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Challenges and Opportunities for Renewable Energy Technology Transfer in Least Developed Countries

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Abstract

This paper, the second of a two-part series, focuses on the role of trade and investment in enabling the diffusion of green technologies to least developed countries (LDCs) to help their transition to renewable energy. LDCs are already making progress in expanding their use of clean energy sources: the total renewable energy generated by all LDCs more than doubled between 2010 and 2020 and, on average across the LDC group, more than half (51.6 per cent) of their total energy generation in 2020 came from renewable sources, compared to a global average of 27.7 per cent. Recognising this potential in the renewable energy sector, this paper argues that LDCs could benefit from the transfer of technology through trade and investment, which would enable them to make greater use of their existing resource endowments and accelerate their energy transitions, while also contributing to their economic transformation and to mitigating climate change.

Contents

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1. Introduction

Technology plays a critical role in supporting the developmental efforts of developing and least developed countries (LDCs) in areas such as agriculture, manufacturing, education and health, the environment and trade (WTO, 2021). For LDCs, access to technology, including through the exchange of knowledge and innovation, is key to accelerating their economic transformation. Its importance is only likely to intensify going forward, as rapid digitalisation and the emergence of frontier technologies alter the dynamics of global production and trade. Newer or more advanced technologies can help LDCs to expand productive capacities and improve productivity, diversify their economies, and accelerate economic growth and sustainable development. They also enable businesses in LDCs to develop new products and services, resulting in positive effects on economic growth and social welfare (Kowalski et al., 2017).

Despite these benefits, there remain large gaps between LDCs and more developed countries in terms of access to – and production and deployment of – technologies, including climate-related technologies and those supporting the green energy transition. LDCs, and many other developing countries, face significant challenges in acquiring and/or adapting these and other technologies. This acts as a major constraint to their pursuit of sustainable economic development and a green transition.

Trade can play an important role in addressing these gaps by increasing openness to new technologies and enabling the flow of information, movement of human capital and transfer of know-how (Bellelli and Xu, 2022). Trade-related access to technology can take place through several channels, such as trade in goods and services, trade in knowledge, foreign direct investment (FDI), and the movement of people (Hoekman et al., 2004; Andrenelli et al., 2019). These channels are influenced by various factors, including the policies of receiving countries. Such policies affect decisions by technology owners regarding whether to provide access to their technology and on what terms (Andrenelli et al., 2019). In this regard, policies that promote access to technology in LDCs can have positive effects on trade and investment by enhancing the diffusion of technology and know-how to these countries for their economic development. On the other hand, accessing foreign technologies can also lead to market distortions, induce rent-seeking behaviour, reducing incentives for innovation and research and development (R&D), create barriers to trade, and generate intellectual property (IP)-related conflict (Kowalski et al., 2017). This makes it imperative for policy-makers in LDCs to consider the various factors and policy measures that will allow them to access technology and benefit from it.

This paper, the second of a two-part series,[1] focuses on the role of trade and investment in enabling the diffusion of green technologies to LDCs to help their transition to renewable energy. LDCs are already making progress in expanding their use of clean energy sources: the total renewable energy generated by all LDCs more than doubled between 2010 and 2020, while, on average across the LDC group, more than half (51.6 per cent) of their total energy generation in 2020 came from renewable sources, compared to a global average of 27.7 per cent (de Klerk et al., 2024). Recognising this potential in the renewable energy sector, this paper argues that LDCs could benefit from the transfer of technology through trade that would enable them to make greater use of their existing resource endowments and accelerate their energy transitions, while also contributing to their economic transformation and to mitigating climate change. It highlights the critical role that trade can play in facilitating LDCs' access to green technologies. It also emphasises the need for LDCs to develop enabling environments that help facilitate their access to technology, including by addressing structural bottlenecks – such as labour-skills mismatches, lack of awareness among the domestic business community about the significance of technology absorption and adaptation, and weak linkages between innovators and their potential clients – that impede access to technology transfers.

The paper continues in the next section by presenting an overview of LDCs' existing technological capabilities and recent innovative activity in the energy sector to highlight

technological gaps that inhibit them from expanding their renewable energy generation capacity and facilitating a clean energy transition. This is followed in Section 3 by a discussion of the significant challenges faced by LDCs in accessing green technologies. Recognising these difficulties, Section 4 looks at existing global initiatives to support LDCs' capabilities in science, technology and innovation (STI) and enhance their access to modern technologies; and examines policies related to trade and investment that are designed to support access to technology in Commonwealth LDCs. The paper concludes by suggesting possible ways to help LDCs access clean technologies to better utilise their renewable energy endowments and accelerate a transition to green energy.

2. Overview of the state of science, technology and innovation in LDCs

To better understand the need to transfer technologies to LDCs, this section examines several indicators of their existing capacity for technological development and innovation, focusing on the 14 LDCs that are members of the Commonwealth. It then turns to a more specific overview of these countries' existing technological capabilities and recent innovative activity in the energy sector. This is done to highlight gaps that need to be addressed to expand their renewable energy technologies and systems and facilitate a clean energy transition.

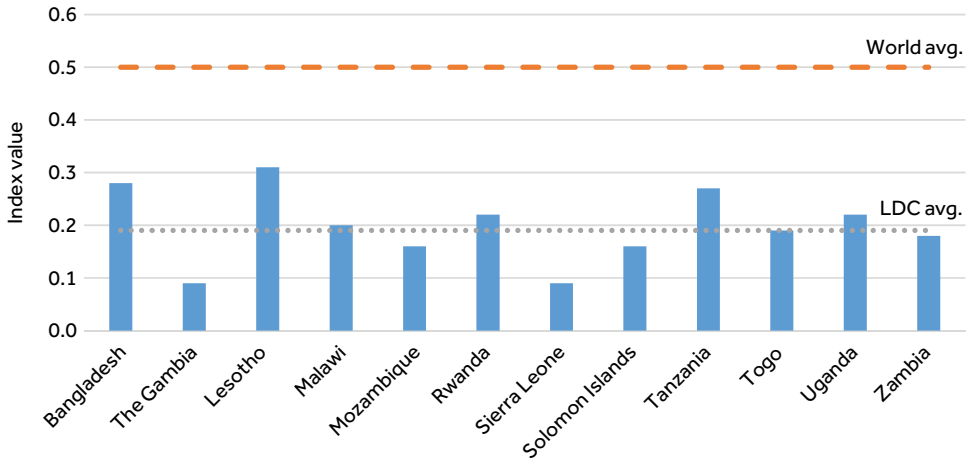
2.1 General purpose technological development and innovation activity in Commonwealth LDCs

The shortcomings in technological capacity in LDCs are widely documented. They are on the wrong side of the digital divide, with inadequate digital infrastructure and low levels of internet access and connectivity. Producers in these countries generally remain heavily reliant on outdated, inefficient or obsolete technologies ('Utoikamanu, 2018). They also have major limitations in human capacity – with particularly wide skills shortages in science, technology, engineering and mathematics (STEM) – which hampers their ability to develop, use and maintain innovative technologies (Adhikari and Tesfachew, 2022). Inadequate policy and regulatory environments, underdeveloped intellectual property rights (IPR) regimes, and a lack of resources and incentives for innovation all serve to further discourage private sector investment and limit the scope to develop new technologies. As a result, LDCs continue to rely heavily on foreign technologies, with little diffusion of technology and innovation domestically.

