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Addressing the Climate Technology Gap Through Effective Technology Transfer

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TESS Forum on Trade, Environment, & the SDGs

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Executive Summary

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 hampering progress towards the achievement of the Sustainable Development Goals by 2030. Developing countries confront the dilemma of having to pursue sustainable economic development while keeping emissions and resource consumption within sustainable ecological boundaries, with many being in a position of structural and institutional weakness. Among these challenges, climate change is a systemic and existential challenge.

To hold global warming to between 1.5 and 2.0 degrees Celsius as stipulated in the Paris Agreement, the global energy and productive sectors must undertake a rapid and systemic transformation towards low-carbon pathways. Most of the necessary emissions reductions can be achieved by deploying and expanding the use of existing, commercially proven low-carbon technologies while stopping deforestation. Developing countries also need technologies to put their economies on climate change-adapted pathways and to address climate change-related losses and damage.

However, despite the possibility of accessing and acquiring technologies through the usual channels (such as trade, foreign direct investment, licensing, or movements of people such as researchers and scientists) and then innovating and adapting such technologies, many developing countries have struggled to move from simple foreign technology acquisition through these channels into adaptation and subsequent endogenous technology development.

These barriers have created a wide technology gap between developed countries and the large majority of developing countries. Such a technological gap reflects the development gap that exists between developed countries and many developing countries.

Developing countries view technology transfer as a key way to address the technology gap, particularly in regard to climate action. The link between technology as a means of implementation and climate action is clearly highlighted in Article 4.7 of the United Nations Framework Convention on Climate Change (UNFCCC) and Art. 10.5 and 10.6 of the Paris Agreement. Many developing countries have indicated the importance of technological innovation, research and development, and technology transfer in their nationally determined contributions. As most technologies that developing countries import, absorb, or adapt are privately owned, and most climate-relevant technologies are developed and produced in and traded by developed countries (with China being the major outlier among developing countries as a producer and trader of such technologies), the main direction of and enhanced efforts for technology transfer will have to be from developed to developing countries, although South-South cooperation will also have an important role to play.

To be effective, technology transfer has to include not only the physical hardware, 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. To be sustainable, technology transfer requires the capabilities to deploy, operate, maintain, adapt, improve, and reproduce the transferred technology and, ultimately, the capacity to invent new technologies. Further, a more evenly spread technological uptake would impact on prices and affordability even for countries that do not immediately absorb such technologies, as more suppliers of technologies enter the currently concentrated market.

A country's ability to access, adopt, and diffuse technological knowledge generated abroad strongly influences technological uptake and innovation. As such, 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. There is no "one-size-fits-all" approach to technology transfer due to the diversity of countries' national circumstances and innovation needs.

As explored in this paper, both the UNFCCC and the Paris Agreement include existing provisions that pertain to technology transfer to support climate change action. Institutions have also been set up under the UNFCCC. Developing countries have undertaken technology needs assessments and developed technology action plans under the UNFCCC.

Through these, developing countries have identified their technology transfer priorities in the mitigation and adaptation sectors, largely in relation to energy, transport, agriculture, water, and infrastructure and settlements. They have also identified the barriers to technology transfer that they experience as well as the enablers that would be needed to support effective technology transfer, such as financing for technology transfer.

Moreover, international trade measures (such as tariffs and non-tariff measure liberalization), when pursued in conjunction with other policy measures designed to increase endogenous technological uptake and innovation, have the potential to support 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. The impact on innovation is less clear, however. By themselves, such trade measures may not narrow the technological gap between developed and developing countries, with the former largely dominating most production and trade of such goods. In this context, trade in climate-relevant goods should be complemented by other supportive domestic policy measures intended to increase the ability of the importing country's economic sectors to absorb such technology, innovate and adapt it to domestic requirements, and develop endogenous climate technologies.

Finally, 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 domestically-generated as well as imported and transferred technologies, with attention "to selecting [intellectual property] standards that recognize the rights of inventors but encourage dynamic competition."[1] Strategic use of intellectual property flexibilities available under the World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights should be explored.

The gap between developed and developing countries with respect to the development, innovation, access, and endogenous production and deployment of climate-relevant technologies is among the key constraints adversely affecting collective progress in global efforts to achieve sustainable development and effective climate action under the UNFCCC and its Paris Agreement. This paper explores various entry points for enhancing international cooperation on technology transfer in the WTO, UNFCCC, and elsewhere.

1. 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.

Abbreviations

CRAFT	Climate Resilience and Adaptation Finance and Technology Transfer Facility
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
COP	Conference of the Parties
CTCN	Climate Technology Centre and Network
CTE	Committee on Trade and Environment
FINTECC	Finance and Technology Transfer Centre for Climate Change
GCF	Green Climate Fund
GEF	Global Environment Facility
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
LDC	Least Developed Country
LDCF	Least Developed Countries Fund
MEA	Multilateral Environmental Agreement
NDC	Nationally Determined Contribution
NTM	Non-Tariff Measure
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
SCCF	Special Climate Change Fund
SDG	Sustainable Development Goal
TAP	Technology Action Plan
TEC	Technology Executive Committee
TESSD	Trade and Environmental Sustainability Structured Discussions
TNA	Technology Needs Assessment
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UN	United Nations
UNEP	United Nations Environment Programme
UNCTAD	United Nations Conference on Trade and Development
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
UNOSSC	United Nations Office for South-South Cooperation
WEF	World Economic Forum
WGTDF	Working Group on Trade, Debt and Finance
WGTT	Working Group on Trade and Transfer of Technology
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

1. Introduction

The realization of sustainable development 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 hampering progress towards the achievement of the United Nations Sustainable Development Goals (SDGs) by 2030. Global economic uncertainty, rapid technological change, demographic change, climate change, ecosystem degradation, and geopolitical tensions are creating major stressors on countries' ability to pursue sustainable development pathways and undertake international cooperation.

In the face of these multiple challenges, the most difficult choices are in developing countries. They confront the dilemma of having to pursue sustainable economic development while keeping emissions and resource consumption within sustainable ecological boundaries, with many being in a position of structural and institutional weakness.[2] Among these challenges, climate change is a systemic and existential challenge that already adversely impacts people's lives and livelihoods, particularly on the prospects for achieving sustainable development in developing countries. Climate change affects countries' economically productive sectors due to physical weather-related impacts (e.g. extreme weather events and slow onset events) and the impacts of the implementation of climate-related policy response measures (such as on energy, trade, finance, taxation, development planning, etc.).

To hold global warming to between 1.5 and 2.0 degrees Celsius as stipulated in the Paris Agreement, governments have agreed to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country parties, and then to undertake rapid reductions 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.[3]

The global energy sector must undertake a rapid and systemic transformation towards low-carbon pathways. 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.[4] Developing countries also need technologies to put their economies on climate change-adapted pathways and to address climate change-related losses and damage.

However, despite the possibility of accessing and acquiring technologies through the usual channels (such as trade, foreign direct investment, licensing, or movements of people such as researchers and scientists) and then innovating and adapting such technologies, many developing countries have struggled to move from simple foreign technology acquisition through these channels into adaptation and subsequent endogenous technology development. According to the Intergovernmental Panel on Climate Change (IPCC), barriers to effective technology transfers of climate-related technologies

2. See e.g. United Nations Conference on Trade and Development (UNCTAD), UNCTAD calls for a bold international economic agenda to avert another lost decade for developing countries (12 April 2023), at https://unctad.org/news/unctad-calls-bold-international-economic-agenda-avert-another-lost-decade-developing-countries; Paul Brenton and Vicky Chemutai, The Trade and Climate Change Nexus: The Urgency and Opportunities for Developing Countries (World Bank, 2021), pp. 12-19, at https://openknowledge.worldbank.org/server/api/core/bitstreams/5d543ded-1163-5fc6-8fe8-319d913cf269/content.
3. See Paris Agreement, Art. 2.1(a) and 4.1.
4. 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 United Nations Framework Convention on Climate Change (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 (REN21, 2017). 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.

may vary according to the specific context from sector to sector and from country to country, and can range from a lack of information; insufficient human capabilities; political and economic barriers (such as a lack of capital, high transaction costs, lack of full cost pricing, and trade and policy barriers); institutional and structural barriers; lack of understanding of local needs; business limitations (such as risk aversion in financial institutions); institutional limitations (such as insufficient legal protection); and inadequate environmental codes and standards.[5] These barriers affect the level, speed, adequacy, and timeliness of technology transfers in meeting the needs of developing countries. Other factors can also affect climate-relevant technology transfer trends, such as volatility in investor sentiments due to shifts in market conditions.[6]

These barriers have created a wide technology gap between developed countries and the large majority of developing countries, especially those in Africa, large parts of South and Southeast Asia and the Pacific, and Latin America and the Caribbean.[7] Such a technological gap reflects the development gap that exists between developed countries and many developing countries, manifested in wide disparities in terms of access to finance, skills, and domestic infrastructure (including research and development infrastructure) that are crucial to building the capacity to absorb technology and adapt and innovate on received foreign technology. As will be noted later in this paper, developing countries have identified the barriers that hamper their access to, acquisition of, and innovation on needed climate-related technologies and the factors that would enable them to absorb and adapt such technologies.

Recognizing such challenges, the UNFCCC and the Paris Agreement state that developed countries "shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of environmentally sound technologies and know-how to developing countries" to support the implementation by the latter of their commitments under the UNFCCC, their nationally determined contributions (NDCs) under the Paris Agreement, and for achieving sustainable development.[8]

IPCC Definition of Technology Transfer

The IPCC in 2000 defined the term "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, NGOs and research/education institutions." The IPCC explained that its treatment of technology transfer "is much broader than that in the UNFCCC or of any particular Article of that Convention. The broad and inclusive term 'transfer' encompasses diffusion of technologies and technology cooperation across and within countries. It covers technology transfer processes between developed countries, developing countries and countries with economies in transition, amongst developed countries, amongst developing countries and amongst countries with economies in transition. 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."

Source: 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.

5. See IPCC, Climate Change 2007: Working Group III: Mitigation of Climate Change, Sec. 3.4.3.3 (IPCC, 2007), at https://archive.ipcc.ch/publications_and_data/ar4/wg3/en/ch3s3-4-3-3.html.
6. See e.g. UNCTAD, Climate Change Investment Affected by the Energy Crisis – Risk of a Temporary Slowdown (UNCTAD Investment Trends Monitor Special Issue 43, October 2022), at https://unctad.org/system/files/official-document/diaeiainf2022d5_en.pdf.
7. The technological gap has, however, rapidly decreased with respect to some developing countries, such as China and Singapore. See e.g. World Bank and Development Research Center of the State Council, PR China, China 2030: Building a Modern, Harmonious, and Creative Society (2013), at https://www.worldbank.org/content/dam/Worldbank/document/China-2030-complete.pdf; Singapore Economic Development Board, Singapore flexes its standing as Asia's technology capital (2 March 2018), at https://www.edb.gov.sg/en/business-insights/insights/singapore-flexes-its-standing-as-asias-technology-capital.html.
8. See UNFCCC, Art. 4.1(c), 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.

Developing countries view technology transfer as a key means to address the technology gap between developed and developing countries. Article 4.7 of the UNFCCC and Art. 10.5 and 10.6 of the Paris Agreement clearly highlight this link between having technology as a means of implementation and climate action.

Many developing countries have indicated the importance of technological innovation, research and development, and technology transfer in their NDCs.[9] 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.[10]

Most technologies that developing countries import, absorb, or adapt are privately owned,[11] and most climate-relevant technologies are developed and produced in developed countries.[12] The main direction of and enhanced efforts for technology transfer will be from developed to developing countries,[13] paying particular attention to ensure 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.[14] Technology transfer among developing countries through South-South cooperation could also play an important complementary role, but has remained limited.[15]

To be effective, technology transfer must 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. To be sustainable, technology transfer requires the capabilities to deploy, operate, maintain, adapt, improve, and reproduce the transferred technology and, ultimately, the capacity to invent new technologies.[16] Further, a more evenly spread technological uptake will also have an impact on prices and affordability even for countries that do not immediately absorb such technologies, as more suppliers of technologies enter the currently concentrated market.

