United Nations
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CLIMATE TECHNOLOGY INCUBATORS AND ACCELERATORS

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A digital copy of this report can be downloaded from: http://www.unfccc.int/ttclear/incubators

About

This document was prepared by the Technology Executive Committee (lead organization), the Green Climate Fund and the Climate Technology Centre and Network with the aim of strengthening incubators and accelerators for the innovation of climate technologies in developing countries. For further information, contact: tec@unfccc.int

The Technology Executive Committee is the policy arm of the UNFCCC Technology Mechanism. It analyses technology policy issues and provides recommendations to support countries in enhancing low-emission and climate-resilient development.

The Climate Technology Centre and Network is the implementation arm of the Technology Mechanism. It promotes the accelerated transfer of environmentally sound technologies for low-carbon and climate-resilient development at the request of developing countries. It provides technology solutions, capacity-building and advice on policy, legal and regulatory frameworks tailored to the needs of individual countries.

The Green Climate Fund is a global fund created to support the efforts of developing countries to respond to the challenge of climate change. It helps developing countries limit or reduce their greenhouse gas emissions and adapt to climate change. It seeks to promote a paradigm shift to low-emission and climate-resilient development, taking into account the needs of nations that are particularly vulnerable to climate change impacts.

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Table of Contents

1 EXECUTIVE SUMMARY

1.1 Incubators and accelerators

- Innovation is the process by which new ideas are developed to respond to societal, environmental and economic needs. By generating new products, services, businesses, organizational models and behavioural changes, innovation speeds up and scales up national efforts to address climate change. It is key to implementing the Paris Agreement and achieving the Sustainable Development Goals.
- Historically, small enterprises have played an important role in technological innovation, often leading to the introduction of paradigm-shifting technologies and changes in the way we live. However, they face many challenges in maturing to a point where they survive and have positive social, environmental and economic impacts. They often have weak entrepreneurial support systems, fragmented linkages to climate technology markets and a lack of finance for entrepreneurial activities. These challenges are exacerbated in developing countries
- Incubators and accelerators play an important role in addressing these challenges by providing crucial support to start-ups, small firms and entrepreneurs. They reduce risk, helping entrepreneurs to transform inventions into technologies that meet societal needs. They act as local intermediary institutions, strengthening the national ecosystem that nurtures entrepreneurship and the growth of small businesses. They facilitate linkages between entrepreneurs, other innovation actors and potential markets of suppliers and buyers, leading to the development of products that are marketable and enhance welfare. They also help entrepreneurs to connect with sources of finance, providing them with the means to innovate
- Incubators and accelerators thus play an important and multidimensional role in supporting new climate-resilient and low-emission technologies to be developed, accepted and used by society. Ultimately, they have the potential to catalyse the development of more sustainable and inclusive societies.

- While no strict definition exists of either, an incubator is any sort of environment designed to support start-up organizations. It generally offers the following services to an entrepreneur: (1) a physical location; (2) business services; (3) marketing services; (4) technical services; (5) financial support (by linking the entrepreneur to sources of finance and investment); and (6) networking and information services. Generally, an incubator will support an entrepreneur for more than a year, and often for up to five years. The concept of the incubator originated in the early 1950s in the United States.
- The accelerator is a more recent phenomenon. Arising in the mid-2000s in Silicon Valley, the accelerator aims to speed up successful venture creation by providing specific support services during an intensive programme of limited duration. An accelerator operates by offering mentoring, peer review and skills transfer over a three- to six-month period to entrepreneurs in exchange for taking a small percentage shareholding in the resulting venture. Accelerators are often privately owned and financed and have traditionally focused on the ICT sector.
- There are estimated to be around 2,000 technology incubators and 150 accelerators worldwide. However, fewer than 70 are estimated to be climate technology incubators and accelerators, and just 25 of the 70 are in developing countries.
- There is a need to develop a greater understanding of why there is such a limited number of climate technology incubators and accelerators in developing countries, given the potential benefits. There is also a need to gather more information on the impact of the existing climate technology incubators and accelerators in developing countries.
- There are examples of incubators and accelerators supporting entrepreneurs to develop adaptation technologies in developing countries. However, there is a need to develop a greater understanding of the challenges entrepreneurs face in developing adaptation technologies in developing country contexts.

1.2 Challenges and opportunities

This paper identifies the following challenges and opportunities for strengthening climate technology incubators and accelerators in developing countries. Key actions for addressing these challenges and harnessing these opportunities may be found in section 6.2 of this paper.

1. A strong entrepreneurial ecosystem unlocks financing for incubators and accelerators

- The entrepreneurial ecosystem is the supporting environment – the system of institutions, actors and linkages – in which entrepreneurs are embedded as they innovate. The system underpins and facilitates their activities and provides them with incentives, training, finance, networks and other kinds of support. A sound entrepreneurial ecosystem is fundamental for sustained entrepreneurial success, but strengthening it requires wide-ranging actions. Such systems in developing countries are often weak, underdeveloped and underperforming, affecting an entrepreneur's ability to innovate effectively. In such a context, incubators and accelerators also face significant difficulties in performing effectively.
- Supporting a developing country in building and strengthening its entrepreneurial ecosystem enhances the effectiveness of its national innovation process and increases an entrepreneur's ability to innovate effectively. A strong ecosystem also unlocks finance, as it strengthens linkages between the private sector and entrepreneurs, and fosters greater awareness and capacity on both the supply and demand side. It also promote strong networks, opening up demand and delivery channels for climate technology solutions. While an ecosystem goes beyond providing support for climate technology, it is necessary for successful innovation.

2. Crowding in private finance helps to transform ideas into solutions

- Enhanced provision of public and private financing for climate technology entrepreneurship is greatly needed. It would enlarge the pool of entrepreneurs and facilitate the development, scaling up and market penetration of climate technology solutions that replace high-emitting and non-resilient incumbents. Globally, private funding for investment in the development and demonstration of climate technologies is scarce. And this is most pronounced in developing countries. There is a multitude of reasons for this:

  (a) Firstly, climate technologies can take a long time to mature and are often capital intensive. It can take more than 10 years for such a technology to reach profitability at scale. For this reason, most investors don't want to lock in an investment in such a sector when other low-capital alternatives exist that could provide quicker returns.

(b) Secondly, technology development is inherently risky. Learning from failure is an important part of innovation as entrepreneurs push technology and market limits in search of new solutions. While such risk is not unique to climate technologies, it compounds the challenges faced in climate technology innovation. This high risk makes such investment unattractive to many investors. In developed countries, venture capitalists and angel investors have filled this gap, but in developing countries this has not generally occurred.

(c) Thirdly, entrepreneurs in developing countries, especially those from the poorest communities, often face challenges in accessing low-cost capital.

(d) Fourthly, uncertainty in implementing climate policies that shape the markets for climate technologies leads to uncertainty of the benefits of undertaking related entrepreneurship.

- Together, these reasons highlight why entrepreneurs in developing countries have limited access to capital for the development and demonstration of climate technologies. They particularly lack access to non-dilutive low-cost capital and financial instruments that they could use to leverage loans and private capital. And this is particularly the case for low-income entrepreneurs. Public funding and effective financial instruments are crucial as many developing countries have little or no venture capital. Enhanced provision of suitable public and private financing for such efforts is greatly needed. Care will need to be taken in designing such financial instruments, however, as subsidized bank loans can put pressure on entrepreneurs to generate cash flow earlier than desired and thus inhibit the innovation process.

3. New incubation models should aim for financial sustainability

- Most current incubators and accelerators are not financially self-sufficient. It is estimated that fewer than five accelerators worldwide support themselves on revenue generated from equity in their successes. Generally, incubators and accelerators support themselves via a variety of sources. These include the government, international sponsorship, private investment and revenue from equity. Each incubator or accelerator will use a different combination, but for those in developing countries typically the first two sources are prevalent, which means they often remain dependent upon continued public support. The incubators and accelerators that support themselves are often part of a seed fund, consulting company or think tank that offers incubation as one of its services.

- Furthermore, current incubator and accelerator models might not be the best fit for developing countries. For instance, the current accelerator model is based on supporting start-ups in ICT in the Silicon Valley, which has one of the strongest entrepreneurial ecosystems in the world. This model might need to evolve to effectively support climate technologies, with regard to both time scale and types of financing. The current accelerator model, generally a short three- to six-month burst of entrepreneurial support with the aim of achieving venture capital at the end, might not lend itself to climate technology development in developing countries. The model might also need to evolve to respond to challenging local market conditions in developing countries. Here entrepreneurs often encounter a lack of local manufacturing capability and weak integration into global value chains. Furthermore, the model might need to evolve to support the development of climate technologies that have limited (or no) commercial profitability but may play an important role in addressing climate change. Thus, incubators and accelerators in developing countries need to work, think and operate contextually.

- To address these challenges, new models of incubators and accelerators are arising in developing countries. For instance, in order to address the need for financial sustainability, new incubators and accelerators are being co-created by public and private financial institutions with a value proposition for a broader range of actors. To address market challenges, new models are evolving that focus on creating linkages with supply chains and markets for the products. In this way, they are taking on the role of a market incubator, working to support not only technology development but also the connection of technology solutions to market users. Finally, new models are considering incubators and accelerators as local intermediary institutions that contribute to strengthening the entrepreneurial ecosystem within which they exist. If designed correctly, these new models could have a significant and long-lasting effect on climate technology innovation efforts.

2 INTRODUCTION

2.1 Background

The Paris Agreement notes that "Accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change…"[1] To facilitate this, the Conference of the Parties (COP) at its twenty-first session requested the TEC and the CTCN to undertake further work relating to research, development and demonstration of climate technologies.[2] The TEC has worked on innovation and research, development and demonstration issues since its inception.[3] It decided to undertake further work on the issue in 2018.

1 Paris Agreement, Article 10.5. https://unfccc.int/documents/9097.

2 Decision 1/CP.21, paragraph 66(a).

3 http://unfccc.int/ttclear/tec/impact.html.