These challenges are reflected in the rankings and scores for LDCs on UN Trade and Development's (UNCTAD's) Frontier Technologies Readiness Index ('the Index', Figure 2.1). All 14 Commonwealth LDCs rank in the bottom third of the 166 countries covered by the Index for 2022, and all but one (Lesotho) fall in the bottom quartile.[2] Three (3) LDCs – The Gambia, Sierra Leone and Mozambique – are placed among the bottom 10. The Index scores for all 14 countries are well below the global average and only 6 of them are deemed to be better prepared to use frontier technologies than the LDC group, on average. Some Commonwealth LDCs perform better on the R&D activity sub-indicator, with 2 in the top half of the rankings (Bangladesh and Tanzania), but 6 of the 14 countries are placed in the lowest quartile and, among these, Togo, The Gambia and Solomon Islands fall in the bottom 20.[3]

These rankings and scores suggest Commonwealth LDCs are generally not well prepared to effectively use, adopt and adapt new frontier technologies such as artificial intelligence (AI), the 'internet of things', big data, blockchain, cloud computing, 5G, 3D printing, robotics, drones, gene editing, nanotechnology and solar photovoltaic (PV). These technologies harness the power of digitalisation and connectivity in new and innovative ways; and are displacing existing processes and reshaping industries and ways of doing business. They have the potential to provide solutions to economic, social and environmental challenges in LDCs and other developing countries. However, by being ill-prepared

Figure 2.1 Commonwealth LDCs' relative performance on the Frontier Technologies Readiness Index (2022)



Notes: Index values range from 0 to 1, with a value closer to 1 indicating a country is ready to use and adopt frontier technologies, while a value closer to 0 indicates a country is less ready to do so. There were no data for Kiribati or Tuvalu. The LDC average is calculated using Index values for 39 LDCs with available data. The world average is calculated based on Index values for 166 countries.
Source: UNCTAD (2023).

to engage with them, Commonwealth LDCs are missing out on opportunities to effectively harness technological change to support their sustainable development.

Most Commonwealth LDCs perform poorly on other general indicators of innovation capacity and activity. All those covered by the World Intellectual Property Organisation's (WIPO's) Global Innovation Index – which monitors the state of technological advancement across 132 countries – fall within the bottom 30 of the 2022 rankings.[4] Their research capacity is also severely limited. Levels of public expenditure on R&D – an indicator of a government's commitment and resource capacity to support R&D and innovation – were equivalent to well below 1 per cent of gross domestic product (GDP), on average, in eight African Commonwealth LDCs between 2005 and 2019 (Table 2.1).[5] Among these countries, The Gambia, Lesotho and Zambia spent less on R&D relative to their GDP compared to other LDCs, on average, and all of them had lower levels of R&D expenditure as a share of GDP relative to the global average.

In addition to low levels of spending on R&D, research and innovation activity in African Commonwealth LDCs is constrained by a shortage of researchers. All nine countries with available data had fewer than 60 researchers per one million inhabitants, with ratios as low as 19 in Tanzania, 24 in Lesotho and 28 in Uganda (Table 2.1). These ratios are below the average across all LDCs (76) and fall far short of the global average of 1,342.

As an extension of these shortages in R&D capacity, IP activity related to technological development and innovation is very limited in several Commonwealth LDCs, especially with respect to applications for patents and industrial designs. In most Commonwealth LDCs, the cumulative numbers of these applications were significantly below the overall LDC averages between 2010 and 2021 (Table 2.1). There were, however, some notable exceptions, with comparatively large numbers of applications for patents, industrial designs and trademarks originating in Mozambique and Bangladesh, and, to a lesser extent, Uganda and Zambia in the case of trademark applications. Even so, combined applications for patents (12,733), industrial designs (26,556) and trademarks (663,197) from Commonwealth LDCs contribute negligibly to the respective global totals, which exceeded 94.6 million for trademarks, 34 million in the case of patents and 11 million for industrial designs.

The limited capacity for technological development and innovation in Commonwealth LDCs is also evident from an examination of the composition of their merchandise trade. More technologically advanced countries tend to produce and export a range of technology-intensive products. Yet most Commonwealth LDCs export only small shares of medium- and high-tech products[6] out of their overall

Table 2.1 Selected indicators of R&D and innovation activity in Commonwealth LDCs

Region	Country	Research and development		Intellectual property (IP) applications (cumulative totals, 2010–2021)		
		R&D expenditure (% of GDP, avg. 2005–2019)[i]	Researchers per million people[ii]	Patents[iii]	Industrial designs[iv]	Trademarks[v]
Africa	The Gambia	0.04	53	40	1	7,732
	Lesotho	0.03	24	5	23	6,203
	Malawi	–	50	27	276	8,875
	Mozambique	0.31	43	530	1,068	40,810
	Rwanda	0.70	59	123	296	12,499
	Sierra Leone	–	–	–	14	11,494
	Tanzania	0.41	19	232	–	14,458
	Togo	0.24	45	–	–	
	Uganda	0.28	28	137	310	34,393
	Zambia	0.15	42	318	460	31,340
Asia	Bangladesh	–	–	4,214	16,818	148,434
Pacific	Kiribati	–	–	–	10	–
	Solomon Islands	–	–	–	–	–
	Tuvalu	–	–	27	–	98
Global	LDC avg.	0.22	76	490	1,021	21,393
	World avg.	0.96	1,342	–	–	–

Notes: [i] LDC and world averages calculated using data for 20 and 144 countries, respectively. [ii] Data are for 2020 or the latest available year: The Gambia (2018), Lesotho and Mozambique (2015), Malawi (2010), Rwanda (2019), Uganda (2014), Tanzania (2013) and Zambia (2008). [iii-v] LDC averages calculated using data for 26, 26 and 31 countries, respectively.
Sources: [i] United Nations SDG Stats; [ii] United Nations SDG Stats and UNESCO Institute for Statistics; [iii-v] Commonwealth Secretariat (calculated using WIPO data).

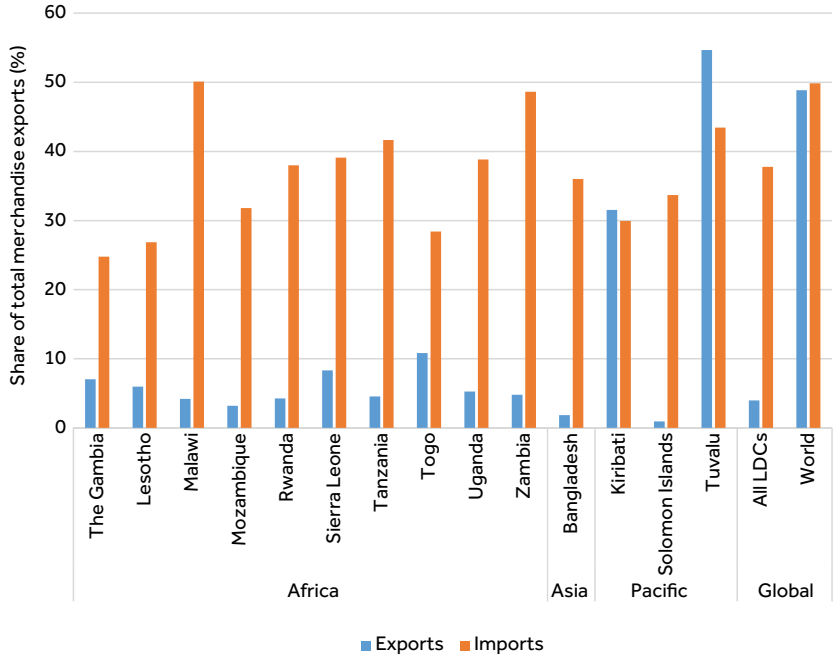
merchandise exports; and are comparatively much more reliant on imports of these products (Figure 2.2). Their limited capacity to export more technology-intensive goods serves as a barrier to participation in regional and global value chains (GVCs) and constrains their trade in higher value-added products. On average between 2019 and 2022, high-tech products accounted for significantly less than 1 per cent of total merchandise exports by Mozambique, Zambia, Tanzania, Lesotho, Solomon Islands, Bangladesh and Malawi (all of which had shares below the LDC average), and less than 2 per cent for Uganda, Rwanda, Togo and The Gambia. Only Kiribati and Tuvalu in the Pacific exported relatively large shares of high-tech products, but these were still far short of the global average (21.5 per cent).

