China and India in the WTO in 2011, to finance the incremental costs of sourcing critical technologies, provide grants for specific green technologies, finance joint research, development and demonstrations, as well as the establishment of technology transfer centres, exchanges and mechanisms.[199]

Using TRIPS flexibilities

Countries could explore the use of flexibilities under the TRIPS Agreement to promote and support climate-relevant technology transfers. Compulsory licensing is an option when the patent holder is unwilling to provide a voluntary licence with reasonable conditions. Some developing countries have previously proposed at the WTO that countries be allowed not to patent environmentally sound technology so that its transfer and use can be facilitated. The relaxation of the TRIPS rules in the case of climate-related technologies has also been proposed by developing countries in the UNFCCC. Governments can also facilitate easier access to voluntary licences. Measures can also be taken to ensure that royalty and other conditions in voluntary licences are fair and reasonable – however, some FTAs (such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)) and bilateral investment treaties (BITs) may restrict this particular flexibility. Another TRIPS flexibility that could be used is to employ "rules of exhaustion" that limit patent protection only to the first sale of the patented

technology, thereby allowing parallel importation and competition (but some FTAs such as the Morocco-US FTA may restrict this flexibility[200]).

Other IP-related initiatives to facilitate green technology transfers could include open-sourcing key green technologies and declaring them as public goods; an agreement to waive the payment of IPR royalties to the patent holders of climate-related goods being transferred to developing countries; or having a tiered fee system for IPR royalty payments to patent holders in which royalties for climate-friendly technologies being transferred to developing countries would be lower. The WTO could also adopt a "Declaration on TRIPS and Climate Change" to clarify existing TRIPS flexibilities and offer new incentives for the transfer of environmentally sound technologies, for both adaptation and mitigation purposes, including for the implementation of TRIPS Article 66.2.[201]

Traded technology disputes peace clause

A "peace clause" to refrain from engaging in disputes (including in the WTO) concerning trade-related environmental measures of developing countries could also be a way to encourage technology transfers into and the development of endogenous climate technologies in developing countries. The scope, objective and duration of such a peace clause would have to be carefully defined and targeted so that it cannot be used for trade protectionist purposes. This could give countries the assurance that they will not face disputes for climate and development-friendly initiatives such as prioritizing a transition to renewable energy, green procurement, and green transition while at the same time ensuring that it would not be used for protectionist purposes contrary to its intent or purpose.[202]

Technology support subsidies

The provision of governmental financial support (subsidies) to specific industries or sectors that are identified as a country's "champions" for sustainable economic diversification and climate-relevant endogenous technology development could also be another key area that international cooperation could enhance. Subsidies are governed by the WTO's Subsidies

and Countervailing Measures (SCM) Agreement.[203] There have been various proposals made among the academic and research community on the need to effect reforms in the SCM Agreement's provisions to make it easier for governments to exercise policy space in providing subsidies to promote climate-relevant technologies and to support the accelerated development of, for example, renewable energy technologies. A dedicated effort in the WTO that could be undertaken jointly by the Committee on Trade and Environment (CTE) and the SCM Committee could be mandated to explore potential reforms to "green" the SCM Agreement.[204] The African Group in the WTO, for example, recently called for flexibilities to be granted to developing countries under the SCM Agreement to enable them to respond to various crises (e.g., climate change, pandemics, economic crisis) and support their structural transformation, industrial development and economic diversification.[205]

Technology transfer provisions in trade agreements

Beyond the WTO, transfer of climate-relevant technologies could also be fostered and promoted through the inclusion of technology transfer provisions in regional trade agreements (RTAs), although, as a study has pointed out, these provisions are usually "best endeavour" in nature.[206] It should also be noted that in many cases, RTAs may in fact impose restrictions that effectively negate technology transfers.

South-South cooperation on technology transfer

South-South cooperation in terms of establishing voluntary arrangements for technology transfer among developing countries could be another important entry point for promoting technology transfers. This could include establishing and strengthening research networks and knowledge-sharing platforms among universities, laboratories and research entities in the South to strengthen their green technological capabilities and facilitate the transfer and sharing of green technologies amongst themselves.[207] This could be undertaken in the context of strengthening existing South-South cooperation initiatives.[208]

Maximize use of existing multilateral processes to raise technology transfer issues

Existing multilateral processes such as those in the UNFCCC and the WTO can be used and expanded in terms of scope of discussion and possible outcomes to support endogenous technology development and technology transfers to developing countries. Existing multilateral processes have the advantage of already being present, have the participation of developing countries (hence they are nominally representative and inclusive), and potentially can serve as jumping boards for multilateral norm setting. The focus should be on developing multilateral solutions and cooperation to enhance a virtuous centripetal effect of multilaterally supported initiatives vis-à-vis international cooperation and hence counteract possible fracturing of the multilateral system.

