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Options for support for technology collaborative research and development – Addendum

Summary

This paper is an addendum complementing document GCF/B.18/12. It provides additional information on collaborative research, development and demonstration (RD&D) and the link to climate technology development and transfer, trends in the collaborative RD&D of climate technologies, application of financing instruments, an analysis and illustration of how key lessons assist in delivering against GCF investment criteria, and illustrative case studies.

For the purpose of this paper, the concept used is collaborative RD&D, consistent with its application by the relevant UNFCCC thematic body.

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I. Introduction

1. The Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), by UNFCCC decision 7/CP.20 (GCF B.14/02), requested that the Board of the GCF is consistent with paragraph 38 of the Governing Instrument for the GCF, which states "The Board shall also ensure adequate resources for capacity-building and technology development and transfer. The Fund will also provide resources for innovative and replicable approaches". By UNFCCC decision 7/CP.21, the COP invited the Board of the GCF to consider ways to provide support, pursuant to the modalities of the GCF, for facilitating access to environmentally sound technologies (ESTs) in developing country Parties, and for undertaking collaborative research and development for enabling developing country Parties to enhance their mitigation and adaptation action.

2. This paper provides supporting information to the options identified in document GCF/B.18/12, which identifies concrete options on how the GCF can support collaborative research and development in developing countries, in line with the operational modalities of the GCF, taking into account decisions B.13/11 and B.13/12, and in the context of the operational framework for complementarity and coherence with climate finance delivery channels.

3. This support material provides information by defining collaborative research, development and demonstration (RD&D), summarizing current trends in collaborative RD&D and how this might support climate technology development and transfer to developing countries. It then sets out key lessons that must guide the Fund's interventions in this field, before providing detail on two different approaches through which the GCF can support collaborative RD&D and the related financing mechanisms.

II. Collaborative RD&D and the link to climate technology development and transfer

4. Collaborative RD&D was adopted under the UNFCCC as a possible means to assist climate technology development and transfer to developing countries to improve low-carbon and climate-resilient development. This sits within the broader context under the Convention's commitments to increase flows and availability of climate technologies for mitigation and adaptation in developing countries. Collaborative RD&D is explicitly recognized in the Paris Agreement in relation to the technology framework: "Other areas may be explored as possible key themes, including, but not limited to: Accelerating, encouraging and enabling innovation, collaborative approaches to research, development and demonstration, and the provision of support" (FCCC/SBSTA/2016/L.8).

5. No universally accepted definition of collaborative RD&D exists. This paper adopts an inclusive definition, including international collaborations, (e.g. Mission Innovation), and collaborations across institutions, particularly public-private collaborations (e.g. the World Bank-funded Climate Innovation Centers).

6. A recent TEC report (TEC, 2017) defines collaborative RD&D as applying to:

> "… existing commercial products as well as to completely new products. It is inherently an uncertain activity, yet it is the only process through which new technologies are developed and brought to market."

2.1 How can collaborative RD&D contribute to climate technology development and transfer?

7. There are a number of ways in which **publicly funded or co-funded** RD&D (i.e. the type of collaborative RD&D the GCF would be involved in) has been cited as potentially contributing to climate technology development and transfer, including:

(1) Improving cost and performance attributes, making climate technologies more competitive against incumbent technologies (TEC, 2017).

(2) Undertaking early stage RD&D that is too risky for private sector actors to undertake (TEC, 2017), particularly where a public good rationale exists for such funding (such as climate change mitigation or adaptation);

(3) Focusing efforts (through funding availability) where collaboration has relative advantages (Eis et al., 2016);

(4) Sharing costs and risks of large-scale innovation challenges that are unlikely to be addressed by the private sector alone (Eis et al., 2016);

(5) Linking markets and RD&D activities across national borders (Eis et al., 2016);

(6) Supporting more extensive knowledge-sharing, with demonstrated knock-on effects in speeding global rates of innovation and technological change (Eis et al., 2016);

(7) Supporting technological capability-building around new climate technologies (Eis et al., 2016). This includes "new to the world" technologies but applies equally to existing technologies being adopted for the first time in new contexts. Such technological capability-building is essential to enabling many low- and middle-income countries in particular to adopt and work with climate technologies; and

(8) Galvanizing climate compatible development in low- and middle-income countries that tend to lack such capabilities, but where significant needs exist for leapfrogging to climate-compatible technologies (Eis et al., 2016).

8. Despite these potential advantages to collaboration, formal collaborations (e.g. EA, CGIAR, EU-Horizon; Climate-KIC) require a range of formally agreed attributes in order to operate effectively and be sustained. These include the need for partnerships to have collaboration agreements, agreed communication channels, platforms, nodes or other dedicated organizational, financial and human resources, including intermediaries (actors who play a key role in linking different organizations up within and outside of formal collaborations).

9. The potential benefits above have been widely acknowledged, in particular via the recent launch of several initiatives that aim to galvanize collaboration around climate objectives, including Mission Innovation, the Breakthrough Energy Coalition, and the Low Carbon Technology Partnership initiative (LCTPi) (Eis et al., 2016). It is critical that they complement existing national, public and private-sector RD&D investments, focusing on areas where cooperation has relative advantages (as indicated by the numbered list above) as well as those areas that are unlikely to be addressed without significant, international public-sector investment. In this sense, the GCF could make a significant difference, providing financial support that could augment existing financial commitments to these existing collaborative initiatives and driving innovation in additional climate-relevant areas at national and regional scales that are currently not met by existing public and private-sector efforts.

III. Trends in the collaborative RD&D of climate technologies

10. Data on trends in climate technology RD&D spending are limited to expenditures on renewable-energy technologies, International Energy Agency (IEA) member country energy efficiency RD&D expenditures, general agricultural RD&D and venture capital (VC) investment in low-carbon technologies and cleantech, which has a degree of overlap with climate technologies. No data are collected on adaptation technologies. Detailed information on trends in the RD&D of climate technologies can be found in annex I of this document.

IV. Financing instruments

11. Public financing of early stage climate technologies is essential. Two types of public RD&D financing need to be considered: direct financing of RD&D (i.e. of the technology development and innovation process itself) and indirect financing of the process – either through capacity-building and partnership and network support, or through broader innovation system support. Within the direct-financing modality, two options are available: funding public RD&D (i.e. of RD&D carried out by universities, research institutes and other public agencies) and subsidizing private RD&D. Both are widely applied. Public resources are more concentrated at basic RD&D and the early stages of technology development. While subsidies for private RD&D are usually allocated to applied RD&D, including the proto-typing and testing of new technologies, and close-to-market technologies (see annex I for more information on sources of finance).

Public financing instruments

12. A number of studies in the United States and Europe into clean energy technologies have analysed the suitability of public financing instruments for direct RD&D financing for different RD&D stages and for different types of climate technology innovation. The selection of financing instruments is primarily driven by innovation process variables (e.g. the stage of technology development, the capital intensity and scale of the development, and pre-deployment), the type of innovation (e.g. radical or incremental, or a new product based on existing mature technologies), the nature of the innovating entity and the target market. The analyses are guided by the principle of triggering innovation at the lowest possible public cost.

13. A recent study (Dechezlepretre, 2015) found that external spill-overs from clean technologies are particularly high, and that optimal subsidies are at least 20 to 30 per cent higher than for technology innovation in general. An overview of relevant innovation variables and factors influencing financial instrument selection is depicted in the diagram below.

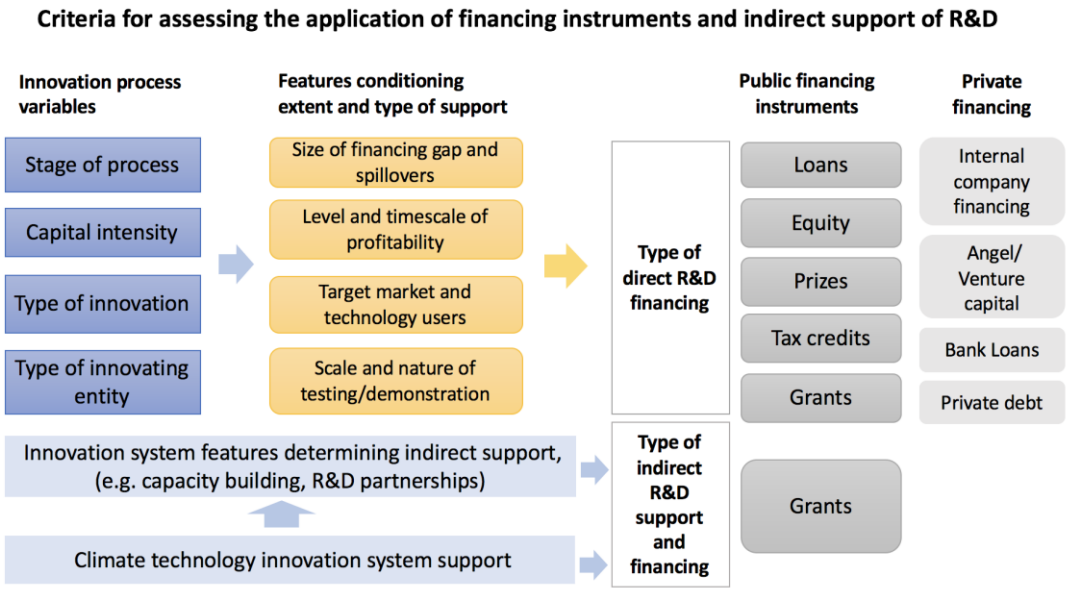


Figure 1: Criteria for assessing the application of financing instruments for RD&D (adapted from Olmos et al, 2012).