A similar pattern is evident for medium-tech products, exports of which accounted for less than 1 per cent of total merchandise exports by Tuvalu, around 1 per cent by Bangladesh, approximately 3 per cent by Rwanda and Mozambique, and less than 5 per cent by Malawi, Uganda, Tanzania and Zambia. These shares are well below the global average of 27 per cent. Moreover, in all cases except for Kiribati and Tuvalu, they are dwarfed by the corresponding shares of medium- and high-tech products in their overall merchandise imports.

2.2 Technological capabilities and innovation in the energy sector in Commonwealth LDCs

Most LDCs lack capacity to produce energy efficiently and sustainably. This is evident from their performance on the energy component of UNCTAD's Productive Capacities Index (PCI). This component measures productive capacity from the perspective of the availability, sustainability and efficiency of power sources, and covers the use of and access to energy, losses in distribution, and the extent to which energy components and sources are renewable. Commonwealth LDCs' PCI scores on the energy dimension

Figure 2.2 Total shares of medium- and high-tech products in LDC merchandise trade (avg. 2019–2022, %)



Note: SITC rev.3 product codes used to group products in medium- and high-tech categories based on Lall (2000) classification using UNCTAD concordance.[7]
Source: Commonwealth Secretariat (calculated using UNCTADstat data)

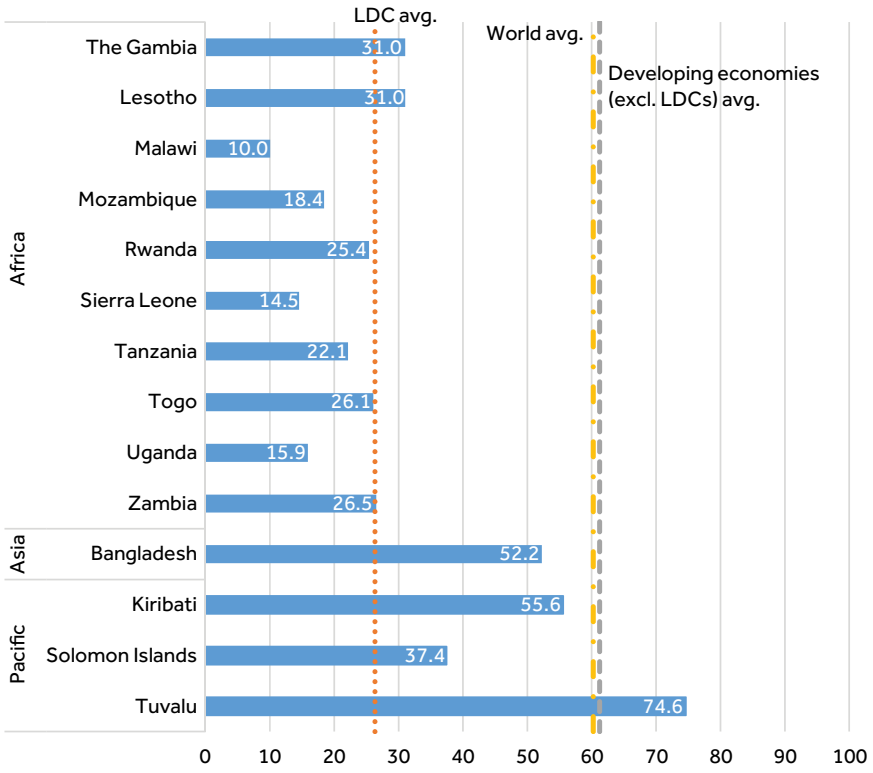
are generally low, with Bangladesh, Kiribati and Tuvalu the only exceptions (Figure 2.3). According to the PCI, Malawi, Sierra Leone, Uganda and Mozambique have the lowest levels of productive capacity in energy generation among the African Commonwealth LDCs, while three others on the continent fare less favourably than the overall LDC average. Of all the Commonwealth LDCs, only Tuvalu performs better than the global and developing economy averages; and has achieved universal access to electricity across its small population. Tuvalu's energy supply is produced almost entirely from non-renewable, fossil-fuel based sources, with a heavy reliance on imported petroleum products for electricity generation, although there has been greater focus in recent years on renewable energy installations, led by solar alongside some wind energy projects. The Government of Tuvalu has set a target to reduce greenhouse gas emissions from the electricity sector to near zero by 2030, with plans to generate 100 per cent of electricity from renewable sources.

Overall, the PCI scores for Commonwealth LDCs suggest there is considerable scope in these countries to produce power more sustainably and efficiently and, in some cases, using a greater share of renewable energy components and sources.

While technological advances could help to improve the efficiency and sustainability of energy production in LDCs and assist their transitions to cleaner forms of energy, most lack the domestic capacity to develop innovative technologies to support these goals and rely heavily on imported technologies (de Klerk et al., 2024). At present, Commonwealth LDCs, and the rest of the LDC group, contribute very minimally to worldwide patent activity in the area of renewable energy technologies. Outside of Bangladesh, where there has been comparatively more patent activity to develop solar PV energy technologies, very few patents for wind energy, solar thermal, solar PV energy, marine energy and hydroelectric technologies have originated in Commonwealth LDCs over the last two decades (Table 2.2).

The shortage of patent activity in these areas is emblematic of a broader problem, with most LDCs poorly placed to develop, adopt and adapt technologies that can drive the transition to cleaner energy. Three (3) of the 4 Commonwealth LDCs included in the World Economic Forum's Energy Transition Index (ETI)[8] for 2023 rank among the bottom 10 of the 120 countries it covers, while Mozambique sits only one place above the bottom 10 (Table 2.3). Their lowly positions

Figure 2.3 Commonwealth LDCs' productive capacity in energy



Note: The values in the chart reflect the respective scores for the energy component of UNCTAD's Productive Capacities Index (PCI). PCI scores range from 0 to 100.
Source: UNCTAD Productive Capacities Index 2022.

on the ETI rankings, and their comparatively poor scores for the overall index as well as the sub-indices related to system performance and transition readiness, show that, relative to many others, these four countries are currently under-prepared to undertake the clean energy transition successfully.