World Trade Organization

For example, the role of the WTO's CTE as a multilateral forum to discuss trade, environment and climate interlinkages, including those pertaining to climate-relevant technology transfers, could be developed. This will require shifting the focus of the CTE by putting more strategically and consistently on its agenda topics for discussion that can help WTO members identify and agree on actions to strengthen multilateral cooperation on climate-related technology transfers.[209] This is particularly important given that there are trade and climate-related issues that have given rise to increased tensions between developed and developing countries and which could hence make multilaterally cooperative climate change action more difficult – e.g., the European Union's adoption and future implementation of regulations relating to a carbon border adjustment mechanism (CBAM) and due diligence with respect to deforestation. The CTE could be revitalized as a place for dialogue among developed and developing countries' policymakers on climate-change-related trade measures (including technical regulations that act as barriers to trade). Such dialogue should aim, among other goals, at facilitating the identification of shared priorities for the adoption, at the international or regional level, of relevant climate-change-related standards or technical regulations.[210]

In addition, the WTO's WGTTT – which has been relatively moribund since the late 2000s although meetings have been taking place regularly – could, for example, commence focused discussions by WTO members to address the constraints inherent in certain WTO agreements which limit the policy space to drive industrialization, economic diversification and structural transformation programmes, including the ability to respond to emerging challenges such as climate change.[211] The WGTTT could also try to identify specific green technological gaps in developing countries and measures to address them, including trade rules that enable green industrial policies, and how to improve coherence between trade measures and the implementation of technology transfer provisions in multilateral environmental agreements (MEAs) (such as those found in the UNFCCC and the Paris Agreement).[212] This revitalization of the WGTTT could be undertaken alongside a similar revitalization of the WTO's Working Group on Trade, Debt and Finance (WGTDF), to explore how transfers of climate-related technologies can be further facilitated through financing.[213]

Developing countries have been active in asking for the WGTTT's work to be more relevant and to be reinvigorated. During 2016, WTO members discussed a submission made earlier in 2008 by India, Pakistan and the Philippines entitled "Facilitating Access to Information on Appropriate Technology Sourcing – A Step to Increase Flows of Technology to Developing Countries", in which the proponents recommended the establishment of a dedicated WTO webpage on technology transfer which would serve as a one-stop-shop on technology-related issues.[214] In 2011, China and India together called for technology transfer to be an integral part of any outcome of the then-ongoing WTO negotiations on the liberalization of trade in environmental goods and services.[215]

More recently, the African Group made a submission on the role of transfer of technology in resilience building in which it called on the WGTTT and other relevant WTO bodies to have discussions on various themes that are related to the issue of trade and transfer of technology.[216] Additionally, India also made a submission in 2023 to reinvigorate discussions on the relationship between trade and the transfer of environmentally sound technologies to developing countries.[217] In March 2024, Colombia, Bangladesh, Egypt and India made a joint submission in the WTO calling for a review of the TRIPS

Agreement and asked the TRIPS Council to examine how the TRIPS Agreement could facilitate transfer and dissemination of technologies to developing countries including LDCs.[218]

Furthermore, the WTO General Council could explore establishing a joint work programme that could be undertaken by the CTE, the Committee on Trade and Development (CTD),[219] the WGTTT, the WGTDF, and the TRIPS Council to discuss the trade-related aspects of just transitions to environmental and economic sustainability and climate change resilience through the use of trade-related measures such as green industrial policy and technology transfer and dissemination to support economic diversification and the adoption of low-carbon pathways. The discussions could engage the expertise of international organizations (such as UNCTAD, ILO, UNIDO, WIPO, World Bank, UNEP, UNDP), taking into account MEA and WTO obligations relating to the provision and mobilization of finance, technical assistance, and technology transfer to support developing countries.

UNFCCC and Paris Agreement

Developing countries could also explore the possible use of the UNFCCC's newly established Just Transition Work Programme,[220] as well as the Katowice Committee of Experts on the Impacts of the Implementation of Response Measures (KCI)[221] and the Technology Executive Committee (TEC),[222] to discuss (either separately within the context of their respective mandates or jointly) trade-related aspects of technology transfer and to explore possible additional international cooperation arrangements that can be recommended for adoption by the COP/CMA (the respective governing bodies) to support UNFCCC/Paris Agreement–based technology transfer promoting endogenous technology development in developing countries.

At the recently concluded 28th session of the UNFCCC COP in Dubai in December 2023, the COP and the CMA adopted decisions related to technology transfer that could be used by developing countries to strengthen their call for a stronger Technology Mechanism within the UNFCCC/Paris Agreement architecture. For example, the COP and CMA explicitly noted "the insufficient transfer and deployment of technology in developing countries" and encouraged "the Technology Executive Committee and the

Climate Technology Centre and Network to continue collaborating with the operating entities of the Financial Mechanism and relevant financial institutions with a view to enhancing the capacity of developing countries to prepare project proposals, facilitating their access to available funding for technology development and transfer and for implementing the results of their technology needs assessments and the technical assistance of the Climate Technology Centre and Network, and strengthening the transfer and deployment of technology and calls for regional balance in this work."[223] The COP also encouraged "the Technology Executive Committee and the Climate Technology Centre and Network to consider opportunities to support developing countries in accessing funding from the Global Environment Facility and/or the Green Climate Fund for work on climate technology incubators and accelerators, taking into account the specific needs of the least developed countries and small island developing States."[224]

This reflects some of the conclusions of the terminal evaluation undertaken by UNEP of work done by the Technology Mechanism's CTCN. The UNEP report highlighted that the technology transfer partnerships that were developed through the CTCN "happened more on case-by-case basis, without systematic and strategic partnership plan/approach", with "particular challenges in implementation coherence; in order to be 'adequate' to the needs of the country, the link to the other interventions (financing mechanism, private sector, academia, etc.) or funding is critical to achieve the desired catalytic effect, impact and continuity (sustainability)." The report also stated that the CTCN overall did not have sufficient resources (financial or human) to respond to the high demand from developing countries for technologies to be transferred; and that the CTCN technical assistance projects often did not necessarily translate into actual technology transfer impacts on the ground.[225] In essence, the report's conclusions seem to say that while the CTCN did well in terms of its adherence to its own institutional mandate and design, the technology transfer technical assistance projects that it did undertake were not adequate and were not sufficiently resourced financially, nor did they have much impact on the ground in terms of actual technology transfer having taken place. These conclusions will be directly relevant to discussions under the COP and CMA in 2024 on the linkage between the Technology Mechanism and the Financial Mechanism and the negotiations on the modalities of the "technology implementation programme" established by the CMA under decision 1/CMA.5.