COP 21 invited the GCF to "consider ways to provide support (...) for undertaking collaborative research and development for enabling developing countries to enhance their mitigation and adaptation action."[4] In this context, at its eighteenth meeting the Board of the GCF requested its secretariat to develop, for the Board's consideration, terms of reference for a request for proposals to support climate technology incubators and accelerators. It also requested its secretariat to continue collaborating with the TEC and the CTCN on related matters.[5]

Since then, the TEC, the CTCN and the GCF secretariat have worked together to develop a comprehensive understanding of climate technology incubators and accelerators. They have also worked to identify how public international financing may support and strengthen such initiatives. As part of their work, the three bodies jointly held a thematic dialogue on climate technology incubators and accelerators, bringing together global experts to identify key actions that the bodies could take in this area.[6]

Drawing on the thematic dialogue mentioned above and a detailed literature review, this paper aims to provide a comprehensive overview of climate technology incubators and accelerators. It also identifies key findings on strengthening such initiatives and climate technology entrepreneurship more broadly.

4 Decision 7/CP.21, paragraph 22.

5 GCF decision B.18/03.

6 http://unfccc.int/ttclear/events/2018_event2.

2.2 About this paper

The world needs existing climate technologies to be fully transferred and deployed, and new climate technologies to be invented and commercialized to mitigate and adapt to climate change. Entrepreneurs and their start-up ventures can be an important instrument for two reasons: entrepreneurial start-up ventures are most often the channel through which new and even disruptive technologies reach the market; and there are huge opportunities in the energy, transport, manufacturing and services markets, to name a few, for entrepreneurs willing to create new goods and services that embody climate technologies.

In exploiting these opportunities, entrepreneurs will be combating climate change and also creating jobs and supporting sustainable development. This is particularly important for developing countries, because that is where adapting to climate change is likely to be at its most challenging and where much of the growth in greenhouse gas emissions will occur.

In recent years, the question has been asked how entrepreneurship in climate technology can best be promoted. One way is through incubators, which are an established model of start-up support, the first having been established in the 1950s. In 2005 a new concept was pioneered in Silicon Valley, namely the start-up accelerator. The first accelerator, Y Combinator, attracted attention because it accelerated a number of high-impact global firms, including Airbnb, Dropbox and Reddit, and seems to have provided a solution to the problem of matching venture capital firms with good start-up entrepreneurs.

Since then the concept has spread worldwide, with around 300 accelerators currently operating. Some of these have started to focus on climate technology entrepreneurship. Hence the question has been asked whether the start-up accelerator approach is one that can be rolled out across the world, in particular to developing countries, to promote climate technology entrepreneurship.

In this light, the purpose of this paper is to investigate the feasibility of the incubator and accelerator approaches towards climate technology entrepreneurship in developing countries. Because an accelerator is a specific type of new venture incubator, this paper will also more broadly consider the suitability of incubators and note the recent emergence of hybrid forms of incubator-accelerators.

The remainder of the paper is structured as follows. Section 3 provides a background to the need for climate entrepreneurship and the objectives of the international community in this regard. Section 4 provides an overview of the nature of incubators and accelerators, and focuses on the recent rise, growth and trends in accelerators. It also provides an analysis of incubators and accelerators as policy tools for enabling climate technology entrepreneurs, and identifies the benefits and shortcomings of these tools for climate technology purposes. Section 0 considers the financing of climate technology entrepreneurship. Section 6 summarizes the key findings of the thematic dialogue on climate technology incubators and accelerators. Section 7 presents conclusions.

3 CLIMATE CHANGE, TECHNOLOGY AND ENTREPRENEURSHIP

3.1 Climate change and technology

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change estimated that the average global temperature over the period 2003 to 2012 was 0.78 °C (±0.03) higher than the reference period 1850–1900 (IPCC, 2013). According to refined estimates using a different base year (1720–1800) Hawkins et al. (2017) estimates the increase over the period 1986–2005 to be between 0.55 and 0.80 °C and finds that 2015 was "the first year to be more than 1 °C above preindustrial levels" (p.1849).

If this warming continues it could have serious negative impacts on human development and natural ecosystems, including reduced agricultural productivity, more extreme weather, health risks and rising inequality. The Johannesburg Declaration on Sustainable Development recognised that "the adverse effects of climate change are already evident, natural disasters are more frequent and more devastating... air, water and marine pollution continue to rob millions of a decent life[.][...]" (United Nations, 2002:1). According to Revesz et al. (2014:174) "leading economic models all point in the same direction: that climate change causes substantial economic harm, justifying immediate action to reduce emissions".[7] The economic harm is not being borne equally by all countries: developing countries are incurring disproportionate damages (Tol, 2010; World Bank, 2010).

The Paris Agreement commits countries to act to hold "the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" and moreover to increase the 'ability to adapt to the adverse impacts of climate change'. It thus recognises that both mitigation and adaptation to the impacts of climate change are imperatives.[8]

In the mitigation of and adaptation to climate change, the role of technology has been receiving increasing attention. Technology is essential for economic growth and human development because it is a conduit for the application of scientific knowledge. Scientific knowledge about the causes of climate change, and the impacts thereof, can result in inventions that, if commercialized and embodied in what can be called 'climate technologies', will assist in mitigation and adaptation and in sustainable development.[9]

The UNFCCC (2017:6) defines climate technology as "any equipment, technique, practical knowledge or skill to reduce greenhouse gas emissions or adapt to climate change." Under the term 'climate technologies', for the purposes of this paper, are included 'clean energy'

7 Revesz et al. (2014) show that economic models of the impact of climate change underestimate total damage because they exclude social unrest, migration and climate-induced conflict, and do not account for slower productivity growth owing to the depreciation of capital stock.

8 To limit average global warming to 2 degrees Celsius by 2100, with a 50 per cent probability, the International Energy Agency determined that concentrations of carbon dioxide (CO2) should be stabilized at less than 450 parts per million (ppm) by 2030 (IEA, 2009). According to the World Meteorological Organization the global average of CO_2 concentration was already 403.3 ppm in 2016 (WMO, 2017).

9 Mitigation of and adaptation to climate change cannot rely only on technological innovations. What may be at least as important, also as a complementary requirement, are changes in human behaviour.

technologies,[10] ('cleantech'), 'environmental' technologies but also more general technologies such as artificial intelligence and nanotechnologies.

The Paris Agreement is explicit about the importance of climate technologies, stating in Article 10 that "Parties share a long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions." It further notes that "Accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development."

In developing countries, the need for climate technologies is getting more urgent. Most of the future growth in emissions will be from developing countries, whose share of emissions is set to double by 2030 under the status quo (Popp, 2012). Developing countries need to reduce emission growth without reducing economic growth and without getting locked in to high-carbon emitting paths of industrialization (UNEP, 2013).

Thus, the the world needs both existing climate technologies to be fully transferred and deployed, and new ones to be invented and commercialized. In this regard, entrepreneurs and their start-up ventures can be an important instrument in the research, development, demonstration and commercialization of new climate technologies (UNFCCC, 2017).

If climate technology entrepreneurship can be successfully undertaken, the benefits to the reduction of greenhouse gases could be significant. For instance, the United Nations Environment Programme (UNEP, 2013) identified a potentially large market for clean energy technologies in Africa, noting that clean energy technology (for example using solar, wind, geothermal and hydro energy sources) can improve access to energy, assist in adaptation to climate change and moreover create jobs. As Diamandis and Kotler (2012:157) remarked: "Africa has nine times the solar potential of Europe and an annual equivalent to one hundred million tons of oil."

10 Examples of clean energy technologies include solar photovoltaic panels, wind turbines, fuel cells, distributed power generators, water treatment systems and energy storage (Malek et al., 2014). The International Finance Corporation website describe these as "technology, products, and/or services that: improve the productive and responsible use of natural resources; greatly reduce or eliminate negative ecological impact; and create sustainable, profitable business opportunities." See http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/climate+business/priorities/cleantech_investment_areas.

3.2 Climate change and entrepreneurship

Entrepreneurs are central agents as far as new technologies and their diffusion are concerned. Entrepreneurs act as connectors or links in the process of knowledge diffusion, by finding and demonstrating appropriate technology (Braunerhjelm et al., 2010; Hausmann and Rodrik, 2003). The support of start-ups has received growing attention from scholars and policymakers in recent years. This is based on the belief that entrepreneurs and small businesses have an important role to play in economic growth and development (Audretsch et al., 2006) and, more specifically, that "start-ups may be more effective in exploiting new technologies and introducing radical innovations, which can help address some of the major challenges of our times [such as climate change]" (Breschi et al., 2018:6).

Regarding climate change, new entrepreneurial ventures can disrupt old, stagnant industries, particular carbon-emitting industries (Phan et al., 2005). However, they do not always fulfil this role adequately. It has been said that the 'typical start-up is not innovative, creates few jobs, and generate little wealth' (Shane, 2009:141). Entrepreneurship is also risky, with only around 1–2 per cent of inventions generally thought to reach the market and generate commercial benefits (Braunerhjelm et al., 2010:107). This is partly because of the market failures that characterizes technological innovation. Historically, technological innovation is subject to large uncertainties, asymmetric information and risk and, in the case of climate technologies, with social returns which exceed private returns (Gompers and Lerner, 2001).

Therefore, policymakers and scholars have focused in recent decades on understanding how to promote and support entrepreneurial start-ups so that more will be innovative[11] and grow, survive and create jobs. This concern is particularly relevant if entrepreneurship is to be harnessed to combat climate change. However, the challenges of promoting such entrepreneurship are complex. High fixed costs in the research, development and demonstration phases and high risks in the commercialization phase, together with market failures in the markets for environment[12] and technology, imply that private investment would be suboptimal without government support to correct these (Popp, 2012).[13] One of the key challenges is thus to design and implement effective government support. Almost all governments and international development organizations have programmes and initiatives to support entrepreneurship in general, and small businesses specifically.[14] They seek to address suboptimal investment in technologies owing to market failures (Martin and Scott, 2000). Large private corporations also increasingly recognise the importance of new venture start-ups in the high-technology sector and support these for strategic reasons.

