

TECHNOLOGY TRANSFER FOR THE GREEN TRANSITION

A summary of observations from the literature

The transition to low-carbon economies for countries depends not only on deploying clean technologies, but also on ensuring that countries, especially developing countries, can access, adapt, and eventually innovate on them. The United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement recognize technology development and transfer as a key means of implementation, while most Nationally Determined Contributions (NDCs) submitted by developing countries identify access to climate technologies, finance and capacity-building as prerequisites for achieving their mitigation and adaptation goals. This has made technology transfer a key issue in international climate negotiations and broader debates on decarbonization and green industrialization. This factsheet summarizes some of the key literature on technology transfer, both from the Global North to the Global South and from the Global South to the Global South, collating crucial observations that can inform upcoming discussions at multilateral fora on fossil fuel phase-out, the trade-climate nexus and green industrialization.

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DEFINING TECHNOLOGY TRANSFER

The Intergovernmental Panel on Climate Change (IPCC) defines technology transfer as the process of learning to understand, use and replicate a technology, including the capacity to adapt it to local conditions and integrate it with indigenous technologies.[1] This differs from technology diffusion, which is simply hardware moving to a new place. Transfer involves knowledge moving alongside hardware. This means the recipient has the knowledge to adapt, integrate, and eventually improve what it receives.

In a 2020 World Bank publication titled *Technology Transfer and Innovation for Low-Carbon Development* by economist Miria Pigato and colleagues, effective technology transfer is framed as a 'technology transfer staircase' running from the import, adoption and diffusion of foreign technology, through local adaptation and imitation, to eventual indigenous invention.[2] Movement up the staircase depends on a recipient's absorptive capacity, i.e. the ability to identify, assimilate and exploit external knowledge—itself a function of workforce skills, domestic R&D institutions, and infrastructure quality.

Transfer thus marks the difference between countries that climb the 'technology transfer staircase' via increasing their absorptive capacity, and countries that stay permanently reliant on imported equipment.

MEANS OF TECHNOLOGY TRANSFER

The literature offers several channels for knowledge to move, such as:

- Licensing,
- Foreign direct investment (FDI) and joint ventures (JVs), including acquisitions and greenfield investments,
- Cooperative R&D, and
- Direct equity or knockdown agreements.

The appropriate channel partly depends on the maturity and characteristics of the technology. Emerging technologies such as hydrogen may require collaborative co-development and co-production rather than one-time technology transactions. More mature technologies such as solar PV can move more readily through trade and licensing.[3]

Because many green technologies are protected by patents, **licensing** is an important channel for accessing proprietary technology. TRIPS Article 28(2) recognizes the patent holder's right to assign or transfer a patent and to conclude licensing contracts. It does not, however, require patent holders to license their technologies to potential recipients.

FDI and JVs offer an alternative way to move firm-embedded knowledge across borders. Subsidiaries of multinational companies play an important role

in transferring green technologies and innovation to host countries, particularly in less-developed and less oil-dependent economies.[4] This effect is strongest for technologies such as wind power, where knowledge transfer relies more on tacit expertise than on traded equipment, unlike solar PV.

The form the investment takes matters as much as its presence.

Acquisitions bring an existing local firm, its personnel and its accumulated technical routines under new multinational ownership, so the new technology attaches to a base with prior absorptive capacity rather than starting from nothing. This creates a more direct channel for two-way learning between the acquiring and acquired firms.

Greenfield investment, by contrast, often involves building a new facility for a relatively narrow function such as assembly, while core R&D remains with the parent company. It can therefore transfer capital and jobs without transferring comparable innovative capability. The broader FDI literature similarly finds that capital transfer

What is TRIPS?

TRIPS (Trade-Related Aspects of Intellectual Property Rights), administered by the WTO since 1995, establishes minimum standards for intellectual property protection and provides a common framework for governing IP-related trade. Its provisions on patents and other forms of intellectual property have important implications for the development and diffusion of green technologies, making TRIPS a key component of the international policy architecture shaping the green economy.

