POLICY MEASURES AND FINANCIAL INSTRUMENTS FOR CATALYSING THE RAPID DEVELOPMENT AND DEPLOYMENT OF GREEN AND LOW-CARBON TECHNOLOGIES

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ADB

A. Technology Landscape and Readiness Levels in Early Stage Climate Technology

The development and deployment of climate technologies is integral to tackling climate change, fostering energy transition, and building climate and disaster risk resilience. New and advanced technologies are important for addressing both the causes and effects of climate change and achieving sustainable development. Typically, climate technologies refer to a range of carbon reduction technology, carbon-free technology, carbon removal technology, carbon management technology, recycling technology, and many more. Developing climate technologies is not a smooth-sailing process as there are challenges in each development stage, making it harder to reach the deployment stage.

Currently, a number of climate technologies with a high potential in tackling climate change are at "early stages" of development. The Technology Executive Committee (TEC) of the United Nations Framework Convention on Climate Change (UNFCCC) considers "early stages" as technologies tested for their climate change mitigation and adaptation potential but are not yet operational technologies.[1] Table 1 displays Technology Readiness Levels (TRL) from IEA and NASA used by the TEC of the UNFCCC, with the green columns as commonly referred to as early-stages, although stages 1–9 in the TRL can also be classified as early-stage.

Table 1: Technology Readiness Levels and Policy Implications

Broad Stage	TRL	Narrow Stage	Policy and Financial Requirement Implications
Conceptual or research phase	1	Initial idea, basic principles observed	At scale of researcher, small company or individual; broad R&D support sufficient
	2	Application formulated; technology concept formulated	At scale of researcher, small company or individual; broad R&D support sufficient
	3	Concept needs validation, experimental proof of concept	Moderate funds may be needed
Small prototype (development phase)	4	Early prototype, technology validated in lab	Moderate: 2 TW globally, but highly regional
Large prototype (development phase)	5	Large prototype, technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)	Moderate costs, no revenue, significant support needed; realm of ARPA-style funding
	6	Full prototype at scale, technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)	Large costs, no revenue, significant support needed. Realm of ARPA-style funding
Demonstration (deployment phase)	7	Pre-commercial demonstration, system prototype demonstration in operational environment	Very large costs, no revenue, significant support needed. Funding needed beyond typical ARPA funding, large firm, venture or state capital investment
	8	First-of-a-kind commercial, system complete and qualified	Strong natural or created lead market necessary, makes compensating revenue generation to balance costs possible
	9	Commercial operation in relevant environment, actual system proven in operational environment	Strong natural or created lead market necessary
Early adoption	10	Integration needed at scale	Moderate natural or lead market support necessary
Mature	11	Proof of stability reached	Natural or created lead market no longer necessary

ARPA = American Rescue Plan Act, R&D = research and development, TRL = Technology Readiness Level.
Note: This table uses the definitions of TRLs from the International Energy Agency (IEA) and National Aeronautics and Space Administration (NASA).
Source: Asian Development Bank using data from the IEA, NASA, and the United Nations Framework Convention on Climate Change.

[1] UNFCCC. 2022. *Emerging Climate Technologies in the Energy Supply Sector*.

Key emerging technologies with the potential for climate change mitigation and adaptation are spread across a few sectors, mainly energy supply, transport and agriculture, as well as technologies relevant to multiple sectors such as carbon removal and digital technologies.[2] A few of these identified technologies are still in early-stages such as airborne wind energy, wave power, tidal power, ocean thermal energy conversion, bioenergy with carbon capture and storage, next generation batteries, and thermal energy storage.

B. FINANCING OF EARLY-STAGE CLIMATE TECHNOLOGIES

Financing early-stage climate technologies requires a combination of policy and legal incentives and frameworks, market development through information provision, as well as public and private finance. Public finance for climate technologies is important to share risks, both real and perceived, between public and private actors to catalyze investments in climate technologies from the private sector.

In terms of finance and access to capital, there are a few different types of financing that are typically available for early-stage technologies with the most common being equity financing, debt financing and grants.[3] The Intergovernmental Panel on Climate Change notes that governments play an important role in the early stages of the TRL; venture capital and angel investors have a significant role during the demonstration phase; and ultimately private equity, commercial banks, as well as mutual funds are crucial in the latter stages of the TRL.[4]

Financing conditions and investment appetite can also be influenced mostly through policy frameworks, specific interventions and course of actions which may affect and determine market factors such as the underlying costs, allocation of risks, and revenue streams. Using technology neutral policies, especially at the diffusion stage, can help avoid lock-in of inferior technologies and guide public support to where it is most beneficial. To reduce future cost of climate action, near-term technology neutral policies may be combined with long-term policies that support specific early-stage technologies. In designing interventions, governments may need to also consider methods, such as reverse auctions, for channeling support to entities that make best use of scarce public resources.