Under the Paris Agreement, as part of the outcome of the first Global Stocktake (GST) agreed in Dubai at COP 28 in December 2023, the CMA reflected the importance of technology transfer as an enabler in enhancing developing countries' climate actions and decided to establish, following proposals from developing countries, "a technology implementation programme, supported by, inter alia, the operating entities of the Financial Mechanism, to strengthen support for the implementation of technology priorities identified by developing countries, and to address the challenges identified in the first periodic assessment of the Technology Mechanism."[226] The modalities for the operationalization of this technology implementation programme are to be discussed, negotiated and agreed upon by the CMA at COP 29 in Baku in November 2024. This presents an opportunity for developing countries to ensure that the modalities will allow for the full consideration and action by the CMA on the various barriers and opportunities that need to be addressed to ensure that technology transfer and development to developing countries fulfil the mandates for such transfer and development under Article 4.5 of the Convention and Article 10 of the Paris Agreement.

8 Conclusion

HISTORICAL experience shows that achieving development – i.e., being able to set up an economy that has adequate infrastructure, energy access and productive capacity, and that provides for decent standards of living and livelihood for the population – requires, among others, a conscious and sustained effort at building up the technological base of the economy. However, for most developing countries, this has now been made more difficult due to the multiplicity of global crises that impact on their ability to develop, particularly given the imperative of ensuring that development pathways now must be low-carbon and sustainable. Unlike in the past, the speed and scale of technological and structural economic transformation within developing countries have to be much faster and higher if the multiplicity of development challenges is to be met.[227]

Efforts need to be made within and among developing countries themselves to develop and use their own endogenous technologies to support climate adaptation and mitigation. A more strategic approach to climate technology development and innovation needs to be undertaken in developing countries, essentially to lay the endogenous technological foundation for long-term sustainable and low-carbon development. Such efforts should be complemented by transfer of low-carbon climate-relevant technologies from developed countries, a key enabling measure.

There are three key areas in which complementary domestic and international cooperation efforts need to be made in this regard: facilitating transfers of climate-relevant technologies from developed to developing countries; providing additional finance for developing countries; and building their capacities to address climate challenges facing their tradeable sectors.[228] These

will require, as noted earlier in this paper, active, nationally appropriate policy approaches with respect to national green industrial policy, for example, given the diversity of national circumstances, development objectives, and capacities and constraints among developing countries.[229]As UNCTAD has noted, given that structural transformation in a climate-constrained world requires a shift from high- to low- (and no-) carbon technologies, it can only be achieved when it is approached in an integrated manner by an effective developmental State, with technological change occurring alongside productivity growth, expanding employment opportunities, and rising living standards.[230]

Doing so means ensuring that technology transfer arrangements can deliver the climate-relevant technologies prioritized and needed by developing countries, as pointed out earlier in this paper. Financing technology transfer, particularly in a manner that is consistent with the provisions of the UNFCCC and the Paris Agreement, will be crucial to ensure both coherence with climate change obligations and the achievement of national sustainable development priorities. The technological gap between developed and developing countries needs to be addressed through effective technology transfer that allows for endogenous technology development.

International cooperation will be needed to enhance domestic capacity so that such transfers can lead to the development and innovation of endogenous technologies. This would require, as suggested in this paper, enhancing international cooperation arrangements to foster effective technology transfer arrangements as well as South-South cooperation leading towards technological self-reliance by developing countries with respect to climate technologies. Such international cooperation arrangements include enhancing the work of existing forums in the WTO and in the UNFCCC with respect to the interlinkages between technology transfer, climate change obligations, sustainable development priorities, and international trade measures.

Endnotes

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[11] See e.g. South Centre, The Role of Decentralized Renewable Energy Technologies in Adaptation to Climate Change in Developing Countries (August 2008), p. 15, at https://www.southcentre.int/wp-content/uploads/2013/07/AN_ENV5_Role-Of-Decentralized-Renewable-Energy_EN.pdf

[12] See e.g. Paul Brenton and Vicky Chemutai, The Trade and Climate Change Nexus: The Urgency and Opportunities for Developing Countries (World Bank, 2021), pp. 9-12, at https://openknowledge.worldbank.org/server/api/core/bitstreams/5d543ded-1163-5fc6-8fe8-319d913cf269/content

[13] See UNFCCC, Art. 2, stating that the ultimate objective of the Convention and any related legal instruments that may be adopted by the Conference of the Parties (such as the Paris Agreement) is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

[14] See Paris Agreement, Art. 2.1(a) and 4.1.

