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KEY POINTS

- The development path of renewable technologies highly depends on preconditions and strategic policy responses
- It is essential for countries to identify opportunities available at each stage of a value chain and coordinate policy efforts across domains, to open and take advantage of green windows of opportunity
- Green windows of opportunity evolve over time; Governments should continuously review and adjust policies to ensure the ongoing success of the green transition

Formulating strategic policy responses to open green windows of opportunity

The depth and speed of green development vary across different environmental technology domains. Accordingly, sectoral and policy responses must be tailored to the "green window of opportunity" in question. Many developing economies have embraced renewable energy sources such as solar power and biofuels, with supportive policies in place to enhance domestic demand. However, the adoption of new and less mature technologies, such as green hydrogen, necessitates considerable investments in research and development, infrastructure and regulatory frameworks, to establish economic feasibility and competitiveness. An overview of renewable energy markets is presented in this policy brief, and four scenarios of green windows of opportunity are highlighted, based on individual responses and preconditions. An "identify-assess-sustain" approach is recommended, to facilitate the transition to green energy.[1]

[1] For further information on and analysis of the topics discussed in this policy brief, see UNCTAD, 2023, *Technology and Innovation Report 2023: Opening Green Windows – Technological Opportunities for a Low-Carbon World* (United Nations publication, Sales No. E.22.II.D.53, Geneva), available at https://unctad.org/publication/technology-and-innovation-report-2023.

Introduction

Green windows of opportunity are favourable but time-bound conditions for latecomer development, arising from changes in institutions, markets or technologies, associated with the global green transformation.[2] They are unique to each green technology, and responses must be tailored according to national-level conditions. For example, with regard to renewable sources of energy, there have been technical and financial challenges in Brazil in the bioethanol sector and in China in the solar photovoltaics sector, yet these countries have established leading positions globally with strong support through government policy.[3] These two technologies are mature and readily available, providing a relatively fast track to boosting economic activities, and they are being widely adopted in many developing countries.

In contrast, emerging technologies such as green hydrogen present a more uncertain green window of opportunity due to the significant investments required in research and development, infrastructure and regulatory frameworks. Countries that possess abundant solar, wind and hydropower resources are ideal locations in which to produce green hydrogen, indicating the presence of a significant untapped market potential for green hydrogen in many parts of Africa, South America and Southern Asia. However, green hydrogen initiatives in these regions have, to date, mainly fulfilled domestic demand and not targeted the international market, due to a lack of technology for storage and transport.[4]

It is essential to identify the conditions needed to be able to develop green technologies and respond strategically in order to seize related opportunities. Otherwise, latecomers may risk remaining on fossil fuel-based pathways, leaving foreign investors to dominate emerging green energy markets.

Matching policy responses with national preconditions

A summary of four possible scenarios based on different preconditions and response levels, with indicative examples, is provided in the table.

Four "green window" scenarios

Responses / Preconditions	Strong	Weak
Strong	**Scenario 1: Open windows** Brazil: Bioethanol Chile: Green hydrogen (potentially) China: Biomass, concentrated solar power, solar photovoltaics	**Scenario 2: Windows to be opened** Bangladesh: Biogas China: Wind India: Solar photovoltaics Morocco: Concentrated solar power
Weak	**Scenario 3: Windows within reach** Namibia: Green hydrogen Thailand and Viet Nam: Biomass	**Scenario 4: Windows in the distance** Kenya: Wind Mexico and Pakistan: Bioenergy

Source: UNCTAD, 2023.

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

[3] See https://news.cgtn.com/news/2021-04-06/Role-of-solar-power-projects-in-poverty-alleviation-in-China-ZeHxotj0Gs/index.html and https://www.scientificamerican.com/article/how-the-oil-embargo-sparked-energy-independence-in-brazil/.

[4] See https://www.oecd.org/publications/innovation-and-industrial-policies-for-green-hydrogen-f0bb5d8c-en.htm and https://www.ispionline.it/en/pubblicazione/chinas-emerging-hydrogen-strategy-30431.

The first and best scenario with regard to opening green windows of opportunity is one in which strong preconditions are combined with strong responses. Two examples are the bioethanol sector in Brazil and the solar photovoltaics sector in China. Both markets have robust preconditions, including substantial domestic demand. There is also a strong emphasis on codesigning policies that foster collaboration between the public and private sectors and encourage the dissemination of knowledge.

In the second scenario, there are strong preconditions but insufficient policy responses to translate them into opportunities. Areas that require improvement across several sectors are intersectoral management and the effective utilization of research and development programmes. For example, in Bangladesh, incentives and awareness efforts could help promote biogas plant installations and waste management benefits for farmers and, in India, greater efforts in training, the promotion of linkages to relevant stages of value chains and research and development could help boost the competitiveness of the solar photovoltaics sector.