14. The characteristics of public finance instruments for RD&D and the kinds of innovations they are used for, are summarized in table 1 below.

Table 1: Characteristics and applications of public finance instruments, adapted from Olson et al, 2012.

Applicability / Financial instrument	Financing gap that can be covered	Technology features	Target type of innovating entity	Type of innovation process
Public loans/loan guarantees	- Potentially large amounts. - Public loans are not able to close the funding gap of most clean innovation activities. Only specific, near-mature technologies requiring incremental innovation can be supported with public loans.	- Technology deemed to be deployed at large scale and profitable. - First-of-a-kind, commercial-scale demonstration projects in the fields of renewable energy and hydrogen and fuel cells.	- Large firms - Also, large projects, public-private partnerships and special-purpose vehicles or projects.	- Capital intensive. - Usually incremental innovation.
Public equity (as in PPEPs)[a]	- Only seed equity investments are employed at the pre-deployment stage.	- Profitable innovation projects by small to medium entities and	- Mainly small entities.	- Early innovation processes with a high commercial potential, like radical innovations

	- Public equity investments are usually small. - Public equity investments, may play an important role by certifying firms to outside investors, who might then be more willing to make further investments.	(radical) promising technologies that do not meet high venture capital goals for return on investment - Equity investments can trigger pre-deployment, commercially attractive RD&D where revenues are expected to surpass expenses.		by university spin-offs. - Closer-to-the-market RD&D with good commercial prospects.
Prizes	- Medium.	- Low-cost innovation processes involving a large amount of RD&D. E.g. the significant improvement of a feature of a specific technology.	- Suitable for small entities that undertake low-cost investments.	- Low-cost early research and new technology products.
Tax credits	- Able to trigger large funding gap. - May make marginal RD&D projects profitable.	- Close-to-market technologies.	- Addressed at large entities that (1) pay large taxes; (2) already perform RD&D.	- With the exception of innovation projects in regulated entities, only close to the market technologies can be supported.
Grants and contracts [b]	- Can close the financing gap of any kind of clean innovation project, even those targeted at the most immature, capital intensive, technologies. - Types of innovation processes that are well suited to being supported through other instruments should not be supported through input driven grants and contracts.	- Very high ability to trigger innovation. - Early stage, immature technologies. - Pioneers serving low-income customers, developing new products that demand continuous RD&D. Low unit margins limits ability to invest in RD&D thus	- Usually small companies.	- Large fraction of clean pre-deployment innovation processes, including research and product development (those not triggered by other instruments). - Founding of high-tech companies.

		justifying grant support.		

[a] *Public-Private Equity Partnerships*
[b] *Grants can be input-driven our output-based. The latter are not suitable for risky, expensive research*

15. The further into the technology development cycle, the more complex financing becomes. At the 'first-of-a-kind' (FOAK) commercial demonstration stage of new low-carbon technologies, financing structures blending private equity, debt, capital market and grant-financing streams are common. Public funding of innovative low-carbon commercial scale demonstration projects in the EU is limited to grants and, more rarely, debt through the InnovFin Energy Demo Project facility.

16. Despite the availability of public grant financing, many innovative low-carbon FOAK projects in the EU do not achieve financial closure because of their inability to raise private equity and debt. This has resulted in a demand by project developers to make available public equity and a wider variety of debt and grant instruments.

Grant financing

17. Given the large financing gap in clean innovation processes, a significant part of RD&D activities can only be triggered through the provision of public grants. Grant financing is particularly important at the stages prior to the commercial demonstration phase of climate technologies, that is at the technology development and early validation stages. Only relatively small sums of money are required at this stage. Many countries have established technology funds that support early stage clean or low-carbon technologies with grant funding, or at least have broad programmes that fund innovation and research in small companies. These funds are usually very competitive, and often emulate VC funds in their staged approach to funding. There are indications that grant funding at the early stages of technology development can be an important stepping stone for start-ups to attract private equity and other forms of investment at subsequent innovation stages (Cleantech Group, 2014). There is also evidence of the importance of grant funding for climate technology RD&D by pioneering companies in low-income markets that serve price-sensitive customers (Shell Foundation, 2014).

18. While **output-driven** subsidies (where public funds provided are associated with the achievement of project objectives) have become increasingly popular, they are less attractive to innovators the higher the risks associated with the concerned project are. They are therefore unlikely to trigger risky, expensive research.

Blended financing instruments

19. It is widely acknowledged that the financing of the RD&D of climate technologies needs to be substantially increased, and that public support is needed to reach a socially acceptable level of RD&D and innovation. It is also recognized that the RD&D and commercialization of climate technologies is being constrained by a lack of risk-tolerant and patient capital, as well as a broader range of public financing instruments that can unlock private sector investment. Private investors seek a safe return on their investment, but innovation is never risk free. The role of public financing is to de-risk private investment in a high-risk asset class such as innovative early stage climate technology companies, as well as to create a pipeline of investible companies and projects through support for innovation enablers such as innovation centres, incubators and accelerators.

20. The constraints of attracting private capital to cleantech, which partially overlaps with climate technologies, have become particularly apparent since the withdrawal of venture capital from hardware-based clean technologies.

21. There is a need for a new range of financing instruments that covers the continuum of pre-commercial technology development stages, including commercial scale demonstration, and the scaling of small companies serving new and challenging markets. New financing models include tiered capital structures and grant-based instruments that allow public and private investors to participate in the same funding vehicle according to their ability to take on risk, with donors taking first loss positions or providing convertible grants.

22. In the impact investment sector, which is increasingly active in the field of energy access and climate-smart agriculture, the same need for the wider availability of patient capital, which offers softer terms and longer timeframes, and layered or blended funding structures has been identified. Blended and layered funding structures using a combination of donor, philanthropic and commercial funding, whereby innovation and development is financed and catalysed via philanthropic or soft capital, and commercial investment can then facilitate the scaling up of the enterprise (UNDP, 2016).

Multilateral experience with financing RD&D

23. Experience of multilateral organizations with direct financing of RD&D of ESTs is limited outside of the CGIAR, and has been mostly concentrated in the demonstration stage of new technologies, for example of concentrated solar power (CSP), and fuel cells for transportation, funded by the Clean Technology Fund (CTF) and the Global Environment Facility (GEF). Financial instruments were mostly grants used to bring down the cost of demonstration projects and, in some cases, to leverage private-sector finance. Loans and concessional loans have also been extended for CSP plants, which is still a relatively untested technology.

24. However, as a result of the increasing importance of the role of cleantech start-ups and entrepreneurs in developing and bringing to market new climate technologies, seed and early stage equity financing of climate technologies has begun to be deployed by multilateral development banks (MDBs) and the GEF. The best-known example is the Climate Technology Program of the World Bank and its Climate Innovation Centers (CICs). The CICs are a novel type of innovation infrastructure and institution that combines grant funding of start-ups and small- to medium-sized enterprises (SMEs) with incubation and accelerator activities. The goal is to develop a pipeline of investible companies. In Kenya (and forthcoming in Ghana), the World Bank also established Climate Venture Facilities to provide early stage climate technology companies with patient and local currency financing twined with the technical assistance that many of these companies need to prepare for the scaling-up stage. Other projects, such as a United Nations Industrial Development Organization multi-country project, do not create new innovation infrastructure, but support clean-technology entrepreneurs and start-ups by organizing acceleration and technology competition programmes, and facilitating access to angel investors, VC funds and strategic investors.

25. The International Finance Corporation (IFC) and the Inter-American Development Bank, for example, are also investing equity in early stage companies, predominantly through VC funds, some of which also function as accelerators. A significant component of these equity investments is going to AgTech (agricultural technology), some of which is focused on innovations in climate-smart agriculture. While the IFC predominantly invests in the growth stage of enterprises, which is less risky, a component of its investments is aimed at early stage companies.

26. Another type of approach is adopted in a GEF-funded World Bank project in Mexico that provides sub-grants to private-sector enterprises for proof-of-concept stage development of advanced clean-energy technologies. It aims to fill a void in the current public and private financing landscape for early stage technology commercialization in the country and incentivizes industry–academia collaborations in technology development (UNFCCC, 2016).

27. The IFC has stressed the importance of working throughout the finance value-chain for entrepreneurs, from incubators through to private equity, and of the role of public finance in creating a deal pipeline of investible climate technology start-ups (IFC, 2016).

V. Recognition of the role of different actors and sectors in RD&D

28. Generally, the RD&D of new technologies relies more heavily on public than private funds, as this is where the risk is highest and commercial viability is the most uncertain and remote. Private-sector firms generally fund less-risky RD&D to improve the performance, reduce the costs of existing products, or build on the results of publicly funded, early stage efforts. Yet it is the more prosaic, incremental RD&D, which improves performance, adapts technology to new conditions and reduces costs, that has enabled the large-scale deployment of commercial renewable technologies for example (IRENA, 2015).

