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Technology and innovation for cleaner and more productive and competitive production

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Report of the Secretary-General

Summary

The discussion in this report is focused on how countries could take advantage of technologies and innovation for cleaner, more productive and competitive production to catalyse economic growth and structural transformation, while addressing the existential threat of climate change. For the most part, the technology required is available; what is needed is the political will to facilitate its deployment widely for people and planet. National policies are crucial for creating green windows of opportunity, the favourable but time-bound conditions for developing countries to catch up economically that are associated with sustainable transformation. At the same time, firms and Governments need to be ready to respond and take advantage of these opportunities. Countries should combine the acquisition of external technologies with gradual and consistent development of domestic technological capabilities. This requires sector-specific strategies, but many countries have low technical and financial resources for designing and implementing them. Thus, there is also a critical role for international cooperation in promoting technology transfer, helping to strengthen capacities for building sustainability-oriented innovation systems in developing countries, adopting a more partnership-oriented approach to green technology development, shifting research for green innovations from the national to the multilateral level, adopting multilateral approaches to technology assessment and supporting North–South, South–South and triangular cooperation on science, technology and innovation for green innovation.

Introduction*

1. At its twenty-fifth session held in May 2022, the Commission on Science and Technology for Development of the United Nations selected “Technology and innovation for cleaner and more productive and competitive production” as one of its priority themes for the 2022–2023 intersessional period.

2. The secretariat of the Commission convened an intersessional panel meeting on 25 and 26 October 2022 to better understand this theme and assist the Commission in its deliberations at its twenty-sixth session. This report is based on the issues paper prepared by the Commission secretariat, the panel’s findings and recommendations, country case studies contributed by Commission Member States and contributions from United Nations entities.[1]

3. Digital transformation and the adoption of Industry 4.0 technologies such as artificial intelligence and the “Internet of things” are transforming business and productive sectors. When guided by a development compass, technological change can help the global community recover post-coronavirus disease (COVID-19) and bring about the transformations needed, such as reduce poverty, tackle climate change and put the world on a sustainable path, to achieve the Sustainable Development Goals. These technologies also offer a window of opportunity for developing countries to catch up technologically and narrow global divides. Critical areas for innovation in this new technological revolution are renewable energy technologies and frontier technologies for sustainable production and consumption. Innovation in these areas could help diversify economies, create higher-wage jobs and catalyse economic growth and structural transformation, while addressing the existential threat of climate change. National policies are crucial to creating these green opportunities. The technologies required for a sustainable transformation of economies and societies, for the most part, already exist. There should be political will to facilitate their deployment in developing countries. At the same time, firms and Governments must be ready to respond and take advantage of them. But many countries have low technical and financial resources for designing and implementing the required sector-specific strategies. There is therefore a critical role for international cooperation in providing the technical and financial support to developing countries to benefit from these green windows of opportunities.

I. Technology and innovation for more sustainable development pathways

4. Innovation is a key driver of economic growth, and science and technology create the basis for regular innovations. Economic growth has increased the overall welfare of society, but climate change, erosion of fertile soils, depletion of fish stocks and eutrophication and contamination of water bodies erode the livelihood of billions of people worldwide and threaten the well-being of future generations. Thus, a transition towards more sustainable development patterns is imperative, increasing incomes and access to basic needs (e.g., clean water and electricity) while bringing environmental pressures (close) to zero.

* All websites referred to in footnotes were accessed in November 2022.

[1] Contributions from the Governments of Austria, Belarus, Belgium, Brazil, Cameroon, China, Cuba, the Dominican Republic, Egypt, the Gambia, Guinea, India, Japan, Kenya, Latvia, Oman, Peru, the Philippines, the Russian Federation, South Africa, Switzerland, Thailand, Türkiye and the United States of America, as well as from the Economic and Social Commission for Asia and the Pacific, Economic and Social Commission for Western Asia, Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Trade Centre, International Telecommunication Union, United Nations Environment Programme, United Nations Industrial Development Organization, World Tourism Organization and Major Group for Children and Youth are gratefully acknowledged. For all documentation from the intersessional panel meeting, see https://unctad.org/meeting/cstd-2022-2023-inter-sessional-panel.

5. There is a pressing need to promote innovations for cleaner and more efficient production (in this report, called green innovation for short) that stimulate economic growth without depleting the planet's natural resources. These innovations also result in new solutions that may help recover some of the highly stressed or damaged elements of ecosystems, e.g., absorbing CO_2 from the atmosphere or restoring contaminated soils or water bodies. Green innovation is usually associated with renewable energy technologies, but several technologies will be necessary to achieve a sustainable transition. These include more traditional technologies and new digital ones, such as artificial intelligence, the Internet of things and blockchain.

6. In developing countries, innovation requires creative adaptation of technologies along and beyond the paths followed by more technologically advanced economies.[2] Latecomer development may follow new directions, skipping some stages or establishing entirely distinct trajectories that build on existing knowledge.[3] These development paths are conditioned by windows of opportunity emerging from radical technological innovation and changes in market demand or major adjustments to government regulations or policy interventions.[4] In latecomers, technical, market and policy changes may lower barriers to entry and reduce learning times, while the incumbents may be locked into routines and dominant know-how. Still, taking advantage of these opportunities is not automatic but depends on existing productive, technological and innovative capacities and the response of firms and Governments.[5]

7. To tackle climate change, it is crucial to support developing countries in making their production cleaner, more productive and more competitive. New and creative approaches are required for developing countries to benefit from green windows of opportunity. Much success will depend on establishing effective innovation systems at the national level; however, international cooperation and political will to facilitate technology transfer are critical.[6]

8. Green innovation has characteristics that imply a more prominent role for global mechanisms. Its benefits exceed economic value reflected in market prices and include various "externalities" beyond the typical spillover effects associated with innovation. These benefits also involve a high degree of global interdependency. Local actions have relatively more significant benefits to third parties, including those quite far removed from the creation and implementation of an innovation. Moreover, these innovations often need to follow a radical transformation of the current growth pathway.