1. Article 27.1 mandates patent availability for inventions in all technology fields.
2. Article 27.2 allows members to exclude inventions from patentability to avoid serious prejudice to the environment.
3. Article 31 permits compulsory licensing under specified conditions.
4. Article 31bis (2005) enables generic export, though this mechanism, born from the 2001 Doha Declaration, remains pharmaceutical-focused with no climate-specific equivalent.
5. Article 66.2 obliges developed members to incentivize technology transfer to least-developed countries, although the extent of its enforcement remains debatable.
6. Articles 7 and 8 articulate balancing IP protection against technology dissemination. The WTO administers enforcement, but proposals for a climate technology waiver remain contested within its TRIPS Council.
7. Article 33 fixes a minimum 20-year protection term from filing. Despite calls, TRIPS has not incorporated any major climate technology-specific mechanism; while the question of whether its cross-sectoral frameworks have helped with technological transfer or not still remains unanswered.

and technology transfer do not necessarily move together, and that acquisitions can bind the two more closely than greenfield investment. Cross-border acquisitions have also been found to be more effective than greenfield investments in building local green innovation capabilities.[5]

Cooperative R&D differs from the channels above in that the recipient participates in developing the technology rather than receiving it after the fact. This is most relevant for technologies that are still pre-commercial, where there is no mature product to license and no established production line to acquire. Because recipient researchers participate directly in the innovation process, the knowledge transferred is more closely tied to the capability to use and adapt it. The channel is also more demanding of the recipient: it presupposes domestic research institutions capable of contributing, which many developing countries lack.

Direct equity and knockdown agreements are generally asymmetric arrangements, typically used by firms entering a sector for the first time. Under a knockdown agreement, imported component kits are assembled locally, and the accompanying package can include blueprints, technical specifications, production manuals and engineer training. Equity stakes, meanwhile, can be traded for access to specific technologies.

The channel therefore matters for what kind of knowledge can be transmitted. But the channel alone does not determine whether that knowledge becomes a lasting local capability.

WHAT DETERMINES WHETHER TRANSFER PRODUCES LOCAL CAPABILITY?

The cases point to two conditions that shape whether technology transfer produces meaningful local capability: bargaining leverage and absorptive capacity.
Bargaining leverage determines how much a recipient can demand from a foreign supplier. Absorptive capacity determines how much of what is transferred can be understood, adapted and built upon. Neither is sufficient on its own.

1. Bargaining leverage

In several successful cases, recipient governments used market access, procurement conditions, export restrictions or local-content requirements to shape the terms of technology transfer.

i. **China** conditioned most of its high-speed rail contracts on foreign suppliers handing over complete technology packages, and patent output in the receiving cities rose 42 per cent as a result.[6]
ii. **Indonesia** banned raw nickel exports and forced CATL, LG Energy Solution and Hyundai to build processing plants on Indonesian soil instead of shipping ore abroad.[7]

iii. **Morocco** paired its Noor Ouarzazate solar concession with mandatory local content and workforce targets.[8]

iv. **Hyundai** itself began as an assembler under a knockdown agreement, i.e. it included transferred technology and explicit knowledge such as blueprints, technical specifications, production manuals and training of Hyundai engineers. It later traded equity for engine technology, and eventually built an independent model of its own.[9]

China, Indonesia and Morocco illustrate how recipient governments can use market access, resources or public procurement to shape the terms of technology transfer. Hyundai provides a complementary firm-level example of how negotiated technology access can support a longer capability-building process.

A recent study mapping the UNFCCC, Paris Agreement and TRIPS legal architecture, along with major IP-management tools for climate technology, including patent pledges, WIPO GREEN and the proposed 'green technology pool', identifies the Technology Executive Committee and the Climate Technology Centre and Network as the two major institutional arms of the UNFCCC/Paris Agreement framework.[10] The study characterizes the existing multilateral architecture as primarily facilitative rather than redistributive: it enables technology transfer in principle but does not compel it.