In recent years, inspired by successes achieved by high-technology entrepreneurship in Silicon Valley, the clustering of organizations in specific areas to stimulate what can be called an 'entrepreneurial ecosystem' has become widely advocated (e.g. Isenberg, 2010). Entrepreneurial ecosystems are 'sets of actors, institutions, social networks, and cultural values that produce and sustain entrepreneurial activity' (Roundy et al., 2018:1).

They can be seen as a 'second best' type of policy whereby governments and other agencies do not target individual firms or sectors, but agglomerations of enterprises and entrepreneurs. They thus decentralize the process through which new ventures emerge and provide holistic, systemic support based on the recognition that innovation and its commercialization comes about from interaction and collaboration among a range of agents (GCF, 2017). Hence entrepreneurial ecosystems are not direct, top-down tools for entrepreneurship promotion, but a "complex adaptive system" that emerges from the "uncoordinated, semi-autonomous actions of individual agents" (Roundy et al., 2018:3) in which governments are actors and shapers of the institutional framework.

A healthy entrepreneurial ecosystem is important because it nourishes all the stages in the tech-entrepreneurship chain, from opportunity recognition to invention and eventual commercialization. It can only fulfil its function well and generate sufficient entrepreneurship if it is built on a partnership of private business, research institutions and government entities.[15] The entrepreneurial ecosystem sustains both new ventures (start-ups), who come up with and commercialize new technologies (these may be new to the world, or new to the specific country or market) and existing businesses, who adopt and adapt climate technologies, including in the form of new processes and organizational forms.

11 Innovation refers to 'putting inventions into practice' (Fagerberg et al., 2004).

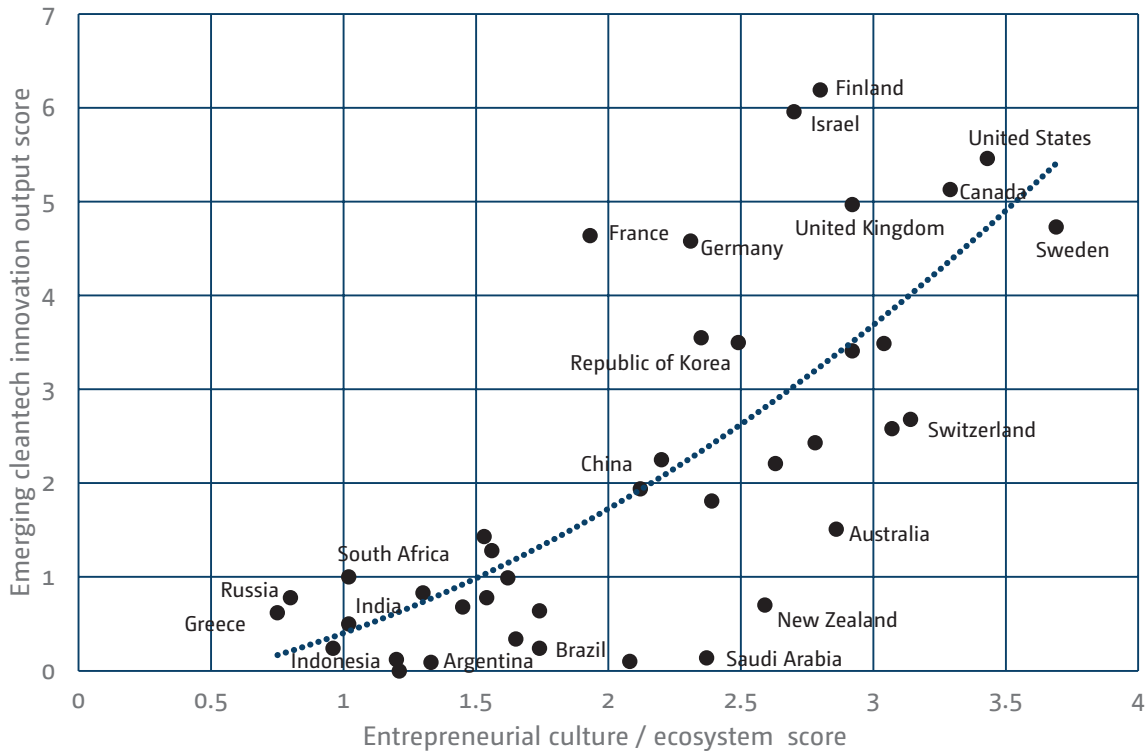
12 Because climate technologies reduce the negative externalities on the environment coming from consumption, production or distribution, there will be a lack of private investment in such technologies without government intervention (Popp, 2012). Climate technologies are subject to a 'double externality' in that the pollution from an activity emitting greenhouse gases is not captured in the market price (*it is a negative externality*) and that the knowledge of the new climate technology generated by innovation is a public good (*it is a positive externality*) (Hall and Helmers, 2010).

13 Technology reflects knowledge, and 'knowledge spillovers' are public goods for which the innovator is not compensated.

14 By 2010 global lending to small and medium-sized enterprises (SMEs) exceeded USD 10 trillion per year. It is estimated that around of 30 per cent goes to developing country SMEs (Ardic et al., 2011).

15 The collaborative nature between government, the business sector and research institutions such as universities that characterises technology incubation tools has been described as the 'triple helix' (Leydesdorff, 2000) or as the 'quadruple helix' when it also involves civil society (Carayannis and Campbell, 2009).

Figure 1 Climate technology innovation output versus entrepreneurial ecosystem



Source: author's compilation based on data from the 2017 *Global Cleantech Innovation Index*.

The entrepreneurial ecosystem and its support for new ventures and existing ventures generating and diffusing climate technologies rests on the foundation of the broad institutional foundation in a country. This institutional foundation includes what has been termed the 'innovation ecosystem' or *national system of innovation*.[16] The national system of innovation includes all the organizations, systems and incentives to encourage the generation and adaptation of technology (Nelson, 1993). The national system of innovation is a contributor to the entrepreneurial ecosystem (Tsai et al., 2009). This is important to note, because attempts to strengthen the entrepreneurial ecosystem will depend on the broader national system of innovation.

Available evidence suggests that countries with a stronger entrepreneurial ecosystem are better at generating climate technology entrepreneurs. Figure 1 uses data covering 40 countries, taken from the *Global Cleantech Innovation Index* in 2017,[17] to illustrate the relationship between country-level performance in terms of generating emerging cleantech innovations and the nature of their entrepreneurial ecosystem. The emerging cleantech innovation score is obtained from various measures of start-up activity, such as the size of early-stage private investment, the number of high-impact companies involved in cleantech, and the number of cleantech patents approved. The input to deliver these innovative outputs is linked to

16 The TEC has undertaken significant work on national systems of innovation for climate technologies. In 2015 it published a policy brief on this issue: https://goo.gl/GS3fvq.

17 https://www.cleantech.com/2017-global-cleantech-innovation-index-a-look-at-where-entrepreneurial-clean-technology-companies-are-most-likely-to-emerge-from-over-the-next-10-years-and-why/

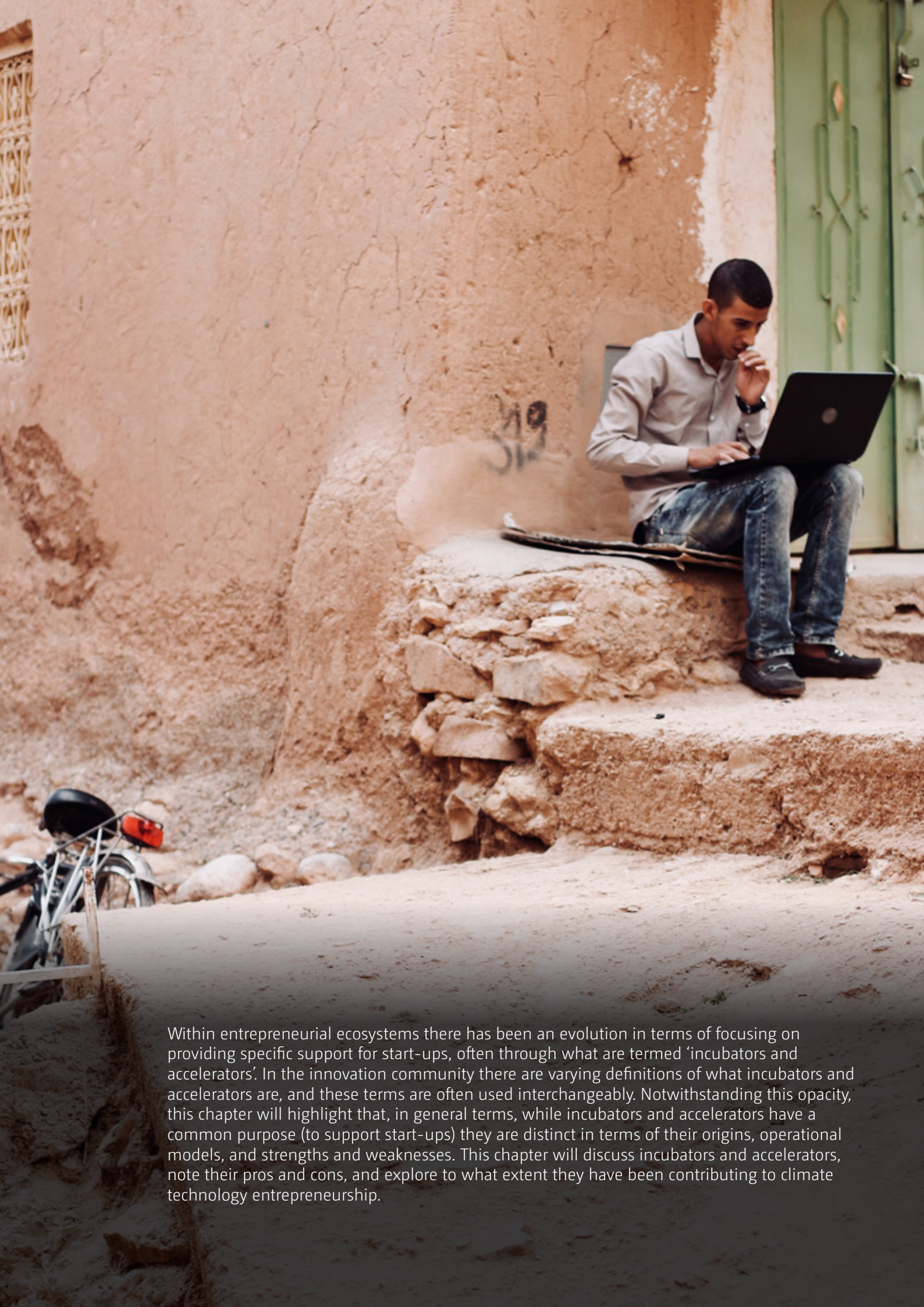
the nature of the entrepreneurial ecosystem, which is measured using metrics of general innovation inputs and the general entrepreneurial culture in the country.[18]

