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Issues Paper

on

Technology and innovation for cleaner and more productive and competitive production

Unedited Draft

Prepared by the UNCTAD Secretariat[1]

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I. Introduction

We live in a time of rapid technological change, at the height of the push for digital transformation and the early stages of the Industry 4.0 revolution. These technological waves have great potential to help the global community to recover post-COVID-19 and bring about the transformations needed to achieve the SDGs, reduce poverty, tackle climate change, and put the world on a sustainable path. They 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 and create higher-wage jobs while protecting the planet.

To contribute to a better understanding of this theme and to assist the Commission in its deliberations at its twenty-sixth session, the Commission secretariat has prepared this issues paper based on relevant literature and country case studies contributed by Commission members.

This issues paper focuses on national strategies and policies related to green technology and green innovation for cleaner, more productive, and competitive production, and the role of international cooperation, including triangular and South-South cooperation, in supporting developing countries to benefit from windows of opportunity for developing, using, adopting and adapting these frontier technologies in production processes for catching up economically and technologically.

There are sound environmental, social, and economic reasons to support green technologies' development, diffusion, and implementation. Not only can they help to address current environmental problems, but there are valuable economic benefits in the form of job creation and alleviation of poverty and socio-economic inequality associated with their implementation. It is mainly in response to global ecological and socio-economic pressures that countries worldwide have begun to focus on sustainable development agendas and green economic growth, in which green technologies play a central role.

Questions addressed in this paper include: What should countries do to take advantage of this window of opportunity? How could the international community support developing countries in this regard?

The paper is structured as follows. The next three sections set the stage by discussing greener growth paths and innovation's role (Section II), examining the concept and main characteristics of green technology and innovation (Section III) and trends affecting green innovation (Section IV). Section V looks at green windows of opportunities for countries to catch up, focusing on three areas: the production of renewable energy technologies, the greening of global value chains through the adoption of Industry 4.0 technologies, and the diversification of economies towards greener sectors. Section VI discusses the facilitation of technology transfer of green technologies through ODA, trade and FDI, while Section VII presents the initiatives of the United Nations System in this regard. Section VIII examines ways for harnessing green technology and innovation for inclusive and sustainable development. And Section IX presents a brief conclusion and recommendations for the consideration of Governments and the international community. The Issues paper also includes two Annexes: Annex A highlights relevant technical cooperation programmes of the United Nations System, and Annex B lists suggested questions for discussion to facilitate the dialogue on green technology at the Intersessional Panel of the Commission in October 2022.

II. Technology and innovation for more sustainable development pathways

Innovation is a key driver of economic growth in a world economy based on competition and market forces, and science and technology create the basis for regular innovations. Economic growth often increases the overall welfare of society, but it may come at extremely and increasingly high costs. Climate change, erosion of fertile soils, depletion of fish stocks and eutrophication and contamination of water bodies erode the livelihood of billions of people, most of them living in developing countries. Thus, a transition towards more sustainable development patterns is imperative. Such a path may be seen as increasing incomes and growing needs satisfaction (access to clean water and energy, SDG6 and 7), especially for the poorer strata of societies, while bringing additional environmental pressures (close) to zero.

Innovations will remain key drivers of progress in a more sustainable and more inclusive economy. However, the questions of "which kind of innovations" and "innovations for whom" will play an important role. Innovations for cleaner production decouple economic growth from the depletion of natural resources and sink capacities of the planet. Decoupling occurs when the growth rate of an environmental pressure is less than that of economic growth over a given period. Decoupling can be either absolute or relative. Absolute decoupling occurs when the environmentally relevant variable is stable or decreasing while the driving economic force is growing. Relative decoupling occurs when the growth rate of the ecologically relevant variable is positive but less than the growth rate of the economic variable.[2] The concept of green innovation should also embrace new solutions that may help recover some of the highly stressed or damaged elements of eco-systems, e.g., absorbing CO2 from the atmosphere or bioremediation to restore contaminated soils or water bodies.

Green technology is associated with significant environmental challenges such as climate change mitigation and adaptation, biodiversity conservation, outdoor and indoor pollution, clean water access, and liquid and solid waste. Alongside green technologies to tackle these issues, several technologies are not strictly "green" but will be necessary to achieve the green transition. These include digital technologies such as artificial intelligence, the internet of things and blockchain.[3] As such, the use of different technologies can help tackling world challenges. For example, the use of smart meters systems implemented in Oman in 2020 has been helping the country significantly reduce water waste,[4] while the Philippines employs AI, machine learning, and satellites to deal with issues related to water and sanitation.[5]

The time dimension should be in the picture when focusing on green innovations. For instance, the basic principles of the steam engine were already known in France and England around 1700. However, it took more than 120 years until the first steam-driven locomotives and steamships started to impact the traffic systems, and some additional decades until steam engines became a driver of the industrial revolution in Europe and North America. Such long lead times cannot be accepted for most green innovations, as the time pressure to find solutions to the threats of humanity transgressing several planetary boundaries is high.

Worrying is the global divide on the capacities in science, technology, and innovation (STI). Without addressing it adequately, achieving many Sustainable Development Goals (SDGs) might be impossible.

In latecomer countries, catching up economically and technologically requires creative adaptation and innovation along and beyond the paths followed by the first movers. Catch-up pathways are multiple

[2] OECD, 2001.
[3] OECD, 2019, and (n/d)
[4] Contributions from the Government of Oman.
[5] Contributions from the Government of the Philippines.

and differ substantially from those taken by advanced economies.[6] Latecomer development may follow new directions, skipping some stages or establishing entirely distinct trajectories building on existing knowledge.[7]

These development paths are prompted by windows of opportunity emerging from changes to the prevailing techno-economic paradigm, as a result of the radical modification in technological innovation and market demand or as major adjustments to government regulations or policy interventions.[8] In latecomers, technological, 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. Based on broad evidence from diverse sectors ranging from steel to cameras, aircraft, and wine, opening the different technological, market, and institutional opportunity windows has been decisive for industry leadership changes. Still, structural changes are not automatic but depend on firms' responses and supporting institutions in advanced and latecomer countries.[9]

Whether or not developing countries can benefit from this shift towards more sustainable production and consumption patterns and new “Green Windows of Opportunity” (GWO) remains an open question. On the one hand, incumbent production systems are being disrupted, which may provide space for new market entrants. These changes and relatively cheaper labour costs may open GWOs to developing countries. In addition, not only exporting to large markets but also substituting imports with locally produced goods can be seen as a GWO, as locally produced goods often have a lower environmental footprint than items imported. On the other hand, many big companies in the large markets have recognized the “green” signs of the time and adapted their processes and included core concepts like “climate neutrality” of “zero waste” in their management and public relations.

It is crucial to support developing countries in making their production cleaner, more productive and competitive to tackle climate change. New and creative approaches are required for developing countries to benefit from GWO. Much of the success will depend on establishing effective innovation systems at the national level; however, these will benefit from complementary efforts at the international level.

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 the innovation. Moreover, these innovations often need to follow a radical transformation of the current growth pathway. These differences make a good case for an enhanced global architecture that facilitates sustainable global growth.[10]

This will require novel business models, new approaches to financing, and policy innovations within national and global institutions.[11] As developing countries' technological needs and capabilities change and international political and economic landscapes shift, innovation cooperation will also follow an evolutionary path.[12]

[6] Perez and Soete, 1988.
[7] Altenburg et al., 2008; (Lee, 2019).
[8] Perez and Soete (1988).
[9] Malerba and Nelson, 2011, Lee and Malerba, 2017.
[10] (Shapiro, 2012).
[11] (Shapiro, 2012) and (These tactics and technologies could speed the net-zero transition, 2022) WEO 2022.
[12] (Pandey et al., 2022).

Broader notions of "innovation cooperation" are needed beyond the elusive "technology transfer" to advance international technology efforts for sustainable development. Such a framing allows for a broader perspective on effective 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.[13]

However, all available evidence demonstrates that 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.

III. Green technology: concepts and main characteristics

There is not a commonly accepted or internationally agreed definition of green technology. The term can be broadly defined as technology that has the potential to significantly improve environmental performance relative to other technologies. It is related to the term "environmentally sound technology", which was adopted under Chapter 34 of Agenda 21.[14] In general, green technologies are considered those that "protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual waste in a more acceptable manner than the technologies for which they were substitutes."[15]

When more narrowing focusing on production process, in concrete terms, technologies for cleaner production may take two forms: 1) energy technologies that are greener and used to power the production; and 2) technologies for process improvement, e.g., reduction of energy or materials used per unit of output which can be achieved with the introduction of new technology.

Several definitions are related to greener energy technologies, such as green energy, renewables, sustainable energy, and clean energy (see Box 1). They are generally associated with solar, wind, biomass/biogas, and green hydrogen technologies (see Table 1 for definitions of these technologies).

Box 1. Definitions of technologies associated with greener energy technologies

Green energy, power: The greatest environmental benefit

Not all sources used by the renewable energy industry are green. For example, power generation that burns organic material from sustainable forests may be renewable, but it is not necessarily considered green due to the CO_2 produced by the burning process itself. Large hydro projects are also typically not regarded as green. Green power/energy is a subset of renewable energy and represents those renewable energy resources and technologies that provide the highest environmental benefit. The United States Environmental Protection Agency defines green power as electricity produced from solar, wind, geothermal, biogas, eligible biomass, and low-impact small hydroelectric sources. Customers often buy green power for its zero-emissions profile and carbon footprint reduction benefits (EPA, 2022).

Renewable energy: An unlimited source of power

Renewable energy is energy collected from resources naturally replenished on a human timescale. It includes sunlight, wind, rain, tides, waves, and geothermal heat (Ellabban et al., 2014).

[13] (Pandey et al., 2022).
[14] (The United Nations Program of Action from Rio, 1992).
[15] (ESCAP, n/d).

"Renewable energy is energy that is derived from natural processes (e.g., sunlight and wind) that are replenished at a higher rate than they are consumed. Solar, wind, geothermal, hydro, and biomass are common sources of renewable energy" (ECE, 2016).

Renewable energy includes resources that rely on fuel sources that restore themselves over short periods and do not diminish. Such fuel sources include the sun, wind, moving water, organic plant, and waste material (eligible biomass), and the earth's heat (geothermal). Although the impacts are small, some renewable energy technologies can have an impact on the environment. For example, large hydroelectric resources can have environmental trade-offs on such issues as fisheries and land use (EPA, 2022).

Renewable energy comes from sources that naturally renew themselves at a rate that allows us to meet our energy needs. It Includes biomass, geothermal, hydropower, solar and wind. Not all renewable energy is also sustainable but improving the sustainability of renewables and fossil fuels can have environmental benefits (Johns Hopkins, 2021).

Sustainable energy: Replenish faster than depleted

Energy is sustainable if it meets the needs of the present without compromising the ability of future generations to meet their own needs (Kutscher et al., 2018).

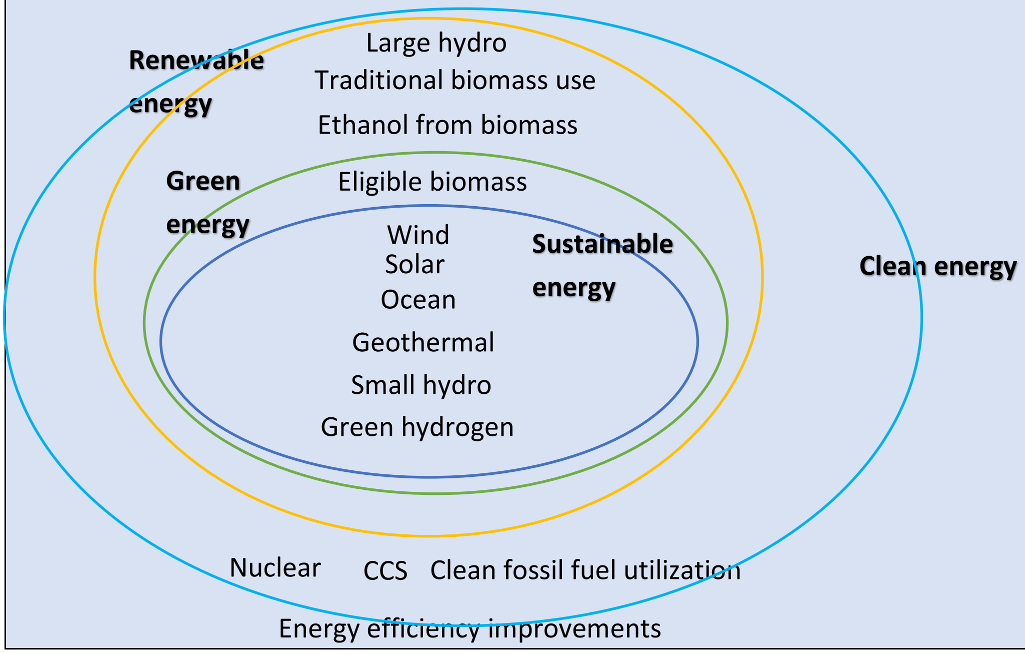
Sustainable energy comes from sources that can fulfil our current energy needs without compromising future generations. It also involves collection and distribution; the energy must be efficiently acquired and distributed to be sustainable. It includes geothermal, hydropower, solar and wind (Johns Hopkins, 2021).

Clean energy: Zero emissions, but not always renewable

Clean energy is defined as energy derived from renewable, zero-emissions sources ("renewables"), as well as energy saved through energy efficiency ("EE") measures.

Renewable energy is derived from sources that can naturally replenish themselves — wind and sun are the two most obvious examples — while clean energy encompasses all zero-carbon energy sources. The clean energy or zero-carbon energy tent is wider; it not only leaves the door open to 100 per cent renewables, but it also includes nuclear energy and the carbon-neutralizing impact of technologies like carbon capture and sequestration (CCS) (Beck and Gordon, 2019).

Figure. The differences between the green-related energy concepts



Source: UNCTAD.

Table 1. Definitions of selected green technologies

Technology	Description
Solar photovoltaic (Solar PV)	Solar photovoltaic (Solar PV) technology transforms sunlight into direct current electricity using semiconductors within PV cells. In addition to being a renewable energy technology, solar PV can be used in off-grid energy systems, potentially reducing electricity costs and increasing access.
Concentrated solar power	Concentrated Solar Power (CSP) plants use mirrors to concentrate the sun's rays and produce heat for electricity generation via a conventional thermodynamic cycle. Unlike solar PV, CSP uses only the direct component of sunlight and can provide carbon-free heat and power only in regions with high direct normal irradiance (DNI).
Biofuels	Biofuels are liquid fuels derived from biomass and are used as an alternative to fossil fuel-based liquid transportation fuels such as gasoline, diesel, and aviation fuels. In 2020, biofuels accounted for 3 per cent of transport fuel demand.
Biogas and biomass	Biogas is a mixture of methane, CO_2 and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment. In comparison, biomass is renewable organic material from trees, plants, and agricultural and urban waste. It can be used for heating, electricity generation, and transport fuels.
Wind Energy	Wind energy is used to produce electricity using the kinetic energy created by air in motion. This is transformed into electrical energy using wind turbines. Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote and offshore.
Green Hydrogen	Green hydrogen is hydrogen generated entirely by renewable energy or from low-carbon power. The most established technology for producing green hydrogen is water electrolysis fuelled by renewable electricity. Compared to electricity, green hydrogen can be stored more easily. The idea is to use excess renewable capacity from solar and wind to power electrolysers which would utilize this energy to create hydrogen, which can be stored as fuel in tanks.

Source: UNCTAD

Concerning process technologies, this paper focuses on the application of Industry 4.0 technologies in manufacturing that may result in energy efficiency and sustainability. The digitisation of manufacturing processes can offer energy-saving opportunities through optimising or replacing higher-energy demand technologies, introducing energy optimisation functionalities and adaptations in the business processes.

IV. Trends affecting green technology and innovation

A. North-South divide in STI is widening

The gap between the developed and developing countries is evident in all indicators referring to the input side of national innovation systems (NIS). Many countries of the EU strive to reach 3 per cent of

R&D expending as a percentage of GDP or achieve this value (e.g., Germany and Denmark), while the top global performers invest 5 per cent of GDP in R&D (e.g., Israel and the Republic of Korea). Few developing countries approach or surpass the 1 per cent level (e.g., Brazil., Egypt, Türkiye). In contrast, many ranges between 0.5 per cent and 1 per cent (e.g., South Africa and Viet Nam), and others stay below, among them even some OECD countries, e.g., Mexico (0.3 per cent) and Colombia (0.3 per cent). In many developing countries, the value is not adequately measurable.[16] The picture is quite bleak for the developing world. From 2013 to 2017, the average R&D expenditure as a percentage of GDP in Lower Middle-Income Countries barely rose from 0.44 per cent to 0.53 per cent, while in the world the figures were 1.99 per cent in 2013, 2.14 per cent in 2017 and 2.63 per cent in 2020 (Table 2).

Table 2. R&D expenditure, selected countries, and regions (percentage of GDP)

	2013	**2017-2020**
World	1.99	2.63 (2020)
Lower Middle-Income Countries	0.44	0.53 (2017)
High Income Countries	2.4	2.97 (2020)
European Union	2.1	2.32 (2020)
United States	2.71	3.45 (2020)
China	2.0	2.4 (2020)
Japan	3.28	3.26 (2020)
Brazil	1.2	1.2 (2019)
Egypt	0.64	0.96 (2020)
South Africa	0.66	0.62 (2019)
Thailand	0.44	1.14 (2018)

Source: UNCTAD based on World Development Indicators (accessed in June 2022).

Another concern is that relatively advanced developing countries, which have long struggled to keep up with industrialized countries in science, technology, and innovation, have not managed to scale up their innovation-related spending. In Brazil, the R&D expenditure as a percentage of GDP has largely remained the same between 2013 and 2019; in South Africa, it decreased. Two exceptions are Thailand, where the figure went from 0.44 per cent in 2013 to 1.14 per cent in 2018, and Egypt, which increased from 0.64 per cent in 2013 to 0.96 per cent in 2020. Similarly, there is a widening gap concerning the percentage of researchers per million inhabitants of a country, which is a second important indicator on the input-side of the national innovation system (Table 3).

Table 3. Researchers in research per million inhabitants

	2010	**2018-2020**
World	1.282	1.597 (2018)
Middle Income Countries	651	814 (2018)
High Income Countries	3.776	4.670 (2019)
European Union	3.092	4.257 (2020)
United States	3.883	4.822 (2019)
China	885	1.585 (2020)
Japan	5.104	5.455 (2020)
Egypt	492	838 (2020)
South Africa	365	484 (2019)
Thailand	539 (2011)	1.790 (2019)

[16] Data from the UNESCO Institute for Statistics (UIS) available at http://data.uis.unesco.org/.

Source: UNCTAD based on World Development Indicators (accessed in June 2022).

The North-South gap is also evident on the output side of national innovation systems, as illustrated by the number of scientific and technical papers annually published in journals. Table 4 shows the relevant data. The table separates China from the statistical group of middle-income countries, as 48 per cent of the total number of publications from the group are from China.

Table 4. Scientific and technical journal articles

Country Group	Absolute number of publications	Publications per 1 million people
Low-Income Countries	5,308	8
Middle-Income Countries (MIC)	1,106,517	192
MIC w/o China	580,254	133
China	528,263	377
High-Income Countries	1,450,446	1,177

Source: UNCTAD based on World Development Indicators (accessed in April 2021).