[15] See e.g. Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (World Bank, 2020), pp. xv-xix, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf. As a UNFCCC study has noted, "as the world ramps up its response to climate challenge, it is deploying climate technologies on an unprecedented scale. For instance, in 2016 the world added more renewable power capacity (161 gigawatts) than capacity from all net fossil fuels combined, with most new renewable energy capacity being installed in developing countries ... Moreover, the costs of such technologies are falling, making them competitive with fossil fuel options in many countries." See UNFCCC, Technological Innovation for the Paris Agreement: Implementing nationally determined contributions, national adaptation plans and mid-century strategies (TEC Brief No. 10, September 2017), p. 9, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf

[16] See UNFCCC, Art. 4.1, 4.2, 4.3, 4.4, 4.5, and 4.7. See also e.g. David Popp, A Perspective Paper on Technology Transfers as a Response to Climate Change (CCC Perspective Papers, 2009), at http://www.ip-watch.org/weblog/wp-content/uploads/2009/09/pp_technology_transfers_popp_v20.pdf

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[19] Nicolas Perrone, Technology Transfer and Climate Change: A developing country perspective (South Centre Climate Policy Brief 28, 14 November 2022), p. 3, at https://www.southcentre.int/wp-content/uploads/2022/11/CPB28_Technology-Transfer-and-Climate-Change_EN.pdf

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[22] See e.g. Nicolas Perrone, Technology Transfer and Climate Change: A developing country perspective (South Centre Climate Policy Brief 28, 14 November 2022), pp. 6-7, at https://www.southcentre.int/wp-content/uploads/2022/11/CPB28_Technology-Transfer-and-Climate-Change_EN.pdf for a discussion on the limitations posed by a private-sector-focused technology transfer model.

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[28] See UNFCCC, Art. 4.5 and 4.7; Paris Agreement, Art. 10; see also e.g. UNFCCC, Technological Innovation for the Paris Agreement: Implementing nationally determined contributions, national adaptation plans and mid-century strategies (TEC Brief No. 10, September 2017), p. 7, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf

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[40] UNCTAD, Transfer of Technology and Knowledge Sharing for Development: Science, technology and innovation issues for developing countries (UNCTAD, 2014), pp. 3-4, at https://unctad.org/system/files/official-document/dtlstict2013d8_en.pdf

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[42] Gabriel Blanco et al., Innovation, technology development and transfer. In IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022), p. 1683, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf

[43] Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), pp. 131-133, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf

[44] See e.g. UNEP, Technology Transfer for Climate Mitigation and Adaptation: Analysing needs and development assistance support in technology transfer processes (2022), pp. 4-5, at https://unepccc.org/wp-content/uploads/2022/11/finalproof-tech-transfer-policy-brief-oecd.pdf

[45] See e.g. South Centre, The Role of Decentralized Renewable Energy Technologies in Adaptation to Climate Change in Developing Countries (August 2008), pp. 24-28, at https://www.southcentre.int/wp-content/uploads/2013/07/AN_ENV5_Role-Of-Decentralized-Renewable-Energy_EN.pdf; World Bank, Technology Transfer and Innovation for Low-Carbon Development (30 March 2020), at https://www.worldbank.org/en/topic/macroeconomics/publication/technology-transfer-and-innovation-for-low-carbon-development; UNCTAD, Trade and Development Report 2021 (2021), pp. 113-115, at https://unctad.org/system/files/official-document/tdr2021_en.pdf

[46] Studies have shown that effective technology transfer depends on the ability to adapt technologies to local needs. This implies transferring goods and skills together with knowledge and innovative capacity-building – i.e., hardware plus software plus organizational capacity. See e.g. Silvia Weko and Andreas Goldthau, Bridging the low-carbon technology gap? Assessing energy initiatives for the Global South (Energy Policy, 169:1113192, October 2022), at https://www.sciencedirect.com/science/article/pii/S0301421522004128. See also Gabriel Blanco et al., Innovation, technology development and transfer. In IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022), p. 1683, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf

[47] See e.g. UNFCCC, Expert Group on Technology Transfer: Five Years of Work (2007), p. 12, at http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/egtt_en_070523.pdf; Gabriel Blanco et al., Innovation, technology development and transfer. In IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022), p. 1687, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf; Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), pp. 13-14, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf

[48] See e.g. Gabriel Blanco et al., Innovation, technology development and transfer. In IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022), p. 1685, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf

[49] See e.g. UNCTAD, Transfer of Technology and Knowledge Sharing for Development: Science, technology and innovation issues for developing countries (UNCTAD, 2014), p. 11, at https://unctad.org/system/files/official-document/dtlstict2013d8_en.pdf; Nicolas Perrone, Technology Transfer and Climate Change: A developing country perspective (South Centre Climate Policy Brief 28, 14 November 2022), p. 6, at https://www.southcentre.int/wp-content/uploads/2022/11/CPB28_Technology-Transfer-and-Climate-Change_EN.pdf

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[51] WIPO, Green Technology Book: Solutions for climate change adaptation (2022), p. 23, at https://www.wipo.int/edocs/pubdocs/en/wipo-pub-1080-en-green-technology-book.pdf

[52] Silvia Weko and Andreas Goldthau, Bridging the low-carbon technology gap? Assessing energy initiatives for the Global South (Energy Policy, 169:1113192, October 2022), at https://www.sciencedirect.com/science/article/pii/S0301421522004128

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[54] UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer Identified in Technology Needs Assessments, Nationally Determined Contributions, and Technical Assistance provided by the Climate Technology Centre and Network (March 2022), p. 21, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

[55] UNFCCC-TEC, Enabling Environments and Challenges to Technology Development and Transfer Identified in Technology Needs Assessments, Nationally Determined Contributions, and Technical Assistance provided by the Climate Technology Centre and Network (March 2022), p. 15, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

[56] UNFCCC, Enabling Environments and Challenges to Technology Development and Transfer Identified in Technology Needs Assessments, Nationally Determined Contributions, and Technical Assistance provided by the Climate Technology Centre and Network (March 2022), p. 29, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf

[57] See UN, Agenda 21 – Chapter 34: Transfer of Environmentally Sound Technology, Cooperation and Capacity-Building, at https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf

[58] See UN, 2030 Agenda, SDGs 1.4, 2.a, 4.b, 5.b, 6.a, 7.a, 7.b, 9.5, 9.a, 9.b, 9.c, 12.a, 14.a, 17.6, 17.7, 17.8, at https://sdgs.un.org/2030agenda

[59] SDG 17.7.