None of the successful cases reviewed here relied on the international architecture alone. Instead, market access, export restrictions and procurement conditions gave recipient governments leverage to negotiate technology-transfer commitments. Evidence from Brazil points in a similar direction, with a study attributing technology transfer to a combination of policy quality, interinstitutional coordination and strategic negotiating capacity within government.[11]

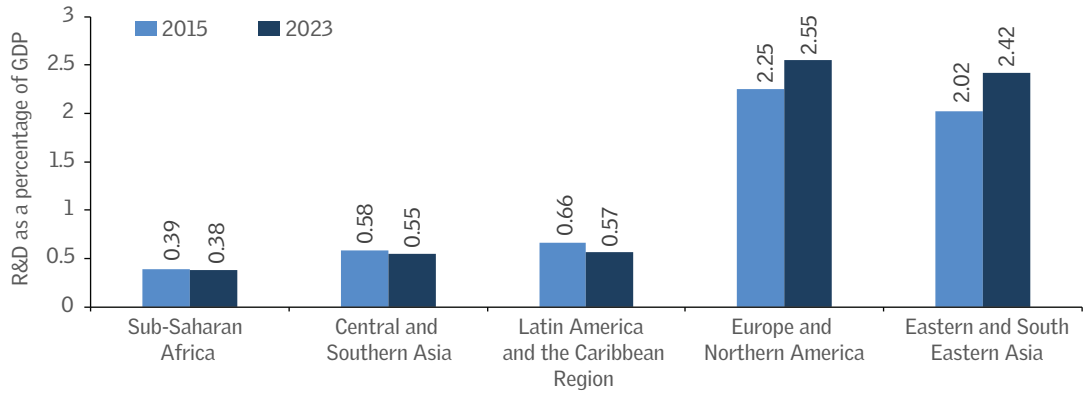
However, although leverage is a necessity in some cases, it is not always enough on its own. A government can extract a technology transfer commitment and still fail to benefit from it if the country lacks the capacity to absorb what arrives.

2. Absorptive capacity

Absorptive capacity is the domestic ability to recognize, assimilate, adapt and exploit knowledge originating elsewhere. It is shaped by skills, R&D institutions, infrastructure, firms and supporting policy.

Global R&D spending averaged 1.92 per cent of GDP in 2023, while Sub-Saharan Africa spent 0.38 per cent, and researcher density in Europe and North America runs at 4,358 per million inhabitants, roughly fifty times higher than in Sub-Saharan Africa's figure of 88 (see *Fig. 1: Research and development (R&D) spending as a percentage of GDP*).[12]

Figure 1: Research and development (R&D) spending as a percentage of GDP



Source: UNESCO Institute for Statistics (2026). 2026 R&D Data Release

A study of Vietnamese manufacturers shows that R&D spending is one of the clearest empirical proxies for absorptive capacity, since a country's own research investment builds the technical competence needed to recognize, interpret and apply knowledge transferred from abroad. R&D support therefore does not simply increase research activity. It can increase the capacity required to convert transferred technology into innovation.[13]

A synthesis of three decades of scholarship on low-carbon technology transfer similarly finds mixed outcomes. Approximately one-third of documented cases were reported as successful and another one-third as failures, with the literature identifying suitable government policies and adequate recipient-country capacities among the core success factors.[14]

THE MAJOR DISAGREEMENTS AND INCONSISTENCIES ACROSS STUDIES

Two disagreements in the literature point to complexities in the technology transfer process and offer multiple possibilities rather than a clean resolution.

I. **The first concerns intellectual property**. An Oxford University study finds no clear evidence that TRIPS protections are the main obstacle to climate technology transfer, and argues that capital, infrastructure, and regulatory constraints matter more than patents do.[15] However, another account, drawn from much of the same broader literature, points the other way. Patent concentration and overlapping patent rights raise the cost of accessing protected technology. Concentration here does not mean multiple patents among a few parties, but rather having many patents associated with the same technology stages, eventually leading to numerous negotiations and acquisitions of rights to

use those processes. This multiplicity and concentration of multiple rights inside one technological process is what acts as thickets and increases costs under TRIPS regulations.

A market oligopoly further compounds this increase, with the top five exporters already controlling over half of global environmental goods trade (see *Fig. 2: Share in global environmental goods trade*).[16]

Both claims are represented in this review, and both are defensible. The best reading is that IP protection is a real cost for some technologies and a distraction from domestic constraints for others, and which one applies likely depends on the specific technology and market.