There is evidence that even in fields highly relevant to the Global South and global challenges, most science is carried out, and its agenda is defined, in the North. For example, an analysis of the institutional affiliation of many scientific publications explicitly dealing with climate change issues found that during the period 2000–2014, more than 85 per cent of the author affiliations of relevant scientific papers published (a total of 93,584 publications) were from OECD countries, while less than 10 per cent were from any Southern country income category (only 1.1 per cent in the case of low-income economies).[17] The North-South divide in environmental research could deprive the scientific community of considerable intellectual capital, influences research priorities and constrain research paradigms into a few cultural settings and perspectives. Similarly, only 10 per cent of funding for health research is spent in the South, where 90 per cent of the world's disease burden resides.[18]

The numbers and percentages of green innovations (expressed in the number of granted patents of green technologies) [19] are increasing over time (from a small basis), but this rise is mainly driven by developed countries and China. There is a high concentration of green patents in traditional industrial (United States, Japan, Europe) and newly industrialized (Republic of Korea and China, Taiwan Province of) economies (Table 5). China is clearly the newcomer in the sphere, with a very fast take-off in green patenting since around the turn of the century.

Table 5. Top green patenting economies - cumulative number of patents, 1975-2017, World

All patent offices			USPTO		
Country	Patents	Percentage of total patents	Country	Patents	Percentage of total patents
Japan	155,501	18.6	United States	133,219	42.7
China	148,032	17.7	Japan	72,837	23.3

[17] Blicharska et al., 2017.

[18] Blicharska et al. 2017: 22.

[19] For a significant period (1975-2017) patents were extracted from a database of the Cooperative Patent Classification (CPC). Green technologies were conceptualized as comprising technologies 1) in climate change mitigation and adaptation and 2) in systems that integrate technologies related to power network operation and ICTs in this area.

United States	143,145	17.1	Germany	21,464	6.9
Republic of Korea	112,699	13.5	Republic of Korea	19,490	6.3
Germany	94,927	11.4	China, Taiwan Province of	9,441	3.1
France	27,764	3.3	France	7,222	2.3
China, Taiwan Province of	22,389	2.7	China	6,238	2.0
Russia	21,915	2.6	Canada	6,191	2.0
United Kingdom	12,813	1.5	United Kingdom	5,249	1.7
Canada	9,477	1.1	Sweden	3,135	1.0

Source: Corrocher and Morrison, 2020

China leads the group of emerging countries (Table 6). From 1975 to 2017, more than 6,200 patents were granted to inventors from China in the USPTO.[20] Two per cent of all patents granted by USPTO in the analysed time have gone to inventors in China. This is remarkable considering that the country started its technological catching-up only around 2000, and a large percentage of the accumulated patents have been granted since then (and not in the 25 years before). All the other emerging economies have very modest shares in the overall green patent numbers, and the gap to the industrialized world does not seem to be narrowing.

In the majority of Lower Middle-Income Countries and Low-Income Countries, patenting activities are hardly measurable. In fact, a study on clean energy patents in Africa over the period between 1980 and 2009 shows that only 1 per cent of all international patents in clean energy were filed in Africa, and 85 per cent of these came from South Africa, pointing to the minor role that developing countries play in green technology development.[21]

Table 6. Top green patenting emerging countries (number of patents and per cent of total)

All patent offices			**USPTO**		
Country	**Number**	**Percentage**	**Country**	**Number**	**Percentage**
China	148,032	17.70	China	6,238	2.00
Russia	21,915	2.62	India	1,003	0.32
Brazil	4,676	0.56	Brazil	277	0.09
India	1,663	0.20	Russia	273	0.09
Mexico	1,130	0.14	Mexico	209	0.07
Turkey	875	0.10	South Africa	202	0.06

[20] This office is considered to have very rigorous procedures and, thus, patents granted there can be seen as a "proxy" for quality.
[21] UNEP/EPO, 2013.

South Africa	437	0.05	Turkey	79	0.03
Argentina	363	0.04	Argentina	75	0.02
Chile	267	0.03	Chile	66	0.02
Egypt	97	0.01	Egypt	21	0.01
Indonesia	35	0.00	Indonesia	9	0.00

Source: Corrocher and Morrison, 2020

B. Insufficient cooperation at regional level

Climate change is a global issue; thus, technological innovations to address this threat might increasingly be generated on the transnational or even global level. However, this is currently not the case. One indicator is the volume of financial resources spent on R&D. The European Union is arguably the most ambitious regional integration programme, and it has a joint R&D strategy for 2021 to 2024. Thus, it was expected the emergence of a regional, European Innovation System. The primary funding line for R&D on the EU level is the ambitious Horizon Europe program. For 2021-2017, 95.5 billion EUR are earmarked for public spending on the regional level, up 19 per cent from around 80 billion EUR in the preceding program Horizon 2020 (2014-2020). This increase could imply that, on average, EU R&D spending will be approximately 13 billion EUR over the program's seven years. This seems to be a solid basis for an emerging regional innovation system. However, it is useful to put it in perspective. Regional R&D spending pales compared to national spending in EU. for instance, public investment in R&D by the German federal government was more than 20 billion EUR in 2020.[22]

To date, regional STI cooperation is not gaining sufficient traction in developing regions to build a solid joint basis for using GWO for sustainable development. Some reasons may be the overall low levels of R&D spending and the lack of incentives for researchers and research institutions to cooperate with their regional peers. It is more attractive for institutions and researchers to enter research projects with developed countries and emerging economies as the opportunities to access world-class research and related hardware (e.g., laboratories and computing power) are better. In addition, for the individual researcher, it is attractive to publish in international refereed journals and cooperate with researchers from well-known universities in the North.[23]

At the same time, South-South cooperation in science and technology is not happening on a broad scale. Over past decades, there have been several attempts to foster regional collaboration, e.g., "Africa's Science and Technology Consolidated Plan of Action (CPA)" launched in 2005 by the African Ministerial Council on Science and Technology (AMCOST). The CPA involved three areas: research and development (R&D); a program for improving policy conditions and building innovation mechanisms; and implementation, governance, and funding. The CPA was later followed by a 10-year Science, Technology and Innovation Strategy for Africa (STISA-2024).

V. Opportunities for catching up through green technologies and innovation

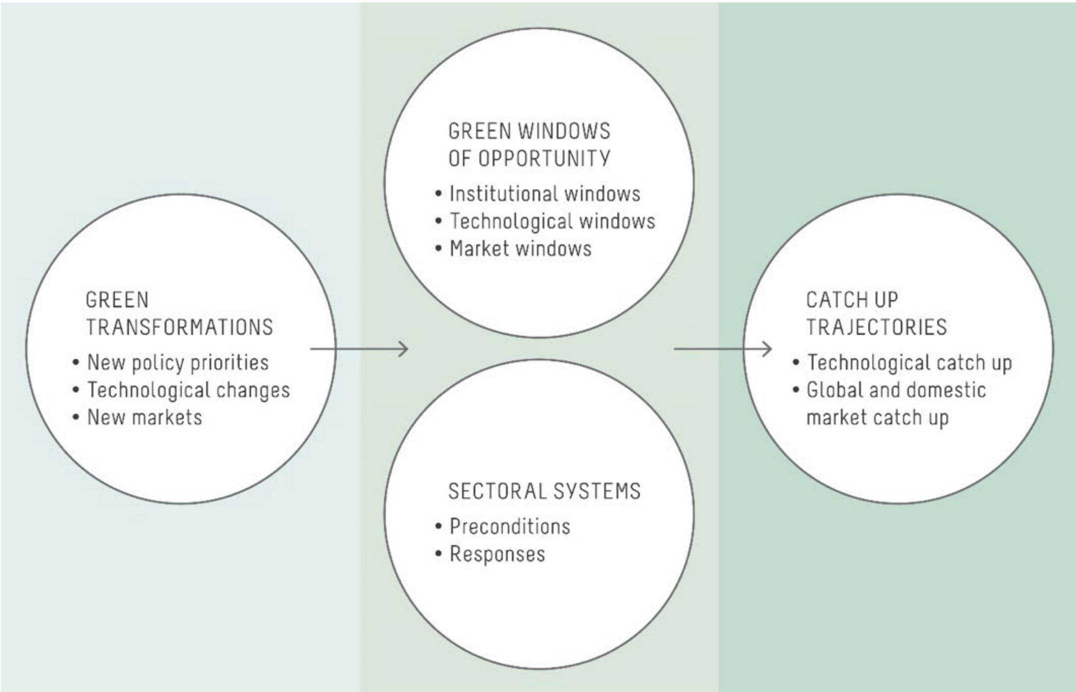
Latecomer catch-up processes in green industries involve three key components: green windows of opportunities (GWOs), sectoral systems, and catch-up trajectories (Figure 1).[24] GWOs arise from significant upheavals in public institutions and policy interventions in technologies and markets. GWO

[22] BMBF, 2020. https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/1/687232_BUFI_2022_Datenband.pdf?__blob=publicationFile&v=4
[23] See, for instance, Blicharska, Malgorzata et al., 2017.
[24] This theoretical framework was proposed by (Lema et al., 2020).

are favourable but time-bounded conditions for latecomer development arising from changes in public institutions and policy interventions, markets, and technologies, associated with the green transformation. The nature and dynamics of GWO are different from the windows of opportunity in other sectors previously investigated in the literature.[25] The reasons are the sectoral specificities of the green technologies, the role played by public policies, their directionality and the externalities generated, and the greater risks and uncertainties associated with the development and commercialization of these technologies.

Sectoral systems include the preconditions and the strategies undertaken by the relevant institutions and strategic public and private actors and their interactions to turn opportunities into reality. Preconditions enable countries to respond effectively to emerging windows. These include public institutions and companies with absorptive capacity, allowing them to recognize the opportunities.[26] In general, the ability to exploit windows of opportunity in specific industries depends on the firm's existing, accumulated capabilities in the same or closely related sectors and the development of the sectoral innovation systems in which they are embedded and formulate their strategies.[27]

Figure 1. From green transformations to catch-up trajectories



Source: Lema et al., (2020).

Catch-up trajectories originate from the interactions of the green windows of opportunity with the preconditions and actions in the sectoral systems. Catch-up is here defined as the successful attainment of leadership by latecomer firms which shifts the balance of economic power between incumbents and latecomers. It could include market and technological catch-up.

Building on the recommendation of UNCTAD's Technology and Innovation Report 2021 for developing countries to adopt frontier technologies while continuing to diversify their production bases by mastering many existing technologies, the following sections will examine the GWO for developing countries due to three main channels: 1) the production of renewable energy technologies, 2) the

[25] (Lee and Malerba, 2017).
[26] (Vértesy, 2017).
[27] (Lee and Malerba, 2017).

application of frontier technologies to greener global value chains, and 3) the diversification of economies towards sectors with lower carbon footprints.

A. Development, adoption and production of renewable energy technologies

What are the key elements for economic and technological catching up through the adoption and production of renewable energy technologies? Based on empirical evidence, GWOs in developing, adopting, and producing renewable energy technologies are often institutional. Although demand conditions and technological changes also influence these green windows of opportunity, they are often promoted by public actions and related adjustments to the institutional framework conditions. In the case of Brazil with biofuels, the institutional window was created by the innovation and industrial policies to address market disruption with the oil crisis in 1973. Examples of institutional windows from the Chinese experience are the implementation of the renewable energy law in 2006, which promoted the initial development of the biomass industry,[28] and sector-focused 'missions' such as the Rooftop Subsidy and the Golden Sun Demonstration Programs implemented in the solar sector.[29] In Egypt, since the issuance of the Renewable Energy Law in 2014, the private sector has been encouraged to play a role in the country's green transformation strategy and produce electricity from renewable resources through several partnerships. In the Philippines, the Renewable Energy (RE) Act of 2008 aimed to accelerate development of renewable energy sources by establishing an enabling environment and providing incentives for technology adoption. Accordingly, and differently from windows of opportunity in other technologies in the past, which focuses on external technology[30] or market changes,[31] these GWO are mainly endogenous to the country. Nevertheless, it also interacts with the external environment and emergent external windows.

Creating a domestic market is another crucial element of the institutional windows of opportunity. In this respect, renewable energy sectors differ from many 'non-green' consumer or capital goods sectors, where government-led demand creation is the exception rather than the rule. 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 Roadmap aims to increase demand for green products and services by integrating the sustainability criteria in the public procurement process.

Increases in market demand can be domestic or global. This is crucial for developing countries, which often have small domestic markets. However, given the limited tradability of many green energy products, domestic market creation is often more important than creating an external market, unless the domestic lead firms have the capacity needed for foreign direct investments.

Institutional windows can also induce technical change in the form of mission-guided public R&D programs. Some examples are the demonstration project on the deployment of solar energy systems in rural health units in the Philippines, and the governmental support for R&D, experimental proof, and technology demonstration projects on Clean Energy in India.

In addition, markets and technology also interact. In the absence of corresponding investments in technical 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 technical

[28] (Hansen and Hansen, 2020).
[29] (Iizuka, 2015).
[30] (Wu and Zhang, 2010).
[31] (Morrison and Rabellotti, 2017)

change is not matched by (domestic or external) market demand, strong technological capabilities may remain dormant.[32]

Therefore, institutional-cum-demand windows are more frequent in renewable energy industries than opportunities emerging primarily from technology breakthroughs. Especially in sectors focused on producing energy generation technologies, not least in more mature technological settings, for example, in the case of solar PV and the context of the large internal market such as in Brazil, China, and India.

Responses to green windows of opportunities in renewable energy technologies are influenced by the techno-economic specificities of the green sectors, which differ in terms of their technological maturity and tradability. In mature sectors, for example, it is relatively easy for firms to acquire world-class technologies, and market success depends more on capital investment and the development of organizational capabilities.

It is also evident that certain firms are better able to exploit opportunity windows, and often these firms have become national champions. They usually play a crucial role in building knowledge linkages within the global economy, moving from initial licensing and more conventional technology transfer to mechanisms such as outward foreign direct investments in technology lead markets and linkages to foreign universities.[33] The diffusion of innovation from first-mover leading firms to followers is also especially important in the domestic industry. Sectoral innovation systems are reinforced by intense interactions among lead firms, suppliers, technology providers, and financial institutions.[34] Stronger linkages within the sectoral innovation system contribute to technological deepening during the more demanding stages of technological upgrading that follow the initial phase of accumulation of production capability.

Firm-level efforts are not enough, and institutional efforts are needed to support a shift from facilitating production capability to active technology development support. This requires public R&D investments and specific programs and projects to address technological challenges such as process improvements and the application of complementary technologies.[35] For example, in the Chinese wind sector, the support provided by the innovation system, such as facilitating university-industry linkages, was fundamental for the shift from onshore to offshore turbine technologies.[36]

To exploit GWOs, the sectoral innovation system must be dynamic and adapt continuously to different sector specificities and changing market and technological opportunities. Also, policies need to be tailored to the stage of catch-up and take account of sectoral specificities.

Concerning policies, it can sometimes be difficult to empirically separate a policy opening a domestic window from a policy response for taking advantage of that window. Ultimately, it is a question of timing, and it can be traced, also considering the nature of the window, in the sequencing of events in sectoral trajectories. 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 the wind plants as a response to the window.[37] Or conversely, in the case of a technological window such as the global shift from combustion engines to electric vehicles,

[32] (Hain et al., 2020).
[33] (Lema and Lema, 2012; Fu and Zhang, 2011).
[34] (Fu, 2015).
[35] (Shubbak, 2019).
[36] (Dai et al., 2020).
[37] (Lema et al., 2013).

innovation and industrial policies are used to react to and internalise 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.[38] The sequencing of such events and the preconditions and responses in the public and private sectors hold the key to explaining catch-up trajectories.[39]

While China provides a strong case, other emerging economies are also making inroads in cleaner technological catch-up.[40] In Brazil, preconditions have been constructed over many years. The sugarcane-based ethanol fuel program was initiated in the 1970s and drew on a knowledge system around sugar canes developed over decades, starting with the first experimentation with bioethanol in 1930. Active efforts have been put in place, especially in bioethanol technology. The country's success in sugarcane-related technology development is an outcome of the technological learning arising from innovation policies, the development of sugar and ethanol processing plants, and interaction with technology suppliers and research institutions.[41] In extension, private sector firms have established collaborative consortia to develop passenger cars' flex-fuelling systems, fully exploiting the GWO around bioethanol. Although the local market initially drove the responses, Brazil later started moving to a leadership position in the global market.[42]

Another case in which we can potentially envisage the combination of adequate preconditions with strong responses is the development of the green hydrogen industry in Chile (see Box 2 for a discussion on opportunities in green hydrogen). The South American country has a relatively well-developed production system and a tradition of public investments in sustainable industrial development. The green hydrogen strategy is part of an ambitious clean energy transition process launched in 2015 with the commitment to decarbonising the electrical matrix by 2040 and carbon neutrality by 2050. Developing a green hydrogen industry will be crucial in accomplishing those national goals, as confirmed by the recent setting up of six new pilot projects selected by the Chilean National Development Agency (CORFO) with significant international investors. What could negatively influence the growth of the Chilean green hydrogen industry is the country’s location on the southwestern coast of South America, very distant from the expected significant markets of Asia and Europe. Chilean exporters will have to overcome a cost disadvantage in shipping. Therefore, making low-cost hydrogen is essential to the nation's green hydrogen plan.[43]

Box 2. Emerging green windows of opportunity related to the global green hydrogen economy

The transition towards a global green hydrogen economy is high on the international policy and research agenda. Green hydrogen is produced via electrolysis, for which the electricity used stems from renewable sources (e.g., solar, wind, geothermal). A related concept is blue hydrogen, produced via natural gas steam, combined with CCS to reduce CO_2 emissions to close to zero. Green and blue hydrogen are considered crucial for de-carbonizing 10-20 per cent of global energy demand, which cannot be made emission-free via direct electrification for techno-economic reasons. These industrial processes require high temperatures, e.g., in the steel industry and heavy transport on road, rail and water. Derivatives of green hydrogen may be used as fuels in air traffic (IEA 2021).

[38] (Konda, 2022).
[39] Lema et al (2020) discuss the sequencing of the various elements of GWOs.
[40] (Fankhauser et al., 2019).
[41] (Furtado et al., 2011).
[42] (Lema et al., 2015).
[43] (Chile awards six new green hydrogen projects | IHS Markit, 2022).

The hydrogen strategies of, e.g., Europe, Japan and Korea are very ambitious regarding the quantities of hydrogen to be internationally traded and the speed of the process. This accelerated energy transition may open important Green Windows of Opportunity for developing countries. Considering the challenges of labour shortage in many traditional manufacturing hubs of the world, advanced developing countries might be involved in global value chains for renewable energy generation equipment and electrolysers. Countries that host large reserves of critical resources, like copper for electricity cables, lithium for batteries or platinum and iridium for PEM electrolysers will be in favourable conditions in the process.