9. Broader notions of "innovation cooperation" are needed to advance international technology efforts for sustainable development. Such a framing allows for a broader perspective on practical international technology transfer cooperation between countries. It also emphasizes the need for equitable partnerships, rather than donor–recipient relationships, and for the development of local innovation capabilities, leading to more effective marshalling of technologies to help developing countries achieve sustainable development.[7] However, such international cooperation for generating green innovations is highly underdeveloped and does not reflect the urgent need to develop new technological solutions to the world's environmental challenges.

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[2] Perez C and Soete L (1988). Catching up in technology: entry barriers and windows of opportunity. In Dosi G et al. eds. *Technical Change and Economic Theory*. Francis Pinter. London: 458–479.

[3] Altenburg T, Stamm A and Schmitz H (2008). Breakthrough? China's and India's transition from production to innovation. *World Development*, 36 (2):325–344, and Lee K (2019). *The Art of Economic Catch-Up: Barriers, Detours and Leapfrogging in Innovation Systems*. Cambridge University Press.

[4] Perez and Soete, 1988.

[5] Lee K and Malerba F (2017). Catch-up cycles and changes in industrial leadership: Windows of opportunity and responses of firms and countries in the evolution of sectoral systems. *Research Policy*. 46(2):338–351.

[6] United Nations Conference on Trade and Development (UNCTAD), forthcoming, *Technology and Innovation Report 2023*.

[7] Pandey N, de Coninck H and Sagar AD (2022). Beyond technology transfer: Innovation cooperation to advance sustainable development in developing countries. *Wiley Interdisciplinary Reviews: Energy and Environment*. 11(2):e422, John Wiley and Sons.

II. Opportunities for catching up through green technologies and innovation

10. Latecomer catch-up processes in greener industries involve three key components: green windows of opportunities, sectoral systems and catch-up trajectories. [8] The components can be summarized as follows:

(a) Green windows of opportunity are favourable but time-bound conditions for latecomer development arising from policy interventions and changes in markets and technologies associated with green transformation.

(b) Sectoral systems include the preconditions and the strategies undertaken by relevant institutions to turn opportunities into reality. In general, the ability to exploit windows of opportunity in specific industries depends on a firm's existing, accumulated capabilities in the same or closely related sectors and the development of the sectoral innovation systems in which those accumulated capabilities are embedded.

(c) Catch-up trajectories originate from the interactions of green windows of opportunity with the preconditions and responses in sectoral systems. They represent latecomer firms' successful attainment of technological and productive capabilities, shifting the balance of economic power between incumbents and latecomers.

11. Building on the finding of the UNCTAD *Technology and Innovation Report 2021* that developing countries could benefit from adopting frontier technologies while continuing to diversify their production bases by mastering existing technologies, in the following sections, the green windows for developing countries will be examined in relation to three main channels: (a) the production of renewable energy technologies, (b) the application of frontier technologies to greener global value chains and (c) the diversification of economies towards sectors with lower carbon footprints.

A. Development, adoption and production of renewable energy technologies

12. Green windows of opportunities for adopting and producing renewable energy technologies are often created by public action and policies. Although demand and technological changes influence these green windows, they are often promoted by public actions and related adjustments to the institutional framework conditions. For example, in the case of the development of the biofuel industry in Brazil, the institutional window was created by innovation and industrial policies to address market disruption with the oil crisis in 1973. In China, sector-focused "missions", such as the rooftop subsidy programme and the golden-sun demonstration programme were critical for developing the solar sector.[9] In Egypt, the Renewable Energy Law (Decree No. 203/2014) encouraged the private sector to produce electricity from renewable resources through several partnerships. In the Philippines, the Renewable Energy Act of 2008 accelerated the development of renewable energy sources by providing incentives for technology adoption.[10]

13. Creating a market is a crucial element of the institutional windows of opportunity. In this respect, renewable energy sectors differ from many consumer and capital goods sectors. In the consumer and capital goods sectors, government-led demand creation is the exception rather than the rule. Increases in market demand can be domestic or global, which is crucial for developing countries with small domestic markets. However, given the limited tradability of many green energy products, domestic market creation is often more

[8] Lema R, Fu X and Rabellotti R (2020). Green windows of opportunity: Latecomer development in the age of transformation toward sustainability. *Industrial and Corporate Change*. 29(5):1193–1209, Oxford University Press.

[9] Iizuka M (2015). Diverse and uneven pathways towards transition to low carbon development: the case of solar [photovoltaic] PV technology in China. *Innovation and Development*. 5(2):241–261.

[10] See https://unctad.org/system/files/non-official-document/CSTD2022-23_c06_C_Egypt_en.pdf and https://unctad.org/system/files/non-official-document/CSTD2022-23_c16_C_Philippines_en.pdf.

critical. Examples of demand-pull policies are feed-in tariffs aimed at creating competitive parity between green energies and fossil fuels by subsidizing the demand. In India, the Faster Adoption and Manufacturing of Electric Vehicles scheme includes stimulation for the purchase and the deployment of charging infrastructure. In the Philippines, the Philippine Green Public Procurement Road Map aims at increasing demand for green products and services by integrating sustainability criteria into the public procurement process.

14. Policies facilitating trade in green technology products also open learning opportunities through observation and reverse engineering. This does not imply that developing countries will automatically be able to use this technological learning in the short term for import substitution of green technology products or building up of their export sector, which would be two modes of realizing the green window of opportunity. Some green technology items, such as solar photovoltaic modules, are globally traded commodities, and the competition is not based on the simple learning of its key features but rather on a highly efficient industrial value chain. Developing countries without a strong manufacturing sector face barriers to adopting new technologies to expand production for import replacement and exports, even in low-technology green innovation with high relevance for the environment.