Figure 1 shows that countries with a better entrepreneurial culture and support for innovation tend to score better in terms of producing new climate technology entrepreneurs, as measured by the 'emerging cleantech innovation' outputs. While the figure does not draw on a list of all countries, it does highlight a positive correlation for the relationship between the innovativeness of the ecosystem and clean tech entrepreneurship. Interestingly, the figure highlights that some countries score well in terms of their entrepreneurial ecosystem in general but perform below average in their output of climate technology entrepreneurship. Other countries perform better in terms of climate technology entrepreneurship than would have been predicted based on their entrepreneurial culture alone.

Bringing all of the above together, it may be concluded that, in order to effectively support entrepreneurs to develop and commercialize new climate technologies and adapt existing ones to new contexts, a country needs to take a holistic approach focused on strengthening its entrepreneurial ecosystem.

18 For more information on the measurement of these scores, and the overall methodology that is used in compiling the *Global Cleantech Innovation Index*, see: https://i3connect.com/gcii.

4 INCUBATORS AND ACCELERATORS



Within entrepreneurial ecosystems there has been an evolution in terms of focusing on providing specific support for start-ups, often through what are termed 'incubators and accelerators'. In the innovation community there are varying definitions of what incubators and accelerators are, and these terms are often used interchangeably. Notwithstanding this opacity, this chapter will highlight that, in general terms, while incubators and accelerators have a common purpose (to support start-ups) they are distinct in terms of their origins, operational models, and strengths and weaknesses. This chapter will discuss incubators and accelerators, note their pros and cons, and explore to what extent they have been contributing to climate technology entrepreneurship.

4.1 Incubators

Business 'incubation' refers to the commercialization of new knowledge through the stimulation of new venture creation (Mian et al., 2016). An 'incubator' can be defined as "any sort of environment designed to support start-up organizations" (Malek et al., 2014:27). The first business incubators originated in California in 1951 (Stanford Research Park) and New York in 1959 (Industrial Center of Batavia) (Mian et al., 2016). They did not begin to spread until the 1980s: Mian et al. (2016) document that the number of incubators in the USA increased from 11 in 1980 to 1250 by 2012.

Incubators are in competition with each other to "attract tenant firms to co-locate in them" (Phan et al., 2005: 175) and offer various services to make themselves attractive (Albort-Morant and Oghazi, 2016:2126). These services include:

- A physical location;
- Business services such as legal and managerial advice;
- Marketing services;
- Technical services, which support the development of the entrepreneur's product or service;
- Financial support, through linking the entrepreneur to sources of finance and investment;
- Networking and information services, through providing proximity and opportunity to interact with potential partners, customers and supporting firms.

There were approximately 7,000 incubators worldwide in 2016 (Main et al., 2016)– but only around 30 per cent were technology oriented. Incubators are often located in science parks or near universities, in order to be close to talent and intellectual property.[19] But incubators can also be stand alone as part of a larger business corporation's in-house research and development laboratories,[20] or be a publicly funded business incubator (Pauwels et al., 2016).

As part of a science park, an incubator is part of a cluster of support services in a specific physical location. This is based on the recognition that there are external economies to be gained from the location of various economic agents in close proximity. The proximity of firms to other firms, to investors and to labourers and customers brings benefits in terms of efficiency and productivity growth. Kremer's 'O-ring theory' explains how the complementarity between people in a region, and within a firm, and the skills of labour and management determine the success of its development and adoption of technology (Kremer, 1993).

19 Science parks differ from general business incubators in that they are typically based at or in close proximity to a university (Mian et al., 2016) and hence are often labelled 'university business incubators'. In such a case, the university's technology transfer office plays the key role of trying to commercialize intellectual property.

20 See, for example, Ford et al. (2009) for a case study of Philips' Technology Incubator in the Netherlands.

Incubators have shortcomings as a tool to support start-up ventures and technology entrepreneurship. The first is that incubators that focus on technology are often located in or near science parks and universities. Those institutions do well in terms of technological know-how and invention, but are generally not very good at commercializing these through small firms and start-ups. Instead, incubators often perform better when connected with larger, established firms (Phan et al., 2005).

The second shortcoming is that of 'adverse selection'. In other words, the benefits that start-ups receive in an incubator may keep inefficient firms artificially alive,[21] thus perpetuating the life of 'zombie firms' (Phan et al., 2005; Andrews et al., 2017). The third is that, because incubators often tend to depend on public funding, they are also more dependent on political support and will, which brings two dangers: incubators may be fragile as organizations, and may exist to "confer legitimacy to the political interest that support them" (Phan et al., 2005:174). This may exacerbate the problem of providing life-support to zombie firms.

21 This is called the 'sick puppy syndrome' by Nauta (2016) who described incubators as a model where 'the good companies leave, the mediocre ones stay behind, struggling to pay the low rent…'.

4.2 Accelerators

The concept of the start-up accelerator has developed more recently, partly as a response to the above-mentioned weaknesses of incubators. An 'accelerator' can be described as a tool that "aims to accelerate successful venture creation by providing specific incubation services, focused on education and mentoring during an intensive program of limited duration" (Pauwels et al., 2016:13). Accelerators are a "new institutional form in the entrepreneurial ecosystem" (Hochberg, 2016: 25).

An accelerator operates by offering intense mentoring, peer review and skills transfer over a three- to six-month period to entrepreneurs, in a cohort setting, in exchange for taking a small percentage shareholding in the resulting venture. At the end of the period the graduates pitch their business to groups of potential investors[22] (Mian et al., 2016). So-called 'seed' accelerators make cash investments in participating start-ups, often in exchange for equity.

As discussed by Pauwels et al. (2016) the typology of accelerators is of: (1) *ecosystem builder* accelerators, financed mainly by large companies to improve the competitiveness of their own businesses; (2) *deal-flow* accelerators, which aim to link venture capital and business angel investors with promising start-up ideas; and (3) *welfare* accelerators, a term which most often refers to those supported by governments.

Accelerators generally: have a strong high-technology focus; follow a rigorous selection mechanism to reduce the adverse selection problem (e.g. which results in zombie firms); strictly limit the duration of their support process; and do not depend on public funding. In this context, accelerators can be seen as an evolution of the concept of the incubator. But accelerators are also different in that they were brought about as a new initiative to deal with the support of start-ups in a fast-changing technology era and industry. The first accelerator was designed to provide a fast-track for high-technology digital ventures in the ICT sector. In this instance, technology cycles were short and a strong sorting mechanism was needed for investors to sift through the many entrepreneurs clamouring for funding.

The world's first start-up accelerator was Y Combinator, founded in 2005 in Silicon Valley. Since then, Y Combinator has accelerated around 1,500 ventures which were, by 2017, estimated to be worth collectively USD 85 billion, including 'unicorn'[23] companies such as Airbnb, Dropbox, Stripe, Instacart and Reddit (Manalac, 2018; Racine, 2017). Other famous accelerators, all with a growing global presence, are Techstars, Startupbootcamp, Wayra and Orange Fab. When a start-up receives this equity, or is acquired by an investor, it is said to 'exit'. The success or value of an accelerator is often measured by the number of start-ups that it has enabled to exit, and the amount of start-up capital raised in this process.

22 'Demo day' at Y Combinator has grown to a three-day event involving around 450 investors (see: http://www.ycombinator.com/atyc/).

23 A 'unicorn' refers to a technology start-up that was founded after 2003 and is valued by the venture capital industry as worth at least USD 1 billion. See: http://extreme.tech/2016/08/04/unicorn-narwhal-dedacorn-hectocorn/.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Although there is no single source of data on the number of accelerators in the world,[24] it may be estimated that there are between 150 and 250 accelerators worldwide.

Table 1 Estimate of the number of accelerators globally in 2017

Africa	19
Asia and the Pacific	46
Europe	23
Latin America and the Caribbean	35
North America	41
TOTAL	**164**

Sources: author's compilation based on data from the Global Accelerator Learning Initiative; Seed-DB; and the *Global Accelerator Report 2016*.

Table 1 can be used to draw two conclusions. Firstly, the accelerator movement has spread to all continents. In fact, there may now be more accelerators in Asia and the Pacific than in any other region. Secondly, there are fewer accelerators in the other developing regions, Africa and Latin America and the Caribbean, than in the developed countries. If the value of the accelerator is measured by the values of their exits and start-up valuations, then this concentration is even more pronounced. For instance, Startup Genome (2017) reports that 11 accelerators in 7 countries are responsible for 78 per cent of this value of accelerators. Data from the Global Accelerator Learning Initiative[25] (GALI) allows a third conclusion to be drawn: the growth in the number of accelerators worldwide has been rapid, and most new accelerators were only started in the last three to four years (see figure 2).