29. Nonetheless, companies engage in different forms of RD&D, contingent on the type of company, the available incentives and funding, and the demand (or anticipated demand) for new technologies. For instance, there is emerging evidence that an expanded set of early-stage capital providers (seed and venture funding provided by angel investors, venture capitalists, corporate ventures and corporations) are beginning to fund early stage energy demand and control technologies, while it has become much harder for renewable energy and energy storage technologies to raise seed and early stage capital (Bumpus and Comello, 2017). Early stage investors are also investing in agriculture and food, energy efficiency and transportation, which by 2016, had attracted slightly over 80 per cent of the total seed investment value from cleantech-focused organizations and angel investors. More capital-intensive sectors, such as hydro and marine power, nuclear and wind, account for a mere 2 per cent of all investments.

30. Although the private sector has a central role in the RD&D of climate technologies, universities, national labs and research centres also serve crucial RD&D functions. Increasingly, national labs are supporting entrepreneurs with lab-based incubation programmes, emphasizing commercialization efforts while offering state-of-the-art experimental facilities and technical capabilities (Incubatenergy, 2017). In the case of more-capital-intensive, hardware-based climate technologies, universities, national labs and other public research institutes with test-bedding and experimental facilities are indispensable in the RD&D and commercialization process.

31. Public RD&D is equally important in the case of pro-poor, ecosystem-based climate adaptation innovations that do not create a basis for profitable business, but have significant social and environmental benefits.

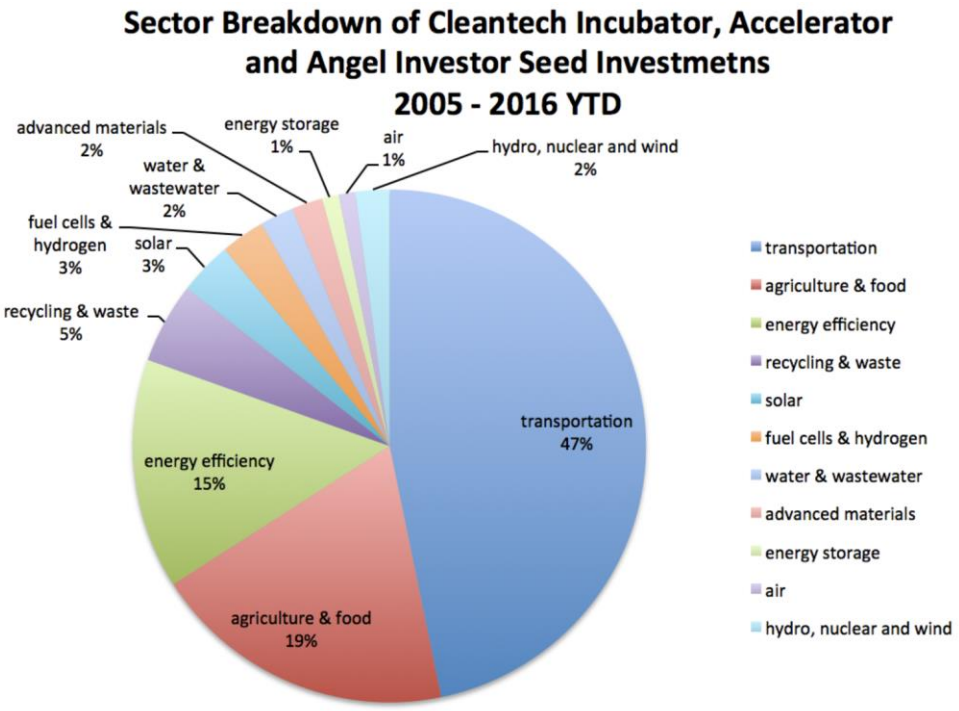


Figure 2: Cleantech seed investments by sector (source: Cleantech Group)

32. **Corporations** perform in-house RD&D that often benefits from RD&D tax credits, and also increasingly rely on a network of smaller high-tech companies for the RD&D of peripheral/non-core technologies. They also invest in early stage technology companies directly or through their venture arms. **SMEs** are increasingly engaged in RD&D (IEA, 2012), a trend that is facilitated by government programmes subsidizing the RD&D of innovative SMEs such as the US Small Business Innovation Research (SBIR) grant programme. With regards to **start-ups**, the trend of the growing role of cleantech start-ups in innovation has been facilitated by the increased availability of government grants, such as through the Advanced Research Projects Agency-Energy, and seed capital provided through incubators and accelerators.

33. **Cleantech innovation hubs, incubators and accelerators** tend to be financed by the public sector rather than the private sector, but can also be co-sponsored by corporations and private investors. Incubators and accelerators are considered critical enablers of innovation and commercialization of new clean technologies (IEA-RETD, 2014). The Cleantech Group credits the success of innovative start-ups in raising their first financing rounds to the recent growth in the numbers of cleantech-focused incubators and accelerators (Incubatenergy, 2017).

34. Although the terms *incubator* and *accelerator* are often used interchangeably, they differ in their business models and respective roles in bringing sustainable innovation to market. While there are variations within each type of organization, innovation hubs, incubators and accelerators tend to follow three similar structures (Cleantech Group, 2016a).

35. An **innovation hub** is an umbrella term for an organizational form that comprises university-based innovation centres, including tech transfer centres and research parks. They support research oriented towards applications in demand in the marketplace. These hubs provide physical workspace, lab access and a network where researchers, entrepreneurs, business leaders and industry experts can collaborate. Innovation hubs are typically funded through government or university grants, and corporate sponsorships or membership fees. Innovation hubs tend to deal with individuals and graduate students, and research conducted can spin off into start-ups (Cleantech Group, 2016a).

36. While some **incubators** may charge membership fees or take small equity stakes, most are funded by university grants or subsidized by the government in order to stimulate economic development and job creation within the local economy. These organizations tend to work for 1-2 years with early stage start-ups that have left the lab with a prototype. During this period, start-ups share an office space with other start-ups working within the same industry to promote collaboration. Additionally, incubators provide financial and marketing services, VC and angel investor introductions, as well as a network of local business leaders, industry experts and mentors. When they graduate, a successful start-up will typically have a sharpened business model, a small team, a refined prototype and the necessary knowledge to take the next step towards raising its first financing round (Cleantech Group, 2016b).

37. **Accelerators** quickly fine-tune start-ups for venture funding and commercialization through a rigorous 3-4 month tailored mentoring and support programme. Accelerators are growth driven, and usually take a small equity stake in admitted companies in exchange for a USD 10,000-50,000 seed investment. Accelerators expect that with the small seed investment, the start-up will go on to successfully raise a Series A round and eventually commercialize. Accelerators are playing an increasingly important role in the entrepreneurial ecosystem for angel and VC investors (Cleantech Group, 2016b; OECD, 2015).

Features of common intermediary innovation institutions

	Innovation hubs	Innovation centers	Incubators	Accelerators
Innovation stage and actors supported	Very early stage applied R&D. Students and aspiring entrepreneurs	Early stage to close-to-market; broad range of innovation actors.	Help start-ups to deliver refined prototype, sharper business model and knowledge to raise first round of finance	Early stage to close-to-market; to early stage companies
Technologies supported	New advanced technologies, including hardware	Broad range of technologies, e.g. hardware and IT/software based	Increasingly shifting towards capital light, software and IOT based technologies	Shift towards capital-light technologies and quick to scale business models
Funding	University and government funding. Corporate sponsors	Public funded, but also leverage private sector funding	Many incubators are funded by university or government grants; combination of public and private sector funding	Mostly fee-based; growth-driven
Key characteristics	Advanced lab and testing equipment. Based at universities.	Broad remit to catalyze and grow an innovation system	Long programs (1-2 years); provide working space and other resources.	Provide start-up capital in exchange for equity in company. Provide short programs to fine-tune companies for VC investment
Potential for collaborative R&D	May collaborate with other hubs for expensive larger scale technologies	Actively seek to spur and support collaborative innovation, through partnerships and networks.	Incubators have begun to form networks and connect internationally to increase opportunities for collaborations and market access.	Collaborate to broaden ecosystem and market access.

Narrower remit

More grant dependent

Figure 3: Features of common intermediary innovation institutions

VI. Options and modalities for supporting collaborative RD&D within the GCF business model

38. The adoption of an innovation systems approach translates operationally in a programme that does not target just one system component (e.g. access to capital or the production of knowledge), but rather addresses critical gaps in innovation and commercialization processes in support of RD&D collaboration across institutional and geographical borders. A mapping and analysis of the innovation system that is being supported (including its weaknesses and strengths) is required to identify opportunities to strengthen existing or create new innovation structures and processes.

39. Table 1 provides a set of overarching lessons to consider for the purpose of this paper and which should be taken into account when engaging in support for collaborative RD&D.

40. Therefore, it is suggested that GCF support for collaborative RD&D be structured around two modalities:

(1) **Support directed at climate technology innovation systems**, at the country, regional and global levels, with the view to facilitate and accelerate new forms of collaborative RD&D and innovation processes. A key component would be the strengthening and creation of intermediary innovation system builders. This modality would reach a range of public and private innovation actors, such as climate technology entrepreneurs, start-ups and SMEs, public innovation and research institutes, community organizations, utilities, local government, development actors and public and private investors.