A country's ability to access, adopt, and diffuse technological knowledge generated abroad strongly influences technological uptake and innovation. As such, 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.[17] There is no "one-size-fits-all" approach to technology transfer due to the diversity of countries' national circumstances and innovation needs.[18]

9. Jon Saalfield, Potential trade implications of Latin America and the Caribbean's climate commitments under the Paris Agreement (UNECLAC International Trade Series No. 172, 2022), p. 15, at https://repositorio.cepal.org/bitstream/handle/11362/48555/1/S2200905_en.pdf ; 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. 5, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf.
10. See e.g. South Centre, The Role of Decentralized Renewable Energy Technologies in Adaptation to Climate Change in Developing Countries (August 2008), p. 17, at https://www.southcentre.int/wp-content/uploads/2013/07/AN_ENV5_Role-Of-Decentralized-Renewable-Energy_EN.pdf.
11. 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.
12. For example, 80% of all low-carbon technology innovations and 70% of exports of such technologies are from developed countries. See e.g. Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (World Bank, 2020), p. 231, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf; United Nations Environment Programme (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; 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. 18-20, at https://library.fes.de/pdf-files/iez/global/06119.pdf.
13. 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. 18, at https://library.fes.de/pdf-files/iez/global/06119.pdf.
14. 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.
15. See e.g. 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. 29, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief9/7a74a2f17f204b6ba17f1ec965da70d7/f4e361cd56d4463a8daa4ab29a1254db.pdf; UNFCCC, Compilation of good practices in effective knowledge-sharing and practical learning on climate adaptation technologies through South-South and triangular cooperation (TEC, October 2017), p. 5, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief9/a5fbac8997e84fef84a47d81dba46279/3762bead33cd42e989361241cfbb6fc7.PDF.
16. 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.
17. See e.g. Martin Khor, Climate Change, Technology and Intellectual Property Rights: Context and Recent Negotiations (South Centre Climate Policy Brief 15, November 2014), pp. 1-2, at https://www.southcentre.int/wp-content/uploads/2015/02/CPB15_Climate-Change-Technology-and-IPRs_EN.pdf; 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
18. 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. 11, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf.

Hence, to support developing countries' efforts to achieve sustainable development in a climate-constrained world, the best appropriate technologies for climate change monitoring, mitigation, and adaptation need to be made available to developing countries. These should be under conditions that are cost-effective or commercially preferential in favour of the developing country recipient. There should also be 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.

The paper first provides an overview of international cooperation arrangements, commitments, and initiatives in relation to climate-related technology transfer to developing countries. This is followed by a review of technology priorities as identified by developing countries in their technology needs assessments, technology actions plans, and nationally determined contributions. The paper then introduces key considerations regarding technology transfer challenges and finance before discussing the trade-related linkages to the transfer of climate-related technologies. Finally, the paper puts forward a set of potential entry points for enhanced international cooperation on technology transfer.

2. Technology Transfer Commitments and Initiatives

International cooperation arrangements agreed by states have repeatedly recognized that developing countries would generally require some level of differentiated treatment and support.

In relation to climate change, the central role of technology transfer to developing countries as well as their development of endogenous technology were recognized in the 1992 Rio Summit, as well as in its related conventions including the UNFCCC.[19] Technology transfer was one of the two key "means of implementation" in Agenda 21 adopted in 1992, the other being financial resources.[20] Access to technology is a key element in the various SDGs,[21] with technology transfer also being a key area of partnership for SDG implementation.[22]

Article 4.1(c) of the UNFCCC requires all governments to cooperate with respect to climate-related technology transfer and Article 4.5 of the UNFCCC lays down a differentiated obligation on developed countries to take "all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention" and "support the development and enhancement of endogenous capacities and technologies of developing country Parties." Article 10.1 of the Paris Agreement lays out governments' 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."[23]

19. See UNFCCC, Art. 4.1, 4.2, 4.3, 4.4, 4.5, and 4.5. 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.
20. See United Nations (UN), Agenda 21 – Chapter 34: Transfer of Environmental Sound Technology, Cooperation and Capacity-Building, at https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf.
21. 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.
22. SDG 17.7.
23. Between 1994 (the entry into force of the UNFCCC) and 2015 (the adoption of the Paris Agreement), many initiatives and processes were undertaken within the UNFCCC to bring about the effective implementation of the UNFCCC's technology transfer provisions. These included the establishment of an expert group on technology transfer in 2001 at the seventh session of the Conference of the Parties (COP7), having a mandate for enhancing action on technology development and transfer under the Bali Action Plan adopted in Bali at COP13 in 2007, setting up in 2010 at COP16 in Cancún some institutional bodies within the UNFCCC to deal with technology transfer issues (including the Technology Mechanism, the Technology Executive Committee, and the Climate Technology Center and Network), and finally the inclusion of technology development and transfer as a key provision in the Paris Agreement at COP21 in Paris in 2015. This gradual development of the policy and institutional architecture within the UNFCCC and Paris Agreement regime with respect to technology development and transfer was largely due to a constant push by developing countries to obtain easier access (through transfers and more flexible intellectual property rules) to needed technologies and to be able to innovate and produce their own technologies, over a generally marked reluctance by developed countries to develop a more robust technology transfer regime under the UNFCCC.

Table 1. Examples of Technology Transfer Provisions in International Agreements

International Agreement	Technology Transfer Provisions	Textual Example
Sustainable Development Goals	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	SDG Target 17.7 – Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed.
		SDG Target 17.8 – Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology.
UNFCCC	Art. 4.1(c)	1. All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall: ... (c) Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors.
	Art. 4.5	5. The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and knowhow to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies.
Paris Agreement	Art. 10.2	2. Parties, noting the importance of technology for the implementation of mitigation and adaptation actions under this Agreement and recognizing existing technology deployment and dissemination efforts, shall strengthen cooperative action on technology development and transfer.
	Art. 10.5	5. Accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development. Such effort 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.
	Art. 10.6	6. Support, including financial support, shall be provided to developing country Parties for the implementation of this Article, including for strengthening cooperative action on technology development and transfer at different stages of the technology cycle, with a view to achieving a balance between support for mitigation and adaptation. The global stocktake referred to in Article 14 shall take into account available information on efforts related to support on technology development and transfer for developing country Parties.

Source: Author's compilation.

Strengthening cooperative action on technology development and transfer, providing support for collaborative approaches to research and development, and facilitating access to technology to developing countries are key common obligations of parties to the Paris Agreement under Articles 10.2, 10.5, and 10.6 thereof, as it is understood 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. These Paris Agreement commitments, in turn, are intended to enhance the implementation of long-standing technology transfer commitments of developed countries under the UNFCCC and to enable developing countries to implement their NDCs under the Paris Agreement.

Over the years, institutions and mechanisms have been created under the UNFCCC to promote technology transfer. In 2010, the Conference of the Parties (COP) established the Technology Mechanism with the objective of accelerating and enhancing climate technology development and transfer, consisting 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 Paris 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,[24] with more than 90 developing countries having undertaken such technology needs assessments.[25]

Other international agencies such as the World Bank, World Trade Organization (WTO), World Intellectual Property Organization (WIPO), United Nations Conference on Trade and Development (UNCTAD), United Nations Industrial Development Organization (UNIDO), United Nations Technology Bank for Least Developed Countries, United Nations Environment Programme (UNEP), and United Nations Office for South-South Cooperation (UNOSSC) also have activities or programmes related to acquiring, using, and learning from technologies that span from the public domain to the current scientific frontiers. For example, several provisions in the WTO agreements mention the need to transfer technology between developed and developing countries (such as Article 66.2 of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement)), with a working group on this issue having been established in 2001.[26] WIPO also undertakes work in relation to intellectual property rights (IPR) and technology transfer, including providing patent information services, innovation support tools and programmes, norm-setting and dialogues, knowledge transfer programmes and resources, multistakeholder platforms, training programmes, and dispute resolution services.[27] 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.[28] UNIDO has a technology cooperation programme to channel technologies

24. 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.
25. UNFCCC, Technology needs assessment: Outcomes, at https://unfccc.int/ttclear/tna/outcomes.html.
26. See e.g. WTO, at https://www.wto.org/english/tratop_e/devel_e/dev_wkgp_trade_transfer_technology_e.htm. The MC12 Outcome Document adopted by the WTO Ministerial Conference on 17 June 2022 reaffirmed, inter alia, "the importance of providing relevant support to developing country Members, especially LDCs, to achieve sustainable development, including through technological innovations." See WTO, MC12 Outcome Document (WT/MIN(22)/24, WT/L/1135, 17 June 2022), para. 14, at https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/MIN22/24.pdf&Open=True. In addition, under the Agreement on Trade-Related Investment Measures (TRIMS), WTO members can arguably use trade-related investment measures (such as local content requirements) that would otherwise be inconsistent with the TRIPS Agreement if such measures can be justified as an exception under Art. 3 of the TRIMS Agreement (which applies the exceptions under Art. XX of the GATT 1994 to the TRIMS Agreement).
27. See e.g. WIPO, at https://www.wipo.int/technology-transfer/en/#.
28. See e.g. UNCTAD, at https://unctad.org/topic/science-technology-and-innovation.

to developing countries through its International Technology Centres.[29] The United Nations Technology Bank for Least Developed Countries is dedicated to promoting technology transfer to least developed countries (LDCs).[30] 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.[31] The UNOSSC supports South-South technology transfer initiatives.[32] The World Bank provides as part of its activities research and analysis on technology transfer issues.[33]

3. Technology Transfer Priorities

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.[34] Many developing countries have made their NDCs under the Paris Agreement conditional on receiving climate finance, technology transfer, and capacity-building support. However, the actual uptake of available climate-relevant technologies in developing countries is often observed to be low.[35]

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, environmental monitoring equipment, and climate adaptation technologies (such as climate-adapted seed varieties, early warning systems, adaptation infrastructure).[36]

Developing countries often face the challenge of identifying the most suitable technology they need, consistent with their 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; otherwise, the technologies that may be acquired might end up

29. See e.g. UNIDO, at 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.
30. 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.
31. See e.g. UNEP, at https://www.unep.org/ietc/who-we-are#.
32. See 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)-
33. See e.g. World Bank, at https://www.worldbank.org/en/topic/macroeconomics/publication/technology-transfer-and-innovation-for-low-carbon-development.
34. Art. 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."
35. 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.
36. 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, and World Economic Forum (WEF), Accelerating Decarbonization through Trade in Climate Goods and Services: Insight Report (September 2022), p. 4 and p. 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 and 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".

being ineffective.[37] Developing countries would have to ask what technologies would be needed for them to be able to diversify viably 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.

Since 2001 within the UNFCCC process, developing countries have identified the technologies they need to shift their economies on to low-carbon sustainable development pathways and undertake national climate change actions. They have done so in four main ways: (i) through undertaking technology needs assessments (TNAs); (ii) developing technology action plans (TAPs); (iii) submitting technical assistance requests to the CTCN; and (iv) identifying in their NDCs the technologies they need to implement their NDCs.

3.1 Technology Priorities Under the Technology Needs Assessments

Developing countries tend to prioritize climate-relevant technologies that are already at a mature or near mature stage. As noted by UNEP, within the setting of UNFCCC, climate technologies have been prioritized as traditional technologies, modern technologies, and high technologies based on the level of maturity. According to the TNAs under the UNFCCC, developing countries' prioritized technologies are mainly modern or traditional technologies. The energy and transport sector, 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 coastal zones, emerging/high technologies represent 21%, 22%, and 15% of the total.[38] This is consistent with other analyses 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 because they demand less research and development.[39]

The TNAs undertaken by many developing countries in the context of the UNFCCC show their priorities with respect to the climate mitigation and adaptation technologies for which they are seeking technology transfer support—more than 90 developing countries have completed their TNAs to address climate change, and 39 developing countries are currently undertaking their TNAs.[40] For mitigation, almost all prioritized the energy sector, with the most prioritized subsectors of the sector in energy industries and transport. For adaptation, agriculture and water were the most prioritized sectors followed by infrastructure and settlements.[41] (See Annex for the priority mitigation and adaptation technologies.)

There are both similarities and differences in terms of technology transfer priorities among countries as shown by an analysis of TNAs from countries in Africa, Asia-Pacific, and Latin America and the Caribbean, as summarized in Table 2.[42]

37. 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.
38. 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.
39. 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.
40. UNFCCC, Technology Needs Assessment: Pathways for climate tech implementation, at https://unfccc.int/ttclear/tna.
41. 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, 57-59, 67-81, at https://unfccc.int/sites/default/files/resource/sbi2020_inf.01.pdf.
42. See 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.