More encouragingly, however, all four Commonwealth LDCs covered by the ETI have registered improved scores on the index since

Table 2.2 Patents for renewable energy technology development originating in Commonwealth LDCs (2000–2019, cumulative total)

		Categories of renewable energy technologies				
Inventor country	Renewable energy generation	Wind energy	Solar thermal	Solar photovoltaic energy	Marine energy	Hydro
Bangladesh	9.89	1.00	0.33	8.56		
Rwanda	0.66			0.66		
Sierra Leone	0.83		0.33			0.50
Tanzania	0.33			0.33		
Uganda	0.50			0.50		
Zambia	1.00				1.00	
All other LDCs	*42.07*	*8.83*	*7.50*	*20.21*	*1.50*	*4.50*
World	*161,654*	*39,780*	*24,237*	*88,356*	*9,058*	*11,628*

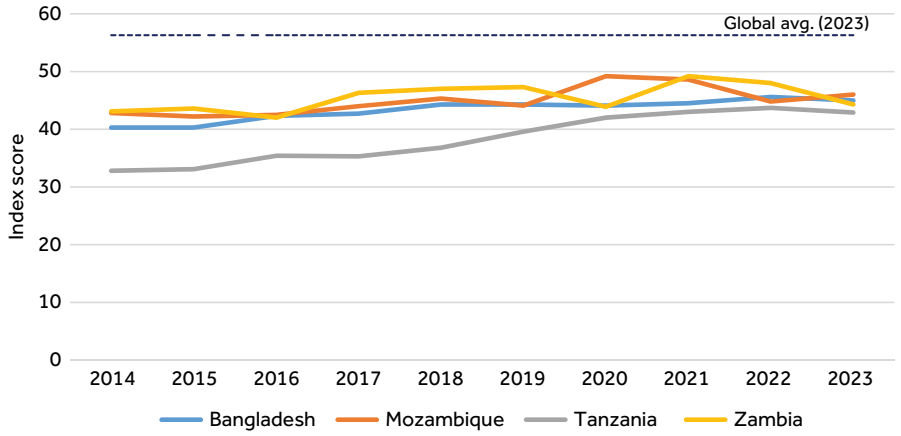
Note: Numbers of patents represent fractional counts by country of residence of the inventor(s); for example, for a patent listing inventors from two different countries, each country will obtain a count of 0.5, to avoid double-counting of inventions.
Source: Commonwealth Secretariat (calculated using Organisation for Economic Co-operation and Development [OECD.Stat] data).

Table 2.3 Energy Transition Index (ETI) rankings and scores for selected Commonwealth LDCs (2023)

	Bangladesh	Mozambique	Tanzania	Zambia	Global avg.
ETI rank (/120)	113	109	118	117	–
Index scores					
Overall ETI	45.0	46.0	42.9	44.3	56.3
Sub-indices					
System performance	56.8	58.1	51.4	56.7	63.0
Transition readiness	27.3	27.8	30.1	25.8	46.2

Source: World Economic Forum (2023).

Figure 2.4 Trend in Energy Transition Readiness Index scores for selected Commonwealth LDCs (2014–2023)



Source: World Economic Forum (2023).

2014 (Figure 2.4). This upward trend suggests they are gradually enhancing their readiness to transition to more secure, sustainable, affordable and reliable energy systems in the future. However, while there has been some convergence, all four countries remain a considerable distance from the global ETI average as of 2023, suggesting there is much room for improvement.

3. Challenges faced by LDCs seeking to access green technologies

The rapid growth in technologies for renewable energy has contributed to the development of several green technologies that are widely used globally. Yet many of these technologies are not produced within LDCs, as these countries often rely heavily on imports of green technologies and associated components. LDCs need to have access to key sources of new green technology in order to transition to clean energy and help mitigate climate change. Trade and investment can facilitate access to these technologies via the exchange of equipment, machinery and knowledge, yet LDCs find it challenging to access technology through these channels.[9]

Transitioning to green energy can be very costly for LDCs as they require financial and human resources to upgrade networks and integrate variable renewable energy sources, while also needing to expand access to electricity. In the short run, new technologies are required for battery and long-duration energy storage, harnessing offshore wind and green hydrogen,

which can be costly, hindering access to technology (Zhuawu and Garg, 2023). Facilitating the early disposal of fossil fuel power plants also comes with costs, for example, financing existing debts (World Bank, 2023). The situation in LDCs is worsened by their lack of institutional capacity and limited financial and human resources to implement and enforce policy measures related to accessing technology (WTO, 2005). Moreover, it is difficult to obtain financing for climate-related technology in LDCs due to uncertainty and risks that are not easy to mitigate in private finance markets, poor credit worthiness, lack of guarantees and limited capital for public investment (United Nations, 2015). This affects their ability to take advantage of trade-related policies to improve access.

In most LDCs, access to clean energy technology through trade and investment is limited to importing intermediates such as machinery and equipment. International trade via GVCs holds the potential to increase exports of technology-intensive goods from the country that owns the technology to LDCs. For example, integration in environmental goods GVCs can provide a channel for green technology diffusion and development (Bellelli and Xu, 2022). However, a lack of information on new and existing technologies can limit LDCs' access to these technologies. The absence of legal frameworks guiding and regulating access to technology in these countries, especially in renewable energy, poses an additional barrier to accessing new technology (Zhuawu and Garg, 2023). In some countries where legal frameworks are in place, there is a lack of clear information about the existing regulations on accessing technology for the benefit of both foreign investors and domestics firms (Gu et al., 2021).

A highly protected domestic market, including tight control on the employment of foreign skilled workers, coupled with a lack of viable export markets can stifle access to green and other technology (ibid.). Many LDCs have historically been unable to attract new investment and related technologies, in part due to limitations imposed on investment and the movement of natural persons, measures which have been less supportive in attracting FDI, knowledge and skills (Table 3.1). In some instances, policy measures that have set up a *quid pro quo* between market access and access to technology, or to discriminate between foreign and domestic industries with a view to forcing technology transfer, have not always delivered the desired outcome. In addition, some measures lack transparency, in both their formulation and application; for example, in the granting of licences and certifications that discourage investment and the transfer of technology (Andrenelli et al., 2019). When governments seek to establish partnerships with foreign investors, concerns may arise about the protection of information that is provided to them for approval or licensing purposes (ibid.). Thus,

Table 3.1 Examples of market access and national treatment limitations imposed by LDCs

Limitation on market access	Limitation on national treatment
Joint venture requirement – approval required for 100% foreign ownership	Investor training of citizen requirement
Valid work permit required before taking on work; limited stay and labour market test	Foreign workers must obtain a work permit and exceptions must be obtained for senior management personnel and technical experts not available in the local labour market
Foreigners only employed as senior management and technical experts if not available locally; limited stay	Employment of foreigners for the implementation of foreign investment shall be agreed upon by the contracting parties and approved by government
Approval owing to economic needs test and registration requirement	Central banks can permit foreign-controlled companies to obtain loans or overdrafts only up to a stated value
Licence requirement	
Investor training of citizen requirement	
Professionals registering with local appropriate bodies	

Source: Authors' compilation from LDCs' General Agreement on Trade in Services (GATS) schedules of commitments.

while policies that limit or regulate the entry and operation of FDI in sensitive or strategic sectors – such as energy – may protect national interests and the public, and safeguard local innovation, they can also deter investment in these sectors and fail to provide suitable incentives to promote access to technology (Kowalski et al., 2017).

Restrictions on the movement of natural persons can also serve as a barrier to the flow of much-needed knowledge and skills relating to renewable energy sectors and applications. Requirements to hire local employees, especially at a senior level, can be seen as a way of accessing technology unintentionally and may discourage foreign investors from entering the market or entering into agreements with local partners. This is because they may feel subjected to pre-established terms or that their ability to control their proprietary technology will be compromised (Andrenelli et al., 2019). In addition, restrictions on cross-border data flows might affect FDI activities in the energy sector, especially in today's knowledge economy.

Access to renewable energy technologies protected by IPRs – which are critical to protect and preserve the technology owner's interests – often comes at a high cost for financially-constrained LDCs. Article 7 of the World Trade Organization's (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) acknowledges that the protection and enforcement of IPRs should contribute to the promotion of technological innovation and to the transfer and diffusion of technology, to the mutual advantage of the producers and users of the technology in a way that is conducive to social and economic welfare, and to ensure a balance of rights and obligations (WTO, 1995). Technology owners benefiting from IP protection have the option to allow a third party to access their technology in exchange for a royalty payment or other compensation. This can be challenging for LDCs that do not have strong IP legal frameworks and lack the ability to compensate. In countries with weak institutions and few guidelines or regulations governing access to technology, there is a possibility of IP violation and related conflict, thereby deterring technology transfer.