However, some technical issues must be resolved for a beneficial integration of developing countries into the global hydrogen economy. To date, it is still unclear how very large amounts of green hydrogen may be internationally transported safely, cleanly, and economically (Roland Berger 2021). Many developing countries, e.g., Chile, Panama, and South Africa, have developed their green hydrogen strategies, which follow a comprehensive sustainable development approach. Green windows of opportunity are seen in the domestic use of green hydrogen, e.g., to substitute imports of fossil fuels for fertilizers and explosives in the mining sectors (Chile and South Africa) or re-fuelling vessels, in the future powered by methanol or ammonia, important derivatives of green hydrogen.

For many developing countries, using green hydrogen to produce nitrogen fertilizers would be crucial, considering the probably long-term increase of prices for natural gas, currently the main input to the fertilizer industry. Green hydrogen can also be used as energy storage in mini-grids fed with intermittent renewable energies, which is highly relevant in countries where a large part of the population has no access to the electricity grid. Technological challenges related to these options should be resolved in internationally coordinated research and development efforts, which could be an essential entry point for South-south innovation cooperation. Developed countries should support this, considering that the transition towards a green hydrogen economy across the planet is important to clean energy provision as a global common good.

Source: UNCTAD.

B. Greening global value chains

The rise of GVCs has allowed many emerging and developing countries to enter the global market based on their specific advantages and specialization in tasks rather than final goods. But entering in GVCs is not sufficient to guarantee sustainable growth. It requires scaling the value-added ladder and moving progressively to more sophisticated forms of GVC participation.[44] One way of increasing the sophistication of GVC participation is to put forward the process that results in greening the GVCs through reducing the firms' ecological footprint, such as the impact on greenhouse gas emissions, biodiversity losses and natural resources overexploitation.[45]

The greening of the GVCs in manufacturing industries has three drivers: 1) new patterns of demand preferences and consumer behaviours, 2) new green strategies by lead firms and global buyers and 3) enforcement of environmental standards and associated patterns of upgrading and downgrading across global supply bases.

The process of greening of GVCs occurs within sustainability-oriented production systems. This process concerns backward linkages - e.g., sourcing of rare earth materials in electric vehicles and wind turbines[46] and reducing and managing chemicals of concern in solar PV manufacturing[47] - and

[44] (World Bank, 2020).
[45] (De Marchi et, 2019).
[46] (Alves Dias et al., 2020).
[47] (Greening solar supply chains, 2021).

circular economy, including re-use after decommissioning.[48] These trends will have profound implications for transforming the renewable energy GVCs in the coming years.

At the same time, this greening of GVCs would unfold in sectors that do not usually belong to what is usually considered greener industries. These include manufacturing sectors of crucial importance to low- and middle-income countries, such as traditional manufacturing industries, including food production, garment and textiles, leather and shoe, and furniture.

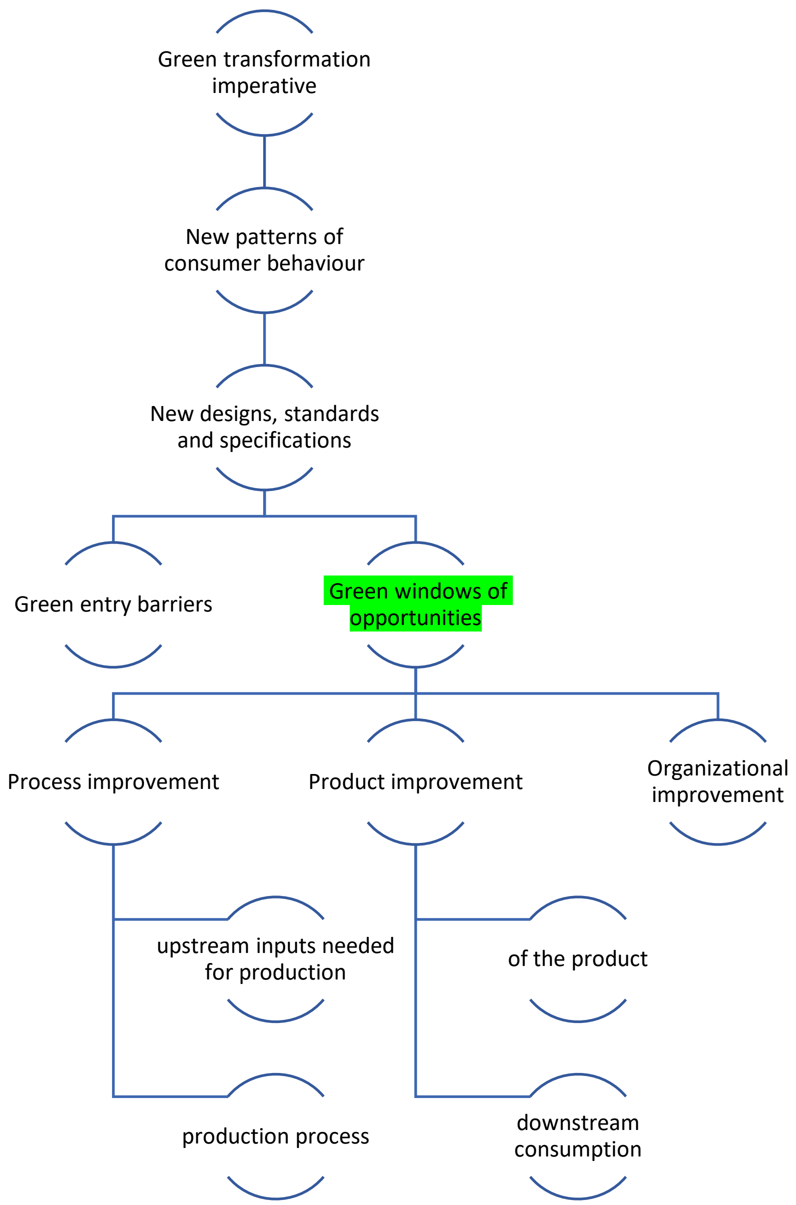
The greening of the global value chain in manufacturing industries unfolds in several steps (Figure 2). First, at the top, the green transformation imperative leads to new patterns of consumer behaviour, new demand preferences changing policy landscapes and increasing NGO activism that also change consumption and reduce the environmental footprint of production and trade. There are also drivers rooted in the profit motive, such as savings derived from decreased material use. Changing demand for less resource-intensive and environmentally friendly products and services has ramifications as new requirements are transmitted through GVCs.

Second, these requirements are typically enforced in the value chains through new designs, standards and specifications. They are usually defined and enforced in 'green lead markets' - countries that are pioneers in environmentally benign products, processes and services.[49] Many of these new requirements are 'private standards' defined and enforced by lead firms. They also internalize several public environmental regulations and semiprivate environmental certifications, such as the Technical Regulations (TRs) Certification (i.e., Round Table on Responsible Soy), which, beyond the core private sector firms and organizations, includes authorities and 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.[50]

Third, these changes in the governance regime of GVCs create both 'green entry barriers' and 'green windows of opportunity' (GWO) for suppliers in the Global South. This is because they may translate into new constraints for suppliers in meeting these requirements, thereby making entry into GVCs more difficult or forcing an exit from GVCs for existing suppliers, in a sustainability-driven supplier squeeze.[51] 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.[52] The embeddedness of suppliers in well-functioning production and innovation systems is crucial.[53]

Figure 2. Steps for the greening of GVCs

[48] (Gallagher et al., 2019).
[49] (Beise and Rennings, 2005).
[50] (Humphrey and Schmitz, 2001)
[51] (Ponte (2020)).
[52] (Lema et al., 2020) (Lema and Rabellotti, 2022).
[53] (Pietrobelli and Rabellotti, 2011).



Source: UNCTAD.

Fourth, provided that the requisite capabilities and support requirements are in place, green windows of opportunities in GVCs may be effectively utilized and foster 'environmental upgrading.' This can be defined as any change that results in the reduction of the ecological footprint of the firm, e.g. reduced greenhouse gas emissions, natural resources use and biodiversity loss.[54]

The adoption of digital, frontier technologies associated with smart manufacturing or, in other words, Industry 4.0, can lead to more sustainable GVCs. Digital transformation has long been promoted to enhance economic competitiveness, while there is increasing recognition that digitization can contribute to sustainability goals and enable the changes needed for a just transition towards more sustainable economies. The twin environmental and digital goals are increasingly seen to complement each other, and digital technologies such as AI, cloud computing, IoT are expected to help the economy become greener. Digital technologies are expected to open green windows of opportunities, such as improving green efficiency, reducing the carbon footprint of current production and

[54] (De Marchi et al., 2019).

consumption modes, facilitating the introduction of new green technologies and eco products, and enhancing the diffusion of business models based on circular economy. At the same time, digital technologies may also pose serious environmental threats, which span from the use of rare materials in their production to the high energy consumption in their utilization.

For analytical purposes, it is possible to distinguish four types of environmental upgrading through frontier technology innovation (process and product upgrading):

- Process upgrading of the upstream inputs needed for production, including the substitution of energy sources, the substitution of energy-intensive materials or scarce natural resources and the substitution of toxic inputs.
- Process upgrading of the production process, including reducing waste from the production process, introducing technology to reduce energy consumption, and optimizing the material flow.
- Product upgrading, including new designs substituting environmentally harmful components, designing recycled products, designing for durability, and substituting complete environmentally harmful products.
- Product upgrading of downstream consumption, including recycling and re-use of waste.

There are several examples of how Industry 4.0 technologies are used in greening GVCs. Concerning environmental upgrading of the upstream inputs needed for production, new hardware technologies play an essential role in formal sustainability standard-setting organizations (SSOs) across agro-industrial sectors such as food, forestry and fisheries.[55] Old verification systems that utilized annual field audits are being replaced by ICT-collected data in real-time with new technologies. For example, fixed and mobile sensors, e.g., in harvesting and logging equipment, and satellite data provide precise information on matters of interest such as tree species, biodiversity counts, or illegal logging and fishing. They are now being adopted for monitoring environmental standards by organizations such as FAO and the World Bank.

With respect to inbound logistics, IoT affects the sustainable transformation of global supply chains in the logistics sector. New data collected from online-connected sensors and GPS tracking systems can optimize logistics and reduce carbon emissions significantly.[56]

Smart manufacturing can also offer opportunities for energy saving and sustainability through optimisation.[57] For example, in a case study, a multinational in the plastics sector deployed Industry 4.0 technologies using energy sensors and IoT, which reduced the power consumption in one of its plants by around 40 per cent, saving over USD 200,000 a year in energy costs.[58] In the case of smart factories that already employ IoT and robots, improvements in the algorithms could result in continuous optimization and increases in energy efficiency. For example, in a case study of a smartphone manufacturer based in China that uses robots, changes in the algorithm to optimize the operation of the robots resulted in an increase in the productivity of these machines by 50 per cent.[59]

The possibility of reducing waste in production processes also offers the opportunity for improving the sustainability of production.[60] The savings in using 3D printing instead of traditional production methods can be substantial. For example, a study found that additive manufacturing on the

[55] Gale et al. (2017).
[56] Mangina et al. (2020) drawing on data from EU and EFTA.
[57] (UNCTAD, 2022).
[58] (Efficiency Vermont, 2020).
[59] (Automate, 2020).
[60] (UNCTAD, 2022).

production of less flight-critical lightweight aircraft parts could result in more than 50 per cent reduction in the weight of these parts, reducing the weight of an airplane by 4 to 7 per cent, and its fuel consumption by as much as 6.4 per cent.[61] Thus, using this technology could have a tremendous impact on reducing carbon emissions in air travel.

Many new data processing technologies, including big data analytics, cloud computing, artificial intelligence and blockchain technology, have a bearing on environmental upgrading of the upstream inputs needed for production. For example, blockchain could be a useful tool for dealing with the growing complexity of global value chains and can improve methods for securing adherence to environmental standards in GVC.[62] Blockchain can enhance sustainability by providing information to buyers on the origin of products and guaranteeing the authenticity of the information. Similarly, blockchains can impact environmental upgrading in GVCs through upstream supply chain management:[63] (a) tracking faulty products or components (with systems such as Echchain, ElectricChain, and Suncontract) to reduce reproduction and recalls results in decreased resource consumption and reduced greenhouse gas emissions; (b) increasing traceability to ensure that designated green products are environmentally friendly, such as in the case of the blockchain based Supply Chain Environmental Analysis Tool (SCEnAT) system to trace carbon footprint of products or the Endorsement of the Forestry Certification to ensure that wood is sustainably sourced. They also have downstream implications, e.g. by enhancing incentives to recycle, such as with the RecycleToCoin system that enables people to return plastic containers for a financial reward.

Artificial intelligence also has important implications for greening in GVCs. This technology is relevant across environmental domains such as energy, production and natural resource management. Firms may also implement AI to improve environmental performance.[64] In energy, for example, to reduce energy consumption in operations, firms are starting to adopt technologies that can optimize green energy use in smart grids. AI may facilitate decision-making that can increase energy efficiency and reduce cost. In agriculture, supply chain professionals can draw on AI inputs to plan shipping and the delivery of perishable goods by monitoring and forecasting the state of the cargo. This is often aided by AI that draws on data from sensors and other technologies involved in smart supply chain systems and intelligent food logistics.

At the same time, some studies have a critical perspective on the possibility of AI providing greener supply chains, arguing that AI is not advancing sustainability to the extent that companies sometimes claim.[65] Lead firms are increasingly adopting sustainability tools to cut operational costs, increase product value, and coordinate GVCs. Measures such as certifications, codes of conduct, supply chain reporting, lifecycle assessments, supplier audits, smart packaging, and eco-efficiency programs may all be aided by AI. In this respect, machine learning and intelligent automation improve environmental management. However, firm managers may have incentives to overstate the value of application of AI because this may boost brand and stock values.[66]

[61] (Huang et al., 2016).
[62] Nikolakis et al (2018).
[63] Saberi et al (2019).
[64] (Toniolo et al., 2020). AI is relevant to addressing several targets across the SDGs but it is also an obstacle in certain cases. In the energy field the data centres used to power AI have a very high energy demand (Vinuesa et al., 2020).
[65] (Dauvergne, 2020).
[66] Ibid.

C. Diversifying toward more sustainable economic sectors

The strategies for inclusive and more sustainable growth assume the government's active role in fostering innovation in greener technologies and products that are new to the world. However, in the context of low-income developing countries, economic diversification is usually associated with the innovative process of absorbing technologies to emulate more productive industries that were the result of previous innovation in more developed countries.[67]

Diversification is a path-dependent process, and possibilities for emulation are not equally available at any given time.[68] Path dependence exists because new economic activities tend to exploit the technologies that were previously developed for other activities.[69] Therefore, the activities that are more likely to be emulated require a set of technologies that largely overlaps with the set required by the existing economic activities in the economy. For example, while the production of goods such as machinery and electronics require technologies that can be the building blocks of the output in many other sectors, the production of primary products usually involves technologies that offer fewer possibilities for further combinations and, thus, diversification. More significant "jumps" in innovation, in which some of the technologies combined are not available in the economy and must be learned or transferred from abroad, require more government support to facilitate innovation. In addition, economic institutions and the expected demand for new products shape the incentives for creating and combining technologies.[70]

However, if countries follow previous growth paths, global greenhouse gas (GHGs) emissions will continue to increase with severe social and economic impacts.[71] Thus, it is critical to find new pathways of economic diversification that are more sustainable.

Therefore, another green window of opportunity for low-income developing countries is to foster the emergence of more productive and sustainable economic activities based on the technological level of the current production base and the incentives created by domestic and global demand. An optimum path of diversification of economic activities may exist, consisting of the continuous move to selected activities that are more productive and more environment-friendly and that are closely related to the existing productive capacities of the country.

Recent research uses information about the level of export diversification of countries and how many countries export each product to compute indices of the level of technologies in the economy or the so-called economic complexity. These indices also estimate the level of technology that goes into the production of each product. More complex products are considered to require higher levels of technology, and development is associated with diversification toward products with above-average complexity in the country.[72]

Recent studies have examined the possibility of countries diversifying towards more complex and greener products. So far, they have found mixed results. Some studies have found an inverted U-shaped relationship between economic complexity and CO2 emissions.[73] Countries with a lower economic complexity show low CO2 emissions; as economic complexity increases, emissions also rise,

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[67] (Reinert, 2008).
[68] (Hausmann and Hidalgo, 2011).
[69] (Arthur, 2011).
[70] (Lall, 1992; Freire, 2019).
[71] (IPCC, 2007)
[72] Freire (2017)
[73] Some of these studies considered 118 countries (Chu, 2021), G7 countries, six European countries (Belgium, France, Italy, Finland, the United Kingdom, and Sweden)(Neagu, 2019), the United States (Pata, 2021), and France (examing the impact of complexity on environmental degradation) (Can and Gozgor, 2017).

but eventually, they start to decrease for countries at higher levels of economic complexity. This relationship, thus, mirrors the Environmental Kuznets Curve (EKC). An increase in economic complexity causes a rise in CO2 emissions only up to a point, and a decrease after that.

