Beyond planning: making climate technology implementation finally happen

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Resumo

Quinze anos após a criação do Mecanismo Tecnológico no âmbito da Convenção-Quadro das Nações Unidas sobre a Mudança do Clima (CQNUMC ou UNFCCC, na sigla em Inglês), a discrepância entre as avaliações das necessidades tecnológicas climáticas e a sua implementação efetiva continua a ser alarmantemente grande. Embora mais de 100 países em desenvolvimento tenham concluído Avaliações das Necessidades Tecnológicas (TNA) no âmbito do Mecanismo

Abstract

Fifteen years after establishing the Technology Mechanism under the UNFCCC, the gap between climate technology needs assessments and actual deployment remains alarmingly wide. While over 100 developing countries have completed Technology Needs Assessments (TNA) under the UNFCCC Technology Mechanism since 2009, the translation of these assessments into actual technology deployment remains limited. The Technology

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Tecnológico da UNFCCC desde 2009, a tradução dessas avaliações em implementação tecnológica efetiva continua a ser limitada. O Programa de Implementação Tecnológica (TIP), atualmente em negociação, representa a inovação institucional mais promissora na cooperação em tecnologia climática desde Cancún. No entanto, o seu sucesso não está garantido. Este artigo analisa as barreiras persistentes ao desenvolvimento e à transferência de tecnologia climática, com base em experiências de implementação em países em desenvolvimento, para identificar o que tem limitado o progresso. Argumentamos que o TIP pode ter sucesso onde os mecanismos anteriores falharam, mas apenas se três condições críticas forem cumpridas: estabelecer uma arquitetura de financiamento dedicada que vá além da assistência técnica para apoiar a demonstração e a implantação; criar estruturas de governança que garantam a verdadeira apropriação pelo país, em vez de prioridades impulsionadas pelos doadores; e desenvolver mecanismos para fazer avançar as tecnologias através do "vale da morte", desde a demonstração até à implantação comercial sustentada. Com as metas climáticas para 2030 se aproximando rapidamente, acertar no TIP não é apenas desejável - é essencial para traduzir a ambição climática em ações mensuráveis.

Palavras-chave: Transferência de tecnologia climática. Implementação de tecnologia. Mecanismo de tecnologia da UNFCCC. Política de inovação. Países em desenvolvimento. Financiamento climático.

Implementation Programme (TIP), currently under negotiation, represents the most promising institutional innovation in climate technology cooperation since Cancún. However, its success is not guaranteed. This commentary analyzes persistent barriers to climate technology development and transfer, drawing on implementation experiences across developing countries to identify what has constrained progress. We argue that TIP can succeed where previous mechanisms have fallen short, but only if three critical conditions are met: establishing a dedicated financing architecture that extends beyond technical assistance to support demonstration and deployment; creating governance structures that ensure genuine country ownership rather than donor-driven priorities; and developing mechanisms to advance technologies through the "valley of death" from demonstration to sustained commercial deployment. With the 2030 climate targets rapidly approaching, getting TIP right is not merely desirable - it is essential for translating climate ambition into measurable action.

Keywords: *Climate technology transfer. Technology implementation. UNFCCC technology mechanism. Innovation policy. Developing countries. Climate finance.*

1. Introduction: the persistent implementation gap

Climate change encounters systemic challenges that demand technological, political, and institutional solutions regarding both mitigation and adaptation needs. While significant progress has been made in setting global climate targets under the UNFCCC and the Paris Agreement, the translation of these commitments into national and local action remains uneven and often limited in scale (UNFCCC, 2022; IPCC, 2022).

The numbers tell a sobering story. While over 100 developing countries have completed Technology Needs Assessments (TNA) under the UNFCCC Technology Mechanism since 2009 (UNEP-CCC, 2025), the translation of these assessments into actual technology deployment remains limited. Although nearly all TNA produce Technology Action Plans (TAPs) as part of the standardized methodology (UNFCCC, 2020), systematic tracking of implementation outcomes has proven challenging, with the Technology Executive Committee noting that "many TAPs were insufficiently bankable, and the eventual success was difficult to monitor" (UNCC-TEC, 2022, p. 13). This implementation gap persists despite more than 70% of countries referencing their TNA in Nationally Determined Contributions (UNEP-CCC, 2025), highlighting a critical disconnect between technology prioritization and scaled deployment in developing countries. This implementation gap is not merely a technical shortcoming: it reflects deeper structural, institutional, and political barriers that have proven resistant to conventional policy interventions.

The development and transfer of climate technologies - commonly referred to as climate technology development and transfer (CTDT) - is essential for turning ambition into effective measures, especially in developing countries where resource constraints and capacity limitations often hinder progress (UNCTAD, 2021). CTDT encompasses the processes through which countries access, adapt, co-develop, and deploy technologies suited to their climate and national circumstances. This includes not only hardware and infrastructure but also the transfer of technical knowledge, skills, practices, and institutional arrangements with co-benefits once the technology is available for use. As recognized by WIPO (2010), UNCTAD (1985), and the UNFCCC (2019), effective technology transfer must go beyond the delivery of tools to include the strengthening of endogenous capabilities, local innovation ecosystems, and long-term cooperation frameworks.