[60] The Convention's technology development and transfer provisions include Article 4.3 (developed countries shall provide financial resources including for technology transfer needed by developing countries to meet their agreed full incremental costs of implementing measures), Article 4.5 (developed countries shall take all practicable steps to facilitate and finance transfer of and access to environmentally sound technologies and know-how particularly to developing countries and shall support the development and enhancement of endogenous capacities and technologies of developing countries) and Article 4.7 (the extent to which developing countries will implement their commitments will depend on effective implementation of developed countries' commitments on financial resources and technology transfer).

[61] The Paris Agreement's technology transfer Article highlights Parties' 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 (Article 10.1), mandates the strengthening of cooperative action on technology development and transfer (Article 10.2), and states that accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development, and "shall be, as appropriate, supported, including by the Technology Mechanism and, through financial means, by the Financial Mechanism of the Convention, for collaborative

approaches to research and development, and facilitating access to technology, in particular for early stages of the technology cycle, to developing country Parties" (Article 10.5).

62 UNFCCC, What is technology development and transfer?, at https://unfccc.int/topics/what-is-technology-development-and-transfer. See also Gabriel Blanco et al., Innovation, technology development and transfer. In IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022), pp. 1685-1687, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf

63 There are several provisions in the WTO agreements that mention the need to transfer technology from developed to developing countries (such as Article 66.2 of the TRIPS Agreement), with a working group on this issue having been established in 2001. See e.g. WTO, at https://www.wto.org/english/tratop_e/devel_e/dev_wkgp_trade_transfer_technology_e.htm and https://www.wto.org/english/tratop_e/trips_e/techtransfer_e.htm. WIPO also undertakes work in relation to intellectual property rights (IPRs) and technology transfer, including providing patent information services, innovation support tools and programmes, norm-setting and dialogues, knowledge transfer programmes and resources, multi-stakeholder platforms, training programmes, and dispute resolution services. See e.g. WIPO, at https://www.wipo.int/technology-transfer/en/#; https://www.wipo.int/patents/en/technology/; https://www.wipo.int/technology-transfer/en/organizations.html; https://www.wipo.int/technology-transfer/en/agreements.html. UNCTAD provides research and analysis, stakeholder forums, intergovernmental dialogue events, training programmes, statistical databases, and technology assessments on issues relating to science, technology, innovation, and technology transfer. See e.g. UNCTAD, at https://unctad.org/topic/science-technology-and-innovation; https://unctad.org/topic/science-technology-and-innovation/technology-facilitation-mechanism. UNIDO has a technology cooperation programme to channel technologies to developing countries through its International Technology Centres. See e.g. UNIDO, at https://www.unido.org/our-focus/advancing-economic-competitiveness/investing-technology-and-innovation/investment-and-technology/science-technology-and-innovation; http://www.unido.or.jp/en/activities/technology_transfer; https://www.unido.org/our-focus/safeguarding-environment/clean-energy-access-productive-use/climate-policies-and-networks/low-carbon-technology-transfer. The UN Technology Bank for LDCs is dedicated to promoting technology transfer to LDCs. See https://unfccc.int/topics/adaptation-and-resilience/groups-committees/adaptation-committee/joint-ac-and-leg-mandates/nap-support/technology-development-and-transfer#un-technology-bank-for-the-ldcs. UNEP has its International Environmental Technology Centre and various projects and activities for research and analysis and policy discussions on technology transfer barriers and opportunities. See e.g. UNEP, at https://www.unep.org/ietc/who-we-are#. The UNOSSC supports South-South technology transfer initiatives. See e.g. https://unfccc.int/topics/adaptation-and-resilience/groups-committees/adaptation-committee/joint-ac-and-leg-mandates/nap-support/technology-development-and-transfer#united-nations-office-for-south-south-cooperation-(unossc)-. The World Bank provides research and analysis on technology transfer issues. See e.g. World Bank, at https://www.worldbank.org/en/topic/macroeconomics/publication/technology-transfer-and-innovation-for-low-carbon-development

64 IPCC, Methodological and Technological Issues in Technology Transfer: Summary for Policymakers (2000), p. 3, at https://www.ipcc.ch/site/assets/uploads/2018/03/srtt-en-1.pdf

65 Article 4.5 of the UNFCCC highlights this objective of technology transfer when it states that "in this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties."

[66] UNCTAD, Transfer of technology and knowledge-sharing for development: Science, technology and innovation issues for developing countries, at https://unctad.org/publication/transfer-technology-and-knowledge-sharing-development-science-technology-and-innovation#; K. Madhava Sarma, Technology Transfer Mechanism for Climate Change (IGSD, 2008), at http://igsd.org/docs/SarmaTT%2024Mar08.pdf

[67] UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), p. xvii, at https://unctad.org/system/files/official-document/tir2023_en.pdf

[68] Silvia Weko and Andreas Goldthau, Bridging the low-carbon technology gap? Assessing energy initiatives for the Global South (Energy Policy, 169:1113192, October 2022), at https://www.sciencedirect.com/science/article/pii/S0301421522004128. The study notes that the studied technology transfer initiatives seem to be "avoiding countries where a threat to competitive business advantages is perceived", aligning with "the interests of technology-holders not to lose control of value creation … and with the interests of developed countries to maintain the existing IPR regime in international technology transfer governance." This implies that technology transfer initiatives are not intended to actually help recipients develop their own technologies but rather to continue the technology control of the IPR owners over the technologies that are the subject of such initiatives.