At the same time, other studies found that the EKC hypothesis does not hold in some cases or is dependent on different factors.[74] The relationship between complexity and environment may depend on the environmental measures used in the analysis. For example, a study has found that economic complexity reduces greenhouse gas emission intensity (measured in kt CO2e/USD billion output).[75] The reasoning is that more complex products result in relatively higher value-added for each unit of pollution, and their production uses newer and more energy-efficient technologies. This study reports that an increase in one unit of complexity (measure using the index ECI) results in a decrease of 23 per cent in kilotons of CO2e per billion dollars of output in the next period.[76]

Other studies examined the relationship between economic complexity and broader environmental performance measures. They found that increasing economic complexity results in better overall ecological performance as measured by the Environmental Performance Index (EPI) in 88 developed and developing countries for the period 2002–2012,[77] although the effect of economic complexity on air quality (PM2.5, CO2, methane and nitrous oxide emissions) is negative.[78] Others found that economic complexity harms the ecological footprint[79] in the 48 most complex economies in the world,[80] the top 10 economies with high complexity from 1980 to 2017,[81] and China.[82]

The relationship between complexity and environmental variables also depends on the level of development of countries.[83] Some studies found that increasing economic complexity in developing countries has resulted in higher carbon emissions but has limited[84] or undetectable[85] environmental degradation in high-income economies. It also reduces the environmental quality in emerging economies while mitigating the ecological footprint for higher economic complexity.[86] Other studies found a positive and significant impact on carbon emissions, particularly on economies with low CO_2 emissions,[87] and in a study considering the Association of Southeast Asian Nations (ASEAN)

[74] such as in an analysis of the relationship in a selected group of 18 top economic complexity countries (Abbasi et al., 2021), selected European Union countries with low and high economic complexity (Neagu and Teodoru, 2019), a group of countries when considering the impact on environmental performance index (EPI), the per capita ecological footprint of consumption, and the per capita ecological footprint of production (Kosifakis et al., 2020), a group of 86 countries with different development levels (Laverde-Rojas and Correa, 2021), and a study on Colombia (Laverde-Rojas et al., 2021), and another on Brazil (Swart and Brinkmann, 2020).
[75] (Romero and Gramkow, 2021)
[76] (Romero and Gramkow, 2021)
[77] (Kosifakis et al., 2020) (Boleti et al., 2021)
[78] (Boleti et al., 2021)
[79] The ecological footprint was introduced by Wackernagel and Rees as a more inclusive and comprehensive indicator of environmental degradation, encompassing built-up land, forest land, grazing land, crop land, carbon footprint, and ocean. It measures the total quantity of natural resources consumed by the population as well as the area of productive land and water needed to support human activities and sequester the waste they generate (Neagu, 2021).
[80] (Neagu, 2020)
[81] (Rafique et al., 2021)
[82] (Ylanci and Pata, 2020)
[83] (Neagu, 2021)
[84] (Neagu and Teodoru, 2019) (Dogan et al., 2019)
[85] (Adedoyin et al., 2021)
[86] (Ahmad et al., 2021)
[87] (Majeed et al., 2021)

countries.[88] Still, others found that increasing the complexity of developed countries results in lower pollution levels[89] and can significantly enhance the ecological footprint in the United States.[90] However, the relationship between the economic complexity and ecological footprint may as well be bi-directional, as suggested in a study of the Japanese economy.[91]

The analysis of these studies point 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 interventions for identifying sectors, technologies and markets, and creating the conditions for their domestic firms (private and public) to enter into these new sectors. Governments in low and lower-middle-income developing countries have to act fast and decisively; otherwise, they will be left further behind. Given that green productive capabilities are path-dependent, the greener production capabilities a country has, the easier it is to diversify into additional new green products.[92]

Another result of this analysis is that since carbon emissions increases 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 the 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 friendly environmental technology will translate into better performance.[93]

VI. Technology transfer for the sustainability and resilience transformation

Given the urgent climate and environmental crises, the question of how sustainable technologies can be accelerated not only in the most advanced but also in developing countries has gained momentum. The lack of advanced technologies and related capabilities to use them has been seen as a core reason for developing countries' lack of socio-economic dynamics. Also, access to technology became an element of concepts for an environmentally sustainable world. Commitments in this direction have been repeated several times, e.g. at the Earth Summit in Rio de Janeiro (1992) and the Paris Agreement of 2015.[94]

Technology transfer cannot be conceptualized as moving physical “hardware” from one geographical and societal context to another, e.g. through the selling of industrial machinery or Foreign Direct Investment (FDI).[95] The question of technology transfer is embedded in the more complex issue of building-up innovative capabilities: the capacities to adopt, adapt, develop, deploy and operate technologies under varying societal and environmental contexts.[96] Successful technology transfer does not only require willingness and abilities by the providers of technology, but also, on the side of technology receivers, it requires absorptive capacity, human capital, trust, social connectedness, prior experience with partnerships, and international experience.[97] It does not only provide the capital

[88] Nathaniel (2021)
[89] (Laverde-Rojas and Correa, 2021) (Dogan et al., 2021)
[90] Shahzad et al., (2021)
[91] (Ikram et al., 2021)
[92] (Mealy and Teytelboym, 2020).
[93] (Chu, 2021).
[94] Kosolapova 2020: 2.
[95] E.g., Bell, 1990.
[96] E.g., Ockwell/Mallett 2012: 9.
[97] Araújo and Teixeira, 2014.

goods and equipment needed to establish physical assets and directly related services, such as engineering services hardware, to a recipient country, but it also enables technology receivers to develop the skills needed to operate and maintain (know-how) and understand, why it is running (know-why), so to replicate and innovate this technology.[98]

Only if local actors acquire certain "know-why" capabilities, a country can be able to adapt a given set of technologies to varying framework conditions and apply it beyond the usage for which it was transferred initially. These capabilities are crucial for green technologies, as their deployment often within and across countries needs adaptations to specific conditions on the ground. In addition, 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 requires, thus, broad and comprehensive development strategies to support national innovation systems.

A. Official Development Assistance to support STI for green innovations

ODA could contribute to the capacities of developing countries to handle technologies and generate innovations as a pre-condition for their abilities to identify and use GWO. No reliable time series are available, but "green" ODA has been increasing over time in most countries, following international agreements, like the Paris Agreement of 2015. [99] In 2016/2017 many of the large international donors committed at least 40 per cent of their development assistance as "green ODA" (see Table 7).

Table 7. Green ODA as a percentage of all ODA in leading donor countries (2016/2017)

Country	Percentage
Canada	41
EU institutions	34
France	67
Germany	42
Japan	48
Sweden	47
United Kingdom	42
Republic of Korea	9
United States	7

Source: UNCATD based on Rijsberman (2021).

The European Union institutions' green ODA share was already above average in 2016/2017 (34 per cent). With the EU Green Deal becoming the backbone of the green recovery for Europe and the "green growth strategy" across all EU policies, this is expected to increase. The formal target for the green share of the EU's ODA has not been set yet, but European development partners are arguing that it should be at least 50 per cent green, for both environment and climate finance combined.[100] The OECD Development Assistance Committee (DAC) declared a new approach to align development co-operation with the Paris Agreement on Climate Change goals, which DAC members adopted on 27 October 2021.

[98] Bell, 1990 and Kirchherr and Urban 2018: 601.

[99] The rather sophisticated methodology of OECD-DAC to collect and disseminate aid data permits to estimate the percentage of ODA addressing international environment goals, written down in Conventions on Climate Change, Biodiversity, Desertification, etc. OECD, 2019.

[100] Rijberman, 2021.

Estimates vary regarding ODA directed to STI, but they show a low level. Some estimates found that the annual amounts of concessional finance to STI were relatively stable from 2011 through 2016, with around USD 10.5 billion per year, representing 5.9 per cent of total concessional finance by DAC members, multilateral organizations and other countries.[101] However, it is unclear which sub-categories are summarized under "ODA for STI" and whether all donors report it similarly. The United Nations estimates that the ODA specifically targeting the development of STI capacities in developing countries has more than doubled between 2014 and 2019, but starting on a relatively low level (2014: US$ 0.9 billion, 2019: US$2.4 billion). This implies that only a very small percentage of international aid flows target STI capacities. In addition, ODA for STI capacity development in the least developed countries, landlocked developing countries, small island developing states (SIDS), and Africa has not grown over the past decade and remained low.[102]

The highest ODA flows (in absolute terms) to support science and innovation come from the United States, the United Kingdom, Germany, Canada, Australia, France, Sweden, Netherlands, Norway and Switzerland. The ranking regarding "ODA for technology" is different and sees the Republic of Korea at the top, with a rather high proportion of non-concessional loans.[103] The priorities that different donors set for their STI support vary significantly:

- The United States is the largest provider of concessional finance to STI, with a large share of its funding directed towards research, capacity building and innovative approaches to fight the spread of infectious and tropical diseases and prevent maternal and child deaths.
- The United Kingdom is heavily scaling up research support. In 2013, the UK Government announced its pledge to provide 0.7 per cent of its gross national income (GNI) as ODA. In the following three years, new research funds were set up to support research activities tackling challenges faced by developing countries (i.e., Newton Fund, Ross Fund, Global Challenges Research Fund). A second aim of the research funds was also to make developing countries benefit from the high-quality standard of research conducted in the United Kingdom.
- Sweden's research co-operation programme focuses on strengthening developing countries' research capacity and financing research projects. It is grounded in the government's Strategy for research cooperation and research in development cooperation 2015-2021. The strategy aims to contribute to strengthened research of high quality and relevance to poverty reduction and sustainable development, with a primary focus on low-income countries and regions.
- Canada funds international STI cooperation mainly through the Ottawa-based International Research Centre (IDRC). The centre champions and funds research and innovation in developing regions to drive global change. It invests in high-quality research in developing countries, shares knowledge with researchers and policymakers for greater uptake and use, and mobilizes global alliances to build a more sustainable and inclusive world.
- Germany has a long tradition of supporting developing countries' technical and vocational education and training systems, which can pave the way for implementing green technologies in businesses and society. In addition, organizations such as the German Academic Exchange Service (DAAD) and Alexander von Humboldt Stiftung (AvH) provide

[101] Eriksson and Mealy 2019: 46. The authors stress important methodological constraints, as STI is not a "marker" in the DAC Reporting System.
[102] (United Nations and DESA, 2019)
[103] Eriksson and Mealy 2019: 53.

scholarships for students from developing countries on the postgraduate and post-doctorate levels.

The amount of ODA 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. Developing countries are increasingly raising this issue in international negotiations. For example, Mongolia has committed to increasing its emissions reduction goal from 22.7 to 27.2 per cent by 2030 if it receives assistance with carbon capture and storage (CCS) and waste-to-energy technologies.[104] Similarly, Thailand has promised to raise its emissions reduction target from 20 to 25 per cent from the projected business as usual level by 2030, with adequate and enhanced access to technology development and transfer, and financial and capacity-building support.[105]

B. Trade and Foreign Direct Investment as channels for technology transfer

The role that trade plays in transferring technologies from industrialized to developing countries depends mainly on the type of technologies in question and the specificities of the host country. In general, increased trade in green technology products opens opportunities to learn by observation and by reverse engineering - two documented modes of technology transfer via trade. This does not imply directly that developing countries will be able to use this technological learning in the short term for import-substitution of green technology products or building up their own export sector, which would be two modes of realizing the green window of opportunity. Some green technology items, such as solar PV modules, are globally traded commodities, and the competition is not based on simple learning of its key features, but a highly efficient industrial value chain.

Developing countries without a strong manufacturing sector face important barriers to adopt new technologies to expand production for import replacement and exports, even in “low tech” green innovation with high relevance for the environment and public health. For example, Improved Cooking Stoves (ICS) are an important tool to reduce deforestation, black carbon emissions and indoor air pollution from which a large number of people (mainly women and kids) die each year. From global diffusion figures, it is one of the most successful green innovations in the past decades. In 2012/13 an estimated 200 million ICS were used.[106] Beyond the environmental and health benefits, one of the key advantages of their diffusion is that it can generally be produced with locally available materials and employing local workers. However, over the years, the market started to differentiate between artisanal, semi-industrial and industrial manufacturing—the latter involving highly mechanized production processes, degree of centralization and large scales of operation.[107]

Developing countries strategically look at technological learning opportunities from trade, including knowledge about the technologies, business models, and how they evolve. There might be opportunities to build up facilities to adapt internationally traded goods to local conditions and to build up green value chains in selected items. South-south cooperation could be seen as a way forward where the markets are small.

Foreign Direct Investment (FDI) is another channel for technology transfer. It can contribute to technological learning in various ways: a foreign company which builds up production facilities in a developing country will usually require specialized inputs from domestic firms. To assure effective and efficient supply chains, a transfer of knowledge through these backward linkages is in the interest of

[104] Kosolapova, 2020.
[105] Ibid.
[106] ESMAP, 2015.
[107] Ibid: 106.

the international company. This implies vertical technology transfer from the home country to the host country and from the FDI to local companies. Horizontal technology transfer may be induced when domestic companies are facing competition by better and cheaper production and upgrading their production. Another mode of horizontal technology transfer happens through labour migration, when workers and managers trained on the job in an FDI switch to local companies or institutions. These positive effects are well documented for conventional goods. However, the picture is not completely clear about the effectiveness of this mode of technology transfer.[108]

Currently, global value chains related to green technology items (e.g. solar PV and wind energy) mainly involve China, Europe, the United States and Japan. No significant modes of industrial division of labour involving developing countries are documented in the literature. This might, however, change soon due to the envisaged transition towards green hydrogen, which requires very significant upscaling of key components of this emerging industry, e.g. electrolysers. Considering the increasing labour shortage problem in some of the traditional hotspots of industrial production (e.g. Europe, Japan), big companies will likely continue to outsource parts of the manufacturing to developing countries and emerging economies. Developing countries' governments should prepare for this green window of opportunity by designing policies to assure a solid contribution of FDI to the development of their countries.

Many green technologies must be adapted to local conditions to be effective and fulfil their economic, social and ecological functions. One important example is utility-scale renewable energy projects like solar and wind farms. They cannot be bought "off the shelf" but require in-situ activities to ensure that the technology is compatible with local conditions. They must be adapted to the geography of the specific sites, solar radiation, wind speed and, in the case of biomass, the specific fuels used.[109] The better the local research capacities, the faster and more cost-effective these activities can be carried out. If international experts must carry out important elements of these complementary activities, the costs will increase significantly, and implementation times will be much longer. Thus, from a mere climate-change mitigation perspective, a higher level of domestic innovation capabilities in Low and Middle Income Countries is very important.

When it comes to utility-scale renewable energy projects in developing countries as a contribution to climate change mitigation, project developers, or Engineering, Procurement and Construction (EPC) companies play an important role in carrying out the siting of projects, identifying the best possible technical solutions and establishing the projects until it is up and running.[110] A large study analysing 863 utility-scale RE projects (>1 MW) implemented between 2007 and 2017 in eighty countries found that international project developers play an essential role in opening new markets in the field of renewable energy, including solar PV, wind and biomass-based energy generation.[111] While Wind and Biomass have developed rather continuously over time, Solar PV had exponential growth after 2009. The main reason for this kick-start was a significant drop in international prices for PV systems around 2010.[112] A "peak" in the diffusion of biomass projects in 2008 is related to the fact that this technology was often used in the context of the international Clean Development Mechanism (CDM), which could be used to offset emissions in countries with emissions-reduction obligations under the Kyoto Protocol. As a large buyer, the EU emission trading system (ETS) has accepted CDM credits since 2008.

[108] Glass and Saggi 2002 and Saggi 2002.
[109] Steffen et al., 2018: 560.
[110] Gunn and Salter, 2000: 956.
[111] Bjarne et al, 2018.
[112] Bjarne et al 2018: 564.

International private project developers have been crucial for the first projects in solar PV (61 per cent) and wind (58 per cent), and biomass (33 per cent). In wind and solar PV, the required value chain of competencies for successful project implementation is brought to the country by the international developer.[113] In biomass, more local competencies have been present in many developing countries. Thus, while both Solar PV and Wind have been "new to the market" innovations in all cases, utilizing available biomass for generating energy has a long history in many developing countries. For instance, already towards the end of last century, the Brazilian sugar sector was self-sufficient in its electricity provision for its industries, combusting sub-products (bagasse) of sugar cane processing.[114]

The participation of international project developers was significantly lower in follow-on projects (37 per cent in Wind, 36 per cent in Solar PV and 12 per cent in Biomass), perhaps because there is a transfer of some of the know-how and build-up of local productive capacities in the process of the implementation of first projects.[115]

EPC companies are often "medium-sized" companies with a limited presence in the host country. They sometimes only as a transitory solution, depending on their business model, which can either follow the Build-Operate-Operate (BOO) mode or the Build-Operate-Transfer (BOT) mode. Under BOO, EPC companies most often sign a long-term power purchasing agreement with a utility of the host country and will continue to operate and maintain infrastructure and equipment for a pre-defined time. Under BOT, the project is handed over to national entities after it has been successfully built and proven to operate properly. In both cases, it can be assumed that the project developer is intrinsically motivated to transfer technical knowledge to the host country, e.g., by training local technicians or advising national institutions. Under BOO, the revenue of the project developer comes from selling electricity over a longer period, which means that a clear business case exists for building up local capabilities to assure smooth operation and maintenance under the best possible cost conditions.

In most cases, the costs will be lower if operation and maintenance can be done by national technicians and not by experts who must be flown in from the project developer's home country or other international project sites. Under BOT, the project's formal responsibility may end with handing over the project to national entities. However, the project developer may take serious reputation risks if a project handed over does not meet expectations. An illustrative case is the "Reppie"-project, meant to be the first modern waste-to-energy facility in Africa.[116] After the project was handed over to the national utility Ethiopian Electric Power (EEP) in 2018, the outcomes stayed far below expectations regarding waste that could be processed, the energy that was generated and local emissions of potentially harmful substances. In a market like climate mitigation technologies, with high amounts of international money which will be invested in the future, international project developers have to do what they can to avoid such disappointing outcomes. One way of assuring satisfactory performance is transferring technological knowledge to local companies.

VII. United Nations' actions for sustainable technology and innovation

A. Providing technical and financial support for facilitating technology transfer

Since its inception in 1991, the Global Environment Facility (GEF) has facilitated technology transfer to help developing countries address the global climate change challenge. With the agreement of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, GEF received the

[113] Bjarne et al., 2018: 571.
[114] Coelho and Bolignini 1999.
[115] Bjarne et al. 2018: 572.
[116] Vidican, Altenburg and Stamm, 2020: 157-159.

mandate to finance the transfer of Environmentally Sound Technologies[117] and has evolved into the largest public-sector funding source in this area. Since 1991, financial contributions by donor countries to the several GEF-related trust funds administered by the World Bank have amounted to over USD 30 billion.[118] The GEF supports innovation and technology transfer at critical early and middle stages, focusing on the demonstration and early deployment of innovative options. Its support addresses elevated risks associated with innovation, mitigating the barriers of technology transfer and piloting promising approaches.

UNFCCC member countries also created the technology transfer framework in 2001, and established the expert group on technology transfer (EGTT) to analyze technology development and transfer issues. The technology transfer framework covers five key technology topics: technology needs and needs assessments, technology information, enabling environments for technology transfer, capacity-building for technology transfer, and mechanisms for technology transfer.

Between 2001 and 2010, the technology transfer framework, with support from the EGTT, supported developing countries in addressing technology transfer issues and implementing technology activities. Through these institutions, countries established and consolidated the technology needs assessment (TNA) process. Since 2001, more than 90 developing countries have conducted TNAs to address climate change, addressing both technologies for adapting to climate change and reducing greenhouse gas (GHG) emissions. Many countries have recently identified climate technology needs in their nationally determined contributions (NDCs).

Since 2008, the GEF has supported climate technology activities under the Poznan strategic program on technology transfer. This program aims to scale up the level of investment for technology transfer, helping developing countries to address their needs for climate technologies. The GEF initially created the program with three windows: supporting TNAs, supporting pilot projects linked to TNAs, and disseminating experience on climate technology activities.

In 2010 countries scaled up efforts on climate technology by establishing the Technology Mechanism consisting of two complementary bodies, the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN) (see Box 3). With the creation of the Technology Mechanism, the mandate of the EGTT ended.

The 2015 Paris Agreement also refers to technologies and technology transfer as a means to keep global warming at controllable levels and help developing countries adapt to climate change. At the 2018 UNFCCC conference in Katowice (COP 24), parties adopted the technology framework under the Paris Agreement. The technology framework shall improve the effectiveness and efficiency of the work of the Technology Mechanism by addressing the transformational changes envisioned in the Paris Agreement and the long-term vision for technology development and transfer.

Outside the UNFCCC, financial and technological support for climate action draws from various sources, including ODA, the multilateral development banks, and multilateral climate funds, such as Climate Investment Funds (CIF) and the Nordic Development Fund (NDF). Over the last 12 years, the CIF mobilized over USD 8 billion for climate action. With the five Nordic countries (Denmark, Finland, Iceland, Norway, and Sweden) providing the capital base, the NDF is a smaller fund. In 2020, it offered EUR 350 million for climate financing. The Global Environment Facility has dispersed some USD 20.5

[117] These technologies have the potential for significantly improved environmental performance and include know-how, goods and services, equipment, and organizational and managerial procedures.
[118] https://www.thegef.org/who-we-are/funding

billion in grants in addition to USD 112 billion in co-financing for over 4,800 initiatives focusing on environmentally sound technologies in developing countries since its conception in 1992.[119]

Box 3. United Nations Climate Technology Centre and Network (CTCN)

The United Nations Climate Technology Centre and Network (CTCN) provides technical assistance in response to requests submitted by developing countries via their nationally-selected focal points, or National Designated Entities (NDEs). Upon receipt of such requests, the Centre quickly mobilizes its global Network of climate technology experts to design and deliver a customized solution tailored to local needs. The CTCN does not provide funding directly to countries but instead supports the provision of technical assistance provided by experts on specific climate technology sectors.