Table 2. Regional Technology Priorities From Technology Needs Assessments

	Africa	Asia-Pacific	Latin America and the Caribbean
Mitigation	Solar energy technologies Forest management, reforestation, and forest conservation technologies Mechanical-biological waste treatment, waste recycling, and composting technologies	Solar energy technologies, such as solar minigrids, solar irrigation pumps, solar lanterns and solar water-heating technologies Clean transport sector technologies Waste management sector technologies	Energy-efficient buildings and lighting systems, bioenergy and solar energy technologies Clean transport sector technologies Sustainable agriculture sector technologies
Adaptation	Technologies for the management and diversification of crops, the development of new crop varieties, drip irrigation, soil management, and food conservation Water storage and harvesting, water management and water catchment technologies Coastal zone management and restoration, climate monitoring and forecasting, and hard coastal protection technologies	Technologies for the development of salt-, pest-, and drought-tolerant crop varieties, drip irrigation systems, precision farming, and windbreaker rehabilitation Water sector management technologies Coastal zone management technologies Technologies to address climate-induced natural disasters such as tsunamis, typhoons, and cyclones	Technologies for rainwater-harvesting, storm-water reclamation and reuse, water mapping and modelling, and water-quality monitoring Technologies for irrigation and farming systems, such as drip irrigation, micro-sprinklers, soil nutrition, soil conservation, and the introduction of climate-resilient crops

Source: Author's compilation based on regional technology needs assessments as noted in footnote 42.

3.2 Technology Priorities Under the Technology Action Plans

A key outcome of the TNA process is the technology action plan—it is the 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. More than 550 TAPs in developing countries are currently seeking support, along with more than 450 project ideas that they prepared between 2009 and 2018. More TAPs are currently being prepared by 23 countries.[43] Support needs range from financial resources for a given technology, the strengthening of institutions and human resources for technology research and development, to capacity building and the establishment of information and awareness-raising programmes.[44]

3.3 Technology Priorities Through CTCN Technical Assistance Requests

Developing countries' technology transfer priorities can also be seen in the 365 technical assistance requests from 109 developing countries received by the UNFCCC's Climate Technology Center and Network as of 31 August 2022 (see Table 3).[45]

43. 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 .
44. 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.
45. UNFCCC, Joint annual report of the Technology Executive Committee and the Climate Technology Centre and Network for 2022 (28 September 2022), para. 81, at https://unfccc.int/sites/default/files/resource/sb2022_04_adv.pdf.

Table 3. Regional Technology Priorities From Technical Assistance Requests

Africa	Asia-Pacific	Latin America and the Caribbean
Requests for support for circular economy and solar photovoltaics in the context of energy, water, and food have increased. Continued support is needed for crosscutting technologies addressing the energy-water-food security nexus, e-mobility regulations, incentive creation, and TNAs.	Demand has increased for renewable energy, energy efficiency, and low-carbon transport. Support has been requested for decision-support systems; crosscutting technologies addressing energy, water, and food security; improved early warning systems; sustainable urban planning; feasibility studies; e-mobility and green hydrogen road maps; and policy and regulatory support for energy efficiency in buildings and for appliances.	Requests have focused on adaptation and cross-cutting technologies (circular economy, TNAs, and TAPs) and mitigation technologies for e-mobility and renewable energy. Adaptation requests cover a broad range of tools addressing risk management for food security, water management, coastal zone management, nature-based solutions, and adaptation monitoring.

Source: Author's compilation based on technical assistance requests received by UNFCCC's Climate Technology Center and Network as cited in footnote 45.

3.4 Technology Priorities in Developing Countries' Nationally Determined Contributions

The most frequently identified technologies in developing countries' 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 to improve 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.[46] 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."[47]

4. Technology Transfer Enablers and Challenges

In spite of these efforts, in a 2014 survey of climate-related international collaborative activities relating to technology development and transfer the UNFCCC's Expert Group on Technology Transfer observed that "a number of large gaps" exist.[48] 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 LDCs continues to widen,[49] with developed countries usually best placed to move to the technology innovation frontier due to higher levels of skill, financial and technical resources, and stronger manufacturing industries.[50]

46. 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.
47. 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.
48. UNFCCC, Report on Options to Facilitate Collaborative Technology Research and Development, Note by the Chair of the Expert Group on Technology Transfer (2010), pp. 4-5 and 26-27, at http://unfccc.int/resource/docs/2010/sbsta/eng/inf11.pdf.
49. UNCTAD, Transfer of Technology and Knowledge Sharing for Development: Science, technology and innovation issues for developing countries (UNCTAD, 2014), p. 14, at https://unctad.org/system/files/official-document/dtlstict2013d8_en.pdf.
50. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), pp. xvii-xviii, at https://unctad.org/system/files/official-document/tir2023_en.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. 1,684, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf ; UNCTAD, Green technologies: Coherent policy action needed for developing countries to reap the benefits (16 March 2023), at https://unctad.org/news/green-technologies-coherent-policy-action-needed-developing-countries-reap-benefits.

Developing countries face several obstacles to technology transfer, and "leapfrogging" towards low-carbon and other relevant climate technologies also faces important challenges.[51] These were identified in TNAs undertaken by many developing countries under the UNFCCC.[52] These obstacles and challenges include:

- financial and economic (such as cost and price) and legal and regulatory (such as standards and policies) barriers,[53]
- gaps in the adaptive and absorptive capacity to be able to build the required technological capabilities (such as gaps in the basic skills, shared language, or prior related knowledge of recent scientific or technological developments in each field that would be needed to be able to recognize the value of new information, assimilate and understand it, and innovate on it),[54]
- implementation gaps with respect to compliance with existing technology transfer commitments under international law (such as the inadequacy of compliance by developed countries of their technology transfer obligations under the UNFCCC or the WTO's TRIPS Agreement),[55]
- institutional constraints (such as lack or inadequacy (in terms of resources, etc.) of domestic research and development institutions),[56] and
- ensuring coherence in both policy design and implementation so there is an integrated approach to structural transformation, climate adaptation, and employment generation (such as ensuring that trade, investment, and climate policies are integrated in approach to foster sustainable development pathways).[57]

There are differences with respect to which of these challenges to technology development and transfer are more prominent for small island developing states, LDCs, and other developing countries, as well as across regions.[58]

The enablers for technology development and transfer for mitigation and adaptation that developing countries most frequently reported in their TNAs under the UNFCCC were economic and financial, information and awareness, legal and regulatory, and technical.[59]

51. 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 ; 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.
52. See e.g. 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.
53. See e.g. 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.
54. 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. 1,683, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf.
55. See e.g. See 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. 1,687, 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.
56. 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. 1,685, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf.
57. 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.
58. 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), pp. 20-21, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/tec_enablingenvironments/d611c896c4dd44c79c79ec8938625a88/b8730b2990284c17887b1f511b5a2f7c.pdf.
59. 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.

5. Technology Transfer and Finance

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.[60] Technology transfer rarely happens without financial support which may take the shape of finance available to risk-takers and entrepreneurs or as incentives provided by governments to improve access to technology.[61]

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 $20.1 billion for mitigation and $4.4 billion for adaptation is needed. For the implementation of technology project ideas, $22.0 billion for mitigation and $14.0 billion for adaptation would be needed.[62] Many developing countries provided quantitative estimates of their financial support needs in their NDCs.[63]

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 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.[64] However, while the primary responsibility for financing inward flows of technology transfers 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 assist developing countries meet the "agreed incremental costs"[65] 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 to measure—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.[66]

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, covering support for both hardware (equipment) and software (know-how, methods, practices) in approximately equal amounts,

60. UNFCCC, Art. 4.3 and 4.5; Paris Agreement, Art. 9.1 and 10.6.
61. UNCTAD, Transfer of Technology and Knowledge Sharing for Development: Science, technology and innovation issues for developing countries (UNCTAD, 2014), p. 3, at https://unctad.org/system/files/official-document/dtlstict2013d8_en.pdf.
62. UNFCCC, Fourth synthesis of technology needs identified by Parties not included in Annex I of the Convention: Report by the secretariat (3 April 2020), pp. 6-7, at https://unfccc.int/sites/default/files/resource/sbi2020_inf.01.pdf.
63. UNFCCC, Nationally determined contributions under the Paris Agreement: Synthesis report by the secretariat (26 October 2022), para. 201, at https://unfccc.int/sites/default/files/resource/cma2022_04.pdf. For region-specific technology transfer financing needs identified by UNEP, see 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.
64. See e.g. UNEP, The Climate Technology Progress Report (2022), p. 42, at https://unepccc.org/wp-content/uploads/2023/03/the-climate-technology-progress-report-2022-web.pdf.
65. For the meaning of "agreed incremental costs" as applied with respect to the climate finance obligation of developed countries under the UNFCCC, see e.g. GEF, Incremental Costs (29 February 1996), at https://www.thegef.org/sites/default/files/council-meeting-documents/C.7.Inf_.5-Incremental-Costs.pdf; GCF, Policy on incremental cost and full cost methodologies (7 June 2021), at https://www.greenclimate.fund/sites/default/files/document/gcf-b29-inf10.pdf.
66. See e.g. UNFCCC-SCF, Fourth (2020) Biennial Assessment and Overview of Climate Finance Flows (2020), para. 77, at https://unfccc.int/sites/default/files/resource/54307_1%20-%20UNFCCC%20BA%202020%20-%20Report%20-%20V4.pdf.

mostly going to mitigation.[67] The sources of funding for supporting the implementation of technology activities were in most cases public, with most activities being undertaken by public-private partnerships (63%).[68] However, it is not possible to calculate how much financing developed countries have provided for technology transfer due to the lack of data contained in their biennial reports under the UNFCCC.

Financing channels for technology transfer under the UNFCCC and the Paris Agreement to developing countries vary. In their biennial reports under the UNFCCC, several developed countries highlighted that they mainstreamed technology transfer activities in their bilateral development cooperation (official development assistance (ODA)) activities.[69] They are doing so through various development cooperation instruments, including direct support and financing, technical assistance and capacity-building financing, policy support financing, and catalysing and mobilizing additional finance.[70]

UNEP has estimated that the amount of technology-related climate development finance more than doubled between 2015–2019, from $13.3 billion to $28.6 billion, outpacing the growth rate of total climate-related development finance. Development cooperation support for mitigation-related technology transfer in the energy sector totalled $8.9 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%).[71]

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 appears 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.[72] 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 and restricts any remaining or available fiscal space to implement climate and other sustainable development measures.[73]

Aside from bilateral development cooperation, financing from developed countries to support

67. There is evidence, however, that technology transfer activities that developed countries have undertaken under the Convention and the Kyoto Protocol, such as through the Clean Development Mechanism, have not been effective. See e.g. Silvia Weko and Andreas Goldthau, Briding, the low-carbon technology gap? Assessing energy initiatives for the Global South (Energy Policy, vo. 169, October 2022), at https://www.sciencedirect.com/science/article/pii/S0301421522004128; Titilayo Soremi, Low Carbon Technology Transfer to Developing Countries (University of Toronto), at https://www.academia.edu/10354032/Low_Carbon_Technology_Transfer_to_Developing_Countries. Despite almost two decades of work on technology transfer and capacity building, there continue to be relatively high levels of weakness in developing countries' national capacities relating to climate technologies for mitigation, adaptation, and cross-cutting issues, as highlighted by a 2021 report by the Technology Executive Committee. See TEC, Building Capacities in Climate Technologies: Understanding gaps, needs, challenges and enabling measures to promote endogenous capacities and technologies (July 2021), at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/endogenous_index/bd4f66e671e0407383c8ed63abc46999/4cc431a03f104b29afeb8d974655481b.pdf. See also UNEP-CCC, The Climate Technology Progress Report 2022 (UNEP, 2022), at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/TEC_documents/f6cb095702554785b53f09b73db063b7/e17ce3e0ef0e4c6ab0c1d78633503a1a.pdf.
68. UNFCCC, Compilation and synthesis of fourth biennial reports of Parties included in Annex I to the Convention: Report by the secretariat – Addendum (12 November 2020), paras. 244-256, at https://unfccc.int/sites/default/files/resource/sbi2020_inf10a01.pdf.
69. UNFCCC, Compilation and synthesis of fourth biennial reports of Parties included in Annex I to the Convention: Report by the secretariat – Addendum (12 November 2020), para. 247, at https://unfccc.int/sites/default/files/resource/sbi2020_inf10a01.pdf.
70. UNEP, Technology Transfer for Climate Mitigation and Adaptation: Analysing needs and development assistance support in technology transfer processes (2022), pp. 13-14, at https://unepccc.org/wp-content/uploads/2022/11/finalproof-tech-transfer-policy-brief-oecd.pdf.
71. UNEP, Technology Transfer for Climate Mitigation and Adaptation: Analysing needs and development assistance support in technology transfer processes (2022), pp. 15-17, at https://unepccc.org/wp-content/uploads/2022/11/finalproof-tech-transfer-policy-brief-oecd.pdf; see also UNEP, The Climate Technology Progress Report (2022), p. 38, at https://unepccc.org/wp-content/uploads/2023/03/the-climate-technology-progress-report-2022-web.pdf.
72. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), pp. 112-113, at https://unctad.org/system/files/official-document/tir2023_en.pdf.
73. See e.g. Lela Achampong, In focus: Reforming climate finance (OECD Library, February 2023), at https://www.oecd-ilibrary.org/sites/98de3607-en/index.html?itemId=/content/component/98de3607-en.