(2) **Targeted climate technology RD&D support with the goal of collaboratively developing, testing, demonstrating or adapting climate technologies**. An array of such collaborative partnerships currently exists, with models seemingly contingent on the type of technology, the sector and institutional characteristics of the innovation system in which a technology is being developed.

Table 1: An analysis and illustration of how lessons assist in delivering against GCF investment criteria.
This table sets out the GCF investment criteria with an explanation in the final column of how key lessons articulated in the report may assist in delivering against the Fund's investment criteria.

Criterion	Definition	Coverage area	Activity specific sub-criteria	Contribution of key lessons for GCF RD&D support to meeting investment criteria
Impact potential	Potential of the programme/project to contribute to the achievement of the Fund's objectives and result areas.	Mitigation impact.	Contribution to the shift to low-emission sustainable development pathways.	Adopting an innovation system approach maximizes potential for deep, broad and long-term impacts, beyond the life of any GCF investment. Different interventions will be required in different contexts in order to maximize impacts and underpin appropriate actions to facilitate shifts to low-emission, climate-resilient sustainable development. Understanding and responding to these myriad specific contexts is critical to achieving and sustaining positive impacts.
		Adaptation impact.	Contribution to increased climate-resilient sustainable development.	
Paradigm shift potential	Degree to which the proposed activity can catalyse impact beyond a one-off project or programme investment.	Potential for scaling up and replication, and its overall contribution to global low-carbon development pathways being consistent with a temperature increase of less than 2 degrees Celsius (mitigation only).	Innovation Level of contributions to global low-carbon development pathways, consistent with a temperature increase of less than 2 degrees Celsius. Potential for expanding the scale and impact of the proposed programme or project (scalability). Potential for exporting key structural elements of the proposed programme or project elsewhere within the same sector as well as to other	Building and strengthening innovation systems around climate technologies in developing countries is the best way in which a paradigm shift can be achieved. The stronger these innovation systems become around appropriate climate technologies, the greater the levels of future innovation that will be achieved and the greater the contribution to global climate mitigation and local adaptation. By understanding what the appropriate investments are within specific contexts, it then becomes possible to understand where else (nationally and globally) different interventions might be scaled up and replicated/exported elsewhere. Sustained attention to context specificities when attempting to export key elements of any given intervention will prevent potential failures due to flawed assumptions about whether one approach might fit all contexts (whilst understanding where one approach, adapted to different local contexts, will work elsewhere).

Criterion	Definition	Coverage area	Activity specific sub-criteria	Contribution of key lessons for GCF RD&D support to meeting investment criteria
			sectors, regions or countries (replicability).	
		Potential for knowledge and learning.	Contribution to the creation or strengthening of knowledge, collective learning processes, or institutions.	Focusing on building and strengthening innovation systems, with due attention to context specificities will maximize the potential for knowledge and learning. The GCF must consider whether stipulations relating to sharing knowledge produced via the RD&D collaborations it funds is possible in relation to different investments. This will depend on the nature of any given investment. Making any resulting knowledge publicly available will maximize long-term and international benefits from knowledge creation and innovation arising from any given investment. However, commercial sensitivities can sometimes mitigate against this and therefore need to be considered on a case-by-case basis to avoid disincentives to certain (mostly private-sector) actors to engage.
		Contribution to the creation of an enabling environment.	Sustainability of outcomes and results beyond completion of the intervention. Market development and transformation.	Innovation systems are enabling environments in and of themselves. They provide a far more articulate and better understood approach to understanding the *enabling environments* within which climate technologies are successfully developed, demonstrated and adopted than much of the bland climate policy literature which refers to *enabling environments* without articulating what these are.

Criterion	Definition	Coverage area	Activity specific sub-criteria	Contribution of key lessons for GCF RD&D support to meeting investment criteria
				By developing innovation systems with due care and attention to context specificities, the sustainability of outcomes and results beyond any single investment, as well as the potential for subsequent development and transformation of markets is maximized. Conversely, if investments are not sensitive to specific contexts, they are likely to fail in the short to medium term.
		Overall contribution to climate-resilient development pathways consistent with a country's climate change adaptation strategies and plans (adaptation only).	Potential for expanding the proposal's impact without equally increasing its cost base (scalability). Potential for exporting key structural elements of the proposal to other sectors, regions or countries (replicability).	By focusing at the level of building innovation systems, collaborative RD&D investments by the GCF will maximize their overall contribution to climate-resilient development. Their impacts will have broader, system-wide impacts, as opposed to representing isolated, individual investments. Close attention to context specificities will ensure continuity with countries' climate change adaptation strategies and plans. It will also enable realistic analyses of the potential for scalability and replicability in other contexts with both similar and different characteristics (as is almost inevitable across the myriad different country, technology, sector, market, environmental, social, political etc. contexts that the GCF will be investing across).
Sustainable development potential	Wider benefits and priorities.	Environmental co-benefits.	Expected positive environmental impacts, including in other result areas of the Fund, and/or in line with the priorities set at the national, local or sectoral levels, as appropriate.	A focus at the level of innovation systems, (as opposed, for example, to individual sectors, technologies, income levels, etc.), will maximize the potential for GCF-funded RD&D collaborations to have impacts that are sustained in the long term. They will have system-wide, sustained impacts as opposed to represented isolated investments. Explicit attention to context specificities, at multiple levels (including environmental, social, economic, gender and, inevitably, political contexts), is the only way in which a solid understanding can be developed of which investments will be sustainable, in which ways, where and when.
		Social co-benefits.	Expected positive social and health impacts, including in other result areas of the Fund, and/or in line with	

Criterion	Definition	Coverage area	Activity specific sub-criteria	Contribution of key lessons for GCF RD&D support to meeting investment criteria
			the priorities set at the national, local or sectoral levels, as appropriate.	It is inevitable that trade-offs between these various pillars of sustainability will be encountered in any given context. Often, (indeed perhaps always), the choice over which element of sustainability is privileged will be a political decision. The GCF must be open in conceding the political realities of sustainability trade-offs and be transparent in how and why decisions are made to support projects that privilege different sustainability concerns, in different places, at different times (e.g. a given project might have significant environmental and economic benefits but potentially negative gender implications – this cannot be always be avoided - being transparent about such trade-offs and related decision-making in such contexts is what will legitimize the Fund's spending of public money).
		Economic co-benefits.	Expected positive economic impacts, including in other result areas of the Fund, and/or in line with the priorities set at the national, local or sectoral levels, as appropriate.	
		Gender-sensitive development impact.	Potential for reduced gender inequalities in climate change impacts and/or equal. participation by gender groups in contributing to expected outcomes.	
Needs of the recipient	Vulnerability and financing needs of the beneficiary country and population.	Vulnerability of the country (adaptation only).	Scale and intensity of exposure of people, and/or social or economic assets or capital, to risks derived from climate change.	The *coverage areas* and *activity-specific sub-criteria* articulated in relation to this investment criterion articulate more ways in which context specificities are likely to differ across myriad different climate technologies, countries, localities, sectors, social, political, environmental and economic contexts. It is the explicit consideration of exactly these types of context specificities that must guide GCF investments in RD&D collaborations. Thinking beyond from these vulnerability-focused criteria to the level of climate technologies, such vulnerabilities are also likely to be reflected in highly uneven innovation systems in different developing countries. By focusing at the level of innovation systems, the GCF will be able to target its investments in ways that respond to different vulnerabilities in different countries, ensuring that interventions are
		Vulnerable groups and gender aspects (adaptation only).	Comparably high vulnerability of the beneficiary groups.	
		Economic and social development level of the country and the affected population.	Level of social and economic development of the country and target population.	
		Absence of alternative sources of financing.	Opportunities for the Fund to overcome specific barriers to financing.	

Criterion	Definition	Coverage area	Activity specific sub-criteria	Contribution of key lessons for GCF RD&D support to meeting investment criteria
		Need for strengthening institutions and implementation capacity.	Opportunities to strengthen institutional and implementation capacity in relevant institutions in the context of the proposal.	appropriate. E.g. in some low- and middle-income countries, RD&D collaborations focused on breakthrough technologies are unlikely to be appropriate, while collaborations focused on adapting existing technologies to local contexts, or building and strengthening indigenous innovations (such as systems for farming in specific rainfall/drought conditions) could have potentially transformative impacts, with high potential for scalability and replicability. Elsewhere, strong innovation systems might already exist around specific climate technologies (e.g. off-grid solar in Kenya) providing ideal contexts for experimenting with new innovations (e.g. mobile payments for off grid solar that make it affordable to poorer, more marginalized women and men).
Country ownership	Beneficiary country ownership of, and capacity to implement, a funded project or programme (policies, climate strategies and institutions).	Existence of a national climate strategy.	Objectives are in line with priorities in the country's national climate strategy.	The explicit attention to context specificities is designed to focus attention on exactly these kinds of country specific concerns. It emphasizes the need to understand and tailor investments to the specific policy spaces that exist in different countries and localities. It also emphasizes the need to develop detailed understandings of the different actors in each context (including civil society) and the level of capacities that exist among these different actors. The systemic focus of innovation system support emphasizes the need to understand which actors are connected to which other actors and where specific needs exist to foster and strengthen linkages and capacities. **It should be noted that** funding proposed intermediary actors, like **CRIBs (Climate Relevant Innovation-system Builders)**, would create capacity in low- and middle-income countries to understand and respond to exactly these kinds of country specific considerations and target RD&D investments accordingly (something in which the existing international climate policy architecture stops short, as do the World Bank
		Coherence with existing policies.	Proposed activity is designed in cognizance of other country policies.	
		Capacity of accredited entities or executing entities to deliver.	Experience and track record of the accredited entity or executing entities in key elements of the proposed activity.	
		Engagement with civil society organizations and other relevant stakeholders.	Stakeholder consultations and engagement.	