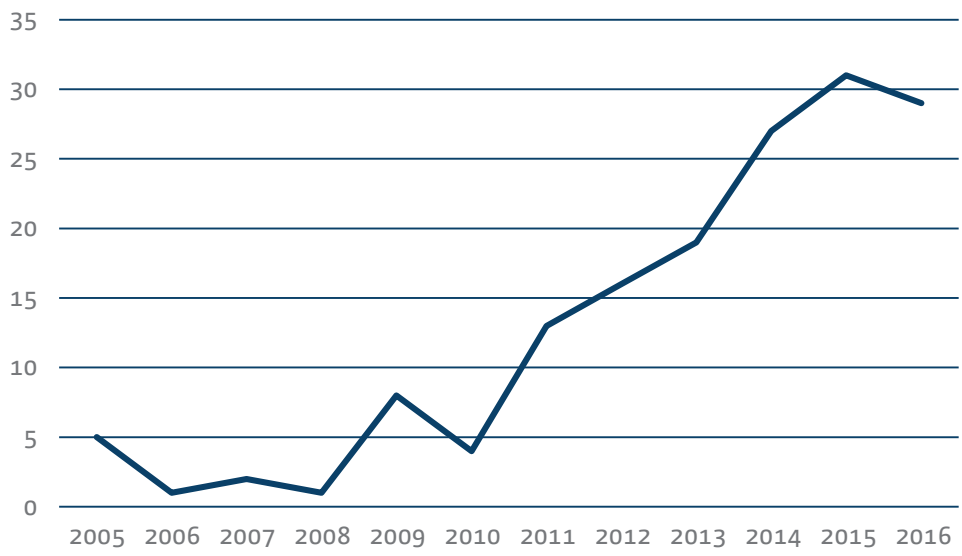
Racine (2017) provides a short critique of accelerators as a tool to promote climate technology entrepreneurship. He lists the shortcomings as: (1) the short time periods involved which may be adequate for digital start-ups, but not for start-ups where hardware is involved; (2) the limited influence they have on new start-ups in terms of management style, governance, choice of technology and orientation; and (3) the little ability they have to influence and change the broader entrepreneurial ecosystem of which they are part, and on which they crucially depend. Racine further notes that accelerators were originally designed to function within the "supportive entrepreneurial ecosystem of high-tech clusters like Silicon Valley and Boston". Malek et al. (2014:29) also voices concern about the short duration of accelerator support, noting that many new technologies, such as climate technologies, often "face long delays and uncertain paths in taking inventions to commercialization".

Questions have also been raised as to the extent to which can accelerators can help the demonstration of new technologies in developing countries (Malek et al., 2014). Indeed, by studying six climate accelerators in Canada, Malek et al. (2014) showed how difficult this is

24 Data on the number of seed accelerators across the world are provided by, among others Seed-DB (https://www.seed-db.com/accelerators), the *Global Accelerator Report 2016* (http://gust.com/accelerator_reports/2016/global/), the Global Accelerator Learning Initiative and New Energy Nexus. This estimate may be underreporting the number of accelerators. Mian et al. (2016) states that there were 213 start-up accelerators worldwide by 2013. And according to the *Global Accelerator Report 2016* there were 576 accelerator 'programmes' worldwide in 2016 (up from 387 in 2015). The European Union has, as part of its Startup Europe initiative, created a network of start-up accelerators known as the Accelerator Assembly. At the time of writing the Accelerator Assembly had a network consisting of 123 accelerators across Europe.

25 GALI is not an accelerator as such, but a project of the Aspen Network of Development Entrepreneurs and Emory University, funded by the United States Agency for International Development, to study the effectiveness of accelerators, particularly in developing countries. GALI conducts surveys and publishes data on the extent and functions of accelerators across the world. See: https://www.galidata.org/about/.

Figure 2 Estimate of the number of new accelerators per year worldwide, 2005–2016



Source: author's compilation based on data from the Global Accelerator Learning Initiative.

even in an advanced economy. The problem is that accelerators were not originally created for the type of technology entrepreneurship that climate technologies need. Rather, accelerators were established to cater for digital economy start-ups in the ICT sector.

In part, these shortcomings have led to the evolution of the accelerator model, along with its accompanying venture capital and business angel financing models. The World Bank's infoDev programme[26] is working to alleviate some of the shortcomings of the typical accelerator model for developing countries, and for climate technology entrepreneurship specifically. This includes providing an advocacy role towards governments to help improve the regulatory environment for sustainable business (the 'doing business' climate) and undertaking initiatives to improve scalability, for instance through consideration of a 'market accelerator' in Ethiopia (Racine, 2017).

Another response has been for accelerators to tend towards specialization in their programmes rather than offering support across the board to all types of start-up ideas (Pauwels et al., 2016). For instance, Propeller Shannon[27] is an Ireland-based accelerator for technology innovation in the aviation, aerospace and travel industries. EyeFocus Accelerator[28] in Germany supports technology start-ups to combat eye disease and blindness prevention and cure. The Fintech Innovation Lab[29] in the UK focuses on financial services start-ups. Brightlands Innovation Factory[30] in the Netherlands focuses on start-ups in the chemical industry, and Canadian-based Colliers PropTech Accelerator[31] focuses on the property and real estate industry. This trend in specialization has also seen the gradual emergence of accelerator initiatives focused on climate technologies. These will be discussed in section 4.4 below.

26 http://www.infodev.org/about

27 https://propellersnn.com.

28 http://www.eyefocus.co.

29 http://www.fintechinnovationlab.com.

30 http://brightlandsinnovationfactory.com.

31 https://www.techstars.com/content/accelerators/proptech-entrepreneurs-ready-accelerate/.

4.3 Differences between incubators and accelerators

As noted, incubators and accelerators have in common the desire to support start-up ventures to become successful through the provision of entrepreneur support services. Both tools involve the interaction of four levels of agents: the individual entrepreneur(s); their ventures or organizations; the incubator or accelerator entity which provides the location and support services; and the surrounding broader 'entrepreneurial ecosystem' (Phan et al., 2005). Often the interactions between agents and their objectives differ quite significantly between an incubator and accelerator.

The first difference to note is that accelerators are a much more recent phenomenon than incubators. The former started out in 2005 and the latter began in 1951 – thus incubators have basically been around for more than 50 years longer than accelerators. There are also much more incubators throughout the world than accelerators: around 7,000 compared with approximately 150-250. Hence, there is more experience with incubators than with accelerators, and the incubator model is more standardized. The fact that incubators have been around so long and have generated so much interest also suggests that it is a model that does add value and for which there is a demand.

A second difference is that, compared with incubators, accelerators are more focused on high-technology entrepreneurship. Only about a third of the incubators in the world seem to have a high-technology focus: most incubators provide support to all types of business. Often, they support more capital-intensive start-ups, particularly those incubators aligned to universities or science parks (Pauwels, et al., 2016). In contrast, accelerators originated to meet the demands of the high-technology ICT industry and was originally designed for the high-technology start-up ecosystems of areas such as Silicon Valley.

A third difference is in the operational model of accelerators, which differs significantly from that of incubators in terms of duration of support, cohort model, taking of equity and selection process (Cohen, 2013). Selection into an accelerator programme is highly competitive. Furthermore, the approach is to work with entrepreneurial teams rather than lone entrepreneurs, and the accelerator will take up equity in the selected start-ups to be accelerated (Malek et al., 2014). Accelerators aim to improve the support system for high-technology start-up companies, and to provide support over a short period through intense mentoring, guidance, and sorting of entrepreneurs. In accelerators, there is a "special emphasis on connecting early-stage ventures with investment" (Racine, 2017). In an incubator, much longer time horizons apply and often zombie firms can continue to exist for some time within the protective support environment of the incubator. In other words, accelerators offer a challenging and mentoring 'process' and not a 'building' which is what incubators essentially do (Nauta, 2016).

Fourthly, the incubators and accelerators themselves (as opposed to the start-ups they support) are funded differently. Mostly, incubators depend on government support whereas the accelerator model developed independently of government funding. Most accelerators are funded by large corporates or venture capitalists.

Which model, incubators and accelerators, is more successful in supporting a start-up venture? Such a question is very difficult to answer at present because incubators and accelerators are characterized by heterogeneity in terms of their governance forms, country and regional contexts, and specific objectives (Phan et al., 2005). It is also a difficult question to answer because there is a lack of studies that evaluate the impact of incubators and accelerators (Malek et al., 2014). This is especially true regarding the impact of incubators and accelerators as tools to promote climate technology entrepreneurship. As Mian et al. (2016:2) have stressed "much of the incubation literature is fragmented and anecdotal". GALI echoes this in their statement that "rigorous research on the effectiveness of acceleration methods has not kept pace. We currently know little about their effectiveness of how differences across programs and models influence entrepreneur performance." (GALI, 2018).

The lack of data and evaluation is even more pronounced in developing countries. Mian et al. (2016: 8) list the top cited papers on technology business incubation, none of which contain any discussion of emerging and developing economies. They noted that less than 1 per cent of research published on the topic between 1985 and 2014 was from authors based in Africa.

Notwithstanding this, as noted previously the accelerator model has arisen as an evolution of the incubator to more effectively harness private funding for high-technology commercialization. And through this, it has aimed to reduce many of the hazards of utilizing public funding for the support of private entrepreneurship, such as rent-seeking, lobbying, government capture and corruption. However, accelerators require excellent entrepreneurial ability and entrepreneurial finance to be available. As these two elements of the entrepreneurial ecosystem are in short supply in developing countries, in the short term it may be that the accelerator model is not the most suitable for strengthening climate entrepreneurship efforts in developing countries.

4.4 Climate technology incubators and accelerators

The number of incubators and accelerators that focus on climate technology are a relatively small proportion of the total number. Precise data are difficult to obtain, because sources tend to group incubators and accelerators together. For example, the New Energy Nexus[32] network reports only 69 climate technology incubators and accelerators worldwide, with the bulk in North America and Europe (see table 2 below).