To facilitate CTDT, the UNFCCC established the Technology Mechanism in 2010 at COP 16 in Cancún. This mechanism was created to support the implementation of Article 4.5 of the Convention, which commits developed countries to promote, facilitate, and finance the transfer of environmentally sound technologies to developing countries. It also advances Article 10 of the Paris Agreement, which strengthens cooperation on technology development and transfer as a means of enhancing resilience and reducing emissions through collaborative R&D, innovation systems, and capacity-building efforts (UNFCCC, 2015; UN, 2016).

The Technology Mechanism comprises two complementary bodies: the Technology Executive Committee (TEC), which focuses on policy guidance and strategic recommendations on barriers and enabling environments for technology development and diffusion; and the Climate Technology Centre and Network (CTCN), which acts as the implementation arm, delivering technical assistance, facilitating South-South and North-South cooperation, and promoting access to technology information and expertise through its global network with over 900 institutions (CTCN, 2022).

Despite this institutional architecture, multiple assessments - including those conducted under the Global Stocktake (GST) and the deliberations of Agenda Item 14 of the Subsidiary Body for Implementation (SBI) - have pointed to persistent weaknesses. Among the main challenges identified are inadequate inter-ministerial coordination at the national level, insufficient coherence in the governance of innovation policies, poor financial alignment between climate and technology portfolios, and limited resources to support the piloting, demonstration, and scaling up of climate technologies (UNFCCC, 2023a; CTCN, 2022).

The first Global Stocktake reaffirmed the urgency of moving from planning to delivery, recognizing that CTDT remains a critical enabler of this transition, especially for enhancing resilience and achieving low-carbon development pathways (UNFCCC, 2023a). Against this backdrop, the Technology Implementation Programme (TIP) has emerged as a potential response to longstanding implementation barriers. Recognized in Decision 1/CMA.5 (para. 110) and currently under development by the TEC, TIP seeks to shift focus from "what is needed" to "how to deliver" climate technologies at scale (UNFCCC, 2023a).

This commentary argues that TIP represents a genuine opportunity to break the cycle of ambitious frameworks yielding modest outcomes, but only if fundamental design questions are addressed. We identify three critical conditions for success, drawing on 15 years of implementation experience, comparative analysis of technology cooperation initiatives, and insights from innovation economics. The stakes could not be higher: with 2030 rapidly approaching, effective technology implementation is no longer optional but imperative for meeting global climate commitments and supporting inclusive, sustainable development.

2. Understanding why implementation fails: structural barriers beyond capacity

Climate policies continue to face a significant gap between international commitments and practical outcomes, particularly regarding the development and transfer of climate technologies. As highlighted by the United Nations Environment Program (UNEP, 2022), the discrepancy between policy ambition and actual progress remains stark, emphasizing the need for systemic approaches to enhance technology development, application, deployment and diffusion across diverse national contexts.

The gap between climate technology needs and actual deployment is not primarily a problem of awareness or aspiration. Developing countries know what technologies they need: the TNA process has made this clear. The problem lies in the systematic barriers that emerge when moving from assessment to action.

Barriers are often framed as “capacity gaps” in recipient countries, a characterization that obscures more fundamental issues. While capacity or resource constraints certainly exist, the persistent implementation gap reflects deeper structural weaknesses in how technology cooperation is organized, financed, and governed. Understanding these root causes is essential for designing mechanisms that can actually work.

2.1. Absorptive capacity and innovation system fragmentation

The absorptive capacity of national innovation systems (NIS) plays a decisive role in determining the effectiveness of technology transfer. Countries with well-developed innovation infrastructures, robust educational systems, and dynamic research and development (R&D) sectors are better positioned to adapt, internalize, and further develop imported technologies. As Cimoli, Dosi, and Stiglitz (2019a, 2019b) emphasize, many developing nations face structural weaknesses in their innovation systems, including limited scientific and technical expertise, insufficient infrastructure, inadequate resources, and fragmented policy and regulation frameworks. These deficiencies reduce the ability of local actors to engage meaningfully with transferred technologies, leading to technological dependency or underutilization that hinders sustainable development.

The challenge of low absorptive capacity extends beyond simple resource scarcity. Resources are yet inert unless they are matched by systemic capabilities (Penna *et al.*, 2025). Many developing countries do possess pockets of genuine innovation capability (for example, universities conducting relevant research, private firms with technical expertise, civil society organizations with deep community knowledge). The problem, then, is fragmentation: these capabilities remain disconnected, unable to coalesce around shared technology priorities, impairing the absorption and deployment of transferred technologies.

Coordination failures within innovation systems have significantly hindered technology deployment despite existing technical capacities. Brazil’s Inova Petro program exemplifies this challenge: launched with BRL 3 billion in resources to support oil and gas supply chain innovation, the program struggled due to a misalignment between technical requirements and industry capabilities, coupled with limited market-shaping capabilities, and to weak coordination between implementing organizations (Penna *et al.*, 2025). Regarding climate technology deployment, Kenya has faced similar constraints from institutional fragmentation and weak operational coordination among government ministries, preventing effective utilization of existing renewable energy capabilities (FAO-UNDP, 2017; UNCC-TEC, 2023a).