The situation in LDCs is often worsened by their lack of capacity to reverse engineer or imitate existing technologies – including clean energy technologies – at a lower cost. Article 31 of the TRIPS Agreement establishes conditions for compulsory licencing. While LDCs might want to issue a compulsory license, the process can be costly, cumbersome and time consuming, especially as some licenses require negotiations with the IP right holders. In addition, determining adequate remuneration might be challenging.[10] LDCs also face constraints such as political and economic pressure from some industrialised countries, complexities associated with practical implementation, inadequate institutional capacity, and lack of co-ordination between patent offices (Vickers et al., 2021). Furthermore, compulsory licensing can be ineffective without the technical know-how to absorb the technology. In this regard, policy-makers must think through the issues to determine if compulsory licensing is required (Andrenelli et al., 2019).

Reliance on imported technology can stifle innovation and the development of R&D capacity in LDCs, as their producers prefer to rely on technology brought in from elsewhere. At the same time, the costs associated with adopting new technologies can be prohibitive. The adoption of green technologies entails new capital costs and higher operational costs; whereas in many cases, countries prefer adopting technologies to reduce environmental impacts and save them money (Allan et al., 2014). Furthermore, gaining access to technology is a complex process and not a one-time purchase, with the transaction costs involved in accessing technology often increasing over time – for example, through the need to service machinery or learn how to use new technology and adapt existing practices and processes to it (Allan, et al., 2014; Zhuawu and Garg, 2023). The introduction of new technologies can thus produce shocks that may cause changes to specialisation patterns in LDCs (Redor and Saadi, 2011).[11] As such, the costs associated with purchasing and/or introducing new technologies can serve as a barrier to accessing green technology in LDCs.

Moreover, many LDCs lack the capacity to absorb clean energy technologies, mainly due to human capital being inadequate in terms of their technical and managerial expertise. This contributes to inhibiting the diffusion of new and existing technologies more widely. In Bangladesh, for instance, several advanced technologies that are already in use by firms are not widely diffused and many firms continue to use basic technologies. For example,

47 per cent of firms still use handwritten processes for business management and 72 per cent of them use manual inspection (Gu et al., 2021). Behavioural factors, such as values and cognitive biases, can also affect the diffusion of technology and, in some instances, only a few adopters try new technologies in the initial stages before technology diffusion accelerates (Allan et al., 2014). Attitudes and knowledge about the environment may also affect access to green technologies; for example, levels of environmental awareness can influence the perceived need to access green technologies (Baumgart-Getz et al., 2012).

4. Promoting access to technology and accelerating the transfer of green technologies to LDCs

The discussion above emphasises the enormity of the challenges confronting LDCs looking to improve their access to new and more advanced technologies, including those required to enable a clean energy transition. With these difficulties in mind, this section outlines existing global initiatives to support LDCs to expand their capabilities in STI and enhance their access to modern technologies (Section 4.1); and examines the scope and efficacy of existing trade- and investment-related agreements and policies that are designed to support access to technology in LDCs (Section 4.2).

4.1 Recent global initiatives

There are currently several multi-country initiatives that aim to provide a platform of support – including through capacity building, technical assistance and technology transfers – to improve LDCs' capabilities in STI and ensure they benefit from access to modern technologies. Among these, the United Nations' Doha Programme of Action (DPoA), which runs from 2022 to 2031, includes commitments to help LDCs build their technological capacity and accelerate the development of renewable energy systems (Box 4.1).

Box 4.1 Facilitating technology transfer and accelerating renewable energy development in LDCs through the DPoA

The DPoA proposes a range of actions to help LDCs build their STI capabilities and capacity. It emphasises the need to develop stronger partnerships and enable greater collaboration between governments, the private sector (especially major technology companies) and academia to advance R&D for STI in LDCs and build their technical competencies to harness the power of technology to support sustainable development. Similarly, the DPoA calls for greater investment in education and training for digital literacy and skills, as well as in STEM.

The DPoA also outlines actions and interventions aimed at facilitating the transfer of technology to LDCs so that they can benefit from better access to modern technologies. To this end, it reiterates the need for developed countries to provide incentives to enterprises and institutions in their territories to transfer technology to LDCs (as per Article 66.2 of the TRIPS Agreement). The plan also calls for the provision of more support to relevant stakeholders in LDCs to increase their understanding of intellectual property rights and the practicalities involved in transferring and safeguarding knowledge and technology. Additionally, it recognises the need to scale-up support for the United Nations Technology Bank for the Least Developed Countries, including through financial and in-kind resources, to help LDCs strengthen their STI capacity.

Recognising the importance of technological innovations supporting the clean energy transition, the DPoA contains several implementable actions intended to substantially increase the share of renewables in the energy mix of LDCs by 2030. It highlights the need for greater consideration of decentralised renewable energy solutions in LDCs' energy planning, including in the form of mini- and micro-grids, stand-alone renewable energy systems, rooftop solar PV panels and storage, digitally enabled solutions, and other technologies. It also calls for greater international co-operation to facilitate access to clean energy research and technology in the areas of renewable energy, energy efficiency, and advanced and cleaner fossil fuel technologies.

In addition, the plan commits to supporting the implementation of the Least Developed Countries Renewable Energy and Energy Efficiency Initiative for Sustainable Development (LDC REEEI). The LDC REEEI was initiated by LDCs to accelerate efforts to harness their renewable energy potential. It targets full access to sufficient, affordable, modern and renewable energy for all citizens in LDCs by 2030; and aims to ensure that LDCs obtain 100 per cent of their electricity from renewable energy sources by 2050.[12]

The DPoA emphasises the important role of the United Nations Technology Bank for LDCs ('the Technology Bank') as a focal point to strengthen STI capacity in the world's poorest countries. The work of the Technology Bank, which began operations in 2018, is focused on enhancing the contribution of STI to sustainable development in LDCs. It acts as a hub to match the STI needs of LDCs with available resources and key STI actors, facilitate LDCs' access to existing technologies, and foster international research collaborations and capacity development initiatives to stimulate the production of high-quality research in LDCs. It also runs a capacity development programme to enhance STI capabilities in LDCs through improved STI policy-making and collaborative innovation networks to connect scientists, technologists and relevant public institutions in LDCs with their peers globally.

The Technology Bank also supports LDCs to undertake technology needs assessments to identify technological solutions to address their developmental challenges. These demand-led assessments help LDCs to identify key areas where they can take advantage of technological opportunities, evaluate their enabling environments and identify barriers to the adoption and application of technologies, devise implementation plans detailing ways to boost their technological development, and identify strategies to facilitate the transfer of priority technologies.[13]

However, there is scope to strengthen the capacity of the Technology Bank and boost the resources at its disposal. This is necessary so that it can provide better support to LDCs to access renewable energy and other technologies, including by facilitating technology transfer and assisting them to adopt and adapt new technologies for local settings (Commonwealth Secretariat, 2022). Lessons can be learned from the implementation of projects under the Technology Bank's Technology Transfer Programme, such as a project supporting the transfer of sustainable and affordable housing material and construction technologies to Mozambique or the now concluded Technology Access Partnership, which helped to facilitate access to health technologies (including diagnostics, medical devices and personal protective equipment) in LDCs. Identifying and addressing the Technology Bank's capacity and resource needs and focusing on what support has been most effective in previous or ongoing projects, can provide a base from which to upscale and expand its support for technology transfer to other priority sectors in LDCs, including renewable energy.