15. Institutional windows can also induce technical change in the form of mission-guided public research and development programmes that go beyond levelling the playing field to fixing market failures and involving broader programmes of market co-creation and shaping. Some examples are a demonstration project on deploying solar energy systems in rural health units in the Philippines and the governmental support for research and development, experimental proof and technology demonstration projects on clean energy in India. In the absence of investments in technological change, market investments in green subsidies can result in a market trap where latecomers may become market leaders but remain technology followers. Conversely, if the induced technological change is not matched by (domestic or external) market demand, strong technological capabilities may remain dormant.[11]

16. Responses to green windows of opportunities in renewable energy technologies are influenced by the technological maturity of and tradability within green sectors. Thus, policies should be tailored to the catch-up stage and consider sectoral specificities to exploit green windows. There are typical patterns, such as using environmental and energy policies to create a demand window, and then industrial and innovation policies to exploit it. For instance, a strategy for wind energy may create a demand window, followed by a subsequent law specifying a share of domestic components in wind plants as a response to the window.[12] Conversely, in the case of the shift from combustion engines to electric vehicles, innovation and industrial policies are used to react to and internalize the opportunity by supporting domestic design and manufacturing. Then transportation policy is used for domestic diffusion in exploiting and consolidating the window in preparation for exports.[13]

B. Greening global value chains

17. The rise of global value chains has allowed many developing countries to enter the global market based on their specific advantages and specialization in tasks rather than final goods. But joining global value chains is not sufficient to guarantee sustainable growth. It requires scaling the value added ladder and moving progressively to more sophisticated

[11] Hain DS, Jurowetzki R, Konda P and Oehler L (2020). From catching up to industrial leadership: towards an integrated market-technology perspective. An application of semantic patent-to-patent similarity in the wind and [electric vehicles] EV sector. *Industrial and Corporate Change*. 29(5):1233–1255, Oxford University Press.

[12] Lema R, Berger A and Schmitz H (2013). China's impact on the global wind power industry. *Journal of Current Chinese Affairs*. 42(1):37–69.

[13] Konda P (2022). Domestic deployment in the formative phase of the Chinese electric vehicles sector: evolution of the policy-regimes and windows of opportunity. *Innovation and Development*. 1–24.

tasks. One way is greening global value chains by reducing the ecological footprint of firms, such as the impact on greenhouse gas emissions, biodiversity loss and overexploitation of natural resources.[14]

18. The greening of the global value chains in manufacturing industries has three drivers: (a) new patterns of demand preferences and consumer behaviours, (b) new green strategies by lead firms and global buyers and (c) enforcement of environmental standards and associated patterns of upgrading and downgrading across global supply bases. This greening of global value chains would unfold in sectors that do not belong to what is usually considered greener industries. These include manufacturing sectors crucial to many developing countries, such as traditional manufacturing industries, including food production, garment and textiles, leather and shoes, and furniture.

19. The greening of the global value chain in manufacturing industries unfolds as follows:

(a) First, the green transformation imperative leads to new patterns of consumer behaviour, new demand preferences, changing policy landscapes and increasing civil activism that also change consumption and reduce the environmental impact of production and trade. There are also drivers rooted in the profit motive, such as savings derived from decreased material use, which is cost-effective and lowers environmental pressure by easing the demand for primary resources. Changing demand for less resource-intensive and more environmentally friendly products and services has ramifications as new requirements are transmitted through global value chains.

(b) Second, new designs, standards and specifications typically enforce these requirements in the value chains. They are usually defined and implemented in countries that pioneer environmentally benign products, processes and services.[15] Many new requirements are "private standards" defined and enforced by lead firms. These designs, standards and specifications also internalize several public environmental regulations and semiprivate environmental certifications, such as technical regulations certification (e.g. the Round Table on Responsible Soy),[16] which includes authorities, governmental agencies and public donors. Thus, the introduction of sustainability requirements has implications for the entire value chain, including its governance, i.e. how some firms in the chain set and enforce the parameters under which others operate.[17]

(c) Third, these changes in the governance regime of global value chains create entry barriers and windows of opportunity for suppliers in the global South. They may translate into new constraints for suppliers in meeting these requirements, thereby making entry into global value chains more difficult or forcing an exit from global value chains for existing suppliers, in a sustainability-driven supplier squeeze.[18] At the same time, certain suppliers may be able to develop sustainability capabilities, leveraging them to their advantage, provided that certain preconditions are in place and appropriate strategic actions are taken. The embeddedness of suppliers in well-functioning production and innovation systems is crucial.[19]

20. To seize this technological window of opportunity, latecomer countries should develop and implement appropriate policy strategies to address critical challenges in digital competency, infrastructures and institutions, building innovation capacity and overcoming financial barriers. National strategies and policies to strengthen the adoption of frontier digital technologies in the manufacturing industry should be aligned with interventions and

[14] De Marchi V, Di Maria E, Krishnan A, Ponte S and Barrientos S (2019). Environmental upgrading in global value chains. *Handbook on Global Value Chains*. Edward Elgar Publishing: 310–323.

[15] Beise M and Rennings K (2005). Lead markets and regulation: a framework for analysing the international diffusion of environmental innovations. *Ecological Economics*. 52(1):5–17.

[16] See https://responsiblesoy.org/.

[17] Humphrey J and Schmitz H (2001). Governance in global value chains. *IDS Bulletin*. 32(3).

[18] Ponte S (2020). The hidden costs of environmental upgrading in global value chains. *Review of International Political Economy*. 29(3):818–843.

[19] Pietrobelli C and Rabellotti R (2011). Global value chains meet innovation systems: Are there learning opportunities for developing countries? *World Development*. 39(7):1261–1269.

initiatives in the environmental and energy domains to unlock the sustainability potential of digital technologies. An essential element of any such strategy is the development of the digital infrastructure, which is a precondition for promoting the adoption and adaptation of Industry 4.0 technologies and for their use to make value chains greener.