Fragmentation is thus compounded by weak coordination among national stakeholders across government, private sector, academia, and civil society. Effective climate technology deployment requires the integration of diverse interests, capacities (resources), and capabilities through collaborative governance mechanisms. Yet institutional fragmentation and policy misalignment often prevail, resulting in disjointed initiatives and missed opportunities for synergistic action (Mabee *et al.*, 2012). The absence of cohesive multi-stakeholder engagement frameworks undermines efforts to build national consensus around climate technology priorities and to leverage collective absorptive capabilities for technology implementation.

2.2. Technology-context mismatches

Technology transfer is also impaired by contextual mismatches between technologies developed in advanced economies and the needs and technological contexts of developing countries (IPCC, 2022). A wind turbine designed for European grid infrastructure may be incompatible with the technical specifications and maintenance requirements of African power systems. Agricultural technologies optimized for large-scale mechanized farming may be inappropriate for smallholder contexts. These mismatches represent fundamental barriers that can render otherwise sound technologies ineffective or unsustainable.

Furthermore, many climate technologies are still at early Technology Readiness Levels (TRL) - meaning, they are still in the initial stages of scientific research or technological development - , thus limiting their immediate applicability. According to the National Renewable Energy Laboratory (Mendoza *et al.*, 2021), innovations at lower TRL require significant investment in research, demonstration, and validation before they can be effectively scaled and deployed at commercial levels. Achieving progress in research, demonstration, and validation depends on economically feasible and sustainable technology transfer, accompanied by sustained systemic efforts to support local innovation, ensuring that technologies are adapted and optimized for specific socio-economic and environmental conditions.

These challenges have historically been framed through the lens of “appropriate technology”: the notion that developing countries should adopt technologies suited to their specific economic, social, and environmental contexts, rather than simply replicating technologies designed for advanced economies (Schumacher, 1973). While this perspective usefully highlights the importance of context-specificity and local adaptation, it should not be interpreted as limiting developing countries to low-complexity or intermediate technologies. Recent experience demonstrates that developing countries can successfully develop and absorb frontier technologies when supported by systemic approaches that build endogenous capabilities, strengthen innovation ecosystems, and foster effective coordination among public, private, and research actors (Penna *et al.*, 2025; Cimoli *et al.*, 2019a; 2019b).

The critical distinction is not between 'advanced' versus 'appropriate' technologies, but rather between technology transfer approaches that build local capacity for continued innovation and adaptation, and those that create technological dependency. Effective climate technology implementation thus requires moving beyond simplistic notions of appropriateness toward systemic capacity-building that enables developing countries to both adapt existing technologies to local contexts and develop frontier solutions tailored to their specific climate challenges.

2.3. The Role of international cooperation - and its limitations

International cooperation is essential given the complexity of technology transfer in terms of actors, financial sources, implementation arrangements, goals, and governance structures (IPEA, 2022). Different cooperation arrangements allow countries to involve national actors of the private sector, academia and industry in various stages of development and technology transfer, depending on specific national realities.

South-South Cooperation (SSC) can reduce contextual mismatches of technology for similar national conditions and better implement shared experiences. Triangular Cooperation (TRC) can facilitate articulation of SSC and North-South Cooperation (NSC), combining financial and technical resources for the least developed country, increasing scale of cooperation provided by developing countries and reducing costs for developed countries (Pino, 2013).

However, international cooperation mechanisms often suffer from their own limitations, particularly when cooperation is shaped by donor priorities rather than recipient needs. Donor-driven technology cooperation frequently creates misalignment with recipient country needs, undermining climate technology effectiveness. The donor interest model demonstrates that climate finance allocation is primarily driven by donor countries' strategic and economic interests rather than recipient vulnerabilities, with climate-vulnerable countries often receiving a small share of available adaptation finance despite their acute needs (Nor, 2025; Climate Policy Initiative, 2022).

Implementation of the Paris Declaration's ownership principles has been superficial, with donors and recipients maintaining pre-existing power dynamics "in form rather than in substance" due to lack of political will on both sides (Brown, 2016). This supply-driven approach has resulted in aid projects being managed by external actors rather than recipient governments, while creating parallel structures that undermine local capacity building and fail to address context-specific technology needs (Pandey *et al.*, 2022).

2.4. Financial architecture: the persistent bottleneck

Limited financial resources to climate technology projects continue to represent a key barrier to the development and transfer of climate technologies. While climate finance has grown in recent years, Buchner *et al.* (2021) note that funding remains largely concentrated in low-risk, short-term initiatives, with comparatively little support directed toward innovative solutions and long-term infrastructure critical for sustained emissions reductions. The issue is not a quantitative one of lack of available financial resources but a qualitative one of where available funding goes to (Penna *et al*, 2023).

Developing countries face persistent difficulties in accessing international climate finance, including complex eligibility criteria, limited technical capacity for project preparation, and challenges in meeting co-financing requirements (IEA, 2022). These constraints slow the deployment of transformative climate technologies and contribute to the implementation gap.