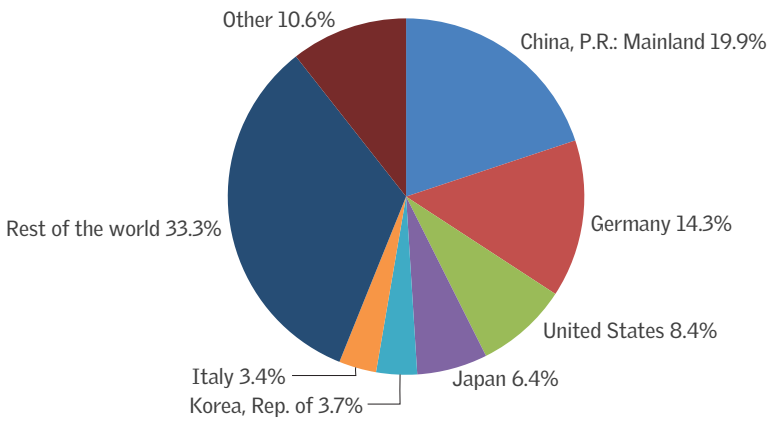
II. The second disagreement is less about evidence and more **about what counts as success**. Indonesia's nickel policy did what it set out to do. But the same study reports that 68 per cent of nickel sector FDI and 94 per cent of processed exports remain tied to Chinese capital and markets. The policy transferred technology and built a new dependency at the same time, and it is not yet clear which fact will matter more in twenty years.[17]

Hyundai's history offers a longer view of the same tension. It took nearly a decade under an asymmetric knockdown agreement before Hyundai could produce anything independently, and decades more before it competed with the firms that once supplied it.[18]

Short-run transfer success and long-run technological independence are not the same achievement, and the case studies here do not let us assume one guarantees the other.

A related but distinct constraint operates through finance: Developing-country recipients can face high capital costs and limited access to affordable long-term

Figure 2: Share in global environmental goods trade



Source: IMF[19]

finance, which can prevent deployment even where the underlying technology is accessible.

The constraint operates at both levels: global financial conditions affect the cost of capital, while domestic creditworthiness, financial institutions and the availability of viable projects determine whether affordable finance reaches firms and projects.[20]

The cases compiled in *Table 1* illustrate how these dynamics have played out in technology transfers outside the green technology sector, where longer-established examples provide clearer evidence on the role of recipient-country capacity and industrial policy.

Table 2 extends this comparison to green technologies, illustrating how similar transfer channels have produced different outcomes depending on the depth of local absorption and the structure of the transaction.

The South–South cases compiled in *Table 3* show that technology transfer can build domestic capabilities while also creating or reinforcing dependence on foreign capital, technology or finance.

Table 4 applies the same lens to South–South transfer of green technologies, where wind projects in Ethiopia and South Africa show that transaction structure and local absorptive capacity shape outcomes regardless of the direction of transfer.

CONCLUDING REMARKS

Three findings emerge from the literature and cases reviewed here:

- **First, the transfer channel shapes what kind of knowledge can move, but it does not by itself determine the outcome**. Licensing, FDI, joint ventures, acquisitions and procurement arrangements each provide different pathways for transferring equipment, explicit knowledge and tacit expertise. The choice of channel therefore matters, particularly for the type and depth of knowledge that can move.

Table 1: Compiled cases of select technological transfers—North–South transfer of non-green technologies

Countries in partnership	Firms in partnership	Year	Case summary
UK–India	Oxford via AstraZeneca to Serum Institute of India	2020	Vaccine technology was transferred through a licensing agreement. The deal was structured to supply vaccines 'at cost' rather than for profit. The Serum Institute of India ended up accounting for 60 per cent of the total output of the particular vaccine (1.5 billion doses). The transfer is regarded as a success.[21]
Germany/ Japan/France/ Canada–China	Siemens, Kawasaki, Alstom, Bombardier to now merged CRRC	2004–05	High-speed rail technology moved through joint ventures and supply contracts. Cumulative contract value reached the multibillion-dollar range. The transfer is considered a major success, later helping China's CRRC (China Railway Rolling Stock Corporation) become a global rail manufacturer.[22]

Source: CSE, compiled from different sources

Table 2: Compiled cases of select technological transfers—North–South transfer of green technologies