The CTCN delivers five main types of technical support on climate technologies: (1) Technical assessments, including technical expertise and recommendations related to specific technology needs, identification of technologies, technology barriers, technology efficiency, as well as piloting and deployment of technologies; (2) technical support for policy and planning documents, including strategies and policies, roadmaps and action plans, regulations and legal measures; (3) training; (4) tools and methodologies; and (5) implementation plans.

Technical assistance on climate technologies is provided to developing countries at the request of their NDEs, free of charge (with a value up to USD 250,000), at local, national or regional levels, to academic, public, NGO, or private sector entities, and for a broad range of adaptation and mitigation technologies. Technical assistance is provided at all stages of the technology cycle: from identification of climate technology needs, policy assessment, selection and piloting of technological solutions to assistance that supports technology customization and widespread deployment.

Source: UNCTAD based on https://www.ctc-n.org/technical-assistance.

Another United Nations framework that addresses the facilitation of technology transfers is the Addis Ababa Action Agenda (AAAA), which provides a global framework for financing development aligned with the 2030 Agenda and its Sustainable Development Goals (SDGs). The AAAA outlines action areas to guide global Financing for Development efforts, including domestic and international resources, public and private resources, international development cooperation, STI and capacity building.

The AAAA established the Technology Facilitation Mechanism (TFM) to support the SDGs by encouraging the development, adaptation, dissemination, diffusion and transfer of environmentally sound technologies to developing countries. The TFM has facilitated collaboration and partnerships on STI for sustainable development through four components: (1) the United Nations interagency task team on STI for the SDGs (IATT); (2) the United Nations 10-Member-Group of High-level Representatives of Civil Society, Private Sector and Scientific Community to support the TFM (10-Member-Group); (3) an online platform for the TFM—"2030 Connect"; and (4) an annual Multi-stakeholder Forum on STI for the Sustainable Development Goals (STI Forum), which also provides formal inputs to the High-level Political Forum on Sustainable Development (HLPF). The STI Forum's main strength lies in its convening power. While it cannot compel stakeholders to share their know-how with others, it provides the space to discuss developing countries' needs and gaps, showcase technologies for the SDGs, and promote networking.

In addition, the United Nations system has several programmes to build new capabilities and skills for all national innovation system actors to develop and deploy technologies for more sustainable and more productive production. International cooperation supports tailored programmes supporting

[119] GEF (2020).

countries in their environmental management efforts, including implementing multilateral environmental agreements and providing sustainable energy. Examples of these initiatives as presented in Annex A.

B. Sharing knowledge and information and conducting research

Governments and other stakeholders should know how firms can absorb new technologies for cleaner, more productive, and competitive production. International cooperation helps to raise awareness in developing countries through sharing lessons learned and best practices, providing foresight about critical trends in STI in key sectors of the economy, the environment and society, and drawing attention to new and emerging technologies.

In this regard, the CSTD is the intergovernmental forum for sharing information and discussing timely and pertinent issues affecting the adoption of frontier technologies for sustainable development. In recent years, the Commission has examined the impact of renewable energy, Industry 4.0, space technologies and blockchain on the economy, society and environment.

The WSIS Forum, established in 2009 as a platform for sharing information and knowledge about ICTs' social, economic, cultural and environmental impacts, is also witnessing an increased number of sessions and workshops for sharing national strategies, policies, laws, programmes and initiatives on clean technologies. In WSIS Forum 2022,[120] out of 200 sessions, more than ten focused on environmental-related policies and strategies, and six discussed the ICTs' role in advancing competitiveness and increasing productivity. WSIS Forum 2023 will feature a special track on Clean Technologies at the request of stakeholders.

In the WSIS Stocktaking database[121] of projects contributing to the implementation of WSIS Action Lines, the importance of a cleaner environment using ICTs has been notably increasing. One hundred forty-five projects submitted in the past five years, 75 per cent of all submitted projects, were in the e-Environment category, while ten ICT projects submitted in 2022 focused on increasing competitiveness.[122]

In an area of rapid technological change, it is critical to identify knowledge and governance gaps and articulate a coherent strategy to advocate for change in international fora. In this regard, UNEP and the European Union launched a global platform called Global Alliance on Circular Economy and Resource Efficiency (GACERE)[123] in 2021 in coordination with UNIDO. Fifteen countries have also joined GACERE to provide a global impetus for initiatives related to the circular economy transition, resource efficiency and sustainable consumption and production.[124]

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[120] http://www.wsis.org/forum

[121] http://www.wsis.org/stocktaking

[122] including Industrial Cluster 4.0 in Mexico (https://industrial-cluster.com/), IT Park in Uzbekistan (https://it-park.uz/), Technological Park of São José dos Campos in Brazil, PROMIS Performance Operational and Multilingual Interactive Services to support Inclusion and Compliance Internationally in Italy (https://www.promis.eu/), Digital Transformation of Small & Medium Business Enterprises project under Ministry of Communication and Information Technology in Qatar (https://godigital.motc.gov.qa/index.php/en/about-dtsme), Exporting Malaysia's Professional & High Value Services Via Digital Freelancing under Malaysia Digital Economy Corporation Sdn. Bhd, and Energy Demand Management under Endeema in Germany (https://endeema.com/). For more details, explore the global WSIS Stocktaking Report 2022 available at https://www.itu.int/net4/wsis/stocktaking/Content/doc/reports/2022/WSISStocktaking2022Report.pdf.

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

[124] GACERE members are: Canada, Chile, Colombia, European Union, India, Japan, Kenya, Morocco, New Zealand, Nigeria, Norway, Peru, Rwanda, South Africa and Switzerland.

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. The collaboration will develop curricula and training on green chemistry practices and document case studies of implementing Green Chemistry in developing countries.[125]

The Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture[126] 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. The Centre conducts adaptive research and development at its own laboratories in Seibersdorf as well as through annual support and coordination of more than 25 coordinated research projects involving some 400 research institutions and experimental stations; capacity-building and technology transfer to over 200 national and regional technical cooperation projects; and technical and policy advice to policymakers. The Joint Centre runs and maintains an information platform in cooperation with the FAO called iVetNet. Launched in 2021, iVetNet[127] brings together laboratories across the globe, enhancing knowledge exchange and learning to improve the prevention and control of transboundary animal and zoonotic diseases for improved animal health and food security. iVetNet contains laboratory infrastructure and facilities data and compiles, disseminates and harmonizes techniques for detecting and characterising transboundary animal and zoonotic pathogens. The Joint Centre also provides technical support and guidance on post-harvest applications of food irradiation techniques to help maintain food quality, reduce the risk of foodborne illness and invasive pests, and support the implementation of appropriate sanitary or phytosanitary controls. Irradiation is environmentally-friendly and safe.

New data and information related to technology and environment are also critical to inform international action. For example, “Greening digital companies: Monitoring emissions and climate commitments,” jointly authored by ITU and the World Benchmarking Alliance, documents the emissions and energy use of 150 of the world's leading tech companies. Beyond assessing corporate climate data and targets, the report highlights best practices for digital companies to slash emissions and achieve carbon-neutral operations. [128]

C. Helping to design policies and strategies

Developing countries’ Governments usually encounter difficulties designing and implementing policies, strategies and initiatives concerning 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 (STIP) Reviews to assist countries in aligning STI policy with their development strategies. STIP Reviews can also provide information on how governments can harness new technologies for cleaner and inclusive economic growth.

UNIDO assists countries in developing a comprehensive range of national strategies, policies, and laws concerning green technology. Through multistakeholder processes, it has assisted in developing

[125] Contribution from UNIDO.
[126] https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/joint-fao/iaea-centre-of-nuclear-techniques-in-food-and-agriculture
[127] https://www.iaea.org/bulletin/strengthening-disease-detection-across-countries-with-ivetnet
[128] https://www.itu.int/en/ITU-D/Environment/Pages/Toolbox/Greening-Digital-Companies.aspx

Health and Pollution Action Plans (HPAP) in Colombia, Ghana, Kyrgyzstan, the Philippines and 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 polychlorinated biphenyls (PCBs),[129] and to reduce plastic pollution, recycle plastics, and produce cleaner plastics at the manufacturing level. As part of the programme "Economic Empowerment of Women in Green Industry" (funded by Germany), UNIDO has 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 (Box 4).

Box 4. Need for gender-responsive green industrial policies

The UNIDO report on Economic Empowerment of Women in Green Industry,[130] based on research carried out in early 2020, found that most green industry policies fail to include concrete gender equality measures. The Policy Assessment report covered four countries: Cambodia, Peru, Senegal and South Africa. Although many policies have good implementation plans, there is significant scope for active policies to become more gender-responsive. Qualitative and quantitative data shows that, in all four countries, there is limited evidence of women's economic empowerment and women's involvement in green industries. The women entrepreneurs interviewed in each country reported similar barriers to starting a green business, including lack of access to funding and financial services, access to technology, lack of information and resources on starting a business, and lack of incentives for businesses operating in green industries. However, the research found that women are more attracted to opportunities as entrepreneurs in green industries than in conventional sectors due to the strong perception that there are more opportunities for women to progress in green industries.

Source: Contribution from UNIDO. Source: UNIDO, How can more women power the transition to green industry? (2021).

D. Helping to set norms and standards

The ITU Telecommunication Standardization Sector (ITU-T) plays a vital role in standardizing digital transformation that supports technology and innovation for cleaner, more productive, and competitive production. Its Study Group 5 on environment, climate change and circular economy[131] 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 (Box 5). ITU-T Study Group 5 has regional groups with representatives from the Asia and Pacific, Africa, Arab, and Latin America regions. These are important platforms that enable understanding those regions' unique contexts and priorities and make sure that their voices are heard in our standard development process. [132]

ITU-T also has established focus groups that identify the standardization needs to develop a sustainable approach to deploying new digital technologies. For example, the Focus on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE) develops technical reports and technical specifications to address the environmental efficiency, as well as water and

[129] PCBs are hazardous chemical that can cause damage to environment and health. Proper management of PCBs will also ensure food safety.
[130] https://www.unido.org/sites/default/files/files/2021-06/Synthesis_Report_Final.pdf
[131] https://www.itu.int/en/ITU-T/studygroups/2017-2020/05/Pages/default.aspx
[132] https://www.itu.int/en/ITU-T/studygroups/2017-2020/05/Pages/default.aspx

energy consumption of emerging technologies, and provide guidance to stakeholders on how to operate these technologies in a more environmentally efficient manner.

Box 5. Examples of guidelines and standards related to green technologies

- Environmental efficiency of digital technologies
  - ITU-T L.1317[133] Guidelines on energy efficient blockchain systems
  - ITU-T L.1331[134] Assessment of mobile network energy efficiency
- Smart Energy Solutions
  - ITU-T L.1380[135] Smart energy solution for telecom sites. Focuses on smart energy solutions for telecom sites, mainly on the performance, safety, energy efficiency and environmental impact, when the system is fed by various types of energy such as photovoltaic (PV) energy, wind energy, fuel cells and the grid. The Recommendation also considers smart energy control; for example, if the grid is off, how can the energy flows be managed to achieve higher energy efficiency, how to get green energy, etc.
  - ITU-T L.1381[136] Smart energy solutions for data centres
  - ITU-T L.1382[137] Smart energy solutions for Telecommunication Room
  - ITU-T L.1383[138] Smart energy solutions for city and home applications. focuses on smart energy solutions in different application scenarios facilitating energy saving and carbon emission reduction. Besides their application in the field of ICT, such as in base stations, data centres and telecom centres, smart energy solutions have been applied in cities and homes as an advanced update to ICTs.
- Circular Economy and E-Waste
  - ITU-T L.1000[139] Universal power adapter and charger solution for mobile terminals and other hand-held ICT devices
  - ITU-T L.1023[140] Assessment method for circular scoring
  - ITU-T L. 1031[141] Guideline for achieving the e-waste targets of the connect 2030 agenda.
- Recommendation ITU-T L.1220[142] introduces the standard for innovative energy storage technology for stationary use. This Recommendation introduces an open series of documents for different families of technologies (e.g., battery systems, super-capacitor systems).
- Recommendation ITU-T L.1470[143] provides detailed trajectories of greenhouse gas (GHG) emissions for the global information and communication technology (ICT) sector and sub-sectors that are quantified for the year 2015 and estimated for 2020, 2025 and 2030.

Source: Contribution from ITU.

[133] https://www.itu.int/rec/T-REC-L.1317/en
[134] https://www.itu.int/rec/T-REC-L.1331
[135] https://www.itu.int/rec/T-REC-L.1380/en
[136] https://www.itu.int/rec/T-REC-L.1381
[137] https://www.itu.int/rec/T-REC-L.1382/_page.print
[138] https://www.itu.int/rec/T-REC-L.1383-202110-I
[139] https://www.itu.int/rec/T-REC-L.1000/en
[140] https://www.itu.int/rec/T-REC-L.1023
[141] https://www.itu.int/rec/T-REC-L.1031/en
[142] https://www.itu.int/rec/T-REC-L.1220/_page.print
[143] https://www.itu.int/itu-t/recommendations/rec.aspx?rec=14084

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

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 the opportunities.

At the same time, many actors are contributing to the uptake of green innovations in developing countries. They do this with varying logic and following different objectives, from purely business cases to contributing to global public goods and philanthropy. These fragmented support structures could hinder faster progress in green innovations 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.[144]

Creating a green innovation ecosystem in developing countries and emerging economies is not a linear process, and diversity of support is necessary. Successful innovations in developing countries, like the mobile payment system M-Pesa, developed in Kenya around 2005, are usually not the outcome of a coherent long-term strategy with different actors working together in a planned way. They always have elements of chance.

However, most actors and lines of support in the field of green innovations focus on the outputs and possible outcomes of green innovation processes, e.g. the implementation of energy-efficient modes of transport or production or the diffusion of fuel-saving improved cooking stoves, but less attention is being paid to strengthening the capacities of developing countries to develop own innovative solutions to sustainability issues and being able to actively take advantage of green windows of opportunities. 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. Among bilateral donors, mainly Sweden, and Canada are clearly committed to promoting research and innovation systems in the partner countries; others like the United Kingdom and Germany support the qualification of researchers from developing countries and their exchange with their peers in Europe.

Focusing on outputs and outcomes of green innovation processes 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. Many authors writing on the fate of technology transfer processes assign a critical role to host country policies and efforts, mainly in building local technological capabilities and absorptive capacity and creating a conducive framework and a good balance between competition and collaboration.

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

1. Establishing the required policies, legislative frameworks and regulations

Environmental and energy policies are critical for the emergence of GWO based on their domestic deployment and market creation effects. At the same time, industrial and STI policies are also important to promote the firm and system-level capabilities to respond to opportunities. This requires that policies, typically developed in separate policy domains, are co-created across the energy-

[144] Pandey, Coninck and Sagar, 2021.

environmental and industrial spheres. For example, demand-driven initiatives to facilitate energy system greening, such as feed-in tariffs or auctions, must develop in alignment with active industrial policy and appropriate measures to ensure domestic localization of economic activities and production and innovation capabilities.[145]

Similarly, in several latecomer countries, there are national strategies to strengthen the adoption of frontier digital technologies in the manufacturing industry, but these strategies are often not coordinated with interventions and initiatives in the environmental and energy domains to unlock the sustainability potential of digital technologies. For instance, a study focusing on the footwear industry in Bangladesh shows that the lack of environmental regulations and low environmental awareness result in low motivation to adopt digital technologies to increase sustainability in the sector.[146] To address opportunities for environmental upgrading, it is critical to align innovation and industrial policies with environmental policies. Besides, digital and green objectives should also be accounted for in global value chain-oriented policies aimed at increasing participation and improving value capturing in GVCs.[147] In the European Union and countries such as Canada and the Nordic-Baltic countries, there is an increasing awareness about the importance of investing in appropriate initiatives to exploit the opportunities offered by digitalization for environmental protection and climate action, and to limit the negative environmental impacts of digitalization itself.[148] To take advantage of the windows of opportunities opening from the digital and green transition in manufacturing GVCs requires that policies, typically developed in separate policy domains, are co-created across the energy-environmental, industrial and foreign investment spheres.

The complementarity among different policies results in the need for effective coordination and cooperation. Also critical is the integration and coordination between agencies, bodies and research centers with the applied agencies and sectors to achieve technology and innovations toward cleaner production, resource conservation and sustainable development. For instance, in the successful case of the biomass industry in Thailand, the Minister of Energy is the key agency promoting environmental legislation encouraging factories to invest in biogas production in coordination with policies to support the strengthening of the sectoral innovation system. This led to a network of cooperation with other relevant actors, such as the Minister of Science and Technology involved in the research and development of biogas technology and demonstration programs, the Board of Investment under the Office of the Prime Minister for the introduction of tax incentive measures to attract private investors to the industry and various public research centres and universities establishing extensive training programs to build domestic capacities in setting up and maintaining the installed systems.[149]

2. Strengthening technical and innovation capacity and building knowledge

Green technologies are usually highly biased towards capital and high-skilled labour and require significant R&D investments. The accumulation of local specialised scientific, technological, managerial and organizational capabilities is also critical for absorbing, adapting and eventually developing relevant knowledge in renewable energy industries. Thus, to transform them into windows of opportunity, latecomer economies need to build up certain production and innovation capabilities, including absorptive capacity, to avoid getting stuck in the development trap.[150]

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[145] (Landini et al., 2020).
[146] Dwivedi et al., 2022.
[147] Pietrobelli et al., 2021.
[148] For more information see consilium.europa.eu and Nordic Council of Ministers (2021).
[149] (Suwanasri et al., 2015).
[150] Lee, 2019.

Policy tools that Governments can use to strengthen green R&D capacities range from subsidies programmes such as the one implemented by the Swiss Federal Office of Energy, to centres for promotion of R&D such as the "Niche Centers in the Regions for R&D" in the Philippines, or RDI support programmes promoting green technologies from R&D to commercialisation and co-creation based RDI platforms such as those being implemented in Türkiye, where university, government and industry actors collaborate and join efforts and capabilities (see Box 6).

Governments can also strengthen technical capacities through a dedicated learning process and investments in training programs, such as those in Thailand universities and research centres.[151] In China, in 2008, the central government launched a recruitment program for attracting global experts, named the "Thousands of Talents Plan", which offered full-time positions in research institutes and universities with attractive salaries and benefits. The program significantly attracted many Chinese researchers with high degrees in western universities who had contributed to advanced research in fields such as PV cell technologies.[152]

Skills learning also happens through learning-by-doing, on-the-job training and interactions within the domestic sectoral system. In the Chinese biomass industry, state-owned design institutes play a crucial role in diffusing technical knowledge within the domestic industry. The design institutes are licensed to undertake the design of construction facilities, and it is mandatory to involve them in constructing biomass power plants. These institutes learned about the industry from their interactions with the pioneer and leading companies and then disseminated the knowledge to other Chinese biomass producers.[153]

In many developing countries, firms, technologists, innovators, and researchers have less experience and exposure to green and frontier technologies. Many firms have yet to acquire and adopt Industry 3.0 technologies, such as automation and ICT, in the manufacturing process, and more advanced companies often operate in ecosystems characterised by an extreme digital gap.[154] Therefore, it is challenging for adopting firms to integrate with potential backward or forward suppliers. Understanding the variety of green technologies in the market is also a challenge to governments and firms in developing countries.