Although there are a range of financing options available for early stage climate technologies, this note introduces convertible notes, government schemes such as grants, venture capital, and guarantee schemes as the four financing options that are particularly relevant for early-stage climate technologies.

Convertible notes. These are a type of debt instrument that can be converted into equity at a later date. Convertible notes are promising and provide several benefits because (i) they are typically issued in rounds of financing; (ii) they provide flexibility on how the funds can be used; (iii) they allow the company to delay setting the valuation which is beneficial for early-stage companies that are still in the process of developing its products; (iv) and can be structured so that the interest accrues and is added to the principal, which can be beneficial if the company is not yet generating revenue (footnote 3).

Government schemes. These schemes and in particular, government grants, can be a key source of funding if such are provisions are made with a particular focus on early-stage climate technologies. There are a number of government schemes tailored towards early-stage climate technologies and these can occur also in the sub-national level with different states having different schemes.

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[2] UNFCCC Technology Executive Committee. 2020. Mapping of Emerging Climate Technologies.
[3] Faster Capital. 2023. Early Stage Financing Options for Technology Companies.
[4] G. Blanco et al. 2022. Innovation, Technology Development and Transfer. In P. R. Shukla et al., eds. 2022. Climate Change 2022: Mitigation of Climate Change—Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA: IPCC. doi: 10.1017/9781009157926.018

Venture capital. This is a key platform of financing climate technologies, through which the private sector manages risks associated with new technologies, especially in early-stage developments. Funds pool risks by investing in a number of different companies with new technologies. Companies are usually start-ups or small and medium sized enterprises (SMEs) with high growth potential. Publicly backed venture capital (VC) and private equity (PE) have been funding climate technology investment ecosystems. Box 1 provides insights from the ADB Ventures Financing Partnership.

Box 1: ADB Ventures Financing Partnership

The ADB Ventures, established in January 2020, supports and invests in early-stage companies with technology enabled solutions that contribute to achieving the Sustainable Development Goals (SDGs) in Asia and the Pacific with a core focus on climate. The initiative includes technical assistance to generate an investment pipeline by reducing market and financing risks ("de-risk") for early-stage companies through ADB Ventures SEED, a reimbursable grant program and ADB Ventures Investment Fund 1, that reached final close in September 2020 at $60 million capitalization and provides equity financing up to $4 million per investment focused on climate impact including cleantech.

Since its inception, ADB Ventures has established various financing partnerships. This includes a Philippines-based satellite analytics company that provides risk assessment information, follow-up investments in five of its existing investee companies that uses drone-based aerial surveying to eliminate wastage in the construction industry, and in gas-insulated switchgear technologies to cut the use of sulfur hexafluoride. It also extended capital for the development of a mass production platform for commercializing high-quality, virus-free seed potatoes as well as to the designer and manufacturer of light electric vehicles supporting last-mile commercial logistics in India.

Source: ADB. ADB Ventures Financing Partnership Facility.

Guarantee schemes. Financial risk management instruments are fundamental to remove barriers and encourage investments that contribute to more efficient energy use, reduce the use of fossil fuels, and mitigate climate change. Credit Guarantee Schemes are widely regarded as one of the most market-friendly interventions that has improved SME access to finance in many countries. In principle, CGS improve SME access to finance by sharing the default risk with lenders, which mitigates information asymmetry and other management issues.

Alongside CGS, Energy Savings Insurance (ESI) are effective performance guarantee instruments for mitigation of financial and technology risks and are being piloted in several countries with local adaptations. Energy Savings Insurance has been developed and led by the Inter-American Development Bank (IDB), with the support of BASE. In Colombia and Mexico alone, the model is expected to mobilize over US$ 45 million in SME investments in energy efficiency technologies. In Latin America, in addition to Mexico and Colombia, the ESI model is currently being developed and implemented in Argentina, El Salvador, Chile, Brazil, Nicaragua, Paraguay, Peru. In Europe, it is being developed in Italy, Portugal, and Spain by BASE with funding from the European Commission's Horizon 2020 Research and Innovation Program. ADB is currently exploring the concept in India and the Philippines.

It is to be noted that these financing schemes are more difficult in the context of developing countries where the financial sector often is less developed, creating additional uncertainty and risks related to barriers such as lack of patient and low-cost capital, poor creditworthiness, lack of guarantees, and low

availability of capital for public investment.[5] A UNFCCC analysis of technology needs assessments (TNAs) confirms that the most commonly reported economic and financial barriers are the lack of or inadequate access to financial resources and inappropriate financial incentives.