C. Diversifying towards more sustainable economic sectors

21. Developing countries could seek to master and deploy existing technologies to diversify their economies with the dual objective of structural transformation and lower carbon emissions. An optimum path of diversification of economic activities may exist, consisting of the continuous move to selected activities that are more productive and more environmentally friendly and closely related to the existing productive capacities of a given country.

22. Recent studies have examined the possibility of countries diversifying towards products associated with greener outcomes and higher levels of technology (so-called more complex products). So far, these recent studies have produced mixed results. Some studies have found that countries with a lower economic complexity show low CO_2 emissions; as economic complexity increases, emissions also rise, but eventually, they start to decrease for countries at higher levels of economic complexity.[20] At the same time, other studies have found that increasing economic complexity results in better overall ecological performance, as measured by the total quantity of natural resources consumed by the population and the area of productive land and water needed to support human activities and sequester the waste they generate.[21]

23. The impact on the environment of increasing economic complexity also depends on the level of development of countries.[22] Some studies have found that increasing economic complexity in developing countries has resulted in higher carbon emissions but has limited or undetectable environmental degradation in high-income economies.[23] It also reduces the environmental quality in emerging economies, while mitigating the ecological footprint for countries with higher economic complexity.[24] Other studies have found a positive and significant impact on carbon emissions, particularly on economies with low CO_2 emissions.[25] Still, others have found that increasing the complexity of developed countries results in lower pollution levels.[26]

24. Analysis of these studies points to the need for a strategic diversification approach, where potential new sectors for diversification are identified based on their level of complexity, relatedness with the existing productive structure, existing global demand and the associated impact on carbon emissions. Therefore, green windows of opportunities in diversifying towards greener sectors require significant public institutions and policy

[20] See Chu LK (2021). Economic structure and environmental Kuznets curve hypothesis: New evidence from economic complexity. *Applied Economics Letters*. 28(7):612–616.

[21] See Boleti E, Garas A, Kyriakou A and Lapatinas A (2021). Economic complexity and environmental performance: Evidence from a world sample. *Environmental Modeling and Assessment*. 26(3):251–270.

[22] Neagu O (2021). Economic Complexity: A New Challenge for the Environment. *Earth*. 2(4):1059–1076.

[23] See Adedoyin FF, Agboola PO, Ozturk I, Bekun FV and Agboola MO (2021). Environmental consequences of economic complexities in the [European Union] EU amidst a booming tourism industry: Accounting for the role of Brexit and other crisis events. *Journal of Cleaner Production*. 305:127117.

[24] Ahmad M, Ahmed Z, Majeed A, Huang B (2021). An environmental impact assessment of economic complexity and energy consumption: Does institutional quality make a difference? *Environmental Impact Assessment Review*. 89:106603.

[25] Majeed MT, Mazhar M, Samreen I, Tauqir A (2021). Economic complexities and environmental degradation: Evidence from [Organisation for Economic Co-operation and Development] OECD countries. *Environment, Development and Sustainability*. 2021, 1–21.

[26] Laverde-Rojas H and Correa JC (2021). Economic complexity, economic growth and CO_2 emissions: A panel data analysis. *International Economic Journal*. 35(4):411–433.

interventions for identifying sectors, technologies and markets and for creating the conditions for their domestic firms (private and public) to enter these new sectors.

25. Another result of this analysis is that, as carbon emissions increase in the early stages of economic diversification and increasing complexity, Governments should increase their efforts to promote the use and adoption of renewable energy to minimize the negative impacts. They also need to speed up economic structural transformation towards more complex sectors, to support the establishment and development of knowledge-intensive industries. Then, the improvement in production input mix and environmentally friendly technology will translate into improved and more sustainable economic performance.

III. United Nations actions for sustainable technology and innovation

26. The United Nations system has supported Member States in strengthening their capacities to harness green technology and innovation for sustainable development. This work is carried out through technical cooperation, joint research and knowledge dissemination activities. The following sections highlight a few examples.

A. Providing technical and financial support

27. The United Nations system has several programmes to build new capabilities and skills for national innovation system actors to develop and deploy technologies for more sustainable and productive production. The Technology Facilitation Mechanism created by the 2030 Agenda for Sustainable Development has facilitated collaboration and partnerships on science, technology and innovation for sustainable development through the United Nations inter-agency task team on science, technology and innovation for the Sustainable Development Goals and the multi-stakeholder forum on science, technology and innovation for the Sustainable Development Goals.[27]

28. The United Nations system also supports countries in implementing multilateral environmental agreements and providing required finance. With the agreement of the United Nations Framework Convention on Climate Change in 1992, the Global Environment Facility received a mandate to finance the transfer of environmentally sound technologies and has evolved into the largest public-sector funding source in this area. Since its inception, the Global Environment Facility has allocated more than $22 billion in grants and blended finance and mobilized $120 billion in co-financing for more than 5,000 projects in 170 countries focusing on environmentally sound technologies in developing countries, supplemented by 27,000 community-led initiatives through the Small Grants Programme. [28]

B. Sharing knowledge and information and conducting joint research

29. International cooperation helps to raise awareness in developing countries through sharing lessons learned and best practices, providing foresight about critical trends in science, technology and innovation in key sectors of the economy, the environment and society, and drawing attention to new and emerging technologies. In this regard, the Commission on Science and Technology for Development has examined the impact of renewable energy, Industry 4.0, space technologies and blockchain on the economy, society and environment. The World Summit on the Information Society Forum also had several sessions and workshops for sharing national strategies, policies, laws, programmes and initiatives on clean technologies. The 2023 edition of the Forum will feature a special track on clean technologies at the request of stakeholders. The United Nations Environment Programme and the European Union launched a global platform called the Global Alliance

[27] See https://sdgs.un.org/tfm.