At COP29 in Baku, Parties to the Paris Agreement agreed to scale up climate finance to developing countries to at least USD 1.3 trillion per year by 2035 from all public and private sources, with developed countries committing to take the lead in mobilizing at least USD 300 billion annually (UNFCCC, 2024a). However, quantity alone is insufficient. The architecture of climate finance - how funds are mobilized, allocated, and disbursed - matters enormously for climate technology implementation. Closing the implementation gap requires not only increased investment levels but also a qualitative change in investment strategies: the prevailing rules that guide investment practices are inadequate to foster the systemic transformations needed for sustainability transitions, necessitating new frameworks that support technology development across the full innovation lifecycle and enable the multi-system changes required for low-carbon sociotechnical systems (Penna *et al.*, 2023).

2.5. The “Valley of Death” in climate technology innovation

An additional challenge, therefore, relates to advancing climate technologies beyond intermediate TRLs to stages where they are fully demonstrated, validated in operational environments, and ready for market deployment (TRL 4-7). The so-called “valley of death” in innovation processes, where promising technologies fail to progress due to a lack of financing and support, is particularly acute in the climate technology domain (Mendoza *et al.*, 2021).

Technologies at TRL 4-7 have proven technical feasibility but have not yet demonstrated commercial viability at scale. This is precisely the stage where public support is most needed but often least available. Research grants support early-stage development; commercial finance becomes available once market viability is proven. The gap in between - where pilot projects must scale to demonstration plants, where manufacturing processes must be refined, where supply chains must be established - remains chronically underfunded.

Overcoming this barrier requires targeted public and private investments that promote later-stage technology development and foster demonstration projects capable of proving technological feasibility and scalability under real-world conditions. There is a pressing need to prioritize long-term investments in climate technology projects. Short-term pilot initiatives, while valuable for initial learning, are insufficient to achieve the sustained technological transformations required for deep decarbonization and climate resilience. As the (IEA, 2022) points out, long-duration projects facilitate institutional learning, technological refinement, and infrastructure development, all of which are essential for embedding climate technologies into national development pathways.

2.6. Private sector engagement: too little, too late

Private sector engagement is another critical dimension in bridging the implementation gap. Firms possess vital resources, technical know-how, and market access necessary for the widespread diffusion of climate technologies. However, as Lee and Mwebaza (2022) highlight, private companies tend to get involved too late in important processes for CTDT. The sector usually engages only in the demonstration, incubation, commercialization, and diffusion phases in the RD&D process, making it harder for the proper incorporation of local customers' needs for creation of new markets.

Multiple barriers hinder earlier private sector participation, including policy uncertainty, perceived investment risks, and underdeveloped markets for green technologies (UNIDO, 2020). Without targeted incentives, risk mitigation instruments, and clear regulatory signals, private sector actors may be reluctant to invest in innovative but uncertain climate technologies, thereby limiting their potential for large-scale deployment (IEA, 2023).

Addressing these barriers requires the establishment of enabling environments that foster public-private partnerships, streamline regulatory frameworks, and enhance market predictability to stimulate private sector innovation and investment. The establishment of public-private partnerships with royalty sharing arrangements, proper intellectual property rights (IPR) negotiations, safe spaces for innovation - like regulatory sandboxes - and investment in research while climate technologies are being developed can guarantee the return on substantial investments to the private sector.

2.7. The Strategic importance of National Designated Entities

Against this backdrop, the role of Nationally Designated Entities (NDE) becomes strategically important. As focal points under the UNFCCC's Technology Mechanism, NDE are mandated to facilitate the identification, development, and transfer of climate technologies at the national level. Strengthening the institutional capacity of NDE is vital for improving policy coherence, enhancing stakeholder coordination, and catalyzing technology partnerships. The UNFCCC underscores that well-functioning NDE can serve as effective intermediaries between domestic actors and international technology support mechanisms, thereby improving access to technological resources and capacity-building initiatives.

However, many NDE operate with limited authority, insufficient resources, and weak connections to actual decision-making processes. For instance, Chile's NDE has demonstrated success stories in technical assistance on biomass-to-energy conversion technology, reporting improvements in policy development and technical capacities, with progress in scaling up climate technologies. However, the NDE of countries like Mongolia and Haiti report that their work is constrained by a lack of technical expertise, understaffing, and limited awareness of available international support mechanisms, directly impeding their ability to function as effective intermediaries (UNCC-TEC, 2024). Strengthening NDE requires elevating their institutional standing, ensuring adequate budgets, and creating formal mechanisms for them to shape national technology strategies.

2.8. Synthesizing the Barriers

The interplay among these multiple factors - policy coordination failures, financial architecture gaps, technology-context mismatches, private sector hesitation, and weak institutional intermediaries - highlights the complexity of addressing the climate policy implementation gap. Table 1 synthesizes these systematic barriers and their manifestations.