NOTABLE INITIATIVES AND COUNTRY FRAMEWORKS

The broad range of financing options are important for early-stage climate technologies and there is evidence of successful case studies from across the globe that are mobilizing finance for early-stage climate technologies. These range from targeted funds, venture capital schemes, loan platforms, CGS, pipeline development, among others.

There is a strong presense of such initiatives in the developed markets. The United States (US) hosts the Small Business Innovation Research and Small Business Technology Transfer programs that fund a diverse portfolio of startups and small businesses across technology areas and markets to stimulate technological innovation, meet federal research and development (R&D) needs, and increase commercialization to transition R&D into impact.[6] They also host the Federal and State Technology Partnership Program and the Growth Accelerator Fund Competition. With regards to guarantees, the US also has a provision of a $40 billion loan authority to guarantee loans for innovative clean energy projects as part of the US Inflation Reduction Act. This will support $3.6 billion in credit subsidy for loan guarantees for innovative clean technologies, including renewable energy systems, carbon capture, nuclear energy, critical minerals processing, manufacturing, recycling, geothermal energy, and other climate change technology.[7].[8]

The European Union (EU) recently launched the Green Deal Industrial Plan that simplifies the regulatory environment and accelerates access to funding for clean tech production. To catalyze private investments, the EU creates a financing instrument called “InvestEU” consisting of 17 implementing partners, that supports public and private investments in net-zero tech and industrial innovation. A portion of the investments is a €101 million guarantee to a fund in support of early-stage technology companies (venture capital) and other low carbon companies.[9] Some technologies covered by InvestEU projects are wave power, tidal power, and next generation batteries.

Specific prioritization of particular sectors, such as climate technology, is also seen in Finland under Sitra, the Finnish Innovation Fund. Although Sitra is not specifically dedicated to clean energy or climate tech, it is noteworthy for its focus on equity investing (among other tools) and has placed the ecological reconstruction of society at the top of its list of five goals for 2021–2024.[10] Since 2006, Sitra has been organizing annual Cleantech Venture Days focused on clean energy start-ups.

Innovation Norway is a state-owned company whose programs and services are intended to stimulate entrepreneurship in Norway. They provide grants via calls to early-stage technologies. loans and loan guarantees, as well as connections to external incubators, market research, grants and loans. Alongside Innovation Norway, ENOVA, the state enterprise for funding climate change solutions, also uses permanently open calls for its three initiatives to support nascent technology projects. Enterprise Singapore has a permanently open call for applications from early-stage companies looking for S$250,000 to S$400,000 ($190,000 to $300,000). Given “call windows” might not necessarily suit early-

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[5] UNFCCC, Technology Executive Committee. Enhancing Access to Climate Technology Financing. *TEC Brief* #6.
[6] SBIR. The SBIR and STTR Programs.
[7] Government of the US, The White House. 2023. *Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act’s Investments in Clean Energy and Climate Action*. Washington, DC.
[8] Green Climate Fund (GCF). 2021. Accelerating and Scaling up Climate Innovation. *Green Climate Fund Working Paper* No. 4. November. Incheon.
[9] European Commission. 2023. A Green Deal Industrial Plan for the Net-Zero Age.
[10] IEA. 2022. How Governments Support Clean Energy Start-Ups.

stage technology companies that are often very close to their next funding crisis, platforms such as Innovation Norway and Enterprise Singapore that provide a permanent window are important.

There are initiatives in the emerging markets and developing economies as well. The Middle East and North Africa (MENA) region, for example, is deemed an attractive region for investors to invest in early-stage climate technology. Egypt, Saudi Arabia, and the United Arab Emirates are some of the MENA countries that have the highest investors' confidence level for climate technology investments.[11] There are currently a number of incubators and accelerators to explore investment opportunities in climate technologies, such as Hub71, in the United Arab Emirates.[12]

The PRC is leading with sodium-ion battery development, an early-stage technology that IEA analysis shows to have a promising future.[13] The PRC, through the Contemporary Amperex Technology Co., Limited (CATL) with funding mostly from institutional investors and state incentives, had been developing prototypes in the past years and recently announced that it would begin a large-scale production in 2023.[14] This shows that with adequate financing and regulatory support, early-stage technologies like batteries could rapidly progress to commercialization over time.

In 2018, India established a joint public–private initiative called the Clean Energy International Incubation Centre (CEIIC) to look for start-ups with innovative solutions to challenges across the entire energy value-chain in India, especially clean energy. This initiative targets early-stage clean energy start-ups with TRL 3–9. CEIIC was set up with a cost-sharing model between the Government of India and Tata Trusts, with operational costs shared with Social Alpha. Selected start-ups are eligible for seed equity investment of up to around $130,000. CEIIC also supports incubation programs with access to infrastructure including prototyping lab and testing facilities (footnote 10).