[28] See https://www.thegef.org/who-we-are.

on Circular Economy and Resource Efficiency[29] in 2021, in coordination with the United Nations Industrial Development Organization (UNIDO), to provide a global impetus for initiatives related to the circular economy transition, resource efficiency and sustainable consumption and production.[30] International cooperation could also assist in developing training on specific green practices in the industry. For example, UNIDO, the Center for Green Chemistry and Green Engineering at Yale University and other international partners have launched a global green chemistry project to increase awareness and deploy green chemistry approaches and technologies.[31] The Joint Food and Agriculture Organization of the United Nations /International Atomic Energy Agency Centre of Nuclear Techniques in Food and Agriculture[32] supports Member States in developing more sustainable agricultural production and consumption, including in plant breeding and genetics, animal production and health, insect pest control, soil and water management and food safety and control.

C. Helping to design policies and strategies

30. Governments of developing countries usually encounter difficulties designing and implementing policies, strategies and initiatives concerning technology transfer, building adoptive capacities and developing and deploying new technologies. In this regard, the international community has assisted Governments in facilitating the adoption of cleaner and more competitive production technologies. For example, UNCTAD has a programme on science, technology and innovation policy reviews to assist countries in aligning science, technology and innovation policy with their development strategies. The reviews can also provide information on how Governments can harness new technologies for cleaner and inclusive economic growth.[33] UNIDO assists countries in developing a comprehensive range of national strategies, policies and laws concerning green technology, such as in health and pollution action plans in Colombia, Ghana, Kyrgyzstan, the Philippines and the United Republic of Tanzania. In Bangladesh, UNIDO has been supporting the Department of Environment and power sector stakeholders in developing strategies, guidelines and rules for the identification, management and disposal of the hazardous chemical polychlorinated biphenyls and to reduce plastic pollution, recycle plastics and produce cleaner plastics at the manufacturing level. As part of the economic empowerment of women in green industry programme funded by Germany, UNIDO published a report to help policymakers and practitioners establish and implement a policy framework to integrate gender into green industry policies and capitalize on women's untapped potential as leaders, entrepreneurs and industrial professionals in a more sustainable economy.

D. Helping to set norms and standards

31. Standardization can facilitate technology transfer and deployment. The Telecommunication Standardization Sector of the International Telecommunication Union plays a vital role in standardizing digital transformation that supports technology and innovation for cleaner, more productive and competitive production. The Sector's Study Group 5 on environment, climate change and circular economy has developed and published a series of international standards related to the environmental efficiency of digital technologies, smart energy solutions and circular economy and e-waste.[34] Study Group 5 has regional groups with representatives from the Asia and the Pacific, Africa, Arab and Latin America regions. These platforms enable understanding those regions' unique contexts and priorities and ensure their voices are heard in standard development

[29] See https://ec.europa.eu/environment/international_issues/gacere.html.

[30] The members of the Global Alliance on Circular Economy and Resource Efficiency are Canada, Chile, Colombia, India, Japan, Kenya, Morocco, New Zealand, Nigeria, Norway, Peru, Rwanda, South Africa, Switzerland and the European Union.

[31] See https://www.global-green-chemistry-initiative.com/.

[32] See https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/joint-fao/iaea-centre-of-nuclear-techniques-in-food-and-agriculture.

[33] See https://unctad.org/topic/science-technology-and-innovation/STI4D-Reviews.

[34] See https://www.itu.int/en/ITU-T/studygroups/2017-2020/05/Pages/default.aspx.

process. The Telecommunication Standardization Sector has also established focus groups that identify standardization needs to develop a sustainable approach to deploying new digital technologies. For example, the Sector's focus group on environmental efficiency for artificial intelligence and other emerging technologies develops technical reports and technical specifications to address the environmental efficiency, as well as water and energy consumption of emerging technologies, and provides guidance to stakeholders on how to operate these technologies in a more environmentally efficient manner.

IV. Harnessing green technology and innovation for inclusive and sustainable development

32. Global transformation towards sustainability could open critical green windows of opportunity for latecomer development across countries and sectors. However, such chances are not homogeneous and need to be activated. They are highly differentiated across various sustainability-related industries and technology domains, and countries with different endowments are characterized by different strategies and responses to opportunities.

33. At the same time, many actors are contributing to the uptake of green innovations in developing countries**,** guided by different objectives, from purely business cases to contributing to global public goods and philanthropy. This fragmented support could hinder faster green innovation in developing countries but could also be seen as an asset by bringing their complementary roles in addressing the complexity and the scale of the capacities that need to be developed.[35]

34. However, most actors in the field of green innovations focus on the diffusion of technologies, e.g. the implementation of energy-efficient modes of transport or production or the diffusion of fuel-saving improved cooking stoves. Less attention is being paid, though, to strengthening the capacities of developing countries to develop innovative solutions to sustainability issues and to being able to take advantage of green windows of opportunities actively. Less than 6 per cent of concessional development finance is assigned to promoting research for development. And from this, only a fraction goes to strengthening innovative capacities and national innovation systems. Some bilateral donors, such as Canada and Sweden, are committed to promoting research and innovation systems in partner countries. Others, such as Germany and the United Kingdom of Great Britain and Northern Ireland, support the qualification of researchers from developing countries and exchanges with their European peers.[36]

35. Focusing on the diffusion of green technologies is understandable, considering the time pressure under which the global sustainability transition must happen. However, there are direct correlations between the abilities of societies to adapt and adopt green technologies and the level of development of innovative capacities on the ground. Host country policies and efforts play a critical role in building local technological capabilities and absorptive capacity.

A. National action for opening and augmenting green windows of opportunities

(a) Establish the required policies, legislative frameworks and regulations

36. Government, with the support of other stakeholders, should continue to craft and expand its national policies and strategies, with clear strategic direction and road maps, and regulatory and legal frameworks to further promote green innovation and the use, scaling-up, development and production of green and renewable energy technologies. These policies should guarantee State commitment and the continuity of long-term plans, creating

[35] Pandey, Coninck and Sagar, 2022.