technology transfers under the UNFCCC and the Paris Agreement to developing countries are 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.[74] The GCF 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, with 65% of GCF projects having at least one technology component.[75]

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 United Nations system, the quantum of such funding and the impact of such initiatives are insufficient.[76] 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."[77]

In response, developed countries and the TEC have focused their attention on the private sector and encouraged public-private partnerships as new providers of finance,[78] such as the Climate Resilience and Adaptation Finance and Technology Transfer Facility (CRAFT),[79] the European Bank for Reconstruction and Development's Finance and Technology Transfer Centre for Climate Change (FINTECC) programme,[80] and the Climate Investment Funds' Clean Technology Fund.[81] The TEC 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.[82]

74. GEF, Support for Innovation, Technology Transfer, and Private Sector Engagement by the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF): Enhanced Support for Scaled-Up Action (2022-2026), p. 3, at https://www.thegef.org/sites/default/files/2023-04/GEF_Support_Innovation_LDCF_SCCF_2023_04.pdf. See also UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), p. 119, at https://unctad.org/system/files/official-document/tir2023_en.pdf ; GEF, Technology Transfer, at https://www.thegef.org/what-we-do/topics/technology-transfer ; GEF, Special Climate Change Fund, at https://www.thegef.org/what-we-do/topics/special-climate-change-fund-sccf ; GEF, Special Climate Change Fund (SCCF) – Serving the Adaptation Needs of Small Island Developing States and Enhancing Technology Transfer, Private Sector Engagement and Innovation for All (2022-2026) (March 2023), p. 3, at https://www.thegef.org/sites/default/files/2023-04/GEF_SCCF_Adaptation_2023_04.pdf.
75. Emerson Resende, GCF Support to Climate Technologies (GCF, 14 September 2021), pp. 20-21, at https://www.ctc-n.org/sites/www.ctc-n.org/files/Agenda%20Item%2012.3_Presentation%20from%20the%20Green%20Climate%20Fund.pdf ; see also GCF, GCF in Brief: Support for Technology, at https://www.greenclimate.fund/sites/default/files/document/gcf-brief-support-technology_0.pdf.
76. See e.g. 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.
77. See e.g. UNEP, The Climate Technology Progress Report (2022), p. 42, at https://unepccc.org/wp-content/uploads/2023/03/the-climate-technology-progress-report-2022-web.pdf.
78. 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.
79. The Lab, CRAFT, at https://www.climatefinancelab.org/ideas/climate-resilience-and-adaptation-finance-technology-transfer-facility-craft-2/. See Nordic Development Fund, CRAFT, at https://www.ndf.int/what-we-finance/projects/project-database/climate-resilience-and-adaptation-finance-and-technology-transfer-facility-craft-c114.html.
80. NDC Partnership, Finance and Technology Transfer Centre for Climate Change, at https://ndcpartnership.org/funding-and-initiatives-navigator/finance-and-technology-transfer-centre-climate-change-fintecc . See also EBRD-FINTECC, About FINTECC, at https://fintecc.ebrd.com/about.html.
81. Clean Technology Fund – Clean Technologies, at https://www.cif.org/topics/clean-technologies.
82. 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. 19, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief10/8c3ce94c20144fd5a8b0c06fefff6633/57440a5fa1244fd8b8cd13eb4413b4f6.pdf.

6. Technology Transfer and Trade-Related Linkages

Technology transfer can be undertaken through many channels, with international trade in climate-relevant technologies being one of them. 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.[83]

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. 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.[84] International trade can be a key vector for the diffusion of climate-relevant technologies, increasing their availability, access, and potential to be used in developing countries to undertake climate mitigation, adapt to the impacts of climate change, and build resilience,[85] but the impact on building endogenous innovation and technology development capacity is less clear.[86]

6.1 Trade in Climate-Relevant Technologies as a Technology Transfer Driver

In 2017, the global market for trade in climate-relevant technologies goods and services reached $1.12 trillion.[87] Trade in such goods amounted to $1.9 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 $2.1 trillion by 2030.[88]

Some studies have pointed out that improved access to climate-relevant technologies through trade measures such as tariff and non-tariff measure liberalization can support switching to low-carbon, efficient, and environmentally sound production processes, adopt cleaner technologies, stimulate innovation, and create employment in renewable energy and climate-friendly sectors.[89]

WTO analysis suggests that liberalizing trade in energy-related environmental goods,[90] for example,

83. 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.
84. See e.g. WTO, World Trade Report 2022: Climate change and international trade (2022), pp. 12-13, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf ; UNCTAD, Making trade work for climate change mitigation: The case of technical regulations (2022), p. 7, at https://unctad.org/system/files/official-document/ditctab2022d7_en.pdf.
85. 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.
86. 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. 1,658, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf.
87. International Trade Administration, Environmental Technologies, at https://www.trade.gov/environmental-technologies-industry-overview. A 2020 World Bank study notes, however, that global trade in climate technologies essentially plateaued between 2014-2020 after steady year-on-year growth between the early 1990s and 2000s. See Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), p. 32, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf.
88. UNCTAD, Global trade slows, but 'green goods' grow (23 March 2023), at https://unctad.org/news/global-trade-slows-green-goods-grow.
89. See e.g. WTO, World Trade Report 2022: Climate change and international trade (2022), pp. 123-124, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf.
90. These include, according to the WTO, clean and renewable energy, energy-efficiency, and resource-efficiency goods. See WTO, World Trade Report 2022: Climate change and international trade (2022), p. 123, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf.

could boost global exports by 5% ($109 billion) by 2030, with the resulting increases in energy efficiency and renewable energy uptake estimated to reduce net global carbon emissions by 0.6% and to generate millions of new jobs in the clean energy and related sectors by 2030. There continue to be barriers (such as tariff and non-tariff measures) to trade in environmental goods and services, and tariff and non-tariff barriers tend to be lower in carbon-intensive industries than in clean industries.[91]

The reduction or elimination of tariff and non-tariff barriers to environmental goods and services was made the subject of multilateral negotiations in the WTO from 2001 as part of the Doha Round.[92] 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 liberalization commitments on tariff and non-tariff barriers to such goods have taken place either multilaterally or on a plurilateral basis in the WTO and discussions have largely moved to the regional and bilateral level.[93] In both negotiations, the failure to conclude were largely attributable to irreconcilable differences over the definition of environmental goods, with WTO members coming up with varying approaches.

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 and 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 exceeding 10–20%).[94] From this, one might conclude that as tariffs on such goods do not pose significant barriers to trade in climate-relevant technologies, technology transfer to developing countries through increased trade in such goods would be facilitated, but this is not borne out by the data as discussed further below.

Recent studies show that non-tariff measures (NTMs) may, in their application, constitute more significant barriers to the international trade of climate-relevant technologies than tariffs.[95] NTMs include a broad array of trade control instruments such as licenses, quotas, price control measures, and finance measures as well as technical regulations that can regulate product characteristics, production processes, and import requirements related to environmental protection or sustainability. According to UNCTAD and the IPCC, NTMs have been widely adopted to limit global greenhouse gas emissions, including technical regulations relevant to mitigation efforts in areas such as energy efficiency, consumer information (labelling), fuel standards, and low emission industrial materials, sometimes with the goal of incentivizing trade partners to adopt domestic climate change mitigation measures or remove disincentives to climate action.[96] Developed countries tend to impose such

91. Between 2009 and 2020, 3,460 trade-related climate change mitigation measures explicitly addressing climate change mitigation, energy conservation and efficiency, and alternative and renewable energy were notified by WTO members, with support measures (such as subsidies) and technical regulations being the main types of notified trade-related climate change mitigation measures. See WTO, World Trade Report 2022: Climate change and international trade (2022), pp. 12-13, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf.
92. WTO, Doha Ministerial Declaration (2001), para. 31(iii), at https://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_e.htm.
93. See e.g. WTO, Negotiations on trade and the environment, at https://www.wto.org/english/tratop_e/envir_e/envir_negotiations_e.htm; Gaelle Balineau and Jaime de Melo, Stalemate at the Negotiations on Environmental Goods and Services at the Doha Round (FERDI, 28 October 2011), p. 2, at https://ferdi.fr/dl/df-UYNHCzmY9guUTr25u4mjSe7v/ferdi-p28-stalemate-at-the-negotiations-on-environmental-goods-and-services.pdf; Aik Hoe Lim, WTO work on trade in environmental goods and services (March 2017), at https://www.unescap.org/sites/default/files/1-2.EGS-Trade2-WTO%20work.pdf; DW, WTO 'green goods' negotiations collapse (DW, 4 December 2016), at https://www.dw.com/en/world-trade-organization-green-goods-negotiations-collapse/a-36637163.
94. See e.g. WEF, Accelerating Decarbonization through Trade in Climate Goods and Services: Insight Report (September 2022), p. 10, at https://www3.weforum.org/docs/WEF_Accelerating_Decarbonization_through_Trade_2022.pdf ; Paul Brenton and Vicky Chemutai, The Trade and Climate Change Nexus: The Urgency and Opportunities for Developing Countries (World Bank, 2021), pp. 56-59, at https://openknowledge.worldbank.org/server/api/core/bitstreams/5d543ded-1163-5fc6-8fe8-319d913cf269/content ; WTO, World Trade Report 2022: Climate change and international trade (2022), p. 120, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf; UNCTAD, Trade and Development Report 2021 (2021), pp. 138-140, at https://unctad.org/system/files/official-document/tdr2021_en.pdf.
95. 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 non-tariff barriers 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, licenses or quotas); government procurement procedures; customs procedures, including licenses and other permits; 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.
96. 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. An exploratory mapping of climate change-related NTMs was conducted by UNCTAD in collaboration with the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). The mapping led to the identification through the UNCTAD TRAINS NTMs database of more than 1,000 NTMs introduced by about 100 developed and developing countries.