[69] See e.g. UNEP, Technology Transfer for Climate Mitigation and Adaptation: Analysing needs and development assistance support in technology transfer processes (2022), p. 8, at https://unepccc.org/wp-content/uploads/2022/11/finalproof-tech-transfer-policy-brief-oecd.pdf

[70] Vicente Paolo Yu, Economic Diversification from Oil Dependency: Practice and Lessons from Persian Gulf Oil-Dependent Developing Countries (TWN Climate Change Series 6, 2022), pp. 38-39, at https://www.twn.my/title2/climate/series/cc06.pdf

[71] For lists or definitions of these technologies, see e.g. Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), Annex B, p. 155 et seq., at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf for a list of "low-carbon technology products"; UNEP, Technology Transfer for Climate Mitigation and Adaptation: Analysing needs and development assistance support in technology transfer processes (2022), p. 5, at https://unepccc.org/wp-content/uploads/2022/11/finalproof-tech-transfer-policy-brief-oecd.pdf; UNFCCC, What is technology development and transfer?, at https://unfccc.int/topics/what-is-technology-development-and-transfer; WEF, Accelerating Decarbonization through Trade in Climate Goods and Services: Insight Report (September 2022), pp. 4 and 9, at https://www3.weforum.org/docs/WEF_Accelerating_Decarbonization_through_Trade_2022.pdf for definitions or listings of "climate technologies"; UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), p. 16, at https://unctad.org/system/files/official-document/tir2023_en.pdf; UNFCCC, Implementation of Just Transition and Economic Diversification Strategies: A compilation of best practices from different countries (KCI, 2023), pp. 90-91, at https://unfccc.int/sites/default/files/resource/A%20compilation%20of%20best%20practices%20on%20JT%20and%20EDT.pdf for descriptions and lists of "green technologies"; UN, Agenda 21 – Chapter 34 (1992), paras. 34.1-34.3, at https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf#page=305 for a definition of "environmentally sound technologies"; GCF, GCF in Brief: Support for Technology, at https://www.greenclimate.fund/sites/default/files/document/gcf-brief-support-technology_0.pdf for a definition of "climate technologies"; APEC, APEC List of Environmental Goods (2012), at https://www.apec.org/meeting-papers/leaders-declarations/2012/2012_aelm/2012_aelm_annexc for a list of plurilaterally agreed "environmental goods"; UNCTAD, Environmentally Preferable Products (EPPs) as a Trade

Opportunity for Developing Countries (19 December 1995), p. 7, at https://unctad.org/system/files/official-document/unctadcom70.pdf for a definition of "environmentally preferable products".

[72] See e.g. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), pp. 23-24, at https://unctad.org/system/files/official-document/tir2023_en.pdf

[73] See e.g. Vicente Paolo Yu, Economic Diversification from Oil Dependency: Practice and Lessons from Persian Gulf Oil-Dependent Developing Countries (TWN Climate Change Series 6, 2022), p. 45, at https://www.twn.my/title2/climate/series/cc06.pdf

[74] As noted by UNEP, within the UNFCCC setting, climate technologies have been categorized as traditional technologies, modern technologies and high technologies based on the level of maturity. According to the Technology Needs Assessments that have been undertaken by UNEP under the UNFCCC, developing countries' prioritized technologies are mainly modern or traditional technologies. The energy and transport sectors, for instance, are characterized by a low share of emerging/high technologies that are prioritized (14% and 32% respectively). Similarly, in adaptation technologies for agriculture, water and costal zones, emerging/high technologies represent only 21%, 22% and 15% of the total. See UNEP, Technology Transfer for Climate Mitigation and Adaptation: Analysing needs and development assistance support in technology transfer processes (2022), p. 10, at https://unepccc.org/wp-content/uploads/2022/11/finalproof-tech-transfer-policy-brief-oecd.pdf

[75] See e.g. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), p. xvii, at https://unctad.org/system/files/official-document/tir2023_en.pdf

[76] UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), p. xvi, at https://unctad.org/system/files/official-document/tir2023_en.pdf (see p. 16 for a description and list of "green frontier technologies")

[77] See UNFCCC, Fourth synthesis of technology needs identified by Parties not included in Annex I to the Convention: Report by the secretariat (FCCC/SBI/2020/INF.1, 3 April 2020), paras. 44-48, at https://unfccc.int/sites/default/files/resource/sbi2020_inf.01.pdf

[78] UNFCCC, Policy brief on linkages between technology needs assessment process and nationally determined contributions process (TEC Brief No. 15, June 2022), p. 18, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TEC_documents/c0cb662d56f54fef8e53d0d1838fa2d7/de6da9e857d145fdbd5b8c2be66fcd26.pdf

[79] UNFCCC, Fourth synthesis of technology needs identified by Parties not included in Annex I to the Convention: Report by the secretariat (FCCC/SBI/2020/INF.1, 3 April 2020), paras. 8-11 and 57-59, at https://unfccc.int/sites/default/files/resource/sbi2020_inf.01.pdf

[80] UNFCCC and UNOSSC, Potential of South-South and triangular cooperation on climate technologies for advancing implementation of nationally determined contributions and national adaptation plans (December 2018), p. 27, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief9/7a74a2f17f204b6ba17f1ec965da70d7/f4e361cd56d4463a8daa4ab29a1254db.pdf

[81] UNFCCC and UNOSSC, Potential of South-South and triangular cooperation on climate technologies for advancing implementation of nationally determined contributions and national adaptation plans (December 2018), p. 27, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief9/7a74a2f17f204b6ba17f1ec965da70d7/f4e361cd56d4463a8daa4ab29a1254db.pdf