Criterion	Definition	Coverage area	Activity specific sub-criteria	Contribution of key lessons for GCF RD&D support to meeting investment criteria
				Climate Innovation Centers, the latter only focusing on the near-market stage of the innovation process).
Efficiency and effectiveness	Economic and, if appropriate, financial soundness of the programme/project.	Cost-effectiveness and efficiency regarding financial and non-financial aspects.	Financial adequacy and appropriateness of concessionality. Cost-effectiveness (mitigation only)	As well as more project/programme specific cost considerations, which must of course be considered on a case-by-case basis, the approaches identified will enable the GCF to create opportunities to maximize the impacts, replicability and sustainability of any given investment. An overarching systemic perspective will ensure that all investments are undertaken with a view to the impact of a portfolio of investments adding up to more than the sum of its parts. Simultaneously, focusing on understanding and responding to context specificities acts to minimize potential for inappropriate investments that yield less value for money and less wider impacts.
		Amount of co-financing.	Potential to catalye and/or leverage investment (mitigation only).	
		Programme/project financial viability and other financial indicators.	Expected economic and financial internal rate of return. Financial viability in the long run.	
		Industry best practices.	Application of best practices and degree of innovation.	

Annex I: Trends, private sector and sources of financing

I. Trends in the RD&D of climate technologies

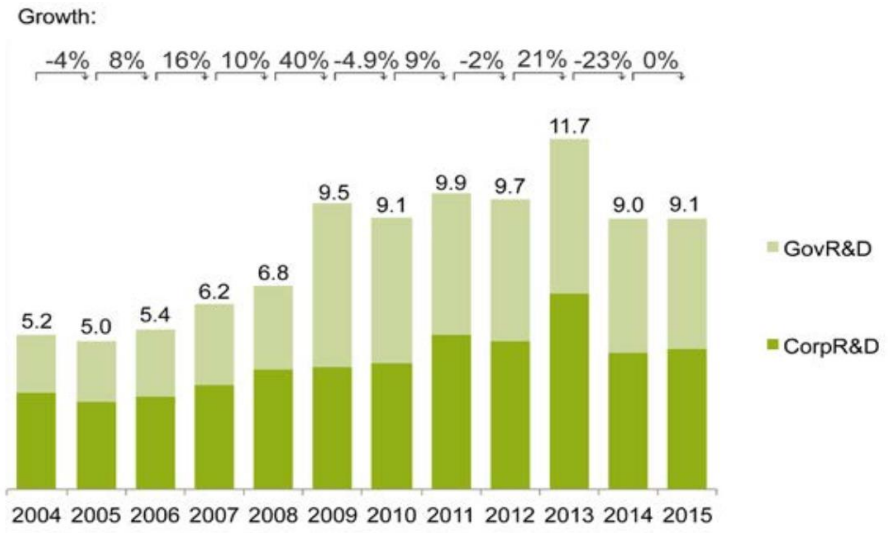
1. A number of trends in the financing and institutional support for the RD&D of climate and clean technologies can be discerned that have implications for developing a programme to support the collaborative RD&D of climate technologies. Data on trends in climate technology RD&D spending are limited to expenditures on renewable energy technologies, IEA member country energy efficiency RD&D expenditures, general agricultural RD&D and VC investment in low-carbon technologies and cleantech, which has a degree of overlap with climate technologies. No data are collected on adaptation technologies.

1.1 Trends in clean energy and cleantech

Trend 1: Recent decline in renewable energy RD&D investment

2. Total renewable energy RD&D investments declined considerably in 2013, and were back at 2010 levels in 2015. The strongest decrease occurred in Europe, but investments have grown in Asia since 2014. Equally, low-carbon innovation as measured by patenting, which has a strong relationship with the price of fossil fuels, declined (Dechezlepretre, 2016). While RD&D investment declined in some regions, there was growth of renewable energy RD&D spending in areas beyond the traditional heavyweight regions, including India, where investment jumped 8 per cent; in the *other APAC* region (Asia-Pacific excluding China and India), up 10 per cent; and *other EMEA* (Africa and the Middle East) where it leapt 16 per cent.

3. In 2015, the IEA called for a tripling of the level of spending on energy RD&D, and for governments and the private sector to work closely together and shift their focus on low-carbon technologies. To put the public cost of RD&D in context, compared with the cost of deployment policy, expenditure on the RD&D of low-carbon technologies by the European Union for example, is paltry, with deployment policy outweighing direct RD&D support by 150 to 1 (GGGI, 2016). While there is no agreement of what the optimal mix between RD&D and deployment government spending should be, the ratio suggested in the literature is not more than 10 to 1.



Source: Bloomberg, Bloomberg New Energy Finance, IEA, IMF, various government agencies

Figure 4: Corporate and government RD&D investments in renewable energy, 2004-2015, in USD billion (Source: FS–UNEP, 2016)

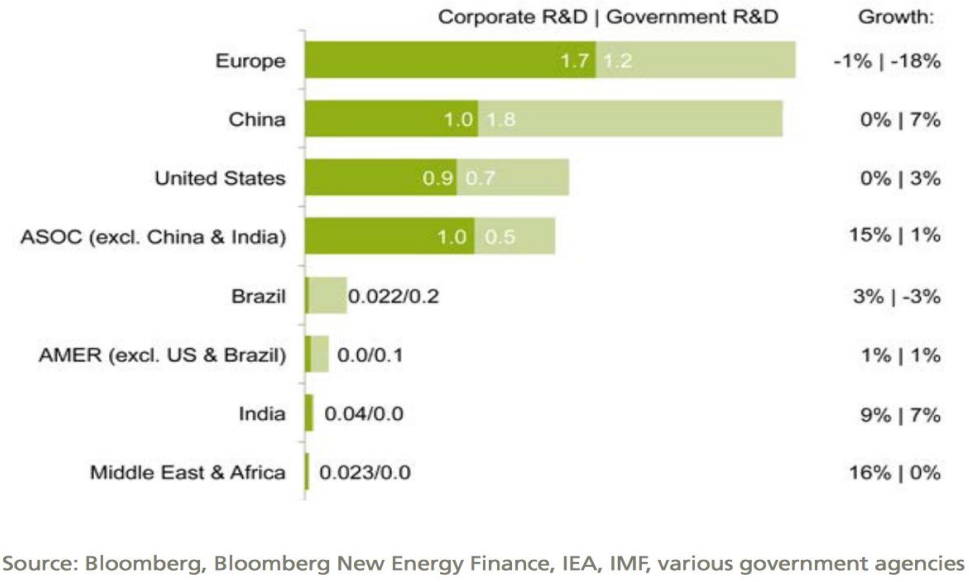


Figure 5: Corporate and government RD&D renewable energy investment by region, 2015, and growth on 2014, USD billion (Source: FS–UNEP, 2016)

Trend 2: Sharp decline of VC investment in hardware technologies

4. A more-recent phenomenon for financing climate RD&D activities, is venture capital (VC) (TEC, 2017). These investments focus on helping small firms to turn a successfully demonstrated new technology into a commercial product. Yet, following a period of growing VC industry funding of renewable energy technology development and a wave of cleantech funding by VC funds that took off in 2006, VC-funding retreated after 2011. In 2014, VC investment in clean-energy companies was less than half of 2011 levels. Since 2009, VC has barely funded 25 new cleantech companies a year. The reason for the retreat of VC funding from cleantech is that hardware companies turned out to be poorly suited to VC investments because they are capital intensive, have long development timelines (10 years and longer, compared to the 5-7 years to exit for VC investments), could not deliver the outsized returns found in other sectors, and were unable to attract corporate acquirers (Gaddy, 2016; FT, 2016; IEA, 2011). Within the cleantech sector, VC funds shifted investments from hardware and materials to cleantech software.

Trend 3: Retrenchment of VC funding to later-stage financing

5. A second shift is the retrenchment to later-stage funding of VC finance since the global financial crisis, creating a gap in seed and early stage investment that is only partially being filled by an increased role of angel investors, incubators and accelerators, and corporates (Baldock et al, 2016; OECD, 2015). Overall, private-sector finance has increasingly focused on lower risk, more established technologies, which offer higher returns (IEA-RETD, 2014).

6. In response to the lack of high-risk and patient capital, and the funding gap in the early stages of technology development and commercialization, two initiatives were launched at COP-21 in Paris. Mission Innovation is an initiative of twenty countries that pledged to double public RD&D funding to USD 30 billion by 2020, and complementing it is the Breakthrough Energy Coalition, a group of wealthy investors led by Bill Gates, which has pledged funding for seed, angel and Series A investment in electricity generation and storage, transport, industry, agriculture and energy efficiency. The initiatives focus on cutting-edge technologies.