Different countries find themselves at varying levels of readiness in terms of capabilities. Most of them need to build their capacities to adopt and adapt digital technologies for greening GVCs. Lack of adequate digital skills is a major limitation. In latecomer countries, there is also a lack of the specific analytical skills needed to adopt, use, and adapt the new technologies. Adopting digital technologies also requires developing complementary, specific skills to the new technologies, such as analytical skills, including science, technology, engineering and math, ICT related skills and soft skills.[155] Education policies should enhance data literacy and digital skills as they are in significant shortage. Policies should also support firms and other stakeholders in providing training on digital competencies and programs to develop lifelong learning capabilities and entrepreneurship skills. In Guatemala, for example, the project Stellar Ixq-Saq'e creates green-powered digital community centres in regions without electricity, extending the access to technology infrastructure. Moreover, the project empowers women community leaders that run the digital centers and provide services such as digital literacy trainings with a gender perspective to contribute to reducing the technology gap[156].

[151] (Suwanasri et al., 2015).
[152] (Shubbak, 2019).
[153] (Hansen and Hansen, 2020).
[154] (UNIDO, 2020)
[155] (UNIDO, 2020).
[156] Contributions from the Government of Guatemala.

Governments also need to support businesses, including SMEs, to have the digital skills needed to use ICT efficiently in business functions such as market research, product development, sourcing, production, sales, and after-sales services.[157]

Box 6. Promoting R&D in green areas

In Oman, the Innovation Park Muscat is an initiative under the Ministry of Higher Education, Research & Innovation that encourages scientific research, innovation, and collaboration between various sectors. It provides access to various facilities and services to create an environment that motivates innovators, entrepreneurs, and companies to develop amazing ideas in energy, food and biotechnology, health, water, and environment sectors.

In the Philippines, the Department of Science and Technology (DOST) supports R&D projects in line with green technology and innovation. Some topics covered are: Machinery for Decontaminating Rice Hull as Litter Floor for Broiler Breeder Production; Black Soldier Fly (BSF) farming for agricultural productivity and waste management; Development of nanofertilizer from poultry waste biogas digestate; and Extraction of Phytohormones from Waste Coconut Water using Biochar Derived from Agricultural Residues. The DOST is pushing for the passage of the Science for Change Bill, which provides programs for establishing research and development (R&D) centres and collaborative R&D between the academe and the industry. This initiative bolsters the productivity and competitiveness of industry players and drives R&D on renewable forms of energy and green technologies. Also in the Philippines, the "Niche Centers in the Regions for R&D" or NICER are R&D centers under the Department’s Science for Change Program (S4CP) that will focus on sectors related to Health and Industry, Energy, and Emerging Technology. This initiative will allow the country's academic and R&D institutions to upgrade their research facilities, develop policies, transfer technologies, and ramp up regional initiatives and efforts toward a competitive innovation ecosystem. Through these R&D centers, the DOST cultivates the innovation landscape in various sectors to ensure no one is left behind in R&D progress.

In Switzerland, the Swiss Federal Office of Energy subsidizes research projects that correspond to the priorities of the current energy research concept of the SFOE 2021-2024. The focus is on application-oriented and development-related research projects. The SFOE's energy research programs cover the entire spectrum of energy research and all major technology fields in renewable energies and energy efficiency. There is also a socio-economic research program and a program on the social aspects of dealing with radioactive waste.

In Türkiye, TÜBİTAK (The Scientific and Technological Research Council of Türkiye) designs its R&D support tools to the areas of compliance with the European Green Deal for achieving impact and for mobilizing the R&D and innovation accumulation within the scope of co-creation models. The 1501 Industrial R&D Projects Grant Programme and 1507 SME R&D Start-up Support Programme are two of these programmes. Also, TÜBİTAK 1512 Entrepreneurship Support Programme’s 2021 call targeted R&D and innovation topics within the scope of the European Green Deal Agreement. 1512 Entrepreneurship Support Programme’s 2022 call also targets “green growth”. In TÜBİTAK’s new call for proposals for the “High Technology Platforms Support” and “Industry Innovation Networks Mechanism (SAYEM)”, areas focusing on sustainable solutions to mitigate and adapt to climate change attracted significant attention.

Egypt owns the biggest research, development, and innovation (RDI) and pilot plants facilities in renewable energy in the region belonging to the Academy of Scientific Research and Technology, including stations for concentrated solar power and water desalination in Borg El Arab and China-Egypt Joint Lab for PV in Sohag.

[157] (UNCTAD, 2022).

Source: UNCTAD based on contributions from the Governments of Egypt, Oman, Paraguay, the Philippines, Switzerland, and Türkiye.

3. Identifying, prioritizing and fostering green technologies and potential new sectors for sustainable diversification and structural transformation

Predicting and selecting which green window of opportunity to develop, for how long and in what way involves choices about transformation based on highly incomplete information over long-time horizons and in the face of 'emergent' developments in green demand, technology and institutional changes. Policymakers should be ready and informed to promote GWO through public actions. This requires building capacity on technology assessment for the development, use, adoption and production of green technologies and new analytical methods to identify potential new sectors for more complex and more sustainable diversification.

The identification and selection processes for green technologies and new green sectors need to be combined with assessing existing technological and productive capacities, global and domestic demand, the potential for natural resources (e.g. wind conditions or agricultural waste for bioenergy), supply creation and dynamic learning curves. Policymakers must be prepared to adjust the institutional framework conditions as the green windows of opportunities unfold.

Critical in this process is the adoption of participatory methods of assessment involving: 1) policymakers (especially those closely related to innovation in Ministries of Science, Technology and Innovation, Trade, Industry, and Education) who have broad decision-making power and the ability to design and implement public policies to increase national STI capacity and effectively support systems of innovation; 2) private sector actors who have an understanding of the challenges faced in building firm-level technology and innovation capacity, the local knowledge of the business environment and the effects of policies in place as well as clear ideas on actions needed for upgrading and innovating; 3) academic and research institutions who know of specific technologies and R&D capacity; and 4) civil society organizations who know the concerns and priorities of marginalized groups, and can voice these concerns and increase awareness in public institutions.

National and local governments could foster the domestic development of green technology sectors and greener economic sectors through vertical policy instruments such as clusters, smart specialization initiatives, pilot and demonstration projects and areas, and technology roadmaps (see Box 7 for examples from CSTD member countries). In non-mature industries such as CSP and green hydrogen, demonstration projects are vital for developing new technologies and designs. In the CSP case in China, the industry development has been supported by promoting "megaprojects of science-research". Through these projects, the Government aimed to build knowledge and experience within domestic firms, developing industrial and commercial projects that could facilitate learning through experimentation with different technical designs on the ground.[158] Similarly, to support the development of a domestic green hydrogen industry, the Chilean National Development Agency (CORFO) is also setting up several pilot projects with the significant involvement of international investors.

Prioritizing new technologies and sectors will also require the associated financial support. For example, in Austria, the Ministry of Climate Protection and Environment will implement a EUR 300 million investment subsidy budget for green energy in 2022.[159] in Belgium, the Walloon Government

[158] (Lilliestam et al., 2021).
[159] https://renewablesnow.com/news/austria-passes-eur-300m-subsidy-budget-for-green-energy-780126/

plans to invest more than 160 million euros to support the development of green hydrogen sector as part of its initiatives to lay the foundations for the hydrogen and synthetic fuels economy.[160]

Box 7. Examples of policy instruments for fostering green technologies and sectors

Clusters

In Austria, to strengthen hydrogen research in the country and contribute to the national hydrogen strategy currently being developed, Graz University of Technology and the Montanuniversität Leoben are intensifying their activities in the field of hydrogen within the framework of a hydrogen cluster that comprises 19 universities and research institutes and several companies in Austria's Green tech Valley.[161]

In Belgium, GreenWin is a regional competitiveness cluster of Wallonia created in 2011. It is a non-profit whose objectives have been decided with the Walloon government. It is dedicated to the industrial and environmental transition of the following sectors: chemicals, innovative construction and renovation processes and materials, environmental technologies (Green Techs). GreenWin facilitates and accelerates technological and non-technological innovation projects capable of meeting these challenges by organising unlikely encounters between companies of all sizes, the academic and scientific communities and key partners in the Walloon, interregional and international ecosystems. GreenWin also assists its members in the ideation of new projects and in the valorisation of their portfolio of products, processes and services, including internationally. The goal is to stimulate the creation of complete value chains in Wallonia, generate new sustainable, eco-responsible and non-relocatable industrial sectors, and contribute to creating and maintaining sustainable Walloon jobs. To this end, each project supported by GreenWin is subject to a life cycle analysis.[162]

In Belarus, the innovation and industrial cluster "Electrotransport" has been created to develop and manufacture new means of electric transport and its components and to effectively coordinate between research and technology, education and industry sectors. Several electric vehicles were developed with the cluster, for example, electric buses, autonomous trolleybuses and trolleybuses with an extended autonomous course and power electronics.

Demonstration areas and projects

In the Philippines, the DOST's Region IVB Office, through its Provincial S&T Office in Marinduque led the 6M-project on the deployment of Solar Energy Systems (SES) to 29 Rural Health Units (RHUs) regionwide. Also, DOST Marinduque office serves as a demonstration area for "green building" using solar energy systems. As a result, different government agencies in the province signified interest in adopting SES.

In India, the Department of Science & Technology (DST) works at the initial stages of the technology and innovation chain for cleaner, more productive, and competitive production. DST supports R&D, technology concepts, experimental proof and technology demonstration projects on Clean Energy.

In the Russian Federation, in February 2021, a pilot program was launched to deploy carbon polygons within the country's territory. A carbon polygon is one or several plots of land where a set of activities is taking place to engage scientific, workforce and infrastructural potential to facilitate the development and testing of technologies for controlling the balance of climatically active gases in natural ecosystems. In addition, the polygon provides training of highly qualified personnel in state-of-the-art methods of environmental control, advanced technologies for low-carbon industry,

[160] Contribution from the Government of Belgium.
[161] https://www.greentech.at/en/hydrogen-research/
[162] https://www.greenwin.be/en/

agriculture and municipal economy. The initiative is expected to play a key role in developing a reliable nationwide system for monitoring greenhouse gas emissions in Russian ecosystems.

In Switzerland, the SFOE Pilot and Demonstration Program (P+D programme) of the Swiss Federal Office of Energy supports the development and testing of new technologies, solutions and approaches in the area of economical and efficient use of energy, energy transmission and storage as well as the use of renewable energies. The P+D program is positioned at the interface between research and the market and aims to increase the level of maturity of new technologies to ultimately bring them to market maturity. [163]

Technology roadmaps

In Türkiye, "Green Growth Technology Roadmap" studies are being carried out by the Ministry of Industry and Technology and TUBITAK for the Iron-Steel, Aluminum, Cement, Chemicals, Plastics and Fertilizer sectors; which are critically important for the Turkish economy and have high carbon emissions. As a result of the Technology Roadmap studies, priority R&D and innovation themes for each sector will be detailed. Benefiting from the outputs of this study, proper STI and investment support programs will be designed in cooperation with Ministry of Industry and Technology especially for projects that will provide domestic solutions to the technological needs of private sector organizations in our country that will enable them to adapt to green transition.[164]

In Chile, CORFO has developed the "Transforma" Strategic Programs, including the Roadmap for the Sustainable Management of Construction and Demolition Waste (RCD), and the Roadmap Circular Economy of Agroindustry, carried out by the Ministry of Agriculture.[165]

In Peru, the Roadmap towards a Circular Economy in the Industry Sector was approved to establish State actions to promote a progressive transition from a linear to a circular economic model of the activities of manufacturing and processing.

Source: UNCTAD based on contributions from UNEP and the Governments of Austria, Belarus, Belgium, Chile, India, Peru, the Philippines, the Russian Federation, Switzerland, and Thailand.

4. Investing in green innovation and reducing financial constraints

Introducing green technologies in new markets usually requires significant and sustained funding. The lack of financial resources for R&D programs on technologies for cleaner, more productive and competitive production is a persistent problem in developing countries.

Also, financing for green SMEs is a significant gap preventing governments from promoting eco-innovation, and better information is needed for policymakers to enact policies to encourage financial institutions to provide financing, particularly for SMEs that make the bulk of national economies, yet still struggle to provide information for financing. Better education and incentives for financing institutions are needed.

Scaling operations often require high-end and capital-intensive technologies, which are difficult to introduce as they require significant capital investment. For example, in the waste sector, companies perform the waste sorting manually as it would require significant capital investment to use machinery. This often prevents new entrepreneurs from entering the industry and prevents existing ones from expanding their businesses to a larger scale. The lack of fiscal incentives for purchasing

[163]https://www.bfe.admin.ch/bfe/de/home/forschung-und-cleantech/pilot-und-demonstrationsprogramm.html
[164] Contribution from the Government of Türkiye.
[165] https://www.corfo.cl/sites/cpp/areas-de-trabajo/programas-estrat%C3%A9gicos-integrados

recycled materials is a barrier to creating a market for recycled outputs for the industrial, manufacturing and service sectors. [166]

In Industry 4.0, financial constraints are a significant challenge among firms, particularly for smaller companies. In a study on India surveying several manufacturing industries as diverse as automotive, metals and machinery, food, textile and electrical equipment, financial constraints are considered the most crucial challenge due to the huge investments needed for acquiring new frontier technologies, especially for SMEs.[167] The lack of investment capacity has also been emphasized in the case of the Brazilian manufacturing industry based on the analysis of a wide collection of technical reports from key stakeholders.[168]

Opportunities and challenges for adopting such technologies are also quite heterogeneous among different industries and companies. Adopting them in high-tech industries and firms with larger financial resources is more feasible than in labour-intensive industries and smaller firms with resource constraints.[169] A study on the plastic industry in Brazil confirms that investments in Industry 4.0 technologies are hindered by financial constraints and the large technological gap characterizing smaller companies.[170] In these companies, changing manufacturing technologies can pose a significant challenge because implementing new technologies can incur high costs.

A further challenge is that it could be rather difficult to convince firms and financial intermediaries to invest in this pioneering area that combines green objectives and digital technologies because there is limited business evidence about the return on investments. Therefore, innovation and technology funds financed by the public sector, international donors and development banks are key to starting demonstration projects.[171] Besides, investments in digitalization in developing countries are still mainly driven by economic motivation rather than social or environmental reasons. For example, a report from the Brazilian National Confederation of Industries confirms that domestic companies have mainly introduced digital technologies intending to increase productivity, whilst social and environmental benefits are not among the top priorities.[172]

Several Governments have implemented programmes to tackle these challenges. For example, in the Philippines, the small enterprise technology upgrading program (SETUP) aims to address the technical and financial challenges by providing MSMEs: (a) seed funds for technology acquisition; (b) needed equipment and equipment upgrading; (c) technical training and consultancy services; (d) packaging and label design; (e) database information systems; and (f) support for the establishment of product standards, including testing, and calibration of equipment.[173] In South Africa, the Economic Reconstruction and Recovery Plan[174] post-COVID includes support for MSMEs 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.[175] In Uganda, the Uganda Green Enterprise Finance Accelerator (UGEFA) facilitates the flow of green finance into the Ugandan SMEs sector by strengthening green SMEs and improving available financial mechanisms for

[166] Contribution from UNEP.
[167] (Lutra and Mangla, 2018).
[168] Cezarino et al. (2019).
[169] (Abdul-Hamid et al., 2021).
[170] (Nara et al., 2021).
[171] (UNCTAD, 2022).
[172] Nara et al. (2021).
[173] Contribution from UNIDO.
[174] https://www.gov.za/sites/default/files/gcis_document/202010/south-african-economic-reconstruction-and-recovery-plan.pdf
[175] Contribution from UNEP.

SME debt financing.[176] The Egyptian Ministry of Planning in coordination with the Ministry of Higher Education and Scientific Research, allocated funds for RDI projects to support Egypt's climate change adaptation efforts. [177] Paraguay, established in 2014 the Paraguayan Program for the Development of Science and Technology (PROCIENCIA), a public funding program for STI that aims at promoting national capacities through calls for research and development projects, incentives for researchers, creation of national postgraduate programs with a focus on research, and other initiatives for the national development of science. In recent years, research related to the potential for hydrogen production from renewable energy sources in Paraguay, the development of technologies for renewable energy applications and the creation of graduate programs focused on chemistry and electronic engineering with an emphasis on renewable energy have been funded.[178]

5. Developing a digital infrastructure

Digital infrastructure is a precondition for promoting the adoption and adaptation of Industry 4.0 technologies and their use to make value chains greener. Digital infrastructure, including ICT networks and digital connectivity, platforms and data centres, submarine cables and cloud infrastructure, is required to deploy industry 4.0 technologies.[179] The quality and speed of Internet connections affect the ability of firms in developing countries to use digital technologies. The divide in Internet connection quality is very significant between developed and developing economies. 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 mobilising 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.

B. International cooperation for green innovation collaboration

1. Promoting sustainability-oriented innovation systems in developing countries

There is a need for a paradigm shift in international cooperation, considering the strategic importance of green innovations to assure a safe operating space for humanity. International cooperation should shift from supporting single green innovations (be it fuel-saving cooking stoves, be it hydrogen-powered busses) to a determined global action to assist developing countries in building and strengthening their sustainable-oriented innovation systems.

Innovation systems that are geared towards the normative approach of contributing to the sustainability transition have three specific characteristics.[180] First, they often operate under conditions of market failures because, in many markets, environmental costs are still not entirely internalized, and green technologies might not be economically feasible, relying exclusively on market forces. Financing new green technologies is a challenge, mainly at the "Valley of Death"; when a technological invention leaves the labs and substantive funding must be mobilized for demonstration

[176] https://ugefa.eu/
[177] Contributions from the Government of Egypt.
[178] Contributions from the Government of Paraguay.
[179] (UNCTAD, 2022).
[180] Foxon et al., 2005, Stamm et al., 2008 and Altenburg and Pegels, 2012.

and pre-commercial projects.[181] Many complementarities in NIS may be partially mobilized through international cooperation, like international climate finance substituting financing by national banks.

Second, a green innovation often cannot unfold on a white map but must compete successfully against incumbent technologies. This is not only a challenge for techno-economic reasons but also for political economy reasons. Incumbent technologies will often have established and strong strategic interest groups on their side, while alternative, green technologies might not have strong political backing in the beginning.

And third, sustainable-oriented innovation systems operate under high time pressure and high degrees of uncertainty. Many countries have committed to becoming carbon neutral in the next two to three decades, which implies serious technological challenges. This means that green technologies must be made technological mature and rolled out on a large scale in a much shorter time than has been the case in economic history.

Innovation cooperation in building a sustainable-oriented innovation system should be the new paradigm in international technology transfer[182] to cover the whole cycle from technology development to implementation. Cooperation is also seen as a more appropriate term than "transfer", given that all partners should work together for common objectives and that achieving sustainable development requires mutual efforts.