[82] UNFCCC, Technologies for Adaptation in the Water Sector (TEC Brief No. 5, November 2014), p. 8, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TEC_column_L/0cac6640a3b945c08e7a54f8e496223e/55e192e14cd6495f975f4098843baf7e.pdf

[83] UNFCCC, Technologies for Adaptation in the Agriculture Sector (TEC Brief No. 4, November 2014), p. 8, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TEC_column_L/544babb207e344b88bdd9fec11e6337f/bcc4dc66c35340a08fce34f057e0a1ed.pdf

[84] UNFCCC, Mitigation benefits and co-benefits of policies, practices and actions for enhancing mitigation ambition: implementation of circular economies with a focus on waste-to-energy technologies and on industrial waste reuse and prevention solutions – Technical paper by the secretariat (30 October 2018), p. 31, at https://unfccc.int/sites/default/files/resource/tp02.pdf; UNFCCC, Mitigation benefits of actions, initiatives and options to enhance mitigation ambition: Technical paper (2015), p. 10, at https://unfccc.int/resource/climateaction2020/media/1223/tp_layout2_web.pdf

[85] UNFCCC, Off-grid and decentralized energy solutions for smart energy and water use in the agrifood chain: Technical paper by the secretariat (2020), pp. iii and 60-61, at https://unfccc.int/sites/default/files/resource/TEMs%202019_TP_Designed%20Version.pdf

[86] UNFCCC, Mitigation benefits and co-benefits of policies, practices and actions for enhancing mitigation ambition and options for supporting their implementation: The social and economic value of carbon and the promotion of efficient public transport and energy efficiency of vehicles – Technical paper by the secretariat (October 2016), p. 45, at https://unfccc.int/resource/climateaction2020/media/1267/161010_mitigation_tp_final.pdf; UNFCCC, Mitigation benefits of actions, initiatives and options to enhance mitigation ambition: Technical paper (2015), p. 10, at https://unfccc.int/resource/climateaction2020/media/1223/tp_layout2_web.pdf; OECD, Green patents, at https://www.oecd.org/env/indicators-modelling-outlooks/green-patents.htm

[87] UNFCCC, Mitigation benefits of actions, initiatives and options to enhance mitigation ambition: Technical paper (2015), pp. 8-10, at https://unfccc.int/resource/climateaction2020/media/1223/tp_layout2_web.pdf; OECD, Green patents, at https://www.oecd.org/env/indicators-modelling-outlooks/green-patents.htm; South Centre, The Role of Decentralized Renewable Energy Technologies in Adaptation to Climate Change in Developing Countries (August 2008), p. 19, at https://www.southcentre.int/wp-content/uploads/2013/07/AN_ENV5_Role-Of-Decentralized-Renewable-Energy_EN.pdf

[88] UNFCCC, Technology Needs Assessment: Pathways for climate tech implementation, at https://unfccc.int/ttclear/tna. A list of technology transfer projects seeking support and those projects that have obtained support can be found on the UNFCCC website at https://unfccc.int/ttclear/projects.

[89] UNFCCC, Technology Transfer, at https://unfccc.int/topics/adaptation-and-resilience/groups-committees/adaptation-committee/joint-ac-and-leg-mandates/nap-support/technology-development-and-transfer

[90] UNFCCC, Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat (26 October 2022), paras. 41 and 206, at https://unfccc.int/sites/default/files/resource/cma2022_04.pdf

[91] UNFCCC, Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat (26 October 2022), para. 205, at https://unfccc.int/sites/default/files/resource/cma2022_04.pdf

[92] Clea Schumer and Katie Lebling, How are Countries Counting on Carbon Removal to Meet Climate Goals (16 March 2022), at https://www.wri.org/insights/carbon-removal-countries-climate-goals

[93] Stacy Davis, NDC Assessment: How Do Advanced Low-Emission Energy and Climate Technologies Factor into Nationally Determined Contributions (CATF, April 2022), pp. 4-12, at https://cdn.catf.us/wp-content/uploads/2022/04/27123938/ndc-assessment-how-

advanced-low-emission-energy-climate-technologies-factor-nationally-determined-contributions.pdf

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95 UNCTAD, Transfer of Technology and Knowledge Sharing for Development: Science, technology and innovation issues for developing countries (UNCTAD, 2014), pp. 51-52, at https://unctad.org/system/files/official-document/dtlstict2013d8_en.pdf

96 See e.g. WTO, World Trade Report 2022: Climate change and international trade (2022), pp. 11-12, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf

97 See e.g. UNCTAD, Making trade work for climate change mitigation: The case of technical regulations (2022), pp. 7-8, at https://unctad.org/system/files/official-document/ditctab2022d7_en.pdf

98 See e.g. UNCTAD, Trade and Development Report 2021 (2021), p. XII, at https://unctad.org/system/files/official-document/tdr2021_en.pdf; UNCTAD, Making trade work for climate change mitigation: The case of technical regulations (2022), p. 6, at https://unctad.org/system/files/official-document/ditctab2022d7_en.pdf

99 See e.g. WTO, Trade and climate change, at https://www.wto.org/english/tratop_e/envir_e/climate_intro_e.htm

100 See e.g. WTO, World Trade Report 2022: Climate change and international trade (2022), at https://www.wto.org/english/res_e/publications_e/wtr22_e.htm

101 Gabriel Blanco et al., Innovation, technology development and transfer. In IPCC, Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022), p. 1658, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf

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106 See e.g. WEF, Accelerating Decarbonization through Trade in Climate Goods and Services: Insight Report (September 2022), p. 25, at https://www3.weforum.org/docs/WEF_Accelerating_Decarbonization_through_Trade_2022.pdf. Such issues are already being raised, for example, with respect to the European Union's carbon border adjustment mechanism (CBAM) and its deforestation regulation.