[36] UNCTAD calculations, based on data from the OECD.Stat database of the Organisation for Economic Co-operation and Development.

an enabling environment for adopting green technologies. This could be done by incentivizing domestic firms to adopt and produce more green technologies through financial grants, subsidies and tax relief. A Government could also extend services to support these activities. Stakeholder coordination at the national and subnational levels requires a sustainable mechanism that enables relevant ministries to convene, exchange information, coordinate plans and actions at central and local levels, and network with the private sector and non-governmental partners. This mechanism can be a national council that integrates subnational level representation. The council should also include representatives of non-governmental actors such as non-governmental organizations, universities, research centres and the private sector.

(b) Strengthen technical and innovation capacity and building knowledge

37. The accumulation of local production and innovation capabilities is critical for absorbing, adapting and developing relevant knowledge for cleaner and more productive production. Governments should facilitate this process by building and strengthening their sustainability-oriented innovation systems. Policy tools that Governments can use to strengthen green research and development capacities range from subsidy programmes, such as one implemented by the Swiss Federal Office of Energy, to centres and technology parks for promotion of research and development, such as Niche Centres in the Regions for Research And Development in the Philippines and the Innovation Park Muscat in Oman, or research, development and innovation support programmes promoting green technologies from research and development to commercialization and co-creation based research, development and innovation platforms, such as those being implemented in Türkiye, where university, Government and industry actors collaborate and join efforts and capabilities.[37] Governments can also strengthen technical capacities through programmes such as the Chinese "Thousand Talents Plan," a recruitment programme for attracting global experts to full-time positions in research institutes and universities with attractive salaries and benefits. Skills learning also happens through learning-by-doing, on-the-job training and interactions within the domestic sectoral system. Policies should support firms, particularly small and medium-sized enterprises (SMEs), to have the digital and technical skills needed to adopt and adapt digital technologies for greening production.[38]

(c) Identify, prioritize and foster green technologies and potential new sectors for sustainable diversification and structural transformation

38. Policymakers should be ready and informed to promote green windows of opportunity through public actions. This requires building capacity on technology assessment of green technologies and new analytical methods to identify potential new sectors for more complex and more sustainable diversification. This assessment should consider existing technological and productive capacities, global and domestic demand, the potential for natural resources (e.g. wind conditions or agricultural waste for bioenergy) and dynamic learning curves. Critical in this process is the adoption of participatory methods of assessment involving policymakers, the private sector, academic and research institutions and civil society organizations. National and local governments could foster the domestic development of greener sectors through vertical policy instruments such as clusters, smart specialization initiatives, pilot and demonstration projects and areas, and technology road maps. Some examples are the hydrogen cluster at Green Tech Valley in Austria,[39] the Green Win regional competitiveness cluster of Wallonia in Belgium dedicated to the industrial and environmental transition of several sectors, the innovation and industrial cluster "Electrotransport" in Belarus to develop and manufacture electric vehicles and its components and the Road Map towards a Circular Economy in the Industrial Sector in Peru

[37] See https://unctad.org/system/files/non-official-document/CSTD2022-23_c16_C_Philippines_en.pdf; https://unctad.org/system/files/non-official-document/CSTD2022-23_c07_CW_Oman_en.pdf; https://unctad.org/system/files/non-official-document/CSTD2022-23_c18_C_Switzerland_en.pdf; and https://unctad.org/system/files/non-official-document/CSTD2022-23_c19_C_Turkiye_en.pdf.

[38] UNCTAD (2022). *Industry 4.0 for Inclusive Development*. (United Nations publication, Sales No. E.22.II.D.8, Geneva).

[39] See https://www.greentech.at/en/.

to promote a progressive transition towards a circular economy in manufacturing.[40] In the case of concentrated solar power in China, industry development has been supported by promoting megaprojects to build knowledge and experience within domestic firms.[41] Similarly, to support the development of a domestic green hydrogen industry, the Chilean National Development Agency is also setting up several pilot projects with the significant involvement of international investors.

39. Prioritizing new technologies and sectors requires financial support. For example, in Austria, the Federal Government has allocated €120 million for 2022 and 2023 to support companies to switch to green energy.[42] In Belgium, the Walloon government plans to invest more than 160 million euros to support the development of the green hydrogen sector.[43]

(d) Invest in green innovation and reducing financial constraints

40. Introducing green technologies in new markets usually requires significant and sustained funding. The lack of financial resources for research and development programmes on technologies for cleaner, more productive and competitive production is a persistent problem in developing countries, particularly for smaller companies. Another challenge is that it could be difficult to convince firms and financial intermediaries to invest in this pioneering area that combines green objectives and digital technologies as there is limited business evidence about the return on investments. Several Governments have implemented programmes to tackle these challenges. For example, in the Philippines, the small enterprise technology upgrading programme aims at addressing the technical and financial challenges by providing microenterprises and SMEs seed funds for technology acquisition, technical training and consultancy services, and support for the establishment of product standards, including testing and calibration of equipment. In South Africa, the Economic Reconstruction and Recovery Plan[44] post-COVID includes support for microenterprises and SMEs to implement green innovation, using retrofitting technologies to improve energy performance, and creates an artificial intelligence institute to focus on advanced manufacturing and new materials. In Uganda, the Uganda Green Enterprise Finance Accelerator facilitates the flow of green finance into the Ugandan SME sector by strengthening green SMEs and improving available financial mechanisms for SME debt financing.[45]

(e) Develop a digital infrastructure

41. Digital infrastructure is a precondition for promoting the adoption and adaptation of Industry 4.0 technologies and their use to make value chains greener. Therefore, a critical area to address is the removal of possible infrastructural and related-institutional bottlenecks, such as electricity and connectivity failures and clear data ownership rules. Governments in developing countries should invest in providing the business sector with affordable, high-quality access to the Internet. Key policy aspects include mobilizing public and private investments in ICT infrastructure and developing a regulatory environment facilitating competition in the telecommunications sector. Governments should also address the connectivity gap between small and large firms and urban and rural regions within countries.