GALI's *Global Accelerator Survey 2016* identified 86 accelerators across the world with at least a partial focus on societal and environmental issues, referred to as 'impact-oriented' accelerators (GALI, 2018). This would imply, given the numbers presented in previous sections that under 2 per cent of all incubators and accelerators are focused on climate technology.

32 New Energy Nexus is a network for climate technology accelerators focusing on clean energy technology start-ups. It is based in California, but collaborates with accelerators and entrepreneurs (start-ups) across the world. It is financially supported by the Asian Development Bank. See: https://www.energynexus.co.

Table 2 Estimates of the number of climate technology incubators and accelerators globally, 2017

Africa	11
Asia and the Pacific	12
Europe and Central Asia	20
Latin America and Caribbean	2
North America	24
TOTAL	**69**

Sources: author's compilation based on data from New Energy Nexus.

Considering the potential benefits of incubators and accelerators for supporting climate technology innovation, there is a need to understand why there are such limited numbers of climate technology incubators and accelerators in developing countries. Despite the limited numbers, there are several notable initiatives to mention as examples. These include the world's first and largest climate technology accelerator, Cleantech Open[33], established in Silicon Valley in 2005. In Europe, the most notable climate technology accelerator is Climate KIC Europe (headquartered in London). Other examples are the Nordic Innovation Accelerator and Bethnal Green Ventures (London). The latter is an example of an 'impact accelerator' supporting social ventures, also supporting start-ups in health, education and civic innovation.

Cleantech Open reports to have supported 1200 early-stage clean technology start-up entrepreneurs who raised USD 1.2 billion and created over 3,000 clean economy jobs. Some of these start-ups are active in developing countries. An example is Khaya Power, located in South Africa, which provides clean energy products to consumers, such as energy efficient cookers, ovens and batteries.

Since 2011, the United Nations Industrial Development Organization (UNIDO) has been running the Global Cleantech Innovation Programme (GCIP) for SMEs and start-ups across nine countries: Armenia, India, Malaysia, Morocco, Pakistan, South Africa, Thailand, Turkey and Ukraine.[34] The GCIP is currently funded by the Global Environment Facility through grants of USD 1–2 million per country, and it leverages co-financing from national governments and private sector in form of in-kind, grants, services and financing to SMEs and start-ups. The GCIP promotes innovation and entrepreneurship ecosystems: by identifying and nurturing cleantech innovators and entrepreneurs; by building capacity within national institutions and partner organizations for the sustainable implementation of the cleantech ecosystem and accelerator approach; and by supporting and working with national policy makers to strengthen the supportive policy framework for SMEs and start-ups. Under the GCIP, potential SMEs and start-ups with climate technology innovation compete for admission into a local accelerator in their own country, from where the most promising SMEs and start-ups are mentored, coached, trained and linked to venture capital, angel capital finance and corporate investors. The winners of the competition are taken to Silicon Valley where they compete with SMEs and start-ups from other countries for a final global prize and connected to technology scouts and potential global investors. Between 2013 and 2017, GCIP accelerated over 860 cleantech SMEs and start-ups across the nine countries. GCIP currently focuses on four climate technologies: renewable energy; water efficiency; energy efficiency and waste treatment; transportation and advanced materials. As part of UNIDO plans to expand the GCIP to 20 new countries, the programme plans to shift focus towards climate technology innovations in impact categories that include energy systems, sustainable cities and food systems.

33 See: http://www.cleantechopen.org.

34 See: https://www.unido.org/our-focus/safeguarding-environment/clean-energy-access-productive-use/climate-policies-and-networks/global-cleantech-innovation-programme and https://www.unido.org/sites/default/files/files/2017-12/GCIP-Brochure.pdf.

Perhaps the most substantial initiative to incubate climate technology start-ups in developing countries is the World Bank's infoDev programme. Generally, this programme supports business incubators, but since 2009, it has been establishing a number of climate innovation centres.[35] Climate innovation centres are currently active or planned in seven locations: the Caribbean, Ethiopia, Ghana, Kenya, Morocco, South Africa and Viet Nam. Each centre represents a holistic and tailored approach to innovation through financing, business advisory, policy advocacy and technical assistance. This effectively harnesses economic opportunities in developing countries through entrepreneurship and SME development in the climate technology sector.[36]

Overall, there is a lack of studies and data on which to adequately evaluate the impact of accelerators and incubators, especially in developing countries. And understanding the impact and experiences of existing efforts is crucial for the effective design and replication of these in other countries and regions. There is thus a need to develop a greater understanding of good practices and lessons learned in climate technology incubation and acceleration in developing countries. In that context, consideration of the impacts of the GCIP and the climate innovation centres may be a good place to start.

However, one can conclude that, for the development and transfer of climate technologies, both incubators and accelerators have advantages and disadvantages. Incubators are an established model that has been around for more than half a century and and, to that extent, are tried and tested. Where they are linked to universities and science parks, they offer the best potential to stimulate the development and adoption of new climate technology. Given also that there are more incubators in developing countries then it is obvious that these offer an existing potential partner for the global community through which to promote climate technology entrepreneurship. On the other hand, accelerators are a new type of start-up support that have shown, where done correctly, to meet the needs of the high-technology industry, particularly in funding high-risk projects, of which climate technologies are a prime example.

There is also a need to develop a greater understanding of how climate technology incubators and accelerators may support entrepreneurs in developing adaptation technologies. While examples do exist (see box 1), there is a need to gather further information on challenges and opportunities for incubators and accelerators to support the innovation of such technologies in a developing country context.

The scaling up and strengthening of initiatives such as the GCIP and the climate innovation centres presents one way for the global development community to support entrepreneurial ecosystems in developing countries in line with the objectives of the Paris Agreement. But the objectives need not be pursued by solely trying to expand climate-focused incubators and accelerators: the accelerator model in general has features which could be considered for integration into all developing country entrepreneurship support programmes.

One such feature is the strong selection of good entrepreneurial talents through competitions and stringent criteria for joining an acceleration programme; the second is the emphasis on nurturing entrepreneurial teams; and the third is to advertise to potential start-ups where the opportunities are. For instance, some accelerators issue a 'request for start-ups', which is a list of areas and topics for which they would like to see start-up ideas to be made and funded.

The most recent request for start-ups made by Y Combinator as of March 2018[37] included a call for start-ups that can bring to the market carbon removal and sequestration technologies, and technologies for cleaner industrial commodities. Given the large number of entrepreneurs than compete each year for admission into an accelerator such as Y Combinator, the model could potentially act to pull in new climate-technology ventures, even in accelerators that are not, per se, focused on climate technology.

35 http://www.infodev.org/infodev-files/resource/InfodevDocuments_1015.pdf.

36 http://www.infodev.org/articles/cicbusinessplans

37 See: http://www.ycombinator.com/rfs/.

Incubation and acceleration of adaptation technologies in developing countries

Both the United Nations Industrial Development Organization (UNIDO) global cleantech innovation programme (GCIP) and the World Bank climate innovation centres support developing country entrepreneurs to develop adaptation technologies.

Tarla.io in Turkey

GCIP has supported Turkish entrepreneurs to developed Tarla.io. 'Tarla.io Risk' is a one-click service that tells a farmer of the climate risks for a certain location. The software checks historical data gathered from many data silos (weather forecasts, stations and radar) for the specific location and provides hyperlocal statistics and insights. It uses precipitation, temperature, hail and thunderstorm distribution and probabilities to determine farming operations, plant health, credit offers and insurance risks. By using the platform, farmers can plant crops with a greater understanding of the climate conditions, increasing resilience to weather events and farmer yield and profit. The enterprise has won 13 awards in Turkey and Europe. It has 22,000 farmers and 100,000 fields in its network. More information: www.tarla.io.

The GCIP is expanding into new focus areas, including sustainable cities and food systems. It envisages that such areas may provide further opportunities for entrepreneurs working on adaptation technologies.