Trend 4: An increased role of government backed venture capital

7. Since the financial crisis, government VC schemes have intensified, driven by the goal to stimulate innovation as private investment retrenched. In Europe, the amount of VC funding from governments increased by 85.4 per cent between 2007 and 2012 (OECD, 2015). Co-investment funds, which use public money to match private investment have become increasingly popular, and function as a driver in building the seed and early stage market and leverage private-sector money (OECD, 2015). Funds can be structured so as to incentivize and leverage private funding through first loss and subordinate mechanisms. Recent research on the impact of European Investment Fund-backed VC suggests that government crowded-in VC financing as it shows that other market players intensified their activity in the aftermath of European Investment Fund's increased investments (EIF, 2016). It is important to monitor the effect of public support so that it does not inadvertently crowd out private investors.

Trend 5: Growing importance of innovation hubs, incubators and accelerators

8. Intermediaries like innovation centres and hubs, incubators, and accelerators are innovation enablers that not only facilitate the process from RD&D to commercialization but also act as central nodes that connect different actors in the innovation system. They play an important role in readying start-ups for private investment and growth by providing seed investment and also mentorship, business development support, and access to investor networks and corporates. As such, they increase deal flow for investors. Many incubators and accelerators receive public funding, or are co-sponsored by corporates and investor groups. Their numbers have surged since 2008: figures 6 and 7 show their growth in numbers and their deal count in the United States. Trends in Europe are similar and they have also begun to emerge in Asia.

9. Cleantech accelerators that are for-profit tend to invest in capital-light, quick-to-scale software-based, energy demand-side and Internet of Things types of technologies. Hardware-based technology entrepreneurs and early stage companies tend to be supported by government-funded university or national lab-based incubators. Increasingly, national labs are supporting entrepreneurs and emphasizing commercialization efforts while leveraging state-of-the-art experimental facilities and technical capabilities.

10. Overall, more-traditional government support for innovation through financing of public RD&D has been extended with additional institutional elements that reach much further down the innovation pipeline, and that is seeking to leverage private RD&D funds and to cost-share investment in pre-competitive RD&D and testing the market validity of projects (IEA, 2011, Bonvillian, 2014). Moreover, public RD&D is also increasingly supporting entrepreneurship.

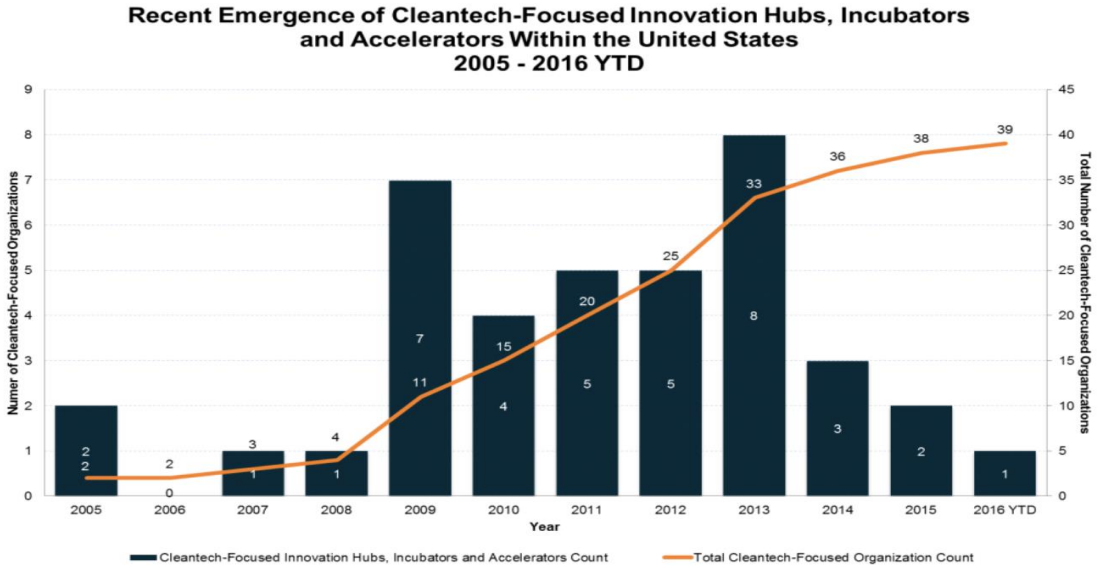


Figure 6: Emergence of innovation enablers in the United States (Source: Cleantech Group (2016))

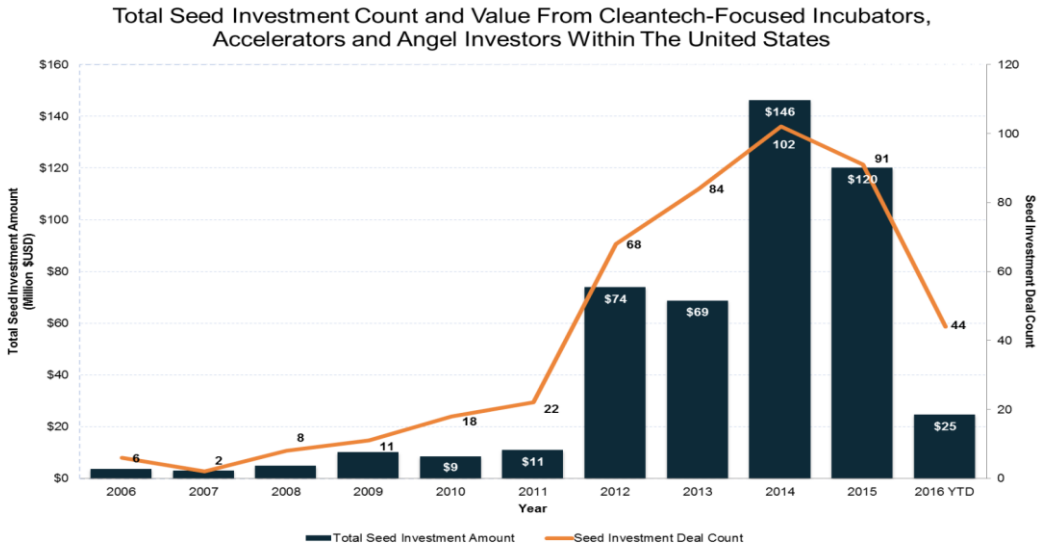


Figure 7: Seed investment by innovation enablers in the United States (Source: Cleantech Group (2016)

Trend 6: Increased opportunities for collaboration and alliances

11. According to the IEA opportunities for collaboration have increased in the past decade, as industry funding for RD&D has grown, the share of RD&D conducted by SMEs has grown, and the role of high-tech start-up companies as a source of innovation that is subsequently adopted and adapted by larger firms has grown (IEA, 2011). These developments have also opened up opportunities for public-private partnerships and for collaborative RD&D between universities, start-ups and industry.

12. Collaborative centres for pre-competitive RD&D, as well as commercialization centres, can be effective platforms for international collaboration, and can bridge gaps between industry, utilities, universities, the financial community and technology users. Internationally, the number of RD&D alliances and partnerships, mergers and acquisitions, and patent licenses have also

increased (IEA, 2011). These alliances and partnerships predominantly focus on the exchange of technical information and expertise rather than direct involvement in specific projects.

1.2 Trends in agricultural RD&D

13. No data are available on the amount of RD&D spending on climate-smart/resilient agriculture, but it can be assumed to be a fraction of overall agricultural RD&D (AgRD&D) expenditure. Nevertheless, trends in AgRD&D spending and focus impact on the opportunities and challenges for climate-resilient AgRD&D.

Trend 7: Shift from public to corporate AgRD&D spending

14. Significant shifts in AgRD&D spending have taken place in the past two decades. The first is a growing shift from public to corporate spending. Until recently, the majority of research on crop breeding, fertilizers, pesticides and food technologies was carried out by universities and government agencies, but in 2011 (the latest year for which data are available) 52.5 per cent of RD&D was done by private firms (Pardey et al, 2016). When excluding food technologies, public-sector RD&D accounted for 55 per cent of the USD 69 billion spent globally. While private-sector AgRD&D spending has been growing robustly in the past decade, public-sector spending has slowed or declined. Private investment in agricultural innovation has been fuelled by an unprecedented convergence of advances in biology, plant and animal science, digitization, robotics, and cloud-based systems and analytics.

15. Public and private RD&D tend to differ in focus and strength, with private-sector RD&D targeted at market opportunities, for example crop genetics and farm-level inputs, such as agro-chemicals and equipment, as well as digital agriculture (embedding software and sensors in equipment, animals and soil). While the public sector is better placed to investigate solutions to landscape-scale, longer-term challenges, for example the management of pesticide resistance, addressing the impact of changing weather patterns, and sustainability goals that go beyond increasing productivity, and pro-poor innovation (WIPO, 2016; Pardey, 2016; CIP, 2017).

16. Another trend is the shift in AgRD&D spending from high- to middle-income countries, and on a per capita basis, RD&D investment by low-income countries has declined (Pardey et al, 2016).