Other major networks and initiatives can also play a central role in supporting the renewable energy technology needs of LDCs. For instance, the Climate Technology Centre and Network (CTCN), established by the United Nations Framework Convention on Climate Change (UNFCCC) in 2011, serves as the implementation arm of the Technology Mechanism of the UNFCCC, providing technology solutions, capacity building, and advice on policy, legal and regulatory frameworks tailored to the needs of individual countries.[14] It aims to speed up the move towards climate resilience and emissions reduction. It responds to country-driven requests with a focus on strengthening the capacity of developing countries and LDCs to address technology challenges and opportunities for adaptation and mitigation to enable them to take effective climate action in the context of the Paris Agreement and associated technology framework. In this regard, the CTCN facilitates a network of national, regional, sectoral and international technology service providers, organisations and initiatives with a view to implementing technical assistance in a resource-efficient manner.

The CTCN has been instrumental in facilitating access to support for LDCs in their energy transitions. For example, in 2015, it facilitated technical assistance to Uganda to formulate a geothermal energy policy, legal and regulatory framework, and to Tanzania to promote the sustainable use of solar photovoltaic technology.[15]

4.2 Trade and investment policies and the transfer of renewable energy technology to LDCs

The WTO also has a critical role to play in such efforts, as well as those aiming to develop STI capacity in LDCs. These priorities are highlighted in several foundational WTO agreements and ministerial conference decisions. WTO members continue to analyse the relationship between trade and technology transfer and consider possible recommendations for steps that might be taken within the mandate of the WTO to increase the flow of technology to developing countries.

Much of this analytical work is undertaken through the Working Group on Trade and

Transfer of Technology (WGTTT), which was established at the WTO's Doha Ministerial Conference in 2001 and reports to the General Council.[16] The WGTTT has an important role to play in unpacking how the transfer of technology between developed and developing countries should take place in practice, as well as examining what specific measures could be taken under the auspices of the WTO to encourage these flows. Past discussions within the Working Group have covered a range of issues, including the linkages between trade and the transfer of technology, the measures and channels through which technology transfer can occur, the interests of the private sector with respect to sharing technology, and ways to ensure WTO provisions related to technology transfer are operational and meaningful. Yet there remains a lack of consensus on certain issues under discussion.

There is scope to afford dedicated attention within the agenda of the WGTTT to identify trade-related mechanisms that increase flows of renewable energy technologies to LDCs and other developing countries, including via sharing country experiences and identifying provisions in WTO agreements that could enable transfers of these specific types of technologies. In a similar vein, there is potential to initiate more systematic discussion of issues related to technology transfer in the context of climate change and the clean energy transition in the WTO TRIPS Council, as well as in the Committee on Trade and Environment and the Trade and Environmental Sustainability Structured Discussions (Kelly et al., 2021). Moreover, there is potential to develop greater synergies between the work of the WGTTT and other WTO technology transfer mechanisms and the commitments within the UNFCCC to assist LDCs to access climate-related technologies (ibid.).

Most recently, in April 2023, the WTO, together with the World Bank Group and the World Economic Forum, launched a pilot initiative for Action on Climate and Trade (ACT), which aims to help participating developing economies, including LDCs, to leverage trade to meet their climate change mitigation and adaptation goals. It seeks to do so by providing action-oriented analysis – tailored to individual countries' needs and local circumstances – of ways in which trade and investment policies can contribute to their National Adaptation Plans and their Nationally Determined Contributions under the Paris Agreement. This presents an opportunity to help LDCs identify how they can use trade to improve their access to climate-friendly technologies – including those enabling the generation and distribution of renewable energy – that support their efforts to accelerate emission reductions.

Despite these varied initiatives, access to technology and technical expertise – including to support climate change mitigation, resilience building and sustainable development – has not materialised in the context of multilateral trade. Furthermore, the links between trade and the transfer of climate-related technologies have received relatively little attention in trade discussions and negotiations related to technology transfer (Kelly et al., 2021). To operationalise technology transfer obligations under existing multilateral agreements, Commonwealth LDCs could propose a more direct approach that links the transfer of technology to efforts to harness raw materials to produce and trade renewable energy, citing the fact that this is key to mitigating climate change and achieving environmental sustainability, as well as meeting the objectives of the TRIPS Agreement to develop a sound and viable technological base (Box 4.2).

Box 4.2 The WTO's TRIPS Agreement

The TRIPS Agreement's preamble contains favourable provisions for LDCs and recognises 'the special needs of the least-developed country Members in respect of maximum flexibility in the domestic implementation of laws and regulations in order to enable them to create a sound and viable technological base'. Article 66.2 of the TRIPS Agreement requires developed country WTO members to provide incentives to businesses and institutions in their territories to encourage them to transfer technologies to LDCs. Since 2008, the WTO Secretariat has conducted yearly workshops to enhance the benefits of the transparency mechanism related to measures on the transfer of technology under Article 66.2 and to promote dialogue between LDC beneficiaries and developed countries. While LDCs have underscored the vital role that technology can play in expanding their productivity and output, diversifying their economies, and helping them to integrate into regional and GVCs, they have expressed disappointment over the limited operationalisation of technology transfer by developed countries under Article 66.2. To date, there has not been a suitable solution at the WTO to enhance the performance of this obligation.

The transfer of technology under Article 66.2 has been limited, despite the presence of a mechanism to monitor the full implementation of the obligations.[17] One reason is that the TRIPS Agreement does not oblige developed countries to transfer technologies to LDCs, but rather to provide incentives to enterprises and institutions in their territories to encourage them to engage in such transfers. The types of incentives provided by most developed countries were covered under technical assistance programmes that were meant to be included under Article 67 of the TRIPS Agreement (Watal and Caminero, 2018). These types of incentives have been provided in the energy sector, including for renewable energy (Table 4.1). However, to date, there is no indication that these incentives have contributed to enabling LDCs to access technology (ibid.).[18] Consequently, LDCs will need to be proactive and craft policies that promote their access to technology and enable them to

Table 4.1 Examples of developed countries' incentives, pursuant to paragraph 1 of the Decision on the Implementation of Article 66.2 of the TRIPS Agreement (2003–2023)

Country/ territory source of technology	Type of technology for transfer	Incentives for technology transfer	Targeted LDC
Canada	Knowledge, know-how, skills, climate change technology	Financial contribution to Clean Technology Fund (CTF) – Climate Investment Fund (CIF)	Multiple LDCs (not specified)
European Union	Hardware and training	Financial support	All Commonwealth LDCs
	Implementation capacities	Financial support	Tanzania
	Technological knowledge of electrical distribution management	Training and capacity building	Tanzania
	Research projects employing techniques and approaches to better integrate technological developments	Joint research projects with LDC partners and projects including LDCs as study areas	Bangladesh, Cambodia, Ethiopia, Lesotho, Malawi, Mozambique, Myanmar, Nepal, Rwanda, Sierra Leone, Tanzania, Uganda and Zambia
	Geothermal exploration methods, geological and geophysical field methods, capacity building, support in geothermal regulations	Not applicable	Ethiopia, Comoros, Djibouti, Democratic Republic of Congo (DRC), Malawi, Tanzania, Rwanda and Uganda
Norway	Various technologies – hydro, wind and solar, as well as biogas, geothermal and waste-to-energy projects	Facilities for pre-investment support, including training; and support to devise framework conditions in developing countries	Ethiopia, Liberia, Mozambique, Myanmar, Nepal, South Sudan, Tanzania and Uganda
New Zealand	Energy infrastructure – solar farm	Financial support	Solomon Islands
	Energy infrastructure – Wind-solar hybrid energy system	Infrastructure; training	Solomon Islands
USA	Power generation and transmission, training and capacity building	Financial contribution to CTF – Programme for Scaling-Up Renewable Energy in Low Income Countries (SREP)	Bangladesh, Benin, Cambodia, Haiti, Lesotho, Madagascar, Malawi, Mali, Nepal, Rwanda, Sierra Leone, Solomon Islands, Tanzania, Uganda, Yemen and Zambia

Source: WTO (2016a, 2016b, 2016c, 2016d and 2017).

acquire appropriate technologies that best fit their green transition and development needs.