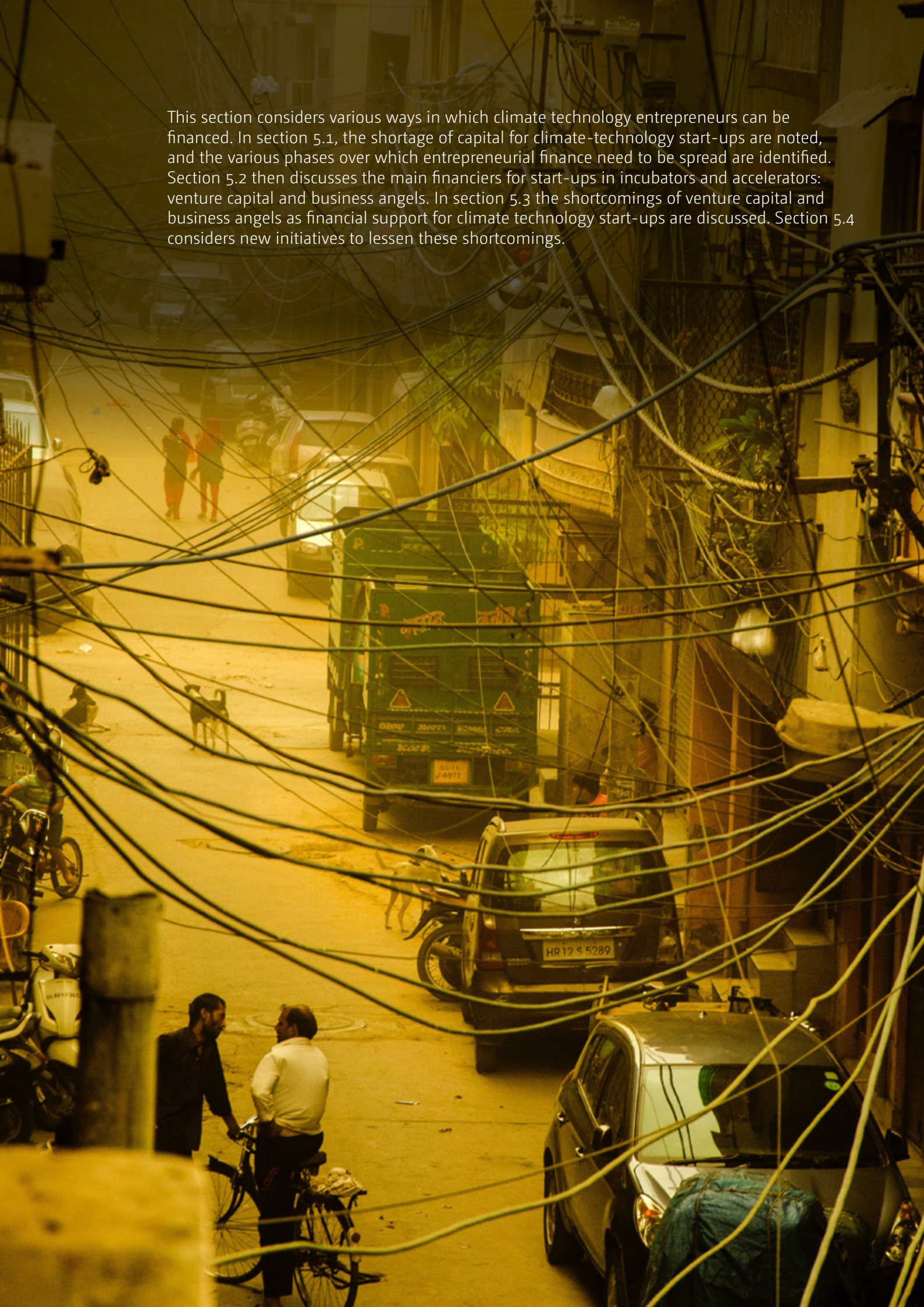
SwissQuest Water Supplies in Kenya

The Kenya Climate Innovation Centre has supported the development of SwissQuest Water Supplies. SwissQuest focuses on supplying, installing and managing smart water metering solutions. The company supplies households with prepaid water-meters that contain advanced infrastructure, including a water valve control function and radio communication. Households access water by purchasing prepaid tokens from water utilities using mobile payment accounts such as Mpesa. This technology allows households to gain greater control over water usage and payments, enhancing the efficient usage of the limited water supply. More information: www.swissquest.co.ke.

On adaptation technologies, the Kenya Climate Innovation Centre supports entrepreneurs particularly in the water and agriculture sectors. As of 2016, together these sectors consisted of 39 per cent of all entrepreneurs at the centre. Technologies supported in the agriculture sector include those related to irrigation, fertilizers, livestock and land management. In the water sector, technologies include filters, purifiers, desalination units and bore equipment.

5 FINANCING CLIMATE TECHNOLOGY ENTREPRENEURSHIP

This section considers various ways in which climate technology entrepreneurs can be financed. In section 5.1, the shortage of capital for climate-technology start-ups are noted, and the various phases over which entrepreneurial finance need to be spread are identified. Section 5.2 then discusses the main financiers for start-ups in incubators and accelerators: venture capital and business angels. In section 5.3 the shortcomings of venture capital and business angels as financial support for climate technology start-ups are discussed. Section 5.4 considers new initiatives to lessen these shortcomings.



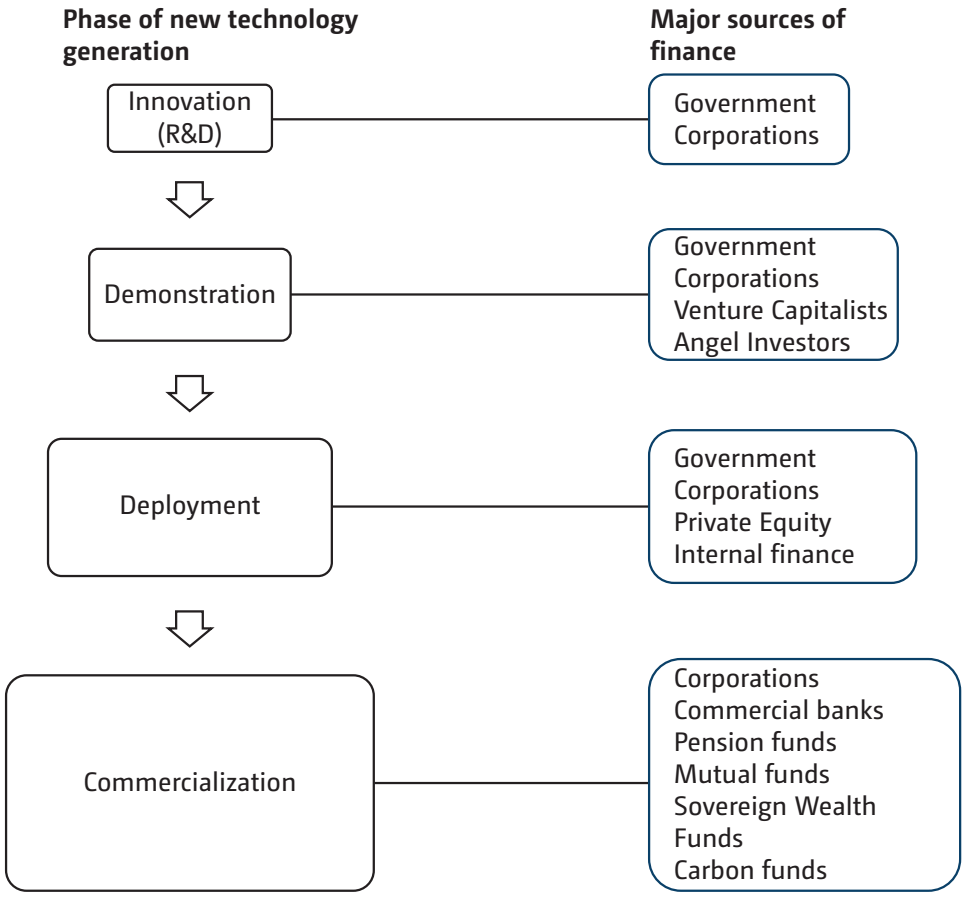
5.1 Sources of finance for climate entrepreneurship

Financing is required for all the stages of the climate technology start-up process, from invention and demonstration, which requires the financing of research, development and demonstration (RD&D) costs, to deployment and to the commercialization (financing the new venture with start-up capital and working capital) and growth of the business. Figure 3 summarises the stages of the start-up process and the major sources of finance. The relative sizes of the blocks indicates the relative need for finance across the stages (e.g. the commercialization of a new technology requires much more finance than when the idea is still being developed). As implied from figure 3, traditional financial channels, such as commercial banks and stock market equity, are not the best sources of finance for the RD&D stages of technology development.

All external finance is generally costly for high-technology start-ups. In addition to the problem of the 'double externality'[38] inherent in climate technologies and the understood barriers to finance in developing countries, climate technology acquisition requires large costs on intangibles which cannot be used as collateral and where hardware purchased is project specific, thus limiting its value as collateral (Yu at al., 2014). There is also strongly asymmetric information about the innovation as well as risk and agency problems that bedevils the relationship between investor and entrepreneur (Gompers and Lerner, 2001).

38 See footnote 12.

Figure 3 Phases of climate technology entrepreneurship and major current sources of finance



Source: author's compilation based on UNFCCC (2017:8).

Therefore, governments are important sources of financing for early-stage climate technology entrepreneurship. They can do this directly (e.g. public R&D in universities or subsidizing private R&D), and indirectly (through supporting networks and learning) (GCF, 2017).

In the case of climate technologies, the uncertainties and costs are even higher than for other technologies such as software or medical. And in the case of developing countries the situation is yet more difficult. As Yu et al. (2014) explain, this is because financial costs, which depend on the lending interest rate, the reliance on internal funds and collateral requirements, are all higher in developing countries. Hence, securing finance for climate technology entrepreneurs in developing countries faces formidable obstacles.

To date, the best financial models to deal with these challenges of entrepreneurial finance at the early-stage of a venture have been venture capital, business angel investment and, most recently, crowdfunding[39] (Wallmeroth et al., 2018). High-technology start-ups have typically depended heavily on venture capital (Bocken, 2015).

39 Crowdfunding is the newest source of entrepreneurial equity finance. Beginning in 2006, it is enabled by the internet and social media. Crowdfunding has been described as 'an entrepreneur's means of collecting equity from an external source represented by a large community through using the internet as a platform to present the venture's business plan to potential investors' (Wallmeroth et al., 2018:77).

5.2 Venture capital and business angels

Venture capital can be defined as "independent, professionally managed, dedicated pools of capital that focus on equity or equity-linked investments in privately held, high growth companies" (Gompers and Lerner, 2001:146). Venture capital investors "may be viewed as the gate-keeper to the emergence of new businesses, as their role is to select venture ideas presented to them by entrepreneurs" (Bocken, 2015:648). These investors can be individuals as well as corporates. Business angels are "high net worth individuals who are accredited investors investing private wealth, usually between USD 100,000 and USD 250,000 for their own reasons into a venture that is typically local, unlisted, and without family connection to the business angel" (Wallmeroth et al. 2018: 59).

Venture capital firms and business angels are key agents or services within the entrepreneurial ecosystem (Phan et al., 2005). This is because they invest in more riskier ventures than banks would; they monitor their investments, they provide expertise and networks (Bocken, 2015), and they stagger their investments in a start-up over time to maintain control and influence (Wallmeroth et al. 2018).

Venture capital has played an important role in the recent past in supporting the emergence of high-technology firms in areas such as semiconductors, biotech and the internet (Breschi et al., 2018; Wallmeroth et al. 2018). Many world-renowned high-technology companies were founded by venture capital funds, including Apple, Microsoft, Alphabet, Facebook, Oracle,

Amazon, Dell, Yahoo, Ebay, Viacom, Adobe and Twitter (Greenwood, 2018). In the United States, the world's single largest venture capital market, total venture capital funding has increased from USD 303 million in 1970 to USD 54 billion in 2015 (in constant prices) (Greenwood et al., 2018).