	Private ag R&D				Public ag R&D			
	1980		2011		1980		2011	
	Amount	Per capita	Amount	Per capita	Amount	Per capita	Amount	Per capita
	(million 2009 PPP$)	*(2009 PPP$)*	*(million 2009 PPP$)*	*(2009 PPP$)*	*(million 2009 PPP$)*	*(2009 PPP$)*	*(million 2009 PPP$)*	*(2009 PPP$)*
Low income	63	0.18	165	0.22	593	1.73	1,112	1.51
Middle	1,498	0.54	11,065	2.41	6,374	2.30	18,995	4.14
High income	7,992	9.75	19,899	19.58	10,863	13.25	18,022	17.73
Total	9,553	2.43	31,129	4.91	17,830	4.53	38,129	6.02

Figure 8: Food and agricultural RD&D by country income groups, 1980 and 2011 (Source: Nature, 2016)

17. Although few details on financing and target investments are available, social-impact funds and philanthropic foundations are increasingly active in supporting and investing in climate-smart and resilient agriculture.

II. Sources of finance

VC funds

18. Predominantly invest in the growth stage of companies that already generate revenue. VC funds prefer capital-light, quick-to-scale, high-return ventures, and have shifted their cleantech focus from hardware- to software-based technologies.

Angel investors

19. Angel investors are often experienced entrepreneurs or business people. They are increasingly recognized as an important source of equity at the seed and early stage equity financing. However, data on angel investments are relatively scant. Like VC funds, they tend to invest predominantly in capital-light, software-based technologies.

Corporate venture groups

20. Strategically invest in and acquire small innovative tech companies.

Corporates

21. Act as strategic investors and acquire cleantech companies for strategic reasons. Strategics generally have longer investment timeframes than VCs. They also understand supply chains, pricing and manufacturing.

Utilities

22. Utilities are showing signals of embracing new technologies by investing in energy start-ups, through investment in funds as limited partners in collective investment groups. Utilities have invested over USD 1 billion in energy startups over the last year alone (Greentech Media, 2014).

Institutional investors

23. Invest at later stages, from the commercial scale demonstration stage onwards for capital intensive technologies.

Alternative sources of financing: Foundations and social impact funds

24. The vast majority of capital invested by social-impact investors is directed at companies in the growth or mature stage and made in the form of private debt and equity (UNDP, 2016). Among respondents to a 2015 Global Impact Investment Network survey, only 9 percent of capital committed to impact investment was invested in venture and early stage businesses. In 2015, approximately USD 60 billion worth of assets were under management worldwide in the impact investment sector. Agriculture and food security, and energy access are among the climate-relevant sectors invested in. There is much scope to develop the sustainable social-enterprise sector ecosystem, for example by facilitating access to academic and research institutions focusing on applied RD&D. The impact investor ecosystem also comprises incubators and accelerators (UNDP, 2016).

Annex II: Case Studies

Climate-KIC

Climate-KIC (knowledge and innovation centre) is Europe's largest public-private innovation partnership focused on climate change, created by the European Institute of Innovation and Technology, consisting of companies, academic institutions and the public sector. Climate-KIC is an innovation catalyst that aims to create market value chains through an innovation project pipeline that spans the entire innovation chain including market identification and development, innovation development, testing and deployment. It provides a test bed for growing collaboration mechanisms among innovation actors in Europe. The KICs are cognizant that business innovation arises from collaboration in increasingly complex networks, and what companies actually need is access to both a thriving local environment and to global markets and technology. The partners of the KICs are closely connected via the co-location centres, representing a novel way of strengthening innovation hubs in Europe and of creating new innovation networks that can also be extended globally.

Incubatenergy Network and InnoEnergy

Incubatenergy Network promotes collaboration among innovation intermediaries. Since 2016, it has formed a consortium of clean energy-focused incubators in the United States, initiated collaboration with InnoEnergy, a leading incubator with locations across Europe, and also connected with the World Bank's emerging network of Climate Innovation Centers. It is expanding collaboration with international organizations to create opportunities for the further commercialization and broad deployment of new technologies (Incubatenergy, 2016). InnoEnergy was established with the vision that innovation and entrepreneurship in sustainable energy, properly leveraged by knowledge triangle integration (across research, academia, and business), could become the key enabler of the energy transition. Founders from 27 organizations across the energy industry, technical universities, research centres, and business schools joined forces to set up InnoEnergy with a long-term strategy. They share the belief that the positive impacts of innovation could be greater if independent actors worked together pursuing common objectives. InnoEnergy supports education, fosters business creation and acceleration, and launches products and services through collaborative projects.

IFC Development Marketplace competition

The International Finance Corporation (IFC) used a challenge approach in 2008 in its Development Marketplace competition for innovative products or services tailored to Sub-Saharan Africa's off-grid lighting market, which resulted in the selection of 16 companies for grant funding. A more recent initiative that uses prizes is the UK's Department for International Development's (DFID) Ideas to Impact program, launched in 2014, with thematic leads on water, sanitation and hygiene, low-carbon energy, and climate adaptation. Examples of the types of technologies and innovations that have been supported include cook stoves, low-cost, off-grid refrigeration and locally developed adaptation approaches.

While the use of prizes has become quite widespread in the United States and Europe, with governments and philanthropic foundations being major drivers, the deployment of incentive prizes in the field of international development has been limited but is growing since the 2015 Financing for Development Conference in Addis Ababa, Ethiopia (Collings, 2015; Di Bella and Minkley, 2017). At the conference, a call was launched for innovation in international development to achieve the Sustainable Development Goals. This has resulted in a proliferation of innovation in development programmes, including the use of challenge funds and innovation

prizes. Well-designed prizes not only promote diversity and creativity in tackling complex problems, but also encourage opportunities for collaboration, help support solutions rooted in particular contexts, and put local actors in the lead, build communities of practice and raise the public profile of both the challenge and the winning innovations (Collings, 2015). A review on prizes by DFID concluded prizes work best in a context of parallel activities which support the innovation process, such as policy reforms, grants and other funding and technical assistance. It recommended that prizes be developed within a wider programme of support (Everett 2011).

Infuse Ventures at the Centre of Innovation and Entrepreneurship

Infuse Ventures is a unique collaborative venture capital fund in India that brings together a global network of cleantech entrepreneurs, investors and corporations to help source, shape and upscale Indian cleantech start-ups. It provides seed and early growth venture capital, targeting early growth start-ups with innovative and rapidly scalable business models, and limited technology risk. It focuses on capital-efficient, low-cost innovation and smart information communications technology and data analytics, including building and industrial energy efficiency and smart grids. Infuse Ventures is housed at the Centre for Innovation Incubation and Entrepreneurship (CIIE), an incubator at the Indian Institute of Management (IIMA) in Ahmedabad. It is more than a traditional VC fund, and is actively engaged, together with CIIE, in creating a support system for India's cleantech entrepreneurs and innovators that extends beyond incubation, to include the identification of cleantech opportunities, spurring interest in cleantech and organizing boot-camps for early stage entrepreneurs. Infuse Ventures was seeded by the Government of India. Other anchor investors include BP Ventures, IIM Ahmedabad and IFC. Infuse also benefited from the Seed Capital Assistance Facility funded by the GEF and from financial support of the Asian Development Bank in the organization of boot-camps and mentorship of entrepreneurs and start-ups.

Fundación Chile

Fundación Chile is a not-for-profit Chilean organization that works across a range of key industrial sectors, several of which are of explicit climate relevance, including forestry, agriculture, marine resources, environment and chemical metrology. It receives funding from the Chilean government and ITT Corporation (based in the United States) and has been highly successful in sustaining its funding base through a process of leveraging private sector funding and involvement. Fundación Chile's main aim is to identify innovations internationally that might be of relevance to improving the performance (including environmental performance) of Chilean industry. It then uses a number of methods to adapt, demonstrate and roll out these innovations thus reducing risk and encouraging uptake amongst Chilean firms. Importantly, Fundación Chile approaches this in a systematic way, working along the entirety of the innovation cycle, from research and development through to entrepreneurship and business creation. It situates this within a broader approach that also engages significantly in networking and education. It therefore represents a working model that could easily be adapted to an explicit climate technology focus.

Climate-resilient and low-carbon cities

City networks, such as C40, ICLEI and United Cities and Local Governments, allow for sharing best practices. Research revealed the unique barriers to the procurement of innovative solutions faced by cities, compounded by the lack of a central marketplace for city solutions. The Living Labs Global Award by the Climate Group was developed in part to address these market failures, creating a centralized forum for cities to access and pilot innovative solutions. Through the Agile

Cities (agilecities.org) partnership, The Climate Group is helping to identify new pre-procurement tools and good practices.

Smart City World Labs and Nanyang Technological University in Singapore are collaborating to accelerate innovation, adaptation and uptake of new start-ups and smart-city solutions through Living Labs. Smart City World Labs is a platform allowing companies to tailor their technologies and business models for new markets through a global network of living labs for testing ideas, products and innovations overseas. By joining forces to break down some of the key barriers to internationalization, Denmark and Singapore will collaborate closely to develop technologies to improve liveability and sustainability of cities.

The Climate-KIC provides a model for promoting and supporting collaborative innovation related to climate-resilient and low-carbon cities. The Climate-KIC model is further elaborated in the Innovation Systems-level support modality section.