NTMs more than developing countries, which can become barriers to trade for developing countries—e.g. varying regulations or standards, inconsistent or non-transparent application of non-tariff measures, lack of harmonized rules, or other forms of regulatory diversity can create complexities and costs that developing countries can face difficulties to overcome.[97] Indeed, many developing countries express concerns about the potential discriminatory impact of climate or sustainability-related labelling or certification requirements on goods that they export to developed countries arising from lack of capacity to comply with such requirements.[98]

The combination of low tariffs for climate-relevant technologies and the application of heterogeneous NTMs on such technologies has likely contributed to the continuing technology gap.[99] Between 2018 and 2021, total exports of green technologies from developed countries jumped from around $60 billion to more than $156 billion, while in the same period, exports from developing countries rose from $57 billion to only about $75 billion (resulting in developing countries' share of global exports of such technologies falling from more than 48% to under 33%).[100] 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%)[101] and low-income developing countries (0.02%).[102] Among developing countries, China has the biggest export share with respect to the global export trade in such technologies.[103]

These figures highlight what UNCTAD has noted with respect to such trade patterns: "[D]eveloped economies are seizing most of the opportunities, leaving developing economies further behind."[104] 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).[105] Developed countries largely remain ahead of and dominate 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).[106]

97. See e.g. Paul Brenton and Vicky Chemutai, The Trade and Climate Change Nexus: The Urgency and Opportunities for Developing Countries (World Bank, 2021), p. 59, at https://openknowledge.worldbank.org/server/api/core/bitstreams/5d543ded-1163-5fc6-8fe8-319d913cf269/content; WTO, World Trade Report 2022: Climate change and international trade (2022), p. 120, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf; 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.
98. 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 measure and its deforestation regulation.
99. As noted by the UNESCAP Secretariat in a 2018 report, "in an era of free trade and international competition, technological upgrading and innovation constitute an essential ladder for developing countries in the region to develop their economies and climb up the global value chains. Relying purely on the market will probably lock developing countries, especially the least developed countries, into their areas of comparative advantage, such as labour-intensive and low-technology industries, and exacerbate their marginalization in the international market." See UNESCAP, Leveraging technology and trade for economic development: Note by the secretariat (ESCAP/CICTSTI/2018/7, 20 June 2018), para. 67, at https://www.unescap.org/sites/default/d8files/event-documents/CICTST~2_1.PDF.
100. UNCTAD, Green technologies: Coherent policy action needed for developing countries to reap the benefits (16 March 2023), at https://unctad.org/news/green-technologies-coherent-policy-action-needed-developing-countries-reap-benefits.
101. With the more than half of middle-income countries' exports being from China.
102. WTO, World Trade Report 2022: Climate change and international trade (2022), p. 119, at https://www.wto.org/english/res_e/booksp_e/wtr22_e/wtr22_e.pdf; see also UNCTAD, Trade and Development Report 2021 (2021), pp. 138-140, at https://unctad.org/system/files/official-document/tdr2021_en.pdf with respect to 2019 figures.
103. See UNCTAD, Trade and Development Report 2021 (2021), p. 138, at https://unctad.org/system/files/official-document/tdr2021_en.pdf with respect to 2019 figures.
104. UNCTAD, Green technologies: Coherent policy action needed for developing countries to reap the benefits (16 March 2023), at https://unctad.org/news/green-technologies-coherent-policy-action-needed-developing-countries-reap-benefits.
105. UNCTAD, Trade and Development Report 2021 (2021), pp. 113-115 and 138-140, at https://unctad.org/system/files/official-document/tdr2021_en.pdf. China's rise as a developing country technology leader has been due to a number of factors, including the use of strategic industrial and technology policy, investment in research and development, and leveraging its domestic labour and consumer market to produce and subsequently export with maximized economies of scale. See e.g. Yanfei Li, Understanding China's Technological Rise (The Diplomat, 3 August 2018), at https://thediplomat.com/2018/08/understanding-chinas-technological-rise/; Naubahar Sharif, China as the World's Technological Leader in the 21st Century: Dream or Reality? (HKUST Institute for Emerging Market Studies Leadership Brief No. 11, February 2016), at https://iems.ust.hk/publications/thought-leadership-briefs/china-as-the-worlds-technology-leader-in-the-21st-century-dream-or-reality; James Schoff and Asei Ito, Competing with China on Technology and Innovation (CEIP, 10 October 2019), at https://carnegieendowment.org/2019/10/10/competing-with-china-on-technology-and-innovation-pub-80010.
106. UNCTAD, Green technologies: Coherent policy action needed for developing countries to reap the benefits (16 March 2023), at https://unctad.org/news/green-technologies-coherent-policy-action-needed-developing-countries-reap-benefits.

These figures also highlight that existing trade approaches and measures have not led to the effective transfer of climate technologies from developed to developing countries in ways that improve capacity for endogenous technology development. This underlines that endogenous technology innovation and development as an outcome of international trade in climate-relevant technologies require more than simply liberalizing tariffs or addressing NTMs with discriminatory effects in connection with climate-relevant technologies. A full suite of complementary policies, regulatory framework, investment, and finance flows are needed to bring about the desired technology transfer outcomes.

In practice, this means that enhancing trade in climate-relevant technologies (whether through tariff shifts or changes in NTMs) will not suffice to effectively transfer technologies absent the necessary fertile policy and innovation ground in the importing country for its innovators and producers to learn from and innovate on such technologies. While in some cases—i.e. where tariffs are still above 5%—further unilateral tariff liberalization might boost imports of such technologies, doing so absent other domestic complementary measures to support domestic research and development and innovation on such technologies would be needed for developing countries to advance up the value chain of such technologies and undertake or increase their own exports.

Additionally, the possible discriminatory effects against developing countries of existing NTMs on climate-relevant technologies need to be addressed. For example, to enhance the transfer of technology embedded in such climate-relevant technologies, a better approach to NTMs relating to the trade of climate-relevant technologies could be to simplify, harmonize, and standardize them multilaterally at the WTO, together with a package for technical and financial assistance for developing countries designed to help them adopt and comply with such NTMs.

To conclude, trade measures for climate-relevant technologies should be complemented by supportive domestic policy measures intended to increase the ability of the importing country's economic sectors to absorb the technology, innovate and adapt such technology to domestic requirements, and eventually develop endogenous climate technologies. This will require implementing an integrated suite of policy measures that would run the gamut of increasing domestic research and development capacity, economic diversification, shifting domestic consumer production and consumption to sustainable or low-carbon patterns using green public procurement, development of green regulations or product standards, and providing technical assistance and capacity-building to domestic innovators and producers.

6.2 Intellectual Property Rights and Climate-Relevant Technologies

Despite existing norms, pledges, and mechanisms for climate-relevant technological transfer, impactful change of the speed and scope deeded has not been achieved. The current dominance that developed countries enjoy in relation to the development, innovation, production, and trade of climate-relevant technologies is based in large part on the advantages they possess over most developing countries in terms of scientific expertise, the financial resources needed to invest in research and development, the access to the underlying technologies and technological infrastructure needed for innovation, and the industrial infrastructure needed to produce such technologies. These advantages are closely linked to the intellectual property rights that are strongly enforced in developed countries and, through the TRIPS Agreement, are sought to be enforced equally strongly in developing countries.

These "rights" (embodied through patents, industrial designs, trade secrets, copyrights, etc.), granted by governments, create economic monopoly privileges over the invention, innovation, and subsequent production and economic fruits from their exploitation (e.g. through trade or other commercial transactions). At the same

Table 4. Provisions Balancing Intellectual Property Rights and Public Policy Interests Under the TRIPS Agreement

Article 7	Article 8
Objectives The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations.	*Principles* 1. Members may, in formulating or amending their laws and regulations, adopt measures necessary to protect public health and nutrition, and to promote the public interest in sectors of vital importance to their socio-economic and technological development, provided that such measures are consistent with the provisions of this Agreement. 2. Appropriate measures, provided that they are consistent with the provisions of this Agreement, may be needed to prevent the abuse of intellectual property rights by right holders or the resort to practices which unreasonably restrain trade or adversely affect the international transfer of technology.

Source: Author's compilation.

time, however, being statutory privileges granted by the state, these private rights are widely balanced with other public policy interests. This balance is recognized in, for example, the TRIPS Agreement's Articles 7 and 8.[107]

This balancing act between IPR and other public policy interests is best addressed domestically to ensure that inflows (whether through trade or investment or other means) of foreign IPR-protected climate-relevant technologies can support domestic endogenous technology development. Attention should hence be paid to ensuring that national IPR systems are geared towards promoting and supporting endogenous learning and follow-on innovation with respect to imported and transferred technologies, with attention "to selecting IP [intellectual property] standards that recognize the rights of inventors but encourage dynamic competition."[108]

The pursuit of such balance is particularly important given ongoing debates about the role of IPR in promoting or impeding technology transfer, technological progress, and innovation in countries at different levels of development.[109] As noted above, 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.[110] Several forms of intellectual property are potentially relevant to climate change mitigation and adaptation initiatives: patents; trademarks, especially certification marks; trade secrets and know-how; plant variety rights; and the suppression of unfair competition. However, climate change discussions touching on the intellectual property system, when they have occurred, have principally concerned patents.[111]

107. For literature on the application and practice of TRIPS Agreement Articles 7 and 8, see e.g. WTO, Analytical Index, at https://www.wto.org/english/res_e/publications_e/ai17_e/trips_art7_oth.pdf; WIPO, Implications of the TRIPS Agreement on Treaties Administered by WIPO (2012), p. 9, at https://www.wipo.int/edocs/pubdocs/en/intproperty/464/wipo_pub_464.pdf; Thamara Romero, Articles 7 and 8 as the basis for interpretation of the TRIPS Agreement (South Centre Policy Brief No. 79, June 2020), at https://www.southcentre.int/wp-content/uploads/2020/06/PB-79.pdf ; Alison Slade, Article 7 and 8 of the TRIPS Agreement: A Force for Convergence within the International IP System (Journal of World Intellectual Property 14:6, pp. 413-440, November 2011), at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1747-1796.2011.00429.x; Alison Slade, The 'Objectives' and 'Principles' of the WTO Trips Agreement: A Detailed Anatomy (Osgood Legal Studies Research Paper No. 50, 12:10, 2016), at https://digitalcommons.osgoode.yorku.ca/cgi/viewcontent.cgi?article=1179&context=olsrps.
108. 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.
109. 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.
110. 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.
111. Antony Taubman and Jayashree Watal, The WTO TRIPS Agreement – A Practical Overview for Climate Change Policymakers (13 December 2010), p. 1, at https://www.wto.org/english/tratop_e/trips_e/ta_docs_e/8_3_overviewclimatechange_e.pdf.

The largest number of patented mitigation technologies is in the energy,[112] manufacturing, and transportation sectors (which also accounted for the biggest share of innovations or inventions in the same period), while carbon capture and storage, a recent and more limited field, accounts for the fewest patented technologies. These innovations or inventions are concentrated in developed countries and China, producing at least 80% of climate-relevant innovations, while lower middle-income and low-income developing countries produced almost none during the same period.[113] 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.[114] Patenting in most adaptation technologies has not surged in the past two decades, unlike the significant increase in patenting in climate change mitigation technologies.[115]

The fact that most patents for climate-relevant technologies are in developed countries has important implications for technology transfer possibilities as the design and use of such technologies may not be directly responsive to the needs of developing countries.[116] Private sector companies in developed countries hold most of these patents, giving them a significant competitive advantage relative to their developing country counterparts.[117] Furthermore, most of the climate-related science and research that contribute to the development of climate-related technologies in one way or another are carried out in developed countries.[118]

International patent data show "negligible levels" of transfers of such technologies to low-income developing countries. Almost three-quarters of all such transfers occurred between developed countries between 2010–2015, around a quarter between developed to middle-income developing countries (with China accounting for half), 4% from middle-income developing countries to developed countries, 1% between middle-income developing countries, and almost no patent transfers (i.e. when a technology originally patented in country A is then patented in country B) took place to or from low-income developing countries.[119] Likewise, 85% of cross-border transfers of adaptation-related patents took place in developed countries and China.[120]

There continue to be academic and policy debates over the impact of patents on technology development and transfer, including with respect to climate-relevant technologies. On one hand, stronger patent rights and enforcement may trigger increased international trade flows as patent-sensitive industries and firms respond

112. It should be noted, however, that in solar photovoltaic, biomass, and wind, the basic technological solutions have long been off-patent. What are patented are usually only specific improvements or features. See John Barton, Patenting and Access to Clean Energy Technologies in Developing Countries (February 2008), at https://www.wipo.int/wipo_magazine/en/2008/01/article_0003.html#.
113. Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), pp. 63-66, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf. International Energy Agency and Organisation for Economic Co-operation and Development (OECD) researchers have found that while patenting of innovations in climate change mitigation technologies related to power generation, transport, buildings, manufacturing, and carbon capture and storage had generally been increasing much faster than other technologies in the period up to 2011–2012, there has been a notable drop-off in the number of these patents since then. See Miguel Cardenas Rodriguez et al., Global patent applications for climate change mitigation technologies – a key measure of innovation – are trending down (International Energy Agency, 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.
114. 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.
115. Kerstin Hotte and Su Jung Jee, Knowledge for a warmer world: A patent analysis of climate change adaptation technologies (Technological Forecasting and Social Change 183:121879, October 2022), at https://www.sciencedirect.com/science/article/pii/S004016252200395X; see also WIPO, Green Technology Book: Solutions for climate change adaptation (2022), pp. 21, 26-29, and 170-171, at https://www.wipo.int/edocs/pubdocs/en/wipo-pub-1080-en-green-technology-book.pdf.
116. 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.
117. IASS, Technology transfer deficits jeopardize climate targets, experts say (6 September 2022), at https://www.sciencedaily.com/releases/2022/09/220906114237.htm. For example, analysis of current patent data in the energy sector shows that the dominant share of "green" patents are focused on modifying the negative effects of conventional energy sources, such as fossil fuels—to make those sources of energy "cleaner"—rather than on renewables receiving research and development investment, and showing that energy companies foresee having fossil fuels remain part of the energy mix in the future. See David Ellis, 'Green' energy patents more focused on 'clean' conventional energy instead of renewables (Digital Science, 25 January 2023), at https://www.digital-science.com/news/green-energy-patents/.
118. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), p. 111, at https://unctad.org/system/files/official-document/tir2023_en.pdf.
119. Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), pp. 64, 67 and 83, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.pdf. Patent statistics can be found on the OECD website – OECD, Patents on environmental technologies, at https://data.oecd.org/envpolicy/patents-on-environment-technologies.htm and OECD, Patent statistics by technology, at https://stats.oecd.org/Index.aspx?DataSetCode=PATS_IPC#.
120. 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; Antoine Dechezlepretre et al., Invention and Global Diffusion of Technologies for Climate Change Adaptation: A Patent Analysis (2020), p. 7 and p. 27, Table 4.3, at https://openknowledge.worldbank.org/server/api/core/bitstreams/f56c8b8c-1b17-58b3-84ee-a3d9f6138f9e/content.