Table 1. Systematic Barriers to Climate Technology Implementation

Barrier	Description	Example
Absorptive capacity and innovation system fragmentation	Weak R&D infrastructure, fragmented policy frameworks, and poor coordination among government, private sector, academia, and civil society limit countries' ability to internalize, adapt, and develop climate technologies	Low investment in R&D and overlapping mandates between environmental and energy ministries in Sub-Saharan Africa delay solar energy deployment due to conflicting policies and limited technical education
Technology-context mismatches	Technologies developed in advanced economies may not align with recipient countries' technological contexts, infrastructure, or needs. Many climate technologies remain at early Technology Readiness Levels, lacking demonstrated viability in diverse contexts	Mismatch between wind technology designs developed in Europe and the grid infrastructure capacity in some African countries, limiting technology transfer effectiveness and requiring context-specific adaptation
Limitations of international cooperation mechanisms	International cooperation mechanisms suffer from fragmentation, poor coordination, and superficial implementation of country ownership principles. Donors and implementing agencies often prioritize their own strategic interests over recipient country needs	Technology transfer projects that fail to align with national development priorities or that duplicate efforts due to lack of coordination among international partners and national agencies
Financial architecture gaps	Limited access to concessional finance and investment capital constrains technology development and deployment. Developing countries face persistent difficulties accessing international climate finance due to complex eligibility criteria and lack of project preparation capacity	High-risk climate technology projects in developing countries struggle to secure funding due to perceived investment risks, limited track records, and inadequate financial instruments tailored to technology lifecycle needs
The 'Valley of Death' in climate technology innovation	Technologies at TRL 4-7 face critical funding gaps preventing advancement from technical feasibility to commercial viability. Lack of demonstration and commercialization support causes promising technologies to stall before achieving scale	Promising carbon capture and storage technologies and advanced battery systems stall at demonstration phases due to insufficient funding for pilot projects and scale-up, preventing progression to commercial deployment
Insufficient private sector engagement	Policy uncertainty, perceived investment risks, underdeveloped markets, and lack of enabling environments deter early private sector participation in climate technology development and deployment, despite firms possessing vital resources and market knowledge	High perceived risks and regulatory uncertainty deter private investment in renewable energy technologies in Latin American countries, resulting in delayed market development and missed opportunities for public-private partnerships
Insufficient Institutional Capacity of NDEs	Weak Nationally Designated Entities (NDEs) struggle to coordinate domestic technology needs and access international support mechanisms (UNFCCC)	Many NDEs lack sufficient staff and technical expertise to facilitate technology partnerships, limiting their role as intermediaries

These barriers are not inevitable features of technology cooperation. They reflect design choices - often implicit - in how mechanisms are structured, financed, and governed. The critical question is whether TIP can make different design choices that address these root causes rather than merely working around their symptoms.

3. The Technology Implementation Programme: promise and preconditions

The Technology Implementation Programme has emerged from recognition that the Technology Mechanism, despite its sophisticated institutional design, has not delivered implementation at the necessary pace or scale. TIP seeks to respond to persistent challenges such as insufficient follow-up to Technology Needs Assessments (TNA), fragmented stakeholder engagement, weak support for National Designated Entities (NDE), and limited investment in late-stage innovation. The program aims to represent a paradigm shift from identifying "what is needed" (TNA) to addressing "how to deliver" (TAP) climate technologies at scale (UNFCCC, 2023a).

The development of Technology Action Plans (TAP) has become an essential instrument to operationalize the priorities identified in TNA. TAP outline concrete actions, timelines, responsible institutions, and potential sources of support for deploying prioritized technologies, serving as a bridge between needs identification and implementation. TIP reinforces the importance of ensuring technical and financial backing for the full implementation of TAP, promoting a more integrated and action-oriented approach. By doing so, it seeks to enhance country ownership, strengthen institutional capacities, and foster greater alignment between national technology priorities and international cooperation and funding mechanisms.

3.1. What Makes TIP Different?

Although not yet formally adopted, TIP has been recognized in Decision 1/CMA.5 (para. 110) of the first Global Stocktake, which invites further development of the initiative (UNFCCC, 2023a). It represents a deliberate shift from assessment to execution by explicitly aiming to address the gaps identified in the first periodic assessment of the Technology Mechanism TIP's stated goal is to promote cross-sectoral collaboration, enhance enabling environments, and mobilize technical and financial support, essentially in developing countries. Its focus on aligning national priorities with coordinated implementation efforts positions TIP as a strategic response to longstanding implementation barriers.

Several design features distinguish TIP from previous initiatives (UNFCCC, 2024b; 2025). Its proposed innovative features include creating "implementation accelerators" to move projects from planning to deployment and establishing "national systems of innovation support" to build endogenous capacity. The TIP is thus designed to provide more integrated support across the technology lifecycle, with a clear mandate to strengthen NDEs and facilitate the implementation of priorities identified in TAPs and NDC.