In the third scenario, notwithstanding weak preconditions, proactive measures are being taken to build capacity and open green windows of opportunity. For example, in Namibia, with regard to green hydrogen, a platform has been established for government and private business interactions and, in partnership with Germany, there are collaborations in research and development and in identifying suitable production sites, while training professionals for this new industry. In Thailand, to help the biomass industry, subsidies, tax incentives and other favourable preconditions have been offered in order to encourage green energy investors. In Viet Nam, efforts are being made to develop a dynamic sectoral system in the biomass industry.

In the fourth scenario, there is limited potential for green windows of opportunity due to weak preconditions and inadequate responses. For example, in Kenya, progress in making the most of large-scale wind power development has been hindered by a relatively weak starting position, and inadequate strategies to ensure local embeddedness and to learn from past projects have led to a missed opportunity to foster learning and supply chain development. Similarly, in Mexico and Pakistan, there is a lack of capabilities to upgrade bioenergy technology.

Navigating maturity and tradability considerations

Two key aspects in adopting frontier technologies and designing relevant policies are maturity and tradability.[5]

Mature technologies have stable and dominant designs, as well as the presence of necessary infrastructure, regulations, markets, technical standards, maintenance networks and user practices.[6] Immature sectors offer opportunities that latecomers can leverage to disrupt industry. However, they can be challenging to operate in, as they require significant initial investments in research and development, which are typically only within the capabilities of strong domestic systems that are equipped with the necessary skilled labour, infrastructure, technology and financial resources to support extensive research in innovation and production activities. For example, in Brazil, the bioethanol industry, and in China, the concentrated solar power industry, feature strong domestic systems, with established infrastructures and sufficient resources to support the development of innovation and production.

Tradability plays a significant role in shaping competitive dynamics and learning modes. Sectors with high levels of tradability may require some form of market protection, as well as carefully designed and implemented strategies in order to stimulate demand.[7] To fully benefit from the high level of tradability of capital equipment related to energy production and storage, it is essential to have strong capabilities in related production domains. If the level of tradability is low, foreign direct investment may initially facilitate learning.

[5] Lema, Fu and Rabellotti, 2020.

[6] Geels FW, 2002, Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case study, *Research Policy*, 31(8–9):1257–1274.

[7] Landini F, Lema R and Malerba F, 2020, Demand-led catch-up: A history-friendly model of latecomer development in the global green economy, *Industrial and Corporate Change*, 29(5):1297–1318.

Policy recommendations

As green windows of opportunity differ across technologies, to effectively seize available opportunities, it is necessary to have not only government support at both the national and local levels but also the involvement of other stakeholders such as those in the private sector. Overall policies to open green windows of opportunity should first identify particular opportunities in terms of the availability of natural resources and national capacity to use or build the necessary technology, then assess what is needed and, finally, sustain the processes. In the meantime, Governments and other stakeholders should prepare to track possible feedback loops for adjustment after initial and follow-up implementation, to ensure uninterrupted advantages.

To ensure a smooth green transition, recommended policies include the following:

- **Identify and adjust to local circumstances**. Policymakers should begin to open green windows of opportunity based on existing sectoral preconditions and identify activities that local firms can feasibly undertake. For each technology, tailored strategies should be developed and adjusted, along with the necessary support systems, knowledge infrastructures and design and engineering capabilities

- **Align policies**. Policies developed in separate domains (for example, the environment, energy, industry and science, technology and innovation) should be aligned, to build up more interconnected local production networks and capacity. Leveraging multiple strategies could create a more comprehensive and resilient development path, to adapt to and meet local needs

- **Find the finance**. Governments should deploy incentive measures to stimulate investments in relevant sectors. Building local capacity also requires investment in different sectors, involving different public and private actors. Along with accessing resources from domestic governments and banks, it is essential to grant access to concessional external finance or international funds, to support green initiatives

- **Build domestic capabilities**. As technologies continue to advance, ongoing support is necessary in order to make process improvements. Moreover, to absorb, adapt and eventually develop renewable energy industries, countries need to take more tangible measures to build up human capital, access external knowledge and diffuse knowledge in the domestic ecosystem

- **Collaborate internationally**. Establishing domestic production often involves drawing upon the experiences of other countries. Developing economies should actively cooperate with international organizations, as well as with other national Governments and non-governmental organizations, to acquire valuable insights into the creation of more varied and cost-effective energy technologies

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