Advanced clean energy technology collaborative RR&D

The Joint Geophysical Imaging (JGI) Methodology for Geothermal Reservoir Assessment, a GEF-funded project in Kenya, is a good example of a successful collaborative RD&D project. The project supported a time-limited partnership between KenGen, Kenya's state electricity generating company, a geothermal research centre at Duke University in the United States, and Iceland's Geological Survey. The objective of the project was to develop JGI methods adapted to the unique conditions of the Rift Valley, with the view of improving the siting of geothermal wells and thereby increasing their productivity (Verbeken, 2012). JGI refers to the combination of geophysical and seismic methods used for the mapping of geothermal resources. KenGen had a good deal of experience in geothermal energy development, but had not previously used this combination method for mapping geothermal resources, which is highly complex. A major component of the project was the adaptation of the equipment to the field conditions of the Rift Valley, and the testing of seismic and other equipment. The soft component involved the method and software development, data collection, interpretation and testing, and training. The method and equipment was used to locate six wells, with very good results. The predicted production of the wells was an average of 5.6 MW per well, compared to 1.4 MW and 2.8 MW per well for KenGen's two existing geothermal fields. Expectations were created for replication in other parts of the Rift Valley (Verbeken, 2012).

Eurosunmed is a 4-year collaborative project in Morocco and Egypt supported by the FP7 programme of the European Commission. The objectives of the project are: (i) developing new technologies in photovoltaics, concentrated solar power and grid integration at European Union research centres, national agencies and SMEs in collaboration with Mediterranean Partner Countries (MPC) universities, research organizations and SMEs from Morocco and Egypt; (ii) testing innovative components under specific conditions of MPCs (irradiation, hot climate, dust); (iii) establishing a strong network between European Union and MPCs through exchanges of students, senior researchers/engineers for transferring knowledge and technologies.

Factor(E)

Factor(E), a joint venture between the Shell Foundation and the Energy Institute at Colorado State University, which was spurred by the need for more effective investments in early stage, energy-related technology ventures. The partnership is helping entrepreneurs and investors to achieve higher impact by combining early stage capital with technology co-development. This serves to de-risk ventures and prepare them for scale (Factor(E) Ventures, 2017). One of their major successes is launching Envirofit International, now one of the largest improved cookstove companies in the world.

Water sector

Partnerships between utilities, large companies, small technology companies and start-ups, and research centres are not uncommon in the water sector. For example, PUB, Singapore's National Water Agency, facilitates collaboration between key local and global players to advance water research and generate new solutions, and has many international links. PUB fosters the growth of these innovations by facilitating the testing of products, processes, systems and services, with the aim of helping these new technologies to establish a good track record. PUB has been offering industrial test-bedding sites to the public and private sectors. Where it does not have expertise, for example in polymeric membrane materials (which are used in seawater desalination and water reuse), PUB partners with proponents so that the cost of performing research and development can be shared and, at the same time, the associated risks reduced (PUB, 2017).

Climate-smart and resilient agriculture

❖ **Information Communication Technologies for generating and disseminating climate information in agriculture. The 2Kuze platform** is a partnership between MasterCard Nairobi Lab for financial inclusion, Cafedirect Producers Foundation and the Gates Foundation. A new mobile application is directly connecting small-hold African farmers with food processing companies, greatly expanding their market access and reducing the role of middle men. MasterCard partnered with technology firms and farmers' representatives to develop 2Kuze, a mobile application that connects small-hold farms directly with buyers in a secure online portal. Prospective buyers log requests for goods and purchase prices via text message, which notify farmers of the request. If a deal is reached, a MasterCard-linked agent collects the produce from the farmers and transports it directly to the purchaser. An initial trial was held in Kenya in January 2017, connecting 2,000 farmers with 127 purchasing companies. 2Kuze will be rolled out in Tanzania and Uganda in 2017. Farmers who wish to apply for loans will be able to prove they have a sustainable revenue stream through the app, which tracks records of sales. 2Kuze was funded through a USD 11million grant from the Bill and Melinda Gates Foundation to the MasterCard Lab for Financial Inclusion in Nairobi (Techcrunch, 2017).

❖ **Soil microbes. CROP-FS collaboration** was launched in 2016 with agricultural plant scientists from universities in the United States, China, India and the United Kingdom. The Climate-resilient Open Partnership for Food Security is examining how climate change will affect microbial communities in agricultural soils and their impact on crop yields and strategies to improve crop yield and improve rhizosphere activity (Yan, 2015). Research has shown they can restore degraded soils and help protect plants from drought, higher temperatures and pests. They have the potential to revolutionize agriculture. Large agricultural companies have been shifting towards biologicals, which are products derived from or include live microorganisms, but their focus is on major cash crops such as soy and corn. The private sector alone cannot be expected to undertake the research and product development needed to serve poor farmers across Africa and Asia. Instead, private companies, public research institutions, governments and other partners need to work together to deliver soil microbial products useful to small-scale farmers in developing countries at a price that is affordable (Scientific American, 2016).

Collaboration among innovation intermediaries:
The case of Incubatenergy Network and InnoEnergy

In 2016 Incubatenergy Network, a consortium of clean-energy focused incubators in the United States, initiated collaboration with InnoEnergy, a leading incubator with locations across Europe, and also connected with the World Bank's emerging network of Climate Innovation Centers. It is expanding collaboration with international organizations to create opportunities for the further commercialization and broad deployment of new technologies (Incubatenergy, 2016). InnoEnergy was established with the vision that innovation and entrepreneurship in sustainable energy, properly leveraged by knowledge triangle integration (across research, academia and business), could become the key enabler of the energy transition. Founders from 27 organizations, coming from the energy industry, technical universities, research centres, and business schools, joined forces to set up InnoEnergy with a long-term strategy. They shared the belief that the positive impacts of innovation could be greater if independent actors work together pursuing common objectives. InnoEnergy supports education, fosters business creation and acceleration, and launched products and services through collaborative projects.

PABRA – Pan-African Bean Research Alliance

PABRA is a consortium of three bean networks (Southern, East and Central, and West African bean networks) in Africa, CIAT (International Centre for Tropical Agriculture) and donors. Today PABRA has a membership of 30 countries. Instead of each individual country investing in breeding programmes and a broad range of supply chain innovations, PABRA offers a faster mechanism to introduce and disseminate innovations across the alliance, and countries without breeding programmes benefit from new bean varieties through collaborative evaluation and sharing of germplasm (CGIAR, 2016). For example, new drought-resilient white beans will be deployed in Ethiopia as erratic weather threatens national production and farmers' incomes (CIAT, 2015). Severe drought in Ethiopia, Africa's largest exporter of white beans, could hit production for millions who cultivate and rely on income from the bean. Transformed from a neglected staple into a cash crop, the grain provides income for around 3 million smallholder farmers in Ethiopia who rely on white bean sales – known locally as "white gold" – to buy food and cover other costs such as school fees. An international research network is deploying the latest drought-resilient bean varieties to Ethiopia, to be tested and evaluated by researchers at the Ethiopian Institute of Agricultural Research (EIAR). **The success of the "white gold" revolution** in the last decade is partly due to the Alliance's efforts to make the high-quality bean varieties that exporters demand readily available to farmers: seed access has risen from 20 to 65 per cent for farmers since 2004. Better bean varieties, bred and released by EIAR with support from the PABRA network, are also more tolerant to drought, pests and diseases.

The lessons learnt from PABRA are that partnership building and network development is a lengthy process that requires substantial resources but that is more sustainable and cost-effective in the longer term provided each partner adds value to the partnership. The CGIAR – NARS (National Agricultural Research System) alliance functioned as an enabler rather than a competitor to seed enterprises, and recognized the complementarity of decentralized and centralized seed systems. The role of CIAT was to transform the NARS towards impact orientated research and delivery of seed systems. It created demand-led breeding programs, ensured diversified seed systems, coordinated actors within PABRA, and it engaged with policy-makers. The PABRA model could be applied beyond beans to other legumes and crops (CGIAR, 2016).

Climate Business Innovation Network

At COP 22 in Marrakech, the World Bank and partners launched a Climate Business Innovation Network, bringing together over 30 foundations, donors, businesses, investors, venture funds, universities and government agencies to help local businesses in 12 developing countries

transition to clean technology and advance climate action. The network will support climate technology businesses with access to expertise and know-how, and link small businesses to global sources of technology, finance and expertise, with the aim of building local capacity to transition to clean energy and other climate-smart solutions. It will connect public and private organizations that will collaborate in providing advisory services, market connections and funding for growing clean technology businesses. It will be a mechanism to diffuse green business and innovation models, a platform for sharing local and global research, and crowd in global sources of finance for climate technology innovation (World Bank, 2016).

The Network builds on the World Bank's Climate Technology Program (CTP) and its Climate Innovation Centers, which catalyse the growth of climate technology sectors in developing countries by strengthening local institutions that support small and growing businesses. In 2017, the Network has expanded its capacity building support and knowledge sharing activities to other intermediary organization that support green business in developing countries. The network is emulating the successful networks and consortia of climate and cleantech innovation actors that have sprung up in North America and Europe. Their critical role in enabling and accelerating innovation processes is outlined in the section on intermediaries.

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