For LDCs, trade and investment policies can help promote their access to green technologies and play a significant role in promoting clean energy generation, lessening technological gaps and stimulating sustainable growth. Well-crafted policies can provide guidelines and regulations to help ensure that LDCs access and benefit from appropriate technologies, to enhance their capacity to generate renewable energy, improve their productive capacities, facilitate industrialisation, diversify their economies and help them better integrate into GVCs (WTO, 2020). In this regard, LDCs have adopted different trade-related policies that guide or regulate and facilitate their access to technology, including access to renewable/green energy technology, especially from their development partners. Some of the common trade and investment-related policies that exist in LDCs include those related to intellectual property (IP), investment incentives, investment promotion, investment restrictions, performance requirements and absorptive capacity (Table 4.2). These categories are non-exhaustive, as there may be other types of measures and policies that are specific to certain sectors, regions or situations.

The policies in Table 4.2 tend to overlap, but they individually affect access to technology, including access to renewable/green energy technology, in different ways, as they have different characteristics and come into force at

Table 4.2 Broad trade-related policies to promote access to green (and other) technologies

Policy category	Broad policy description	Examples of policy measures to promote access to green technologies in LDCs
Intellectual property rights	This category comprises policies that affect the creation, protection and enforcement of IPRs, such as patents, trademarks and copyrights. Broadly speaking, these policies outline how IP rights are provided, managed and protected in the context of technology transfer, including in renewable energy, covering aspects such as ownership, disclosure, evaluation, licencing and revenue sharing generated from IP (Pigola et al., 2022). Such policies can influence the incentives and costs involved in providing access to technology, both from the perspective of technology owners and recipients. For instance, stronger IPR protection, including patent box incentives[19] designed to attract and retain foreign technology, can provide an incentive for FDI accompanied with access to technology (Andrenelli et al., 2019). It can also help incentivise innovation, foster collaboration, and ensure fair and ethical use of IP.	The Government of Bangladesh provides 100% tax exemption to all power generation companies, excluding coal-based ones, that began operations before 31 December 2022. These companies also enjoy full tax exemption on income from their power generation business until 2034, as well as tax exemptions on interest from foreign loans, royalties, technical know-how and assistance fees, and profits from trading in shares of these power companies.[20]
FDI promotion	This includes policies aimed at attracting FDI from investors possessing appropriately advanced technology, including green energy. Such measures include tax incentives, subsidies, grants, loans or other financial support to foreign investors, as well as providing information, facilitation and matchmaking services.	In Malawi, the National Energy Policy 2018 establishes a guiding framework for achieving increased access to affordable, reliable, sustainable, efficient and modern energy for every person in Malawi. The policy emphasises the importance of private sector participation in the energy sector and of providing an environment conducive for such participation, in the form of direct investment, public–private partnerships, independent power producers, or other participation vehicles.[21]

(*Continued*)

Table 4.2 Broad trade-related policies to promote access to green (and other) technologies

Policy category	Broad policy description	Examples of policy measures to promote access to green technologies in LDCs
Investment incentives	This category encompasses policies that offer support to domestic firms that invest in obtaining or developing new technology. Such measures include providing tax breaks, subsidies, grants, loans and other financial assistance to domestic investors. They also include measures facilitating access for domestic investors to foreign technology through licensing agreements and joint ventures.	In Zambia, the Solar Industry Association of Zambia redrafted the fiscal exemptions for solar products by removing import duties and VAT (value-added tax) for solar equipment.[22]
FDI restrictions	These policies limit or regulate the entry and operation of FDI in sensitive or strategic sectors (such as energy) or activities, especially for national security or public interest reasons. Such measures include the imposition of caps on foreign ownership, requirements to establish joint ventures with local partners and national security review requirements.	In Uganda, a foreign investor, including in renewable energy, is required to acquire an investment license from the Uganda Investment Authority. The minimum investment threshold for foreign investors is US$250,000.[23]
Absorptive capacity	Absorptive capacity policies seek to enhance the ability to uptake, adapt and use foreign technology - for instance, by investing in education, R&D, infrastructure and IPR protection. These policies also aim to attract investment and maximise the capacity for positive spillovers to the domestic economy (Andrenelli et al., 2019). They may also encourage collaboration with foreign partners and help leverage the resources and expertise of both the public and private sectors to advance scientific and technological innovation. Such collaboration can also involve the transfer of technology to help enhance the quality of R&D, stimulate interest in science and technology careers, and foster long-term partnerships (Koca et al., 2021).	Proposals in Lesotho aim at strengthening the private sector's capacity and developing a conducive environment for cleantech investments, with a focus on three areas: capacity building, strategic environment creation and investment-grade solution development.[24] The Government of Rwanda has established a US$48 million Renewable Energy Fund managed by the Rwanda Development Bank to provide low-cost debt financing to households and companies for the purchase of off-grid solar home systems and the development of renewable energy mini-grids.[25]
Performance requirements	These policies impose certain conditions or obligations on FDI in exchange for market access. Such policies include local content requirements, technology transfer, export performance and/or employment generation.	The Rwanda Energy Policy (2015) highlights measures that need to be undertaken to promote energy efficiency, such as regulations, new codes and standards.[26]

different moments during implementation (Bellelli and Xu, 2022). In addition, access to renewable technology is not secured in isolation and requires consideration from the perspectives of both the provider and receiver of technology, as well as the adaptability of the technology itself (Watal and Caminero, 2018). Furthermore, complementary policies that promote access to green technology and technology in general, such as education and training policies, and those that help create a supportive business environment, are also required.

5. Conclusion

A lack of access to renewable energy technologies in LDCs greatly impedes their efforts to transition to clean energy and reduce their carbon footprint. Using green technologies to generate clean energy can help LDCs diversify their energy sources and reduce their dependence on fossil fuels and imported energy, while also enhancing their energy security, stability and resilience (International Energy Agency, 2021). It will also help LDCs attain the Sustainable Development Goals (SDGs), particularly Goal 7 on access to affordable, reliable, sustainable and modern energy for all; Goal 12 on ensuring sustainable consumption and production; and Goal 13 on climate action.

Some LDCs have begun to take policy measures to enable them to transition to clean energy by utilising their considerable resource endowments to generate renewable energy, including hydroelectricity, solar energy and biomass energy (see de Klerk et al., 2024). For example, to transition to renewable energy and continue to meet the energy requirements of its garment industry and the country as a whole, Bangladesh adopted several measures to enable technology transfer into the generation of renewable energy. It targeted FDI to facilitate the transfer of technology through material supply chains, which helped to develop local capacity in renewable energy (Geroge, 2021). To attract FDI and the associated technology, Bangladesh has also developed a one-stop online platform to reduce delays and ensure transparency, thereby improving the country's investment regime.