Most elements of such systemic international cooperation are well-known and often applied by governments, private and third sector; an example is the Network for Resource Efficient and Cleaner Production (RECPnet)[183] (see Box 8). However, most often international cooperation is fragmented and not consistent over time. The core of such cooperation must be supporting developing countries in developing their strategy for establishing an innovation system which empowers them to contribute to global climate efforts and tackle additional sustainability challenges. Based on such a strategy and related gap analysis, international actors may decide 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. Following the OECD principles of aid and development effectiveness, national governments of the host countries must coordinate the contributions.

Box 8. Network for Resource Efficient and Cleaner Production (RECPnet)

The Network for Resource Efficient and Cleaner Production (RECPnet), jointly created by UNEP and UNIDO, brings together over 70 providers of specialized advisory services to companies and institutions in 60 countries. In its mission of facilitating North-South, South-South and South-North-South collaborations, the RECPnet disseminates relevant knowledge and innovative technologies, promotes best practices and real experiences to emerging economies for supporting the advancement of environmentally sustainable growth. Within its overarching mission, RECPnet members have positioned themselves to an increasing extent as facilitators between business and public institutions, for which they often serve as partners or consultants on matters related to cleaner production and sustainable consumption. Through this, the Network is already an important ally of the 2030 Agenda, helping translate and optimize the SDGs' targets and indicators into relevant business metrics and support initiatives. Developing countries' private sector and the government will require financial and technological support to adopt these technologies. The

[181] Etzkowitz, 2006: 314.
[182] Pandey, Coninck and Sagar, 2021.
[183] https://www.greenindustryplatform.org/initiatives/recpnet

international community, including the CSTD can take advantage of these platforms and work with the relevant UN organizations to support the promotion of cleaner technologies in the industries.

Additionally, technical intermediaries (also known as national cleaner production centres) are tasked with identifying green innovations and helping SMEs to adopt and implement them. They are often part of the RECPnet. Their engagement in eco-innovation projects has proven an effective means of building country ownership and sustaining results. Experience shows that these technical intermediaries continue to support businesses in countries to advance over time in adopting green technologies and innovation and work closely with national partners, including governments, to create the enabling environment.

Source: Contribution from UNIDO.

2. Towards a more partnership-oriented approach to green technology development

Global efforts should be put in place to accelerate the development and deployment of green technologies under the philosophy of common contributions to common goods.[184] The groundbreaking work of the Intergovernmental Panel on Climate Change (IPCC) might serve as a role model. Even under such an approach, governance mechanisms should be put in place to avoid the North-south divide in knowledge management and ensure that developing countries' views and priorities are considered equitably.[185] A global partnership is also the main philosophy of the Paris Agreement of 2015 and the Sustainable Development Goals (SDGs), especially SDG 17 "Partnership for the Goals". As nearly all governments have approved Paris Agreement and SDGs, this should also be a guiding principle for public promotion of green innovations through politics and funding.

A general focus on partnership and common goods orientation does not mean the absence of conflicting views and diverging interests. This can be shown by the current discussion about a global transition towards a "green hydrogen economy". The recent debate about the EU energy "taxonomy" made clear that countries have different views on what clean energy as the basis for green hydrogen production should be. For Germany, the term "clean energy" should be exclusively reserved for renewables (wind, solar), while France opted for including nuclear energy among the clean energy sources.

The partnership-oriented approach requires enlightened international leadership to push for the common good beyond the apparent tensions between public and private goods and national and global interests. Green innovations often result from significant R&D investments by private actors who strive to protect their intellectual capital through patents and link its usage by third parties to the payment of royalties. National societies hosting inventors and innovators expect social benefits, e.g. in the form of employment. This contradicts the rapid and widespread diffusion of innovations, for example, to reduce emissions and save energy, necessary to protect the environmental fundaments for the survival of future generations.

Loud calls for cooperative and partnership approaches to green technology development are required to influence private and national interests that shape international cooperation for green innovations. It is more the case as the green transformations imply not only GWO for developing countries but also disruptive changes and tensions for many more technologically advanced societies, e.g. loss of employment in fossil fuel sectors or rising prices for energy and mobility. Under such conditions, policymakers, in the search for legitimacy and ownership for the green transformation, will be keen to assure that national companies can benefit from emerging windows of opportunity and that employment will be built up at home. This might become an even more critical point on governments'

[184] See Pandey, Connick and Sagar, 2021.
[185] Blicharska, Malgorzata et al., 2017, and Stamm, 2022.

agenda, as the war in Ukraine leads to a prolonged economic crisis in different parts of the world. International and national governance of green innovation have to be able to deal with these tensions.

3. Shifting research for green innovations from the national to the multilateral level, including open innovation approaches

The largest parts of global STI efforts are governed at the national level. This means that national stakeholders define agendas and priorities of research, and financing comes from public and private sources in the country. In most cases, national companies and societal groups are first addressed when designing pathways to impact.[186] To some extent, research and innovation have been reluctant to follow the train toward globalization. The problem has deep structural roots considering the huge North-South divide in STI performance and that, to some extent, the countries which are especially affected by climate change and other environmental crises (e.g. depleting fish stocks, loss of biodiversity) are those that have the least resources available for STI. STI agenda and priorities must identify and tackle this structural problem.

Countries with different levels of socio-economic development and ecological conditions will set diverse priorities in their R&D agenda. In high-income countries, R&D in the agricultural sector has declined, reflecting that food availability is no longer an issue and overall consumption patterns are changing towards processed food and eating out. Middle-income countries face different challenges in the food sector, such as swelling populations and increased prosperity. They focus, thus, aggressively on R&D to increase agricultural productivity.[187] Similarly, in energy research, much of the focus in industrialized countries is on decarbonizing grid-connected energy systems (which is good from a global common goods perspective). However, very little is done, for instance, to develop easy-to-roll-out mini-grids, fed by renewable energies, which is a topic mainly relevant to Low-Income Countries in Africa and Southern Asia. In the current green hydrogen debate, the main focus is on hydrogen to decarbonize the steel industry. In contrast, a developing country's perspective would likely focus on using green hydrogen to produce clean ammonium and, thus, green nitrogen fertilizer to avoid an extended food security crisis.

Shifting research for green innovations from the national to the multilateral level could be an important step forward. Examples of multilateral modes of research and research cooperation are few (see Box 9 for a brief presentation of three examples).[188] The Consultative Group on International Agricultural Research (CGIAR) 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. International organizations and donors could replicate the CGIAR model in adaptive ways to other sectors to shift research toward the needs and conditions of developing countries.

What would require a closer analysis is whether multilateral research should cover the whole STI value chain. One approach could be to develop and bring research and development close to technology maturity and invite private companies to take care of rapid deployment. An alternative would be to focus much more on earlier stage research and bring a technological concept to the laboratory stage and perhaps early demonstration projects. Both approaches make sense but would require differing

[186] Stamm, Figueroa and Scordato 2012.
[187] Pardey et. Al, 2016.
[188] These cases have been analyzed in more detail in an international research project under the umbrella of the OECD (2012).

institutional setups and funding. They might both be valid but with varying relevance in different sectors, such as green energy or hydrogen applications.

What could be conceptualized as an element of modern modes of multilateral research are open innovations. The research questions developed 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 currently no central repository of such technologies, making it difficult for producers in developing countries to locate, access and incorporate them in 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.[189] This 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 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.[190]

What would be important is to combine the strength of multilateral and publicly funded research with the creativity and endeavours of the private sector. The outputs of the multilateral R&D efforts could be made available to interested stakeholders who commit to bringing them to societal practice quickly.

Box 9. Examples of multilateral modes of research and research cooperation

Consultative Group on International Agricultural Research (CGIAR): CGIAR was formally launched in May 1971 by the World Bank and 16 donors, including governments of industrialized countries and other organizations CGIAR has, since then, become a major player for world agricultural research and a reference in terms of how scientific research can help develop agricultural solutions for the poor (Fabre/Wang 2012: 45). CGIAR is the largest global partnership focusing on "agricultural research for development" particularly in developing countries with a vision to create a "world free of poverty, hunger and environmental degradation". It operates globally through its 15 research centers in close association with "hundreds of partners, including national and regional research institutes (NARIs), civil society organizations, academia, development organizations and the private sector" (Pardey / de Conink / Sagar 2020:7). CGIAR's mandate is to contribute to regional or global public goods and, thus, technologies and knowledge generated are in principle freely transferred of shared (Fabre / Wang 2012: 50).

Global Carbon Capture and Storage Institute: When the Global CCS Institute was launched in 2009 it had 15 governments and more than 40 companies and industry groups as foundation members. By 2010 membership had increased to 263 members, including 26 national governments. The mission of the Global CCS Institute is to accelerate the roll-out of commercial CCS for a low-carbon future. To achieve this objective, a set of CCS demonstration projects shall be rolled out and capacity building and knowledge sharing are crucial. The role of IPR has been intensely discussed since the institute's formation. While on the one hand, IP rights of partners are respected, the goals are 1) to gather and package non-proprietary information on CCS and make it accessible to all stakeholders, 2) to make IP generated through program activities as widely accessible to members as practical

[189] https://unctad.org/system/files/official-document/ecosoc_res_2021d30_en.pdf
[190] https://unctad.org/system/files/official-document/presspb2021d8_en.pdf

and to make IP jointly generated by the Institute and its partners through Institute activities available in reasonable terms to other Institute activities (Delegation 2012: 237).

International Energy Agency (IEA) Implementing Agreements: The IEA, an intergovernmental organization, acts as an energy policy advisor to its member countries. Through its work, IEA supports their efforts to ensure reliable, affordable and clean energy for their citizens. The triple goals are energy security, economic development and environmental protection (Figueroa 2012: 132-133). IEA also provides opportunities for exploring alternative energy and conservation sources through long-term cooperation. One important mode of multilateral cooperation is the IEA Implementation Agreements (IA). By IEA rules and regulations, participation in an IA is to be based on equitable sharing of obligations, contributions, rights and benefits. Patents resulting from work within an IA may be filed in countries as appropriate by the inventing participant. Participants may be required not to disclose information related to these patents for a fixed period.

Source: UNCTAD based on OECD (2012).

4. Multilateral approaches to technology assessment

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 (see Box 10 for examples from Brazil, the Philippines and Türkiye). Technology assessment is often conducted with a rather skeptical or concerned attitude towards technologies, with possibly far-reaching impacts, for instance, using nuclear energy to generate electricity. However, 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. Artificial intelligence in agriculture, for instance, may empower farmers in developing countries to radically reduce applications of fertilizer and pesticides through precision IT-enabled farming. Or it can lead to the loss of jobs for agricultural workers (often women) when IT-powered robots are applied to harvesting fruits and vegetables.[191] How technologies are assessed regarding their opportunities and risks is often related to the specific value systems of a society and the challenges it faces. One example is CRISPR-CAS, a new technology for using genome editing in agriculture and medicine with potentially good impacts on food security but a series of risks and ethical issues. A 2018 ruling by the EU court of justice made progress in Genome Editing technologies depending on bureaucratic procedures and, thus, slowed down the innovation process. Therefore, a decision based on normative considerations from one world region potentially has a significant global impact.[192]

There is, currently, no provision which would allow that new technologies are assessed based on the challenges that different world regions face and weigh opportunities and risks based on a global discourse. UNEP, through the Climate Technology Centre & Network (CTCN) conducted a Technology Needs Assessment in Brazil on the use of Industry 4.0 technologies, particularly on how they can help create a circular economy.[193] UNCTAD is currently 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 developing countries can be systematically supported in their capacities to implement TA. In addition, it could be discussed how to assess new technologies on the multilateral level, bundling international expert knowledge to answer questions that – due their

[191] Stamm, 2022
[192] Ibid.
[193] https://www.ctc-n.org/system/files/dossier/3b/D2.4_Brazil_Evaluation_Report_CE_FINAL_ENG_CTCN.pdf

complexity - cannot be dealt with at the level of nation-states. Some examples are artificial intelligence and drone technologies in agriculture or gene editing technologies (e.g. CRISP CAS9).[194]

Box 10. Examples of initiatives with technology assessment elements in emerging economies

In Brazil, the project "Evaluation of the Technological Needs to the Implementation of the Climate Action Plans in Brazil" (TNA Brazil) aims at reinforcing the Brazilian government's technical capacity through comprehensive evaluations of technological needs. It contributes to achieving national goals of mitigation of greenhouse gases, taking into consideration Brazil's Nationally Determined Contribution and Brazil's strategy for the Green Climate Fund.[195]

In the Philippines, the Clean Energy – ALERT (Alternative Energy Research Trends), a program of the DOST-National Research Council of the Philippines (NRCP), aims to investigate alternative energy sources in the Philippines. As the Philippines continues to modernize and industrialize, its energy needs are expected to double over the next 20 years. The challenge is to meet these needs while trying to stem accelerating greenhouse gas emissions (GHGs) that contribute to climate change. This program is expected to lay out how renewable energy can reduce government's costs, bring jobs to the country, create wealth, expand access to energy for the most vulnerable in poor communities, and foster national energy independence.[196]

In Türkiye, the Science and Technology Commission was established to foresee the future technologies required and will contribute to the country's 2053 net zero emission target and green development policy. Ground-breaking R&D and innovation-based solutions are discussed in specific themes chosen following the EU Green Deal topics. The objective is to foresee future technologies for adaptation and mitigation to climate change, to enable the country to develop its R&D and innovation capacity in these technologies, and thus to turn the climate change crisis into an opportunity in the medium and long term. With a multidisciplinary holistic approach, the Commission has held more than 40 online meetings with the participation of 97 experts from universities, the private sector, NGOs and public institutions. It has prioritized 34 technology main topics and 262 sub-topics consisting of targets. The outcomes of the Science and Technology Commission are translated into prioritized RDI topics in TÜBİTAK's R&D, and innovation support programs and "Prioritized R&D and Innovation Topics within the Scope of Green Deal Agreement Compliance" has been identified accordingly to be tackled by academia and industry.

Source: UNCTAD based on contributions from the Governments of Brazil, the Philippines and Türkiye.

5. Support South-south STI cooperation for green innovation

South-south cooperation in 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 or changing precipitation patterns in large parts of Sub-Sahara-Africa. In addition, regional approaches to green innovation may improve the possibility of making use of opening green windows of opportunity. Relatively small and poor countries may not provide a sufficiently interesting home market to attract FDI in green technologies and/or build up their own manufacturing of related items. International cooperation should give solid incentives to overcome cooperation barriers, e.g. by supporting regional centers of excellence for green technologies and innovation. Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) and West African Science Service Centre on Climate Change and Adapted Land Use are examples.

[194] Ibid.
[195] https://antigo.mctic.gov.br/mctic/opencms/ciencia/SEPED/clima/tna_brazil/tna_brazil.html
[196] https://sdg.neda.gov.ph/clean-energy-alert/

IX. Conclusions and recommendations

The North-South divide in innovation performance is very pronounced, both regarding input and output indicators to the innovation systems. The possibilities for developing countries to catch up with industrialized countries are hindered by low levels of technical and financial resources for a broad-based strategy of catching up on STI. 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 impacts of climate change are also hitting many developing countries, which would need scaling up 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.

Thus, there is an urgent need to embed STI into concepts of fair globalization, implying that the needs of developing countries receive adequate attention in international agenda and priority setting and can benefit adequately from knowledge and benefit sharing. 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 all policy space required to take advantage of opening green windows of opportunities as a basis for sustainable development.

In this regard, developing countries are encouraged to:

- **Develop and expand national policies and strategies:** The government, with support of other stakeholders, should continue to craft and expand its national policies and strategies, with clear strategic direction and roadmaps, and regulatory and legal framework to further promote green innovation and the use, scaling-up, development, and production of green and renewable energy technologies. New strategies and policies are required to capitalize on the potential of current megatrends (digitalization and automation of production, global economic power shift, and industrial greening) in the path of building digital capabilities and absorptive capacities, fostering economic resilience through diversification, and investing in technologies that decouple industrial development from environmental damage. These policies should guarantee state commitment and the continuity of long-term plans, creating 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 reliefs. The government and other relevant agencies could also extend services to support these activities.
- **Establish a national mechanism for coordination:** Stakeholders' coordination at the national and sub-national levels requires a sustainable mechanism that enables ministries relevant to the sustainable development strategy and the use of green technologies 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 take the form of a National Council, also integrating the sub-national level representation. The council should also include representatives of non-governmental actors such as NGOs, universities, research centres, and the private sector.
- **Raise awareness and develop necessary human resources for applying green technologies:** The Government, private sector and other stakeholders must work in close coordination to raise awareness of the technological development happening in green technologies. They should provide necessary technical education and skills development training to increase

firms' capacity for applying green technologies. Capacity-building activities are needed to upskill and prepare the manufacturing sector to adopt green technology outputs from research and development institutes. Moreover, green technology subjects could be institutionalized in basic education to create mass awareness of sustainable development. There should also be efforts to inform and educate the private sector and consumers on these technologies and their benefits to reducing carbon footprints.

- **Identify, prioritize and foster green technologies and potential new sectors for sustainable diversification and structural transformation:** The Government, private sector and other stakeholders should develop the capacities and build the institutions to continuously and strategically identify new technologies and potential new sectors for diversification that are more complex and greener, considering existing technological and productive capacities, global and domestic demand, the potential in terms of natural resources, supply creation and dynamic learning curves. The priority sectors should be supported through vertical policy instruments such as clusters, smart specialization initiatives, pilot and demonstration projects and areas, and the associated finance.
- **Invest in R&D:** Tackling climate change's environmental, economic and social impacts requires significant transformation across all sectors. Governments must invest in research and development and focus on these technologies' diffusion and market transformation. For university research to be more responsive to innovation-driven demand for scientific and technological knowledge, the funding system should encourage more research based on public-private partnerships. The private sector should invest in green R&D and innovation as it can lead to new technologies and production techniques that can also boost productivity.
- **Support effective technology transfer ecosystems:** Governments should develop effective strategies for green technology transfer that meets the needs of the private sector. Greater priority should also be given to measures that encourage spin-offs from public research, the creation and operation of incubators and more efficient management of IPRs by universities and public research institutes. The private sector also plays a vital role in importing needed equipment and infrastructure for adopting green technologies.
- **Strengthen innovation networks and linkages:** Governments, the private sector, organized civil society and other stakeholders should increase partnerships and cooperation to enable green technologies' production and broader diffusion. Constant consultation amongst stakeholders is necessary to ensure that the social aspect of sustainable development is considered and all potential consequences of green technology adoption are beneficial. The challenges and appropriate strategies in implementing these technologies must also be considered. The academe-industry-government collaborations should be enhanced so that the technologies created can benefit industries outright.
- **Support consumer demand:** Consumer demand is crucial in ensuring sufficient incentives to shift to circular business models while ensuring a just transition to meet the needs of developing countries and all population segments, with adequate access to necessary resources. Governments can ensure that infrastructure and incentives exist for the consumer demand shift to circularity.
- **Promote green technology diffusion in SMEs:** SMEs are the backbone of economies, and relevant policies should be designed and implemented to better guide and support SMEs in reducing carbon emissions. Policymakers should design policies for easing restrictions that bar SMEs from procuring and adopting green and renewable energy technologies, such as

providing risk guarantees, supporting R&D in renewable energy to reduce technology costs, carbon pricing, finance, and providing subsidies and tax deduction. In addition to financing aspects, comprehensive support must be extended to these SMEs, including advice on intellectual property rights (IPRs), market analysis and mentoring throughout the commercialization process. Certifications, eco-labelling, standards and green public procurement are other important areas supporting green technology adoption. Strengthening the commercialisation of green technologies may require support to selected SMEs with innovation potential.