In parallel, other initiatives under the UN system reinforce the importance of implementation. The Climate Technology Centre and Network (CTCN) continues to support implementation-oriented technical assistance aligned with TNA, NDC, and adaptation strategies. The CTCN's regional and thematic programs connect national priorities to knowledge transfer and matchmaking services, aiming to catalyze real-world climate solutions (CTCN, 2022). TIP distinguishes itself through five key innovations: (1) functioning as an "implementation accelerator" with structured processes for TAP execution; (2) integrated support across the technology lifecycle connecting multiple planning instruments; (3) strengthened NDE capacity through regional dialogues; (4) explicit linkages between technology and Financial Mechanism entities; and (5) national systems of innovation focus on building endogenous capacities beyond individual technology projects.

3.2. Three critical conditions for success

TIP's promise is real, but so are the risks of repeating past patterns of ambitious initiatives yielding incremental results. Drawing on the barriers analyzed above and comparative experience with technology cooperation mechanisms, we identify three critical conditions that TIP must fulfill to achieve transformative impact.

Condition 1: a dedicated financing architecture for the full technology lifecycle

The most fundamental requirement is establishing a financing architecture specifically designed to support technology implementation, not merely technical assistance for planning. Current climate finance mechanisms, while valuable, are poorly suited to the specific needs of technology deployment. They tend to fund either early-stage research or large-scale infrastructure, leaving the critical middle stages - demonstration, piloting, early commercialization - chronically underfunded.

TIP must include dedicated financial resources with several distinctive features. First, funding must be available across the entire technology readiness spectrum, with particular attention to TRL 4-7 where the "valley of death" is most acute. Second, financing mechanisms must be accessible to the institutions actually implementing technologies - not just national governments but also subnational entities, research institutions, private firms, and civil society organizations. Third, approval processes must be streamlined to match the timelines of technology development, which often move faster than typical multilateral funding cycles.

This does not necessarily require creating entirely new funds, but new finance frameworks that involve diversity of resources and sources. Existing mechanisms like the Green Climate Fund could establish dedicated technology implementation windows with appropriate design features.

What matters is that finance explicitly targets implementation, with eligibility criteria, risk tolerance, and disbursement mechanisms aligned with that purpose.

The COP29 commitment to mobilize USD 1.3 trillion annually by 2030 provides a promising context, but without intentional allocation to technology implementation - and particularly to the middle stages of the innovation process - this finance may flow around rather than through the implementation bottleneck (UNFCCC, 2024a). TIP should establish clear targets: for example, that at least 15-20% of climate technology finance should support demonstration and early deployment projects.

Condition 2: governance structures ensuring genuine country ownership

Technology implementation succeeds when driven by national priorities and embedded in country-led development strategies. It fails when shaped primarily by donor preferences or international templates applied uniformly across diverse contexts. TIP must embody genuine country ownership, which requires more than rhetorical commitment.

Strengthening NDE is essential but insufficient. Many countries have established NDE as required, but these entities often lack the authority, resources, and institutional positioning to shape technology priorities. TIP should support elevating NDE to positions of genuine influence, ideally with direct connections to ministerial decision-making, cross-sectoral coordination mandates, and adequate budgets for their coordination functions.

Beyond NDE strengthening, country ownership requires that TAP development and implementation be genuinely participatory processes. This means early and sustained engagement with private sector actors, research institutions, civil society organizations, and affected communities. The Senai Cimatec and Innovation Institute's model in Brazil (Box 1) demonstrates how involving diverse stakeholders from the outset - particularly the private sector, which will ultimately deploy many technologies - creates alignment and shared investment in success.

Box 1. The Brazilian SENAI CIMATEC and Innovation Institute's Model

The *Serviço Nacional de Aprendizagem Industrial* (Senai) is a Brazilian private and non-profit institution of public interest. SENAI's goal is to stimulate industrial innovation through education, consultancy, applied research, technical and technological services for the competitiveness of Brazilian companies. It is recognized as a model of professional education and quality and one of the largest educational complexes worldwide. The Integrated Center for Manufacturing and Technology (Cimatec) of Senai was created to meet the demands for industrialization in Bahia.

Cimatec is a center of excellence in education, research and industrial innovation, associated with SENAI and recognized nationally and internationally for its work in technology and development. Transformed into a University Centre in 2017, it stands out for its high-level engineering courses, master's and doctoral programs, and partnerships with different kinds of institutions from public and private sectors, such as Fraunhofer and companies like Petrobras and Embraer. This articulation allows early involvement of the private sector in the planning of technology development, creating opportunities for market creation, adjustments to local realities and guarantee of economic sustainability for development, deployment and diffusion phases. The case of Senai Cimatec exemplifies how early involvement of private sector, academia, and government makes the process of developing, adapting, maturing, and transferring technologies possible. This model has yielded significant outcomes, including a portfolio of over USD 55 million in R&D&I projects and more than 60 registered patents (SENAI CIMATEC, n.d.). Its success, in contrast to linear technology transfer approaches, lies in its integrated ecosystem that fosters co-creation by involving private sector partners like Shell and Embraer from the earliest stages of development, ensuring that innovation is demand-driven and embedded within the national industrial context.