Yet, it needs to be emphasised that realising the potential benefits afforded by these technologies will be challenging. The issues affecting access to technology in LDCs are complex. While it is essential for LDCs to access the necessary technology to harness their renewable energy potential, there is no simple answer to how this should be realised in practice. Much depends on the policies of both LDCs and their development partners. For their part, LDCs should evaluate their policies relating to access to technology on a case-by-case basis, considering their objectives, design, implementation and impact. It is also essential for these countries to foster international co-operation and dialogue on technology transfer in renewable energy in the context of shared goals and mutual benefits in combating climate change.

There is room to leverage international support for technology transfer and diffusion in the generation of renewable energy. This is imperative to achieve SDG 17.7, which seeks to promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms. However, it is first necessary to generate more evidence on the actual technological gaps and technology requirements in LDCs in order to develop the right policies to support technology transfer and ensure the most appropriate sector-specific technologies are identified and acquired. This should be accompanied by efforts to strengthen government capacity to target areas that require vigorous support to attract investment and technology transfer and adoption. At the same time, there should be deliberate efforts to strengthen national capacity for technology absorption in LDCs and tackle challenges that hinder technology adoption, both of which are critical to enable the level of technological diffusion necessary for a successful transition to clean energy.

Private sector involvement through joint ventures and other strategic partnerships can enhance LDCs' access to technology in the renewable energy sector. Yet, LDCs may generate concerns if they impose conditions requiring mandatory transfer of technology, which the technology owner might view as preconditions to be party to a joint venture. Lessening the burden of trade and investment restrictions could encourage technology transfer and adoption by making the energy sectors in individual LDCs more open to international markets and investors. In this respect, LDCs should look to remove unnecessary limitations that discourage FDI in renewable energy and related technologies. This can be done through appropriate reforms to investment policy and IP frameworks in LDCs and, at the same time, through the provision of meaningful incentives for investment in clean energy.

Since training and the exchange of experts play an essential part in technology generation, access and adoption, LDCs should also

consider ways to encourage the movement of scientists, technologists and technicians under the WTO's General Agreement on Trade in Services to facilitate their access to technology (WTO, 2005). In addition, LDCs should assess how their IPR policies, together with other institutional and regulatory measures, may affect access to and diffusion of green technology in their territories.

The developers of technology and LDCs should consider regulatory co-operation in relation to access to technology for the generation of green energy, with the aim of ensuring mutual benefit in efforts to contribute to mitigating climate change. Such co-operation can bring clarity and certainty through joint efforts to reduce market imperfections related to accessing technology and its diffusion in the green energy sector, while also encouraging investment by the private sector. According to Bellelli and Xu (2022), in the event of co-ordination failures, unilateral policies should focus on investment in clean energy research and favour the transfer and spread of green technologies. Technology partnerships have the potential to mitigate the risk of climate change and other environmental challenges by encouraging technology diffusion in LDCs and helping to refine associated policies, regulations and procurement processes for green technologies (World Bank, 2023). In addition, international co-operation is vital to mobilise and allocate resources in a co-ordinated, systematic and well-targeted manner (United Nations, 2015). It is also critical to find ways to operationalise relevant provisions in WTO agreements that relate to technology transfer and develop clear implementation and monitoring processes (WTO, 2005).

Environmental awareness can influence the need to access and adopt green technologies. In this regard, LDCs can pursue environmental policies that encourage the transfer of technology from their developed country counterparts. This is crucial because accessing green technology is central to achieving environmental policy objectives. In doing this, it is crucial to consider technologies that contribute to building resilience to climate change and natural disasters. In addition, environmental policies should be accompanied by other policies that support investment in clean energy and favour the transfer and diffusion of green technologies.

In conclusion, the trade and investment policies of LDCs can play a critical role in not only facilitating their access to technology, but also in enabling them to effectively engage in multilateral, regional and bilateral discussions and negotiations on access to technology. In this regard, Commonwealth LDCs need to take a more direct approach that links their access to green technologies with their efforts to harness their raw materials to produce and trade renewable energy. This is key to mitigating climate change and achieving environmental sustainability, as well as to them meeting their SDGs.

Notes

1 The first paper in the series examines the renewable energy landscape in LDCs and explores the scope to expand renewable energy generation and trade in these countries by maximising the potential of their renewable energy endowments (see de Klerk et al., 2024).

2 The ranks of the Commonwealth LDCs on the overall Index are: Lesotho (121), Bangladesh (126), Tanzania (127), Rwanda (139), Uganda (138), Malawi (141), Togo (142), Zambia (147), Solomon Islands (151), The Gambia (160), Sierra Leone (161) and Mozambique (162).

3 The Commonwealth LDCs' rank on the R&D activity sub-indicator as follows: Bangladesh (67), Tanzania (79), Uganda (91), Rwanda (99), Zambia (115), Malawi (117), Lesotho and Mozambique (both 123), Sierra Leone (131), Togo (146), The Gambia (149) and Solomon Islands (160).

4 The Commonwealth LDCs are ranked as follows: Bangladesh (102), Tanzania (103), Rwanda (105), Zambia (118), Uganda (119), Togo (122) and Mozambique (123).

5 No comparable data were available for the Asian and Pacific Commonwealth LDCs.

6 See https://unctadstat.unctad.org/en/classifications/dimsitcrev3products_ldc_hierarchy.pdf for a detailed classification of products according to technological categories.

7 https://unctadstat.unctad.org/en/classifications/dimsitcrev3products_ldc_hierarchy.pdf

8 The ETI provides a data-driven framework for measuring the current performance of a country's energy system (based on the extent to which it is equitable, secure and sustainable) and its readiness for the energy transition (based on the state of regulation and political

commitment, infrastructure, education and human capital, innovation, and finance and investment).

9 The challenges faced are like those associated with accessing technology more generally.

10 'Compulsory licencing' involves the granting of specific permissions to a producer other than the patent holder to produce, import, sell or use the patent-protected product, or use of the patent-protected process by government or the responsible authority. Here, patent owners are, in principle, entitled to receive some payment or remuneration.

11 Policy-makers need to demonstrate the spillovers to justify accessing certain technologies.

12 See http://ldcreeei.org/ for more details on the initiative.

13 More details on the work of the United Nations Technology Bank for the LDCs can be found at: www.un.org/technologybank/

14 www.ctc-n.org/

15 www.ctc-n.org/technical-assistance/data

16 Paragraph 37 of the Doha Ministerial Declaration

17 The WTO Council for TRIPS monitors the operations of the TRIPS Agreement, including members' compliance with their obligations. The decision to set up a monitoring mechanism was reached by the Council for TRIPS in 2003 (WTO, 2003).

18 LDCs have not provided evidence at the WTO regarding whether the incentives programmes provided by developed countries have led to technology transfers in their favour, which makes it difficult to assess the impact of these incentive programmes (Watal and Caminero, 2018).

19 This is a government initiative designed to encourage companies to develop and retain their intellectual property within the country.

20 www.legal500.com/developments/press-releases/bangladesh-government-provides-100-tax-exemption-for-power-generation-companies/

21 https://iclg.com/practice-areas/renewable-energy-laws-and-regulations/malawi

22 www.pv-magazine.com/2021/07/02/are-siaz-sign-mou-to-accelerate-universal-energy-access-in-zambia-with-renewables/

23 www.eac.int/operating-environment/243-sector/investment-promotion-private-sector-development/investment-guide/2501-setting-up-and-operating-an-investment-in-uganda

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25 www.mininfra.gov.rw/updates/news-details/rwanda-targets-60-of-renewable-resources-by-2030-permanent-secretary-uwase-patricie

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