[40] See https://unctad.org/system/files/non-official-document/CSTD2022-23_c01_C_Austria_en.pdf; https://unctad.org/system/files/non-official-document/CSTD2022-23_c02_C_Belarus_en.pdf; https://unctad.org/system/files/non-official-document/CSTD2022-23_c03_C_Belgium_en_0.pdf; and https://unctad.org/system/files/non-official-document/CSTD2022-23_c15_C_Peru_es.pdf.

[41] Lilliestam J, Ollier L, Labordena M, Pfenninger S and Thonig R (2021). The near- to mid-term outlook for concentrating solar power: mostly cloudy, chance of sun. *Energy Sources, Part B: Economics, Planning, and Policy*. 16(1):23–4.

[42] See https://www.bmf.gv.at/en/current-issues/Support-to-cushion-consumers-against-high-energy-costs-.html.

[43] See https://unctad.org/system/files/non-official-document/CSTD2022-23_c03_C_Belgium_en_0.pdf.

[44] See https://www.gov.za/sites/default/files/gcis_document/202010/south-african-economic-reconstruction-and-recovery-plan.pdf.

[45] See https://ugefa.eu/.

B. International cooperation for green innovation collaboration

(a) Strengthen the capacity of developing countries to build sustainability-oriented innovation systems

42. International collaboration should shift from supporting single green innovations (e.g. fuel-saving cooking stoves or hydrogen-powered busses) to a determined global action to assist developing countries in strengthening capacity to build sustainable-oriented innovation systems. Such innovation cooperation should be the new paradigm in international technology transfer to cover the whole cycle, from technology development to implementation. The core of that cooperation must be supporting developing countries in developing their strategy for establishing an innovation system that drives inclusive and sustainable economic growth and empowers them to contribute to global climate efforts and tackle additional sustainability challenges. Based on such a strategy and related gap analysis, international actors need to contribute to human resource development (technical and vocational training, higher education), physical research infrastructure and incubators for innovative "green" start-ups, linking mechanisms between research and businesses and financing mechanisms for green innovations. National Governments of host countries must coordinate contributions.

(b) Facilitate technology transfer for sustainability transformation

43. Given the urgent climate and environmental crises, developed and developing countries must increase access to and adopt sustainable technologies. Commitments to technology transfer have been repeated several times, e.g. at the Earth Summits in Rio de Janeiro (1992, 2012) and the Paris Agreement of 2015. Successful technology transfer provides capital goods and related services and enables a recipient country to develop the skills needed to operate, maintain, replicate and innovate the technology. Only if local actors acquire these capabilities can a country adapt a given set of technologies to varying framework conditions and apply it beyond its initial use. Some green innovations have still not reached complete technological maturity and require significant adaptive research to allow a large-scale roll-out envisaged and required to achieve real impact in mitigating climate change and other environmental degradation. Enabling and empowering developing countries to take advantage of green windows of opportunities thus requires comprehensive development strategies to support national innovation systems.

(c) Shift research for green innovations from the national to the multilateral level, including open innovation approaches

44. The global challenge of climate change requires global solutions. However, the current approach to green innovation leaves most developing countries out. Most research and development efforts for green innovations are at the national level, and countries with different socioeconomic development and ecological conditions set diverse priorities in their research and development agendas. Developing countries with the least capacity to deal with the effects of climate change and other environmental crises also have the least resources available for research and development. Shifting research for green innovations from the national to the multilateral level could be an important step forward. The Consultative Group on International Agricultural Research [46] could serve as an important role model. Internationally financed, located mainly in developing countries, intensively embedded in multi-stakeholder networks and with a clear common goods approach, it has proven to contribute to innovative solutions for a climate-smart, innovative and socially inclusive agriculture. The Consultative Group on International Agricultural Research recently established an impact area platform on climate adaptation and mitigation, and it could consider extending research to further cover related green technology and innovation.[47] International organizations and donors could replicate the Consultative Group model in adaptive ways to other sectors, to shift research towards the needs and conditions of developing countries.

[46] See https://www.cgiar.org/.

[47] See https://www.cgiar.org/research/cgiar-portfolio/climate-adaptation-mitigation/.

45. Open innovation is an important element of multilateral research. The research questions and intermediate results could be made available to international experts and epistemic communities, inviting them to contribute to finding the best possible solutions in the shortest time possible. Open-source technologies can also provide a means of effective international collaboration on innovation. Countless open-source designs and technologies are shared by innovators worldwide. Yet, there is no central repository of such technologies, making it difficult for producers in developing countries to locate, access and incorporate them into their innovations. In this regard, the Economic and Social Council of the United Nations recently adopted resolution 2021/30 on open-source technologies for sustainable development.[48] The resolution calls for building and sharing the creation of a centralized repository of open-source technical information as a global stock of knowledge to help developing countries shift towards sustainable development. The success of such a database will depend on solid support from Member States of the United Nations and on collaboration and cooperation among United Nations agencies. UNCTAD has contributed by examining and disseminating proposals for ways to move forward in implementing the resolution.[49]

(d) Adopt multilateral approaches to technology assessment

46. Technology assessment is a well-established interdisciplinary methodology for assessing opportunities and risks of new technologies. To date, it has been applied nearly exclusively in developed countries and emerging economies, e.g. a project for the evaluation of the technological needs to the implementation of the climate action plans in Brazil.[50] Many technologies with important potential may have both positive and negative consequences, depending on how their development is framed and which accompanying measures are taken. Some examples are artificial intelligence and drone technologies in agriculture and gene editing technologies.[51] Currently, no mechanism assesses new technologies based on the challenges different world regions face nor weighs opportunities and risks based on a global discourse. UNCTAD is carrying out pilot projects involving three African countries to build capacity for technology assessment in Africa. Based on the outcomes of this project, a discussion could be started on how to assess new technologies on the multilateral level, bundling international expert knowledge to answer questions that, due to their complexity, cannot be dealt with at the level of nation States.