The Senai Cimatec model is closely related to the way Senai deploys a network of innovation institutes. In Brazil. The model's distinctive features include integration of technology centers with academic programs, early private sector involvement through demand-oriented contract research, Fraunhofer-modeled governance with systematic lifecycle management, and advanced financial engineering targeting 100% cost recovery through own revenues (Will et al., 2020). A 2025 peer-reviewed study by Fraunhofer IPK found that Senai's network of 26 Innovation Institutes contributed 0.66% to Brazil's GDP, executed thousands of R&D projects totaling 2.5 billion Brazilian reais with more than 800 companies, with 56% involving SMEs, connecting over 185 startups with 90 large enterprises through technological challenges (Schubert *et al.*, 2024).

Country ownership also has implications for how international support is provided. Technical assistance should respond to country-articulated needs rather than predetermined packages. Financial support should align with TAP priorities rather than requiring countries to adjust their strategies to fit available funding categories. Monitoring and evaluation frameworks should measure progress against country-defined objectives, not standardized international metrics that may not capture what matters locally.

This principle extends to the modalities of international cooperation. South-South and Triangular Cooperation arrangements often provide better ownership dynamics than traditional North-South transfers, as they involve countries with more similar development contexts and fewer historical power asymmetries. TIP should explicitly encourage and facilitate these cooperation modalities, creating platforms for countries to share implementation experiences and adapt successful approaches to their contexts.

Condition 3: mechanisms to advance technologies from demonstration to sustained deployment

The third critical condition addresses the "valley of death" directly. TIP must include specific mechanisms to help technologies progress from successful pilots and demonstrations to sustained commercial deployment. This is where many promising climate technologies have stalled: proven technically but unable to achieve the scale needed for meaningful climate impact.

Several elements are necessary. De-risking instruments can help attract private investment to early-stage deployment by reducing perceived financial risk. These might include partial guarantees, first-loss capital, or results-based finance that rewards successful deployment milestones. Regulatory sandboxes and other safe spaces for innovation allow technologies to be tested under real-world conditions with appropriate oversight but without facing the full regulatory burden designed for mature technologies.

Market creation mechanisms are equally important. Many climate technologies face a chicken-and-egg problem: they cannot achieve cost competitiveness without scale, but cannot achieve scale without initial markets willing to accept higher costs. Strategic public procurement, feed-in tariffs, carbon pricing, and other demand-side policies can create initial markets that allow technologies to move down cost curves and become commercially viable.

Long-term partnership arrangements between technology developers and deployers can provide the sustained engagement necessary for successful adaptation and refinement. Technologies rarely transfer seamlessly, as they require ongoing technical support, training, troubleshooting, and incremental improvement. TIP should facilitate multi-year partnerships that provide this sustained engagement rather than one-off transfers.

The framework must also address intellectual property considerations, which remain contentious in climate technology discussions. While respecting legitimate IP rights, TIP should explore mechanisms like technology pools, voluntary licensing arrangements, and patent clarity initiatives that can reduce IP-related barriers to deployment without undermining innovation incentives.

In the global health sector, for instance, the UN-backed Medicines Patent Pool (MPP, 2024) has successfully accelerated access to affordable medicines in developing countries by negotiating voluntary licenses from patent holders and sub-licensing them to generic manufacturers. A similar mechanism for climate technologies could facilitate access to key patented designs for renewable energy or adaptation technologies, contingent on establishing a trusted intermediary to manage licensing and ensure quality.

4. Moving forward: recommendations for tip design and implementation

If TIP is to fulfill its promise, specific design decisions in the current negotiation phase will prove decisive. We offer recommendations for UNFCCC negotiators, the Technology Executive Committee, Nationally Designated Entities, and development partners.

4.1. For UNFCCC negotiators and the Conference of the Parties

First, formal adoption of TIP should include explicit commitments on financing, not merely aspirational language about mobilizing resources. Negotiators should establish a dedicated TIP financing window, either within existing climate funds or as a new mechanism, with clear annual targets. Currently, CTCN, Technology Mechanism's implementing arm, has an operational budget of 10 million. Nevertheless, an initial goal for a real global climate technology implementation should be at least USD 500 million annually, scaling to USD 2 billion by 2030. This would represent a serious commitment to implementation; implementation, despite COP29 actual results in terms of finance mobilization.

Second, TIP's governance structure should ensure developing country voice and leadership. The program should be guided by a steering committee with majority representation from developing countries, particularly Least Developed Countries and Small Island Developing States. This ensures that implementation priorities reflect the needs of those most affected by climate change and most constrained in their implementation capacity.

Third, establish mandatory biennial reporting on TIP implementation outcomes, with quantitative indicators on TAP implementation rates, technologies deployed, finance mobilized, and capacity built. This accountability mechanism should feed into the Global Stocktake process, making technology implementation a visible component of climate progress assessments.

4.2. For the Technology Executive Committee and CTCN

The TEC should develop standardized but flexible methodologies for assessing TAP readiness for implementation support. Not all TAPs are equally ready for scaled implementation: some require additional planning, others additional capacity building, and still others are ready for immediate financial support. Clear criteria help prioritize resources effectively while avoiding the perception that implementation support is allocated arbitrarily.