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[124] WEF, Accelerating Decarbonization through Trade in Climate Goods and Services: Insight Report (September 2022), p. 13, at https://www3.weforum.org/docs/WEF_Accelerating_Decarbonization_through_Trade_2022.pdf. These NTMs are listed in Table 3 of the WEF report and include standards, technical regulations and labelling requirements; conformity assessment procedures, product testing and certification; local content requirements; export-related measures (subsidies, licences or quotas); government procurement procedures; customs procedures, including licences and other permits; and infringement of intellectual property. See also Paul Brenton and Vicky Chemutai, The Trade and Climate Change Nexus: The Urgency and Opportunities for Developing Countries (World Bank, 2021), pp. 56-57, at https://openknowledge.worldbank.org/server/api/core/bitstreams/5d543ded-1163-5fc6-8fe8-319d913cf269/content

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WEF, Accelerating Decarbonization through Trade in Climate Goods and Services: Insight Report (September 2022), p. 25, at https://www3.weforum.org/docs/WEF_Accelerating_Decarbonization_through_Trade_2022.pdf

127 See e.g. Nils Meyer-Ohlendorf and Christiane Gerstetter, Trade and Climate Change: Triggers or Barriers for Climate Friendly Technology Transfer and Development? (FES Dialogue on Globalization Occasional Paper No. 41, February 2009), p. 10, at https://library.fes.de/pdf-files/iez/global/06119.pdf

128 WTO, World Trade Report 2022: Climate change and international trade (2022), pp. 124-126, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf

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130 Keith Maskus, Encouraging International Technology Transfer (UNCTAD-ICTSD, May 2004), p. 4, at https://www.files.ethz.ch/isn/111411/2010_01_encouraging-international-technology-transfer.pdf. For example, non-WTO members and LDC WTO members do not have to comply with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Switzerland developed its chemical industry by keeping IP standards low so inputs for manufacturing would be cheap while its inventors made monopoly profits by exporting to Germany, France and other countries where IP had greater protection. See e.g. Richard Gerster, Patents and Development: Lessons Learnt from the Economic History of Switzerland (TWN, 2001), at https://www.twn.my/title2/IPR/pdf/ipr04.pdf. Pharmaceuticals were only patentable in Spain in 1992, Italy in 1979, and West Germany in 1967; see also Ha Joon Chang, Intellectual Property Rights and Economic Development – Historical Lessons and Emerging Issues (TWN, 2001), footnote 8, at https://www.twn.my/title2/IPR/pdf/ipr03.pdf. Pakistan has a more tailored solution to help its few inventors: it helps and pays for them to patent abroad etc instead of raising the level of IP protection in the whole country and therefore making consumers, manufacturers, patients etc. pay more for patented technology; see Intellectual Property Organization of Pakistan, Incentive for Patent Filing, at https://www.ipo.gov.pk/patent_incentives.

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Cardenas Rodriguez et al., Global patent applications for climate change mitigation technologies – a key measure of innovation – are trending down (IEA, 11 July 2019), at https://www.iea.org/commentaries/global-patent-applications-for-climate-change-mitigation-technologies-a-key-measure-of-innovation-are-trending-down

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[225] See UNEP, Terminal Evaluation of the "Joint UNEP-UNIDO Programme to host and manage the Climate Technology Centre and Network" and "Support to Climate Technology Transfer Services and Partnership" (December 2023), paras. 243-246, at https://wedocs.unep.org/handle/20.500.11822/45568

[226] See UNFCCC, Decision 1/CMA.5, paras. 8, 32, 34, 101-110, at https://unfccc.int/sites/default/files/resource/cma2023_16a01E.pdf

[227] See e.g. Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), p. 19, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf

[228] See e.g. UNCTAD, South-South Cooperation for Climate Adaptation and Sustainable Development (2022), p. 12, at https://unctad.org/system/files/official-document/tcsgdsinf2022d1_en.pdf

[229] UNFCCC, Technological Innovation for the Paris Agreement: Implementing nationally determined contributions, national adaptation plans and mid-century strategies (TEC Brief No. 10, September 2017), p. 2, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf. See

also UNCTAD, Trade and Development Report 2021 (2021), p. 156, at https://unctad.org/system/files/official-document/tdr2021_en.pdf, which highlights the need for green technology transfers without restrictive patents, appropriate special and differential treatment in environmental goods and services so that providers of these goods and services in the developing world can have a level playing field, and preserving policy space to encourage export diversification.

230 UNCTAD, Trade and Development Report 2021 (2021), p. XII, at https://unctad.org/system/files/official-document/tdr2021_en.pdf

TECHNOLOGY TRANSFER TO SUPPORT JUST TRANSITIONS TOWARDS SUSTAINABLE DEVELOPMENT IN DEVELOPING COUNTRIES

To diversify away from fossil-fuelled economic growth and effect structural transformation, developing countries need access to technologies that support low-carbon production and adaptation to climate change. Overcoming the financial, technical and legal barriers to the transfer of these technologies from developed to developing countries requires in turn a coherent policy approach combining national action and international cooperation. Encompassing areas ranging from finance to trade and intellectual property, such an approach should aim to not only boost technology flows to developing countries but also foster endogenous innovation geared towards climate action and sustainable development.

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