(e) Support South–South science, technology and innovation cooperation for green innovation

47. South–South cooperation in science, technology and innovation STI is still incipient, resulting in a loss of opportunities to tackle climate and other environmental challenges, which are often similar across countries in a certain region (e.g. sea level rising in the Caribbean and changing precipitation patterns in large parts of sub-Saharan Africa). In addition, regional approaches to green innovation may improve the possibility of using green windows of opportunity. Relatively small and poor countries may not provide a sufficiently attractive home market for foreign direct investment in green technologies and for them to build up their manufacturing of related items. International cooperation should give solid incentives to overcome cooperation barriers, e.g. by supporting regional centres of excellence for green technologies and innovation. The Southern African Science Service Centre for Climate Change and Adaptive Land Management and the West African Science Service Centre on Climate Change and Adapted Land Use are examples.

(f) Provide official development assistance to support science, technology and innovation for green innovations

48. Official development assistance focusing on areas and activities related to science, technology and innovation STI can also contribute to the capacities of developing countries to handle technologies and generate innovations. Estimates vary regarding official

[48] See E/RES/2021/30.

[49] See https://unctad.org/system/files/official-document/presspb2021d8_en.pdf.

[50] See https://unctad.org/system/files/non-official-document/CSTD2022-23_c01_CW_Brazil_en.pdf.

[51] For example, clustered regularly interspaced short palindromic repeats and CRISPR-associated protein 9 (known as CRISP CAS9).

development assistance directed to science, technology and innovation, but they show a low level. Official development assistance specifically targeting the development of science, technology and innovation capacities in developing countries more than doubled between 2014 and 2019, but starting from a relatively low level ($0.9 billion in 2014, $2.4 billion in 2019).[52] This implies that only a small percentage of international aid flows target science, technology and innovation capacities. In addition, official development assistance for science, technology and innovation capacity development in the least developed countries, landlocked developing countries, small island developing States, and Africa has not grown over the past decade and remained low.[53] The amount of official development assistance directed to science, technology and innovation should increase to meet developing countries' need for more advanced capacities in technology development to enable the transition to renewable energy sources and long-term, low-emission development.

V. Suggestions for consideration by Member States and the Commission on Science and Technology for Development at its twenty-sixth session

49. The North–South divide in innovation performance is pronounced. This implies that many developing countries will need strong support from developed countries in identifying and implementing innovations to tackle global challenges. This happens at a time when the impacts of climate change are also hitting many developing countries, which would need scaling up of research to understand the impact chains related to global warming and science and technology to develop mitigation options and take advantage of green windows of opportunities.

50. Thus, there is an urgent need to embed science, technology and innovation into concepts of just and fair globalization, implying that the needs of developing countries receive adequate attention in international agenda and priority setting and they can share fully the knowledge and benefits of innovation science technology and innovation. This is more urgent than ever in times of worsening climate change and its impacts on the developing world, e.g. exposure to natural disasters and deteriorated food security. Another element of fair globalization has to be that developing countries are granted the policy space required to take advantage of opening green windows of opportunities as a basis for sustainable development.

51. Member States may wish to consider the following suggestions:

(a) Develop and expand national policies and strategies, with clear strategic direction and road maps, and regulatory and legal frameworks, to further promote green innovation and the use, scaling up, development and production of green and renewable energy technologies;

(b) Establish a national mechanism for the coordination of sustainable development strategies and the deployment of green technologies;

(c) Raise awareness and promote technical education and skills development to increase domestic firms' capacity for applying green technologies;

(d) Identify, prioritize and foster green technologies and potential new sectors for sustainable diversification and structural transformation;

(e) Invest and promote private sector investment in research and development on the application of technologies for cleaner production;

(f) Support effective green technology transfer ecosystems that meet the needs of the private sector and in particular promote green technology diffusion in SMEs;

[52] United Nations, Inter-agency Task Force on Financing for Development (2019). *Financing for Sustainable Development Report 2019* (United Nations publication, Sales No. E.19.I.7, New York).

[53] Ibid.

(g) Strengthen innovation networks and linkages to increase partnerships and cooperation to enable green technologies' production and broader diffusion;

(h) Ensure that infrastructure and incentives exist for the consumer demand shift towards products with lower environmental impact, including through prioritizing cleaner and more productive technologies and solutions in public procurement;

(i) Support the engagement of organized civil society in promoting the diffusion and adoption of green technologies;

(j) Intensify efforts in establishing and improving bilateral and multilateral partnerships and North–South and South–South cooperation to facilitate the transfer of technologies for cleaner and more productive production.

52. The international community may wish to consider the following suggestions:

(a) Facilitate the exchange of knowledge, experience, success stories, research and best practices on green innovation with leading innovators, policymakers and regulators in developed and developing countries;

(b) Establish policy research platforms and provide technical and policy advice on greener technology and innovation to policymakers;

(c) Create a cross-border system of open green innovation facilitating efficient communication and collaboration, between authorities, corporations, researchers, academia and individuals, and providing avenues and incentives to those who collaborate;

(d) Establish, expand and strengthen international research and development and innovation support programmes on greener technologies and clean production;

(e) Establish international innovation hubs, maker spaces and centres focusing on innovation towards cleaner and more productive production;

(f) Promote South–South, North–South and triangular cooperation for knowledge and technology transfer on greener technologies;

(g) Support developing countries in their capacities to implement technology assessment towards cleaner and more productive production, including on how to assess new technologies on the multilateral level;

(h) Increase the amount of official development assistance directed to science, technology and innovation STI and to build advanced capacities in technology development to enable the transition to renewable energy sources and long-term, low-emission development;

53. The Commission is encouraged to take the following steps:

(a) Collect and share success stories and business cases demonstrating the impact of new technologies on inclusive and sustainable development;

(b) Facilitate international partnerships for mobilizing resources and providing technical assistance on effective policy mix for incentivizing the adoption of technologies for cleaner and more productive production in developing countries;

(c) Support the participation of actors of the innovation system of the member countries in international networks and programmes to build their capacity in innovation for cleaner and more productive production.