Create an "implementation mentorship" program pairing NDEs from countries with successful technology deployment experiences with counterparts in countries earlier in their implementation journeys. South-South learning is often more effective than North-South technical assistance for implementation challenges, as successful developing countries have recent experience overcoming similar barriers.

The CTCN should focus on existing networks bringing together countries working on similar technologies to establish sector-specific technology deployment. For example, the network could focus on the deployment of small-scale renewable energy in island contexts, or climate-smart agriculture in semi-arid regions. Reinforcing these networks facilitates peer learning, enables joint procurement to achieve scale economies, and creates communities of practice around specific implementation challenges.

4.3. For national governments and designated entities

National governments should elevate NDE institutionally, positioning them with clear cross-ministerial coordination mandates and direct access to ministerial decision-making. Where possible, locate NDE within or closely linked to national innovation agencies or development planning ministries rather than isolated in single sectoral ministries.

Establish national climate technology development funds with mandatory private sector co-investment requirements. These funds can support demonstration projects, provide de-risking capital, and create initial markets for promising technologies. The co-investment requirement ensures private sector engagement from the outset while public finance reduces perceived risk.

Develop regulatory frameworks that facilitate technology piloting and demonstration, including regulatory sandboxes for climate technologies. These frameworks should balance appropriate oversight with the flexibility needed for genuine innovation and adaptation.

4.4. For development partners and international financial institutions

Bilateral development assistance should explicitly align with TAP priorities rather than donor-determined technology preferences. This requires discipline from development partners to let country priorities guide support rather than promoting technologies where donors have existing capabilities or commercial interests.

International financial institutions should develop specialized financial products for climate technology implementation, particularly for the TRL 4-7 range. These products should have higher risk tolerance than conventional project finance, longer repayment periods that match technology deployment timelines, and streamlined approval processes.

Create results-based financing mechanisms that reward successful technology deployment rather than only funding inputs. For example, payments could be triggered when a technology achieves specific deployment milestones - successful operation for 12 months, replication in multiple sites, transfer of capabilities to local operators - rather than simply upon project completion.

4.5. Beyond TIP: toward genuine technology partnerships

While TIP represents important institutional innovation, truly transformative change in climate technology implementation will require evolving from “transfer” paradigms toward genuine technology partnerships and co-development. The Senai Cimatec’s and Innovation Institutes’ model hints at this alternative approach, where developing country institutions are innovation partners from the outset rather than recipients of completed technologies.

Technology implementation also brings significant co-benefits for development. It enables access to clean energy, strengthens climate resilience, fosters industrial modernization, and supports job creation in emerging environmentally sound sectors. These multidimensional benefits reinforce the importance of embedding technology strategies into broader national development plans and highlight the strategic relevance of implementation for both mitigation and adaptation.

To fully realize this potential, it is critical to institutionalize national implementation mechanisms, enhance inter-ministerial coordination, and provide long-term support to innovation ecosystems. Multi-stakeholder collaboration platforms, such as those envisaged under TIP and currently operational under the CTCN, can promote inclusive governance, align technical cooperation with country-driven objectives, and unlock synergies between actors. Furthermore, the incorporation of implementation agendas into South-South, North-South, and triangular cooperation frameworks is essential to accelerate technological transitions globally.

5. Conclusion: a closing window of opportunity

The current momentum around TIP offers a unique window of opportunity to translate climate technology ambition into implementation reality. Fifteen years of experience with the Technology Mechanism have clearly identified what constrains progress: fragmented national coordination, insufficient and inappropriately structured finance, weak mechanisms to advance technologies through demonstration to deployment, and implementation approaches that privilege donor priorities over country ownership.

TIP can address these barriers, but only through intentional design choices in the negotiation and operationalization process. The three conditions we have identified - dedicated financing architecture, genuine country ownership structures, and mechanisms for advancing technologies through the valley of death - are fundamental requirements for breaking the cycle of planning without delivery that has characterized climate technology cooperation for too long.

The 2030 climate targets are no longer distant aspirations - they are rapidly approaching realities against which progress will be measured. Technology implementation is not one component of climate action: it is the means through which climate commitments translate into emissions reductions and enhanced resilience. Getting TIP right is therefore essential not just for the Technology Mechanism but for the credibility of the entire climate regime.

The path forward requires both optimism and realism. Optimism that TIP represents genuine institutional innovation and that the barriers to implementation, while substantial, are not insurmountable. Realism that success is not guaranteed, that past mechanisms have disappointed despite initial promise, and that transformative outcomes require sustained political commitment and adequate resources.

Brazil's hosting of COP30 provides an important opportunity to advance TIP's operationalization. As a Global South country with demonstrated capability in technology innovation, strong traditions of South-South cooperation, and leadership on climate action, Brazil is well-positioned to champion effective technology implementation as a COP30 priority.

The window for effective climate action is narrowing. TIP offers a chance to widen the bottleneck in climate technology implementation that has constrained progress for far too long. The question is whether the international community will seize this opportunity with the seriousness, resources, and design sophistication required. The evidence of 15 years suggests caution; the urgency of the climate crisis demands optimism. TIP must succeed because the alternative - continued planning without delivery - is no longer acceptable.

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