Countries in partnership	Firms in partnership	Year	Case summary
Germany–India	REpower systems to Suzlon Energy	2007	Wind turbine technology was transferred through Suzlon's acquisition of REpower. The deal was valued at roughly Euro 1.2 billion. Outcomes were mixed, reflecting only partial absorption of the technology and eventual sale of the subsidiary.[23]
Germany–China	Vensys Energy to Goldwind	2008	Wind turbine technology moved through Goldwind's acquisition of Vensys Energy. This was considered a two-way knowledge transfer, evidenced by joint development of new turbine designs, and was followed by an expansion of Goldwind's own R&D activity into Germany. The transaction was valued at about Euro 41.2 million. The transfer was acclaimed as a success, along with other protectionist policies, helping Goldwind grow into a major turbine manufacturer.[24]

Source: CSE, compiled from different sources

Table 3: Compiled cases of select technological transfers—South–South transfer of non-green technologies

Countries in partnership	Firms in partnership	Year	Case summary
China–Indonesia	Tsingshan Holding Group to PT Indonesia Morowali Industrial Park/ PT Sulawesi Mining Investment	2009–13	Nickel ore processing technology was transferred through FDI and joint ventures. An initial US $1.2 billion investment grew into a cumulative commitment exceeding US $6 billion. The transfer was acclaimed as a success, though it also deepened Indonesia's dependence on Chinese capital.[25]
China–Indonesia	Beijing Yawan HSR consortium to PT Kereta Cepat Indonesia–China (KCIC)	2015–23	A joint venture transferred high-speed rail technology, backed by a concessional loan. Project cost rose from an original US $5.5 billion to about US $7.3 billion. However, by October 2025, 513 Indonesian personnel had been certified to independently operate and maintain the line, with more in final certification. Results were mixed, with cost overruns complicating the actual transfer.[26]

Source: CSE, compiled from different sources

Table 4: Compiled cases of select technological transfers—South–South transfer of green technologies

Countries in part-nership	Firms in partnership	Year	Case summary
China–Ethiopia	HydroChina Corporation/ CGCOC Group (EPC), to Ethiopian Electric Power Corporation	2009–15	The EPC contract was meant to transfer wind turbine technology and was backed by a concessional loan. The project was valued at roughly US $460 million. The transfer is considered a major failure, with little technology or knowledge retained locally.[27]
China–South Africa	Longyuan Power (CHN Energy) with South African partners	2013–17	Wind turbine technology was transferred via FDI and a joint venture structure. The deal was valued at approximately US $352 million. Outcomes were mixed, with only partial technology absorption by local partners.[28]

Source: CSE, compiled from different sources

South–South transfer remains understudied

Most of the technology transfer literature, and the legal architecture built to support it, assumes a North–South direction. The synthesis of thirty years of scholarship already discussed above shows that this North–South literature is comparatively mature, while South–South transfer remains understudied. The South–South cases included here, such as Ethiopian wind development and China–South Africa cooperation on renewables, suggest that some South–South arrangements may involve deeper local participation across the technology value chain. However, the evidence is too limited to establish whether this is a distinctive feature of South–South transfer or instead reflects differences in technology, project structure or recipient-country conditions.[29] Whether this constitutes a genuinely distinct transfer mechanism specific to South-South cooperation, or merely reflects an earlier, less-examined stage of the same North-South dynamic, is not something we can currently answer.

- **Second, bargaining leverage and absorptive capacity appear consistently across the cases as determinants of meaningful outcomes**. Bargaining leverage can secure stronger transfer commitments, while domestic skills, firms, R&D institutions, infrastructure and finance determine how much of the transferred knowledge can be absorbed and built upon. International frameworks can facilitate these processes, but they do not automatically create the conditions for successful transfer.
- **Third, successful technology transfer should not be equated with technological independence.** Indonesia's nickel policy illustrates the tension: it generated technology transfer and domestic processing capacity while also deepening dependence on Chinese capital and markets. Similarly, Hyundai's long trajectory shows that moving from imported technology to independent innovation can take decades.

These findings carry a clear implication for climate action. Technology transfer does not happen automatically once a legal framework exists. It has to be negotiated, absorbed, and evaluated against its longer-term effects. The effectiveness of international technology-transfer frameworks therefore depends not only on the rules they establish, but also on whether recipient governments can use available bargaining leverage and build the absorptive capacity needed to turn transferred technology into local capability. International cooperation, finance and capacity-building can help create these conditions, particularly where recipient governments have limited bargaining leverage.

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Citation: Kushal Kabra 2026, *Technology Transfer for the Green Transition: A summary of observations from the literature*, Centre for Science and Environment, New Delhi