positively to the strengthening of patent rights among middle-income and large developing countries. In addition, patents do not prevent countries from taking measures (such as compulsory licenses in the public interest[121] or other IPR flexibility measures[122]) to promote climate-related technology transfer (so long as the TRIPS Agreement is complied with).[123] On the other hand, stronger patent rights enforcement can prevent endogenous innovation, by blocking reverse engineering and adaptive copying. They can also be expected to raise considerably the rents earned by international firms as patents become more valuable and oblige developing countries to pay more for the average inward protected technology,[124] and thus not result in technology transfer to developing countries, especially low-income developing countries.[125] There are also studies that show that the picture will likely be mixed, depending on the circumstances in which the technology transfer efforts and the patented technology interact, including factors such as licensing arrangements, investment rules, and partnerships.[126]

As the evidence on whether patents promote or hinder climate-relevant technology transfer continues to be unresolved, it would be useful for developing countries to explore and maximize the strategic use within their domestic policy space of IPR flexibilities available under the TRIPS Agreement to promote and support endogenous learning and follow-on innovation with respect to imported and transferred climate-relevant technologies.[127] Such exploration could be undertaken in light of national circumstances, technological and innovation capacities, and strategic national sustainable development and climate change actions and objectives.

121. For example, the US Clean Air Act (42 USC Sec 7608 (2006)) allows for a compulsory license under certain conditions with respect to devices to reduce air pollution – the patented innovation is necessary to comply with emission requirements, no reasonable alternative is available, and non-use of the patented innovation would lead to a "lessening of competition or a tendency to create a monopoly." A district court can, with the Attorney General's assistance, determine whether a compulsory patent license should be granted and set the reasonable terms. See e.g. Congressional Research Service, Compulsory Licensing of Patented Inventions (14 January 2014), p. 6, at https://crsreports.congress.gov/product/pdf/R/R43266; see also Knowledge Ecology International, Statutory authority for compulsory licenses on patents in the United States, at https://www.keionline.org/cl/statutory-authority-us; K. Ravi Srinivas, Climate Change, Technology Transfer an Intellectual Property Rights (RIS, April 2009), p. 27, at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1440742.
122. For listing of these flexibilities that can be used in regard to patented technologies, see e.g. Martin Khor, Climate Change, Technology and Intellectual Property Rights: Context and Recent Negotiations (South Centre Research Paper No. 45, April 2012), pp. 14-19, at https://www.southcentre.int/wp-content/uploads/2013/05/RP45_Climate-Change-Technology-and-IP_EN.pdf.
123. See e.g. John Barton, Patenting and Access to Clean Energy Technologies in Developing Countries (February 2008), at https://www.wipo.int/wipo_magazine/en/2008/01/article_0003.html#; General Electric, Innovation, Protection and Transfer of Green Technologies (2011), at https://www.wipo.int/edocs/mdocs/mdocs/en/wipo_inn_ge_11/wipo_inn_ge_11_ref_t.pdf ; Antony Taubman and Jayashree Watal, The WTO TRIPS Agreement – A Practical Overview for Climate Change Policymakers (13 December 2010), pp. 17-19, at https://www.wto.org/english/tratop_e/trips_e/ta_docs_e/8_3_overviewclimatechange_e.pdf ; Cristina Tebar Less and Steven McMillan, Achieving the Successful Transfer of Environmentally Sound Technologies: Trade-Related Aspects (OECD Trade and Environment Working Paper No. 2005-02, 25 August 2005), pp. 23-25, at https://www.oecd.org/environment/envtrade/35837552.pdf.
124. See e.g. South Centre, Direct Monetary Costs of Intellectual Property for Developing Countries: A Changing Balance for TRIPS? (South Centre, 2 March 2022), at https://www.southcentre.int/wp-content/uploads/2022/03/SC-Report-DIRECT-MONETARY-COSTS-OF-INTELLECTUAL-PROPERTY-FOR-DEVELOPING-COUNTRIES-FINAL.pdf.
125. See e.g. Wenting Cheng, International Clean Technology Diffusion: Pathways and Prospects (Southviews No. 243, 15 November 2022), pp. 1, 6-7, at https://www.southcentre.int/wp-content/uploads/2022/11/SV243_221115.pdf ; Aidan Hollis, Patent law is hampering climate mitigation. We have a solution (Fix Solutions Lab, 16 August 2022), at https://grist.org/fix/opinion/climate-technology-patent-law-innovators-solution/; UNCTAD, Trade and Development Report 2021 (2021), pp. 113-115, 141 at https://unctad.org/system/files/official-document/tdr2021_en.pdf; UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), pp. 124-125, at https://unctad.org/system/files/official-document/tir2023_en.pdf; South Centre, Accelerating Climate-Relevant Technology Innovation and Transfer to Developing Countries: Using TRIPS Flexibilities under the UNFCCC (August 2009), pp. 1-3, at https://www.southcentre.int/wp-content/uploads/2013/07/AN_ENV8_Using-TRIPs-Flexibilities-under-UNFCCC_EN.pdf; Martin Khor, Climate Change, Technology and Intellectual Property Rights: Context and Recent Negotiations (South Centre Research Paper 45, April 2012), pp. 7-8, at https://www.southcentre.int/wp-content/uploads/2013/05/RP45_Climate-Change-Technology-and-IP_EN.pdf; 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. 24-26, at https://library.fes.de/pdf-files/iez/global/06119.pdf.
126. See e.g. Keith Maskus, Encouraging International Technology Transfer (UNCTAD-ICTSD, May 2004), p. 3, https://www.files.ethz.ch/isn/111411/2010_01_encouraging-international-technology-transfer.pdf; Miria Pigato et al., Technology Transfer and Innovation for Low-Carbon Development (2020), pp. 16, 72-73, 79-81, at https://documents1.worldbank.org/curated/en/138681585111567659/pdf/Technology-Transfer-and-Innovation-for-Low-Carbon-Development.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), pp. 1681, 1687-1688, 1699, at https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter16.pdf; UNEP, Trade in Environmentally Sound Technologies: Implications for Developing Countries (2018), p. 61, at https://wedocs.unep.org/bitstream/handle/20.500.11822/27595/TradeEnvTech.pdf?sequence=1&isAllowed=y; Carolyn Deere Birkbeck, Greening International Trade: Pathways Forward (May 2021), pp. 43-44, at https://www.graduateinstitute.ch/sites/internet/files/2021-05/Greening%20report%20001%200602-CH.pdf.
127. See e.g. Martin Khor, Climate Change, Technology and Intellectual Property Rights: Context and Recent Negotiations (South Centre Research Paper No. 45, April 2012), pp. 14-19, at https://www.southcentre.int/wp-content/uploads/2013/05/RP45_Climate-Change-Technology-and-IP_EN.pdf. In 2012, a group of developing countries in the UNFCCC made a submission that, inter alia, proposed that "consistent with the principles of the Convention and to enable meaningful mitigation and adaptation actions in developing countries, the flexibilities of the international regime of intellectual property as articulated by the Agreement on Trade-Related Aspects of Intellectual Property Rights may be used to the fullest extent by developing country Parties to address adaptation or mitigation of climate change, in order to enable them to create a sound and viable technological base; accordingly, consistent with the Agreement on Trade-Related Aspects of Intellectual Property Rights, each Party retains its right to grant compulsory licenses and the freedom to determine the grounds upon which such licenses are granted; specific and urgent measures shall be taken by developed country Parties to enhance the development and transfer of technologies at different stages of the technology cycle covered by intellectual property rights to developing country Parties; and all Parties shall ensure removal of all obstacles to ensure the transfer of technology to developing countries." See Argentina, Bolivia, Democratic Republic of the Congo, China, Dominica, Ecuador, Egypt, El Salvador, India, Iran, Iraq, Kuwait, Malaysia, Mali, Pakistan, Philippines, Saudi Arabia, Sri Lanka, Sudan, Draft Decision on Shared Vision (UNFCCC, 5 September 2012), para. 7, at https://unfccc.int/files/adaptation/application/pdf/18parties5sep12.pdf, https://unfccc.int/resource/docs/2012/awglca15/eng/crp11.pdf, and https://sdg.iisd.org/news/unfccc-secretariat-releases-submission-from-group-of-parties-on-shared-vision/.

7. Entry Points for Enhanced International Cooperation on Technology Transfer

The technological 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 under the UNFCCC and its Paris Agreement. National action and international cooperation are needed to promote the transfer of technology from developed to developing countries and to encourage the development of endogenous technologies in developing countries.

7.1 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 with structural transformation of the national economy to be the goal. 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.[128]

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.[129]

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 analysing new sectors and identifying and acquiring the skills, infrastructure, and resources needed for the transformation. This will require evaluating the country's te chnological and productive capacities,[130] 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 must be made to institutional frameworks and economic systems.[131]

A key tool in this regard would be the employment and use 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 export goods so 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 goods); phasing out significant climate-damaging sectors (e.g. removing subsidies to entrenched vulnerable sectors such as the fossil

128. UNCTAD, Trade and Development Report 2021 – From Recovery to Resilience: The Development Dimension (2021), at https://unctad.org/system/files/official-document/tdr2021_en.pdf.
129. See e.g. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), pp. xxii-xxiii, at https://unctad.org/system/files/official-document/tir2023_en.pdf ; UNCTAD, Trade and Development Report 2021 – From Recovery to Resilience: The Development Dimension (2021), at https://unctad.org/system/files/official-document/tdr2021_en.pdf.
130. Such an evaluation could make use of international tools such as UNCTAD's Catalogue of Diversification Opportunities 2022. See UNCTAD, Catalogue of Diversification Opportunities 2022, at https://unctad.org/publication/catalogue-diversification-opportunities-2022
131. See e.g. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), p. xix, at https://unctad.org/system/files/official-document/tir2023_en.pdf.

fuel industry); and supporting the development of entirely new low-carbon and climate-adapting sectors of economic activity (e.g. using regulatory, fiscal, and trade measures, including maximizing the use of IPR flexibilities, to support the development of and diversification to new clean energy technologies, transportation systems, or production methods).[132] Using green industrial policy to promote technology transfer could also involve a range of technology-related host country measures, including regulations on the employment of foreign personal and the training of local personnel, performance or local content requirements, mandatory joint ventures or licensing, restrictions on royalty payments, and research and development requirements.[133]

A question that often comes up in this context is whether green industrial policies would be compatible with WTO rules. A survey of literature shows some that argue that such policies may be difficult to justify under or may in fact violate WTO rules,[134] others argue that the constraining effect of WTO rules on green industrial policy may be overstated,[135] while yet others focus on identifying policy tools or measures that would be WTO-consistent.[136] There is also literature now extant exploring the rise of trade conflicts among countries applying industrial policies currently.[137]

7.2 International Cooperation

A broad range of international cooperation arrangements seek to support developing countries' national actions to pursue climate-resilient development. This includes international cooperation consistent with the implementation of technology transfer obligations under the UNFCCC and the Paris Agreement. Recognition of this need is reflected in a range of technology-related initiatives within the UN system and beyond intended to support developing countries, including:

- The UN Technology Facilitation Mechanism established pursuant to the Addis Ababa Action Agenda to support the SDGs.[138]
- The UN Technology Bank for LDCs to support technology transfer to LDCs.[139]
- The CTCN, hosted by UNEP, to support technology matchmaking, technical assistance, international collaboration, and capacity building.[140]

132. See e.g. Aaron Cosbey, Climate policies, economic diversification and trade (3 October 2017), at https://unctad.org/system/files/official-document/ditc-ted-03102017-Trade-Measures-Coseby.pdf. According to UNCTAD, green industrial policy aims not only at shifting the economic structure towards higher-productivity activities, but at aligning productivity-enhancing structural transformation with shifts from high carbon-intensive to low carbon-intensive resource-efficient activities, and particularly at exploiting the synergies between these two processes of structural transformation. See UNCTAD, Trade and Development Report 2021 – From Recovery to Resilience: The Development Dimension (2021), Chapter 4, at https://unctad.org/system/files/official-document/tdr2021ch4_en.pdf. See also T. Altenburg et al. (eds.), Green Industrial Policy: Concept, Policies, Country Experiences (UNEP, DIE, 2017), at (https://www.unido.org/sites/default/files/files/2017-12/green_industrial_policy_book.pdf. Green industrial policy, however, needs to be undertaken carefully and strategically to address concerns and skepticism that have been raised with respect to its usefulness. See e.g. Dani Rodrik, Green industrial policy (Oxford Review of Economic Policy 30:1 469-491, 2014), at https://drodrik.scholar.harvard.edu/files/dani-rodrik/files/green_industrial_policy.pdf and David McKenzie, What is the empirical evidence for the different arguments for and against government support for firms in developing countries? (World Bank Blogs, 10 April 2023), at https://blogs.worldbank.org/impactevaluations/what-empirical-evidence-different-arguments-and-against-government-support-firms.
133. See e.g. UNCTAD, Transfer of Technology (UNCTAD, 2001), at https://unctad.org/system/files/official-document/psiteiitd28.en.pdf.
134. See e.g. Todd Tucker, Recent WTO rulings may complicate green industrial policies (Washington Post, 20 December 2022), at https://www.washingtonpost.com/politics/2022/12/20/recent-wto-rulings-may-complicate-green-industrial-policies/; Mark Wu and James Salzman, The Next Generation of Trade and Environment Conflicts: The Rise of Green Industrial Policy (Northwestern University Law Review 108:402, 2014), at https://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=1022&context=nulr.
135. See e.g. Vinod Aggarwal and Simon Evenett, Do WTO rules preclude industrial policy? Evidence from the global economic crisis (Business and Politics 16:4, pp. 481-509, December 2014), at https://www.cambridge.org/core/journals/business-and-politics/article/abs/do-wto-rules-preclude-industrial-policy-evidence-from-the-global-economic-crisis/F13C5B924728ACD99EA50B6EE921CE51; Ilaria Espa, New Features of Green Industrial Policy and the Limits of WTO Rules: What Options for the Twenty-first Centure? (Journal of World Trade 53:6, pp. 979-1000, 2019), at https://kluwerlawonline.com/journalarticle/Journal+of+World+Trade/53.6/TRAD2019039.
136. See e.g. PAGE, Green Industrial Policy and Trade: A Tool-Box (2017), at https://www.unido.org/sites/default/files/files/2017-12/PAGE_GITA.pdf.
137. See e.g. Jiandong Ju et al., Trade Wars and Industrial Policy Competitions (18 April 2023), at https://www.sas.rochester.edu/eco/assets/pdf/trade-wars-and-industrial-policy-competions.pdf; WEF, Industrial Policy and International Competition: Trade and Investment Perspectives (WEF White Paper, February 2022), at https://www3.weforum.org/docs/WEF_Industrial_Policy_and_International_Competition_2022.pdf; Jiandong Ju et al., Trade Wars and Industrial Policy along the Global Value Chains (November 2020), at https://www.freit.org/ETOS/papers/zhu.pdf; Laura Tyson and John Zysman, Cooperation or conflict? Will industrial policy produce solutions or generate unmanageable conflicts? (Bruegel Blueprint 2033, August 2023), at https://www.bruegel.org/sites/default/files/2023-08/Bruegel%20Blueprint%2033_chapter%205.pdf.
138. See United Nations Department of Economic and Social Affairs, UN Technology Facilitation Mechanism, at https://sdgs.un.org/tfm; UNEP, Technology Facilitation Mechanism, at https://www.unep.org/explore-topics/technology/what-we-do/technology-facilitation-mechanism.
139. UN, UN Technology Bank for Least Developed Countries, at https://www.un.org/technologybank/sites/www.un.org.technologybank/files/untb_intro_brochure.pdf. See also https://www.un.org/technologybank/.
140. CTCN, About the Climate Technology Centre and Network (CTCN), at https://www.ctc-n.org/about-ctcn; CTCN, CTCN: Connecting countries to climate change technology solutions, at https://www.ctc-n.org/file-download/download/public/31067.

- WIPO GREEN, WIPO's online matching platform and database, to facilitate technology exchange in support of global climate efforts connecting providers and seekers of environmentally friendly technologies.[141]
- UNCTAD's Division on Technology and Logistics to help 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.[142]
- UNIDO's Investment and Technology Promotion Office to promote selected sound, productive, and environmentally friendly technologies and know-how of Japanese companies seeking partners overseas.[143]
- The WTO's Working Group on Trade and Transfer of Technology (WGTT) 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,[144] along with reporting requirements on the implementation of Article 66.2 of the WTO TRIPS Agreement, which covers the obligation for developed countries to provide incentives for technology transfer.[145]

There are various entry points for enhancing international cooperation on technology transfer that could be explored in this regard, including:

- Creating a global voluntary patent pool of patented climate-relevant technologies that can be accessed by developing countries or supporting collaboration among developing countries to pool their needs for such patented technologies together and collectively negotiate access to these technologies with the patent holders.[146]
- Creating green technology banks, where identified patent-free green technologies and new technologies developed through new South-South research partnerships can be made available as public goods.[147]
- Establishing a new multilateral fund dedicated to stimulating climate-relevant technology innovation and trade and enhancing technology cooperation between countries.[148]

In the WTO, discussions have mostly focused on exploring the use of flexibilities under the TRIPS Agreement to promote and support climate-relevant technology transfers such as compulsory licensing, "rules of exhaustion," open-sourcing of key green technologies as global public goods, or establishing tiered fee system for IPR royalties waiving payments for patent holders who authorize transfer of climate-friendly technologies to developing countries.

This could be supplemented by having a multilateral understanding or agreement that climate-relevant technological inventions or innovations resulting from

141. See WIPO, WIPO GREEN – The Marketplace for Sustainable Technology, at https://www3.wipo.int/wipogreen/en/. It recently published, for example, the Green Technology Book 2022, a report that looks at the state of play of green technologies, technology trends, and solutions to combat climate change impacts on sectors such as agriculture, forestry, water, and cities. See WIPO, Green Technology Book 2022: Solutions for climate change adaptation (2022), at https://www.wipo.int/en/green-technology-book/.
142. UNCTAD, Science, technology and innovation, at https://unctad.org/topic/science-technology-and-innovation.
143. UNIDO ITPO, Technology Transfer, at http://www.unido.or.jp/en/activities/technology_transfer/.
144. WTO, Working Group on Trade and Transfer of Technology, at https://www.wto.org/english/tratop_e/devel_e/dev_wkgp_trade_transfer_technology_e.htm.
145. See WTO, TRIPS: Issues – Technology transfer, at https://www.wto.org/english/tratop_e/trips_e/techtransfer_e.htm; See WTO, Implementation of Article 66.2 of the TRIPS Agreement – Decision of the Council for TRIPS of 19 February 2003 (20 February 2003), at https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=Q:/IP/C/28.pdf&Open=True.
146. See e.g. Menno van der Veen, The Green Climate Fund as a patent pool for innovations (Nature Biotechnology 30:916-917, October 2012), at https://doi.org/10.1038/nbt.2378; Andrea Nocito, Innovators Beat the Climate Change Heat with Humanitarian Licensing and Patent Pools (Chicago-Kent Journal of Intellectual Property 17:1 164-188, January 2018), at https://scholarship.kentlaw.iit.edu/cgi/viewcontent.cgi?article=1190&context=ckjip; Wei Zhuang, Patent pools for clean energy technologies: a cooperative mechanism for combating climate change (Elgar, March 2023), at https://www.elgaronline.com/display/book/9781785369520/b-9781783476985-XI_53.xml; Ilian Iliev and Karsten Neuhoff, Intellectual Property Cross-licensing, Patent Pools and Cooperative Standards as a Channel for Climate Change Technology Cooperation (September 2009), at https://climatestrategies.org/wp-content/uploads/2014/11/isda-intellectual-property-september-2009-report.pdf; Michael Mattioli and Robert Merges, Measuring the Costs and Benefits of Patent Pools (2017), at https://www.repository.law.indiana.edu/cgi/viewcontent.cgi?article=3643&context=facpub; Garrard Beeney and Renata Hesse, Why patent pools are the right answer for a new era (14 July 2021), at https://accessadvance.com/2021/07/14/why-patent-pools-are-the-right-answer-for-a-new-era/; Michael Renaud et al., The Patent Pool Explained: An Effective Mechanism When the Burden is Shared (IPW, 30 October 2020), at https://ipwatchdog.com/2020/10/30/the-patent-pool-explained-an-effective-mechanism-when-the-burden-is-shared/id=126859/.
147. UNCTAD, South-South Cooperation for Climate Adaptation and Sustainable Development (2022), p. 21, at https://unctad.org/system/files/official-document/tcsgdsinf2022d1_en.pdf.
148. UNCTAD, Technology and Innovation Report 2023: Opening green windows – Technological opportunities for a low-carbon world (2023), pp. xxii-xxvi, at https://unctad.org/system/files/official-document/tir2023_en.pdf ; UNCTAD, Trade and Development Report 2021 (2021), pp. 141, 151, at https://unctad.org/system/files/official-document/tdr2021_en.pdf ; UNCTAD, South-South Cooperation for Climate Adaptation and Sustainable Development (2022), p. 13, at https://unctad.org/system/files/official-document/tcsgdsinf2022d1_en.pdf.

publicly funded research, even where patented by the inventor or innovator, can be made available for public use through appropriate regulations or licensing arrangements to promote the public interest.

Some have also proposed the idea of a climate waiver covering a circumscribed set of climate change-related measures that might be inconsistent with WTO rules. Others have proposed the adoption of a "declaration on TRIPS and climate change" to clarify existing flexibilities and offer new incentives for the transfer of climate-friendly technologies, both for adaptation and mitigation purposes, including temporarily suspending certain IPR to enhance access to and the affordability of environmentally sound climate-relevant technologies.[149]

Another avenue relates to the triennial reporting on the implementation of TRIPS Art. 66.2. It has been suggested here that the TRIPS Council could specify reporting guidelines that would mandate developed countries to report on the extent to which their technology transfer activities under TRIPS Art. 66.2 correspond to the TNAs of recipient developing countries or specifically response to the TAPs of developing countries.

Outside of discussions on IPR, there have been numerous calls for reforming the provisions of the WTO Agreement on Subsidies and Countervailing Measures to make it easier for members to promote climate-relevant technologies and support the accelerated development of, for example, renewable energy technologies.[150]

Beyond the WTO, the transfer of climate-relevant technologies could also be fostered and promoted through the inclusion of technology-transfer provisions in regional trade agreements although, these provisions are usually best endeavour in nature.[151] South-South cooperation in establishing voluntary arrangements for technology transfer among developing countries could be another important entry point for promoting technology transfers,[152] particularly if such cooperation reflected good practices.[153]

Existing multilateral processes such as those in the UNFCCC and the WTO could also be harnessed and the scope of discussion and possible outcomes expanded to support endogenous technology development and technology transfer to developing countries. Such processes have the advantage of already being established, include the participation of developing countries (hence they are nominally representative and inclusive), and can serve potentially as springboards for multilateral norm setting. The focus

149. See e.g. UNCTAD, Trade and Development Report 2021 (2021), pp. 141, at https://unctad.org/system/files/official-document/tdr2021_en.pdf; Martin Khor, Climate Change, Technology and Intellectual Property Rights: Context and Recent Negotiations (South Centre Research Paper 45, April 2012), p. 4, at https://www.southcentre.int/wp-content/uploads/2013/05/RP45_Climate-Change-Technology-and-IP_EN.pdf; James Bacchus, The Case for a WTO Climate Waiver (2017), at https://www.cigionline.org/sites/default/files/documents/NEWEST%20Climate%20Waiver%20-%20Bacchus.pdf; Carolyn Deere Birkbeck, Greening International Trade: Pathways Forward (May 2021), pp. 43-44, at https://www.graduateinstitute.ch/sites/internet/files/2021-05/Greening%20report%20001%200602-CH.pdf.