Since 2010, Chile's government agency, Corfo, started Start-Up Chile as a business accelerator and provides grant financing as well as services, including for early-stage technologies.[15] While it is not energy-specific, it has issued calls for proposals in the areas of solar and energy efficiency management (footnote 10). There are three stages eligible for financing application, which are pre-acceleration (TRL 1–3), acceleration (TRL 4–6), and scale (TRL 7–9). Grants at pre-acceleration stage are around $12,000 for new ventures moving from a validated idea to an early-stage prototype with the possibility to win another $6,000 (footnote 10).

While these initiatives exist, they also need to be complemented by frameworks to provide longevity and certainty in the market. Preliminary research indicates that there are not many policy frameworks that exist in the national or the sub-national level that seek, as a direct objective, to create an enabling environment to finance early-stage climate technologies. Many countries have scattered initiatives or a nodal agency with the mandate to promote investments in technologies, as highlighted in this section in the previous paragraphs, as opposed to having an overarching legal or policy framework guiding these discussions.

Nonetheless, there are some lessons that can be learned from the frameworks that countries have put in place with the objective to catalyzing investments technologies, including early-stage climate technologies. Two notable patterns are visible based on literature review of country initiatives and frameworks.

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[11] UAE Ministry of Economy. 2022. Venture Capital in MENA Climate Tech.
[12] P. Rajkumari. 2023. Inside 8X Ventures' $25M Bid on MENA's Clean Tech, Climate Tech Ecosystem. *Your Story Gulf Edition*. 16 February.
[13] IEA. 2023. *Global EV Outlook 2023.*
[14] CATL is a company from the PRC that is the world's largest battery manufacturer. IEA. 2023. *Global EV Outlook 2023.*
[15] *Corporación de Fomento de la Producción* (Production Development Corporation)

First, countries have nodal agencies and a suite of offerings to create a holistic framework and support financing of early-stage technologies, which serves as the overarching framework. Singapore has taken a holistic approach in setting a framework to establish itself as a technology developer. This started with enhancing the research and development capacity within research institutes and universities as well as establishing funding programs, incubators, and accelerators to translate the research and development into market products through Enterprise Singapore as the government agency leading the work on enterprise and technology development (footnote 10). Although Singapore has traditionally focused on information and communication technology, it is gearing toward becoming a hub for clean energy start-ups, especially in the areas of electricity generation and electrification. In the United Kingdom (UK), Innovative UK sets the overarching direction as the UK's national innovation agency that supports business-led innovation in all sectors, technologies, and UK regions. Innovative UK helps businesses grow through the development and commercialization of new products, processes, and services, supported by an outstanding innovation ecosystem that is agile, inclusive, and easy to navigate.[16]

Second, some countries have overarching acts for technology development and innovation that include some reference to early-stage climate technology such as the Italian Start-up Act and the Spanish Start-up Law. Other countries provide regulatory frameworks that ease investment processes such as multiple free zones and no minimum capital policy such as in the United Arab Emirates. Although these are measures that broadly support start-ups and development of sector agnostic technology, they also provide an enabling environment for climate technology research and development.

It is worthwhile noting that countries generally seem to invest heavily in developing a robust and full cycle ecosystem by combining policy frameworks such as tax incentives for startups with financial innovation such as through public funded guarantee-schemes that effectively allow for a transformation from "conventional" capital to more long-term "patient" capital. In addition, well designed and incentive compatible profit sharing schemes for those successful start-ups (such as through convertible notes) can support with loss absorption in the case of failure across the TRL stages. In this way, there is a collective underlying pooling of risk over the initially supported initiatives and that can lead to some form of recovery and not a pure deadweight economic loss. To the extent that technological spill overs to the rest of the economy are significant, public funding can ensure a degree of economic returns over the medium term.

CONCLUSION

The scale of finance for early-stage start-ups needs to be enhanced substantially, including through the existing mechanisms and innovative investment products. Countries need to build an enabling policy and legal ecosystem to harness and mainstream climate technologies, including to explore new financing streams and incentives, ease regulatory frameworks, and establish international partnerships. The exchange of country experiences helps diffuse knowledge and scale the finance required for early-stage climate technologies.

However, this note and our research show that more comprehensive frameworks are needed, especially on a national-level, in ensuring the creation of supportive ecosystem for early-stages climate technologies. Most of the case studies cited here indicate that early-stage development requires more access to funding and services support from the government. Therefore, it is critical for governments to start setting up frameworks that will guide participants in scaling up early-stages climate technologies.

[16] UK Research and Innovation. Innovate UK.