- **Expand financing opportunities for the adoption and innovation of green technologies:** The government and the private sector should expand financing opportunities and improve access to both public and private funding sources for developing and commercialising green technologies. Investment funds for green technology, technical assistance in innovation and technology, and advisory services are emerging as other instruments that can help achieve the objective. When promoting the development of new green sectors, government and donor agencies should come forward as early investors to address the financial constraints of the entrepreneurs and the sustainability of the technologies (de-risking investment on green technologies).
- **Adopt green procurement reforms:** As the largest procuring entities, governments should adopt green procurement. This could help create a ripple effect across the rest of the economy and lead to the wide-scale adoption of green innovations.
- **Maximize the role of public-private partnerships:** Governments should forge public-private dialogue that ensures that public leadership meets national priorities and objectives and simultaneously engages the private sector to encourage innovation and growth according to the environmental, social and governance principles. Good practices must be considered from practical experience in managing existing PPP projects. When streamlining the numerous schemes to promote innovation, the balance between competitive and unconditional grants and between project-based and programme-based support should be considered.
- **Support civil society initiatives:** Government and other stakeholders should support the engagement of organized civil society in promoting the diffusion and adoption of green technologies. Organized civil society can play an important role in transferring knowledge on green technologies through awareness raising, sensitizing the public about the significance of green technology, and capacity development activities for famers and other stakeholders; in addition to implementing pilot projects that can be scaled-up by the governments. Civil society and organizations can also be incubators or accelerators for young entrepreneurs interested in starting businesses in green agricultural technologies.
- **Tackle gender imbalances:** All stakeholders should increase their efforts to tackle gender imbalances in green technology sectors. Some of the possible actions include raising awareness of opportunities for women in green industries; increasing access to technical vocational education and training (TVET); investing in training and capacity-building initiatives for women who are professionals in green industries, and promoting women entrepreneurs who are successful in the green industry as role models.
- **Strengthen international collaboration:** Governments should also intensify efforts in establishing and improving bilateral and multilateral partnerships, and North-South and South-South cooperation, to acquire new and existing technologies on green innovation from

various countries. Strengthened international cooperation is also needed to execute and implement green technology and innovation projects.

To support developing countries in developing, producing and adopting green technologies and in building their capacity for greener innovation, the international community could consider the following recommendations:

- **Exchange knowledge and experiences:** Exchange information on national initiatives supporting green technology and innovation development, and examples of how to transition from fossil fuel jobs to clean energy jobs. The incorporation of sustainable materials and the use of renewables are important priorities. The Commission studies, meetings and discussions are useful platforms which let countries share their best practices and challenges. Better facilitation of exchange between countries can help their governments support green technology adoption and promote innovation.
- **Establish policy research platforms and provide technical and policy advice to policymakers:** Promote policy platforms such as cross-national regulatory sandboxes to further build an enabling ecosystem for experimentation and design. These multilateral platforms could provide opportunities for benchmarking and campaigning for policy provisions in green technologies and innovations. This will further enhance multilateral policy innovation in response to exponential technological growth in green technology and innovation. Countries can learn from other countries' experiences, good practices and even failures while designing new policy instruments or creating new strategies for promoting green technology innovation and commercialization.
- **Establish marketing and engagement platforms**: Create marketing and engagement platforms where green technologies and innovation of different communities and countries are showcased and properly presented for others to adopt. This could include platforms for networking within the industries for collaboration projects and business-to-business platforms between technology providers and seekers in green technologies for accelerating technology diffusion.
- **Cross-border system of open innovation for green innovation**: Create a cross-border system of open innovation for green innovations facilitating efficient communication and collaboration between authorities, corporations, researchers, academia, and individuals, and providing avenues and incentives to those who collaborate.
- **Establish, expand and strengthen international R&D and innovation support programmes**: International R&D support programmes, such as Horizon Europe, has a vital role in the advancement of green technologies by supporting, promoting and financing international R&D projects on green technologies and clean production. These should facilitate the involvement of Higher learning institutions in green technology-related projects and help coordinate research projects involving research institutions worldwide.
- **Establish international innovation hubs, maker spaces, and centres**: This will encourage start-ups and spin-offs to scale up through cross-border collaboration and expansion. International shared facilities such as fabrication labs, workshops, manufacturing centres, and makers spaces are important in lessening the cost of failure and innovation.
- **Help build capacity in government and private sector:** Implement capacity-building for policymakers to enhance awareness of the policy instruments and incentives for encouraging private sector participation and establish an effective regulatory ecosystem for cross-border

trade of green technologies and products. Capacity building and training should also be conducted and sustained to ensure appropriate and continuous implementation of green technologies by the private sector. These could be based on case studies and business models on green technology transfer and commercialization and could also target start-ups, business incubators and technology promotion agencies in member states. They could cover a wide range of topics, including preparing robust business proposals for green technology start-ups, technology transfer, intellectual property rights, technology valuation, and financing.

- **Build capacities for technology assessment**: The international community could systematically support developing countries in their capacities to implement technology assessment, including on how to assess new technologies on the multilateral level, bringing international expert knowledge to answer complex regional and global questions about technology trajectory and social-economic impact.
- **Implement technical cooperation projects:** The international community, including the Commission, could create and implement technical cooperation projects to facilitate the adoption, development and production of green technology and promote green innovation in developing countries.
- **Facilitate South-South cooperation.** Facilitate South-South Collaboration in green technology research, development, technology transfers and commercialization in member states. It could also establish networks for South-South Cooperation for technical and policy advice to policymakers.

Annex A - Examples of United Nations System's technical cooperation for cleaner and more productive and competitive production

ITC

ITC's NTF Programme – funded by the Netherlands – developed the Greening ICT training and delivered the training to 80 tech start-ups and IT companies in Africa, covering: 1. Energy efficiency, 2. Electronic Waste Management, and ICT Sustainability Standards. This programme has been rolled out in several African countries (including Rwanda, Tanzania, Uganda, and Zambia), and ITC will continue to deliver the training to more companies.[197]

ITU

ITU helps to create a circular economy for electronics, such as through improving expertise in the collection of e-waste data, increasing coverage of national e-waste policy and regulation, and identifying and mapping technological interventions in the e-waste management space. Currently, ITU is providing technical assistance to Botswana, Dominican Republic, Namibia, Rwanda, The Gambia, and Uzbekistan on Implementing the EPR Concept in Policies and Regulations for the Sound Management of E-waste.[198] Member States can request ITU technical assistance and capacity building to support national or regional e-waste policy development.

In Rwanda, a national level awareness raising campaign was launched in May 2022 with the aim of increasing collection of e-waste at dedicated drop-off points and sensitize the population on the issue of e-waste. ITU in collaboration with UNEP and also with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) will continue supporting Rwanda in the revision of the regulation governing e-waste management and development of the ministerial order on e-waste, study into the financial mechanisms possible for EPR in Rwanda, development of an e-procedure and e-registration platform for EPR in Rwanda and finally the preparation of EPR Implementation Guidelines to support the regulation on governing e-waste management and the ministerial order on e-waste.[199]

In Malawi, a national e-waste policy is being finalized before a validation workshop planned for later in 2022.[200]

ESCWA

ESCWA implemented several activities under the project on "Enhancing resilience and sustainability of agriculture in the Arab region":[201] In partnership with the Arab Organization for Agricultural Development (AOAD), ESCWA organized in October and November 2021 five national consultation sessions on enhancing resilience and sustainability of the agriculture sector in Algeria[202], Egypt[203], Jordan[204], Lebanon[205] and Sudan[206]. These consultations aimed at identifying ways of enhancing the agricultural sector's resilience and sustainability at national level in the face of climate change, the unsustainable use of natural resources and the COVID-19 pandemic. On promoting the use of green

[197] Contribution from ITC.
[198] https://www.itu.int/en/ITU-D/Environment/Pages/Priority-Areas/National-WEEE-Policy-Support.aspx
[199] https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/WEEE-Policy-in-Rwanda.aspx
[200] https://www.itu.int/en/ITU-D/Environment/Pages/Spotlight/WEEE-Policy-Support-Malawi.aspx
[201] https://bit.ly/3BnT21d
[202] https://www.unescwa.org/events/enhancing-resilience-and-sustainability-algerias-agricultural-sector
[203] https://www.unescwa.org/events/enhancing-resilience-and-sustainability-egypts-agricultural-sector
[204] https://www.unescwa.org/events/enhancing-resilience-and-sustainability-jordans-agricultural-sector
[205] https://www.unescwa.org/events/enhancing-resilience-and-sustainability-lebanons-agricultural-sector
[206] https://www.unescwa.org/events/enhancing-resilience-and-sustainability-sudans-agricultural-sector

technologies in agriculture, a working paper on "unlocking the potential of rainfed agriculture in the Arab region" through the adoption of agricultural technologies and practices such as rainwater harvesting among other practices was presented and discussed during these consultation sessions. Additionnally, national and regional success stories on enhancing the resilience and sustainability of the agricultural sector were shared, including ESCWA's work on developing the five technical booklets on agricultural green technologies and implementing capacity development activities related to promoting these technologies. Recommendations that resulted from these consultations focused on the environmental and socio-economic dimensions of enhancing agriculture resilience with a focus on the role of women and youth. National priorities and indicators towards enhancing the agricultural sector's resilience in the face of climate change and the unsustainable use of natural resources were also identified.

ESCWA also organized a "buyers-sellers" meeting[207] following the training workshop on promoting agricultural green technologies which was implemented in the Bekaa region in Lebanon. This meeting targeted local agricultural cooperatives, mainly women, working in the agri-food sector. It aimed at putting them in contact with stakeholders who can help them directly or indirectly to successfully access the market, and to encourage them to adopt green technologies in their production. Following this meeting, cooperatives were inspired to use social media and more specifically WhatsApp to stay in contact, a handy and accessible application for all. Through their WhatsApp group, they were able to share news and information in a timely manner about latest expositions, local markets and possible support from donors or other entities.

UNEP

UNEP implements several programmes and activities for capacity building on green technology. Through the Climate & Clean Air Coalition (CCAC), UNEP provided technical assistance to the city of Sao Paulo, Brazil on the operation of composting plants, assessment of a pilot composting plan, and capacity building on organic waste treatment. This assistance helped increase the number of decentralized composting plants in Sao Paulo. The CCAC also provided technical assistance for a financial work plan on technical, regulatory environment, and financial feasibility aspects of an Eco-park Waste facility integrating different technologies for the treatment/recovery of two waste streams: mixed waste from households and biowaste separated at source from the large generators.[208]

The CCAC also developed a guideline for the management of organic waste based on technical assistance provided to Novi Sad and Vrbas (Serbia) and Bijeljina (Bosnia-Herzegovina). For the city of Bijelfina, technical assistance included a study to divert organic waste, an assessment study for the implementation of a composting plant, and a compost market study. For the city of Novi Sad, a study was conducted that assessed the capacities of diverting and composting organic waste in the South Backa region. For the city of Vrbas, an implementation plan to source segregated organic waste was developed.[209]

In Penang, Malaysia, CCAC designed an output-based program to incentivize organic waste diversion and valorization from multi-family dwellings.[210]

[207] https://www.unescwa.org/events/buyers-sellers-meeting-value-chain-development
[208] https://www.ccacoalition.org/es/node/3035
[209] https://www.ccacoalition.org/en/activity/guideline-bio-waste-management-south-east-europe
[210] https://www.ccacoalition.org/en/resources/penang-state-municipal-solid-waste-minimization-and-recycling-project-output-based-program

In the Laos Peoples Democratic Republic, UNEP, through the CTCN is providing Technical Assistance to the Laotian Government to create a power to gas-related masterplan on the steps needed to increase use of green gases via commercially available power-to-gas to replace fossil fuels. Technologies on bioenergy, biogas streams, biomass plants, carbon capture utilization and storage technologies, and combination of hydrogen with CO2 will be assessed for their suitability in this masterplan.[211]

UNEP's work on the role of trade and trade policy in shifting the textile value chain towards circularity between Kenya and Thailand has contributed to South-South cooperation and a deeper understanding of the trade policies that can facilitate or hinder eco-innovation in the textiles sector. [212] [213] UNEP's InTex project facilitates exchange cooperation between Kenya, South Africa, and Tunisia on green business models for SMEs in the textiles sector. Links have also been made between country partners and textile stakeholders in Bangladesh and Romania. [214] [215]

UNEP, through the CTCN and Japan supported Thailand on a bilateral cooperation basis for the Benchmarking Energy & GHG Intensity in Thailand's Metal Industry.[216]

UNESCO

Conducted with the support of UNESCO, the project to Promote the Use of Renewable Energy and Energy Efficiency Technologies in Households in Rural Areas of Cameroon (PUERTEM) aims to improve access to clean and sustainable energy for populations in the Northern and Far North regions of Cameroon. This involves the training and distribution of renewable energy and efficiency equipment to at least 6,000 people (especially women and young people). Currently, 1,000 households have already been identified, 36 agents are trained in household supervision. A training of 05 "mama solar" on the assembly of solar equipment in Dakar, Senegal was completed in November 2021 and the distribution of 1030 solar kits to households is imminent. Finally, household training has already begun, with more than 600 households already impacted.[217]

UNIDO

UNIDO helps create new green industries, establishing national road maps for greening the supply chain, determining benchmarks and indicators, disseminating and sharing best practices, running clean technology programmes, undertaking various capacity-building exercises and contributing to international forums with the necessary research and expertise. Projects implemented by the UNIDO Environment Department demonstrates the use of green technology and innovation for cleaner and more productive and competitive production. With funds from EU, UNIDO implements the "SWITCH to circular economy value chains" project, which aims to support enterprises within selected value chains to adopt circular economy practices.

UNIDO is supporting its member states in reducing plastic waste leaking into the environment, improving resource efficiency of plastic industry (Egypt), strengthening recycling industry though policy support (Israel), establishing a circular economy framework for the plastics sector (Ghana), integrated approach towards sustainable plastics use and (marine) litter prevention (Bangladesh),

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[211] https://www.ctc-n.org/technical-assistance/projects/developing-power-gas-masterplan-lao-pdr
[212] https://www.ctc-n.org/technical-assistance/projects/developing-power-gas-masterplan-lao-pdr
[213] https://www.unep.org/explore-topics/green-economy/what-we-do/environment-and-trade-hub/textiles
[214] https://www.ctc-n.org/technical-assistance/projects/developing-power-gas-masterplan-lao-pdr
[215] https://www.unep.org/intex
[216] https://www.ctc-n.org/technical-assistance/projects/benchmarking-energy-ghg-intensity-thailands-metal-industry
[217] Contribution from the Government of Cameroon.

improving packaging design and promoting new business model (Egypt), promoting sustainable alternative materials (South Africa, Egypt, Kenya), strengthening recycling capacity through waste picker integration (South Africa), strengthening plastic value chains (Nigeria), and increasing knowledge on the challenges and opportunities of plastic value chain (Egypt, Kenya and Nigeria).

In Bangladesh, UNIDO piloted cleaner production (efficient use of chemicals, water, electricity, natural gas and occupational safety and health) in the tannery sector through a SWITCH Asia funded project between 2009 and 2012. The project also demonstrated how modern technologies can reduce water pollution. Based on the experience of Bangladesh, UNIDO developed in India and in few other countries an online training platform (free of charge) for the practitioners. UNIDO also developed animated online training on handling of hydrogen sulphide, a very dangerous by-product of industrial processes. The training is targeted at workers handling hydrogen sulphide in any kind of industries.

UNIDO also developed online training on the construction and management of Central Effluent Treatment Plant (CETP). This training manual can reduce water pollution and save life under water and it is available at letherpanel.org website.

Switch Med programme is promoting circular value chains for a greener and more competitive textile industry in Egypt, Morocco, and Tunisia.

In Colombia, UNIDO's Global Eco-Industrial Parks programme promotes the transition of industrial parks to become Eco-industrial parks, adopting sustainability policies and practices both at the park level and within the tenant enterprises.

In Cameroon, UNIDO implements a project for promoting integrated biomass and small hydro solutions for productive purposes.

In Gambia, Ministry of Petroleum in collaboration with UNIDO implemented the UNIDO/GEF project "Greening the productive sectors in the Gambia" to promote the use and integration of small to medium scale renewable energy system in the productive sector, to provide electricity power supply that resulted to a clean, sustainable energy supply. The MRC unit the Gambia at the London school of hygiene & Tropical Medicine in Fajara also benefited from this project and installed the largest renewable energy solar system in the Gambia with total capacity of over 500 kilo watts at peak power while also breaking down the gender barriers by organizing capacity building trainings for women on solar installation.

UNIDO and UNEP are jointly implementing a global programme on Resource Efficient and Cleaner Production (RECP) since 1994, which helps with the continuous application of preventive environmental strategies to processes, products and services to increase efficiency and reduce risks to humans and the environment.

UNIDO has also established the Global Cleantech Innovation Programme (GCIP) to promote cleantech innovation and entrepreneurship to address urgent environmental challenges. The Global Environment Facility (GEF) is a key partner for GCIP, as well as the Green Climate Fund and other bilateral partners.

UNWTO

The UNWTO SDGs Global Startup Competition[218] received responses from 10,000 participants from 138 countries and all economic sectors. The 25 winning projects entered a curated programme of benefits with the support of 21 partners and collaborators (such as, Globalia, Qatar Airways, Qatar National Tourism Council, Amazon Web Services, Mastercard, Google, Amadeus, IE University,

[218] https://www.unwto.org/sdgs-global-startup-competition

Telefónica, IDB Lab and Plug and Play), including mentorship, access to technological support, connection to Member States, corporates, and investors for opening the doors to funding and pilot projects opportunities. Likewise, Top 25 Innovators Working for a More Sustainable and Innovative Tourism catalogue[219] was created to facilitate Member States and private sector access to solutions which cover projects for decarbonization, monitoring of sustainability indicators, water access, women empowerment, smart mobility, amongst many others.[220]

[219] https://www.unwto.org/sdgs-global-startup-competition
[220] Contribution from UNWTO.

Annex B – Suggested questions for discussion during the Intersessional Panel of the Commission

This annex presents a set of questions for the discussion during the Intersessional Panel.

Key issues on green technology and innovation and sustainable development

- What challenges have governments faced or may face in promoting green technology and innovation to contribute to national development priorities and accelerate the progress towards the SDGs?

Creating the ecosystem for green technology and innovation

- How could governments better support the creation or strengthening of national and sectoral systems for green technology and innovation?
- What are the policy instruments that governments have used in this regard?
- What are the most effective ways to support the improvement of skill levels for harnessing green technology and innovation for inclusive and sustainable development?
- What should the private sector and other stakeholders do so that developing countries can benefit from these technologies?

Providing directionality to the sustainable and inclusive application of green technology and innovation

- What are the examples of STI policies, projects, initiatives intended to promote and give directionality to green technology and innovation to make it work for inclusive and sustainable development?

The role of partnerships and international and regional collaborations

- What actions can the international community, including the Commission on Science and Technology for Development, contribute to support green innovation collaboration?
- What are the success stories in this regard?

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