150. See e.g. Steve Charnovitz, Green Subsidies and the WTO (2014), at https://scholarship.law.gwu.edu/cgi/viewcontent.cgi?article=2341&context=faculty_publications; Douglas Nelson and Laura Puccio, Nihil novi sub sole: the need for rethinking WTO and green subsidies in light of United States: renewable energy (2021), at https://cadmus.eui.eu/handle/1814/70361; Daniel Peat, The Wrong Rules for the Right Energy: The WTO SCM Agreement and Subsidies for Renewable Energy (Environmental Law and Management 24:3, 2012), at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1998240; Mark Wu, Re-examining 'Green Light' Subsidies in the Wake of New Green Industrial Policies (August 2015), at https://e15initiative.org/wp-content/uploads/2015/07/E15_Industrial-Policy_Wu_FINAL.pdf; David Kleimann, Climate versus trade? Reconciling international subsidy rules with industrial decarbonization (Bruegel, 8 February 2023), at https://www.bruegel.org/policy-brief/climate-versus-trade-reconciling-international-subsidy-rules-industrial.

151. See e.g. Christophe Bellmann and Mahesh Sugathan, Promoting and Facilitating Trade in Environmental Goods and Services: Lessons from Regional Trade Agreements (June 2022), p. 25, at https://tessforum.org/latest/promoting-and-facilitating-trade-in-environmental-goods-and-services-lessons-from-regional-trade-agreements.

152. UNCTAD, South-South Cooperation for Climate Adaptation and Sustainable Development (2022), p. 23, at https://unctad.org/system/files/official-document/tcsgdsinf2022d1_en.pdf ; 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. 5, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief9/7a74a2f17f204b6ba17f1ec965da70d7/f4e361cd56d4463a8daa4ab29a1254db.pdf; UNFCCC, Compilation of good practices in effective knowledge-sharing and practical learning on climate adaptation technologies through South-South and triangular cooperation (TEC, October 2017), p. 6, at https://unfccc.int/ttclear/misc_/StaticFiles/gnwoerk_static/brief9/a5fbac8997e84fef84a47d81dba46279/3762bead33cd42e989361241cfbb6fc7.PDF.

153. See e.g. UNOSSC, Good Practices in South-South and Triangular Cooperation Series, at https://unsouthsouth.org/category/good-practices-in-sstc-series/; International Labour Organization, Global and Regional Good Practices in SSTC: Promoting South-South and Triangular Cooperation (ILO, 16 February 2022), at https://www.ilo.org/pardev/south-south/WCMS_837398/lang--en/index.htm; Task Team on South-South Cooperation, Unlocking the Potential of South-South Cooperation (July 2011), at https://www.oecd.org/dac/effectiveness/TT-SSC%20Policy%20Recommendations.pdf; UNCTAD, South-South cooperation for climate adaptation and sustainable development (UNCTAD, 5 September 2022), at https://unctad.org/publication/south-south-cooperation-climate-adaptation-and-sustainable-development; UNOSSC and South Centre, Climate Partnerships for a Sustainable Future: An initial overview of South-South cooperation on climate change in the context of sustainable development and efforts to eradicate poverty (November 2017), at https://www.southcentre.int/wp-content/uploads/2017/12/Report-on-Climate-Partnerships-for-a-Sustainable-Future-Nov-2017_EN.pdf; ISDB and South Centre, Policy Paper on National Strategies for South-South and Triangular Cooperation (April 2021), at https://www.southcentre.int/sc-and-isdb-joint-publication-april-2021/.

should be on developing multilateral solutions and cooperation to enhance a virtuous centripetal effect of multilaterally supported initiatives while counteracting the fracturing of the multilateral system.

There are a number of possible actions that could be taken in this area. For example, the role of the WTO's Committee on Trade and Environment (CTE) as a multilateral forum to discuss trade, environment, and climate interlinkages, could be enhanced by putting more strategically and consistently on its agenda topics for discussion that could help WTO members identify and agree on actions to strengthen cooperation on climate-related technology transfers.[154]

Additionally, the WTO's WGTT—established in 2001 to examine 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 transfers[155]—could pursue the following options. First, the working group could begin 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.[156] For example, the African Group has tabled a proposal calling for the reinvigoration of discussions in the WTO on trade and transfer of technology with a view to developing possible recommendations on various thematic areas.[157] Second, the working group could identify specific green technological gaps in developing countries and the measures that can be deployed 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).[158] A similar revitalization of the WTO's Working Group on Trade, Debt and Finance (WGTDF) could be undertaken to explore how technology transfer of climate-related technologies can be further facilitated through financing.[159]

The WTO General Council could also explore establishing a joint work programme that could be undertaken by the CTE, the Committee on Trade and Development,[160] the WGTT, the WGTDF, and the TRIPS Council to discuss the trade-related aspects of just transitions to sustainability and climate change resilience through the use of measures such as green industrial policy and technology transfer and dissemination to support economic diversification and the adoption of low-carbon pathways. It could engage the expertise of international organizations (such as UNCTAD, International Labour Organization, UNIDO, WIPO, World Bank, UNEP, United Nations Development Programme), taking into account MEA and WTO obligations relating to the provision and mobilization of finance, technical assistance, and technology transfer to support developing countries.

Furthermore, the Trade and Environmental Sustainability Structured Discussions (TESSD) at the WTO[161] could consider setting up an additional working group to discuss ways and means of fostering and

154. The mandate of the CTE can be found here: WTO, The Committee on Trade and Environment, at https://www.wto.org/english/tratop_e/envir_e/wrk_committee_e.htm . See also UNCTAD, Making trade work for climate change mitigation: The case of technical regulations (2022), p. 34, at https://unctad.org/system/files/official-document/ditctab2022d7_en.pdf.
155. WTO, Working Group on Trade and Transfer of Technology, at https://www.wto.org/english/tratop_e/devel_e/dev_wkgp_trade_transfer_technology_e.htm. The meetings of the working group have generally focused on panel events or presentations from individual WTO members or experts from international organizations, but the working group has not been able to substantively discuss any possible recommendations on the steps that might be taken within the mandate of the WTO to increase technology flows to developing countries. See e.g. WTO, Report (2022) of the Working Group on Trade and Transfer of Technology to the General Council (WT/WGTTT/24, 7 December 2022), at https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/WGTTT/24.pdf&Open=True.
156. See e.g. African Group, Policy Space for Industrial Development – A Case for Rebalancing Trade Rules to Promote Industrialization and to Address Emerging Challenges such as Climate Change, Concentration of Production and Digital Industrialization (1 March 2023), at https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/GC/W868.pdf&Open=True.
157. See African Group, The Role of Transfer of Technology in Resilience Building: Reinvigorate the Discussions in the WTO on Trade and Transfer of Technology (3 July 2023), at https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/WGTTT/W34.pdf&Open=True.
158. See e.g. Carolyn Deere Birkbeck, Greening International Trade: Pathways Forward (May 2021), pp. 43-44, at https://www.graduateinstitute.ch/sites/internet/files/2021-05/Greening%20report%20001%200602-CH.pdf.
159. See WTO, Working Group on Trade, Debt and Finance, at https://www.wto.org/english/tratop_e/devel_e/dev_wkgp_trade_debt_finance_e.htm.
160. See WTO, Committee on Trade and Development, at https://www.wto.org/english/tratop_e/devel_e/d3ctte_e.htm.
161. See WTO, at https://www.wto.org/english/thewto_e/minist_e/mc12_e/briefing_notes_e/bfenvir_e.htm.

promoting technology transfer arrangements between developed and developing countries in support of climate action and sustainable development.

Another option would be to explore the possible use of the UNFCCC's newly established Just Transition Work Programme,[162] as well as the Katowice Committee of Experts on the Impacts of the Implementation of Response Measures[163] and the Technology Executive Committee,[164] to discuss (either separately within the context of their respective mandates or jointly) trade-related aspects of technology transfer. These fora could also look into possible additional international cooperation arrangements that can be recommended for adoption by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement to support UNFCCC/Paris Agreement-based technology transfer promoting endogenous technology development in developing countries.

8. Conclusion

History shows that achieving development—i.e. being able to establish and sustain an economy that has adequate infrastructure, energy access, productive capacity, and provides for decent standards of living and livelihood for the population—requires among other aspects a conscious and sustained effort to build up the technological base of the economy. For most developing countries, this challenge has been made more difficult by the multiplicity of global crises impacting their economies, including the imperative of ensuring that development pathways are low-carbon, resilient to climate shocks, and sustainable. Compared to the past, the speed and scale of technological and structural economic transformation within developing countries has to be much faster and higher if the multiplicity of development challenges is to be met.[165]

Efforts must 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-relevant 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 with technology transfer of low-carbon climate-relevant technologies, particularly from developed to developing countries, as 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 technology transfers of climate-relevant technologies from developed to developing countries; creating additional finance for developing countries; and building their capacities to address climate challenges facing their tradeable sectors.[166] This will require, as noted earlier in this paper, active nationally appropriate policy approaches with respect to green industrial policy, for example, given the diversity of national circumstances, development objectives, and the capacities and constraints that

162. See UNFCCC, Decision 1/CMA.4, para. 52, at https://unfccc.int/sites/default/files/resource/cma2022_10a01_adv.pdf.
163. See UNFCCC, Katowice Committee of Experts on the Impacts of the Implementation of Response Measures, at https://unfccc.int/process-and-meetings/bodies/constituted-bodies/KCI#.
164. See UNFCCC, Technology Executive Committee, at https://unfccc.int/ttclear/tec?gclid=EAIaIQobChMI4NCBpISK_wIVGweLCh3a_A04EAAYASAAEgI1n_D_BwE.
165. 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.
166. 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.

developing countries have.[167] 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.[168]

Doing so means ensuring that technology transfer arrangements respond to the climate-relevant technologies prioritized and needed by developing countries, as observed earlier in this paper. Financing technology transfer 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 must be addressed through effective technology transfer that allows for endogenous technology development.

In this context, further policy research and innovation could be explored at the national and international levels to identify good practices for effective and efficient technology transfers. This could include, for example, exploring the interlinkages between national and international investment policy regimes, domestic subsidies for research and development and for production as major factors in the transfer of technologies, and the development of endogenous ones.

Another area for possible research could be the role of bilateral and regional trade agreements and investment agreements with respect to technology transfers and their impacts on domestic policy space. The financing of technology transfers to developing countries is also a key area for policy research and innovation that needs to be explored, especially given that, for example, under Art. 4.5 of the UNFCCC, the technology transfer commitment of developed countries includes the provision of such financing. Various financing approaches could be explored, including licensing, financing at various stages of the value chain, public funding, and other possible innovative approaches.

International cooperation will be needed to enhance domestic capacity so that such technology transfers can lead to the development and innovation of endogenous technologies. This would require, as suggested in this paper, enhancing international cooperation arrangements (within the WTO and elsewhere) to foster effective technology transfer arrangements as well as South-South cooperation to support technological self-reliance by developing countries with respect to climate technologies. Such international cooperation arrangements could include enhancing the work of existing fora 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.

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

Annex. Technology Prioritization

Table A.1. Technologies Prioritized in Technology Needs Assessments

Prioritized Mitigation Technologies in Technology Needs Assessments	Prioritized Adaptation Technologies in Technology Needs Assessments
For mitigation, parties identified more than 950 technology options in their preliminary lists (or long lists) of technologies within their prioritized mitigation sectors or subsectors. Parties prioritized more than 350 technology options. Within the energy sector (the most prioritized mitigation sector), most of the technologies prioritized for the energy industries subsector were related to electricity generation. The most prioritized were solar photovoltaic and hydroelectricity generation technologies. 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 applications (i.e. grid-connected plants). For the transport subsector of the energy sector, 39% of the parties prioritized 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 sectors, 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.	For adaptation, 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 to be 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 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 were 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.

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