The likelihood that a start-up will be successful in attracting venture capital finance has been found to depend on the entrepreneurial and managerial quality of its entrepreneur teams; their age and experience, the scalability of their ideas, as well as the extent to which the new start-up is engaged in patenting its intellectual capital (Wallmeroth et al. 2018; Greenwood et al., 2018). Venture capital-backed start-ups are generally more R&D intensive (Greenwood et al., 2018). This is seen as a signal of quality and can also serve as a possible form of collateral for the intangible assets (Breschi et al., 2018). Hence, the strengthening of the entrepreneurial ecosystem in this respect can serve to raise the likelihood of deal-flow.

The return that a venture capital or business angel can earn from its investment in a start-up, either in an incubator or accelerator, will depend on the value of the investor's shares in the new venture when it exits from the incubator or accelerator. It can exit either through being acquired by another firm, or by raising funding through an initial public offering (Bocken, 2015). An example of a successful climate technology start-up that was acquired is that of Nest Labs, which provides thermostat sensors for households to regulate the temperature of their homes, and which was bought by Google for USD 3,2 billion in 2014 (Gaddy et al., 2016). An example of a success climate technology start-up that raised successful initial public offering funds is *Tesla Motors*, who exited in 2010 with a market value of US$ 1,6 billion (Gaddy et al., 2016).

5.3 Shortcomings of venture capital and business angels

Despite the importance of venture capital and business angels for accelerators, and the clear role these entrepreneurial equity financing models have played in generating high-technology ventures through collaboration in accelerators, the venture capital and business angels models have a number of weaknesses as far as the financing of climate entrepreneurship is concerned.

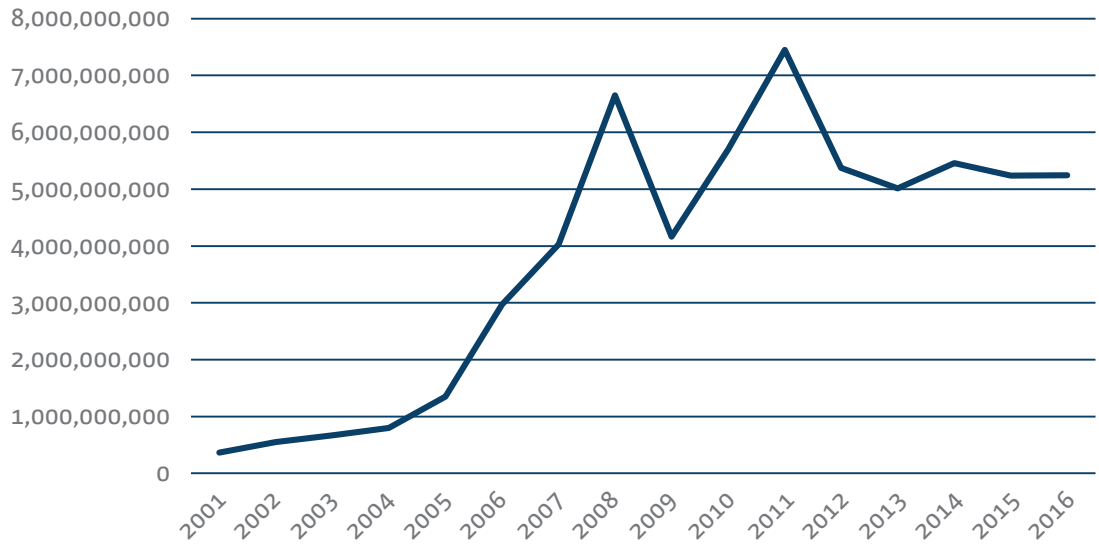
The first is the fact that, even in developed countries such as the United States only between 2.5 per cent and 6 per cent of all venture capital goes into financing of energy technologies (and most of this goes into solar energy) (UNFCCC, 2017:12). Second, there is a general and relative lack of venture capital and business angels in developing countries, although not a complete absence. Fal (2013) reported from a survey of entrepreneurs in Africa that venture capital contributed only 5 per cent to their financing and business angels only 4 per cent. This reflects the relative underdeveloped nature of the entire entrepreneurial ecosystem in these countries, and illustrates how it hampers the start-up accelerator and incubation of climate technology entrepreneurs significantly. Most venture capital funds, and moreover venture capital linked to climate accelerators, are in the larger emerging economies such as Brazil, China, India and South Africa.[40]

Third, venture capital funding for climate technology has actually been declining since 2011.[41] Gaddy et al. (2016:2) describe this decline as reflecting a cleantech sector in the United States that was in "shambles" where "almost all of the 150 renewable energy start-ups founded in Silicon Valley over the past decade had shut down or were on their last legs."

40 An example of venture capital aligned to a climate accelerator in the developing world is Infuse Ventures, in India at the Centre for Innovation Incubation and Entrepreneurship (GCF, 2017).

41 This has been accompanied by a decline in public funding for energy R&D (UNFCCC, 2017).

Figure 4 Venture capital expenditure on climate technologies in the United States of America since 2001 (United States dollars)



Source: author's compilation based on data from Saha and Muro (2017b).

This decline in venture capital for climate technology entrepreneurship has led to reduced amounts of venture capital going into climate technology and means that what is invested is going into only a few areas. Such capital also prefers mature technologies as opposed to early-stage technologies. The latter is identified by Wallmeroth et al. (2018:15-16) as a noticeable trend in venture capital investment. They also note that in Europe there is less appetite among venture capital for early-stage technology investments than in the United States.

As figure 4 shows, the venture capital investment in climate technology entrepreneurship declined by 30 per cent between 2011 and 2016. Saha and Muro (2017b) report that the share of total venture capital invested in cleantech in the United States fell from 17 per cent to 8 per cent over the same period. Most venture capital investments in technology go into software and medical technologies.

What are the reasons for the decline in innovative activity and venture capital investment in climate entrepreneurship as evidenced above? One reason, noted by the GCF (2017) and echoing Ockwell and Byrne's (2015) concerns is that the 'long development timelines' of climate technology do not match the preferences of venture capital funds. Financial returns have tended to be lower and longer to realize when compared with those for non-climate technologies (Bocken, 2015; Gaddy et al., 2016). According to Saha and Muro (2017b) it is also because of the relative high capital intensity of climate technology start-ups, and the high cost to commercialize these, relative to opportunities in software or medical technology start-ups.

Furthermore, venture capital and business angel investors face an opportunity risk in investing in climate technology start-ups in that the venture capital and business angel is locked in for five to ten years while investing in a climate technology start-up, and is consequently unable to take advantage when another (non-climate technology) opportunity comes along. This is particularly the case in the current environment where technologies change fast and where many high-technology start-up investment opportunities appear quickly.

5.4 New finance for climate technology entrepreneurship

In response to the limitations of business angels and venture capital as financiers of early-stage technology innovation, several new developments are broadening the scope of entrepreneurial equity finance for climate technology entrepreneurship:

- The establishment of high-risk and 'patient' capital through collaboration by a number of global private firms, as in the Breakthrough Energy Coalition with its USD 1 billion fund to support start-ups in clean energy and announced by Bill Gates in 2015;[42]
- The 'Mission Innovation' commitment at the COP 21 by 20 countries to double R&D investment in climate technology by 2020, raising total R&D in this to USD 30 billion;[43]
- Proposals that the global finance for combating climate change should focus more on early-stage climate entrepreneurship (Combes et al., 2017; FS-UNEP, 2017). This is where the gap is: there is "no shortage of private funding for investments in mature technologies" (FS-UNEP, 2017:1);
- InfoDev's work to address shortcomings of the typical accelerator model for developing countries, and climate technology entrepreneurship specifically. This includes providing an advocacy role towards governments to help improve the regulatory environment for sustainable business and undertaking initiatives to improve scalability;

42 http://www.b-t.energy/coalition/.

43 http://newsroom.unfccc.int/clean-energy/mission-innovation-clean-energy/ and http://mission-innovation.net/our-work/.

- The rise of so-called 'impact investing', which now includes 'cleantech venture capitalists' or 'sustainable venture capital'. Through 'impact investing' they aim to "generate measurable social and environmental impact alongside financial return" (Bocken, 2015:649);
- The evolution in the climate accelerators model away from a focus on hardware towards climate accelerators that "tend to invest in capital-light, quick-to-scale, software-based, energy demand-side and Internet-of-Things types of technology" (GCF, 2017:20). Climate-KIC (2014) argues that many entrepreneurs are starting up new businesses that benefit the climate but have "managed to avoid the cleantech categorization";
- The Board of the GCF requesting its secretariat to develop for its consideration terms of reference for a request for proposals to support climate technology incubators and accelerators;
- The evolution in the accelerator model towards what has been called a 'public accelerator incubator' model, which is a hybrid of an incubator (in focusing on the long term) and an accelerator (in focusing on seed capital financing) (Rodela, 2018). This is an innovation in the accelerator model to unlock venture capital or business angel investment earlier (Sheikh, 2018). The concept is that the business angel takes equity in a start-up, which also gives equity to an investment company that has a diversified portfolio of investments in what are called 'smart money' start-ups.[44] The investment company will give a shareholding to the business angel, which they can liquidate within 24 months. The first public accelerator incubator is Digital Arts Media Network[45] (Sheikh, 2018). It is a novel experiment at present and it is not clear if the model will endure, develop further and be replicated.

44 A 'smart-money' start-up is a "start-up that is being supported by curators of the world's best-known unicorns and other top performing start-ups" (Sheikh, 2018).

45 See: http://digitalartsmedianetwork.com

6 STRENGTHENING CLIMATE TECHNOLOGY INCUBATORS AND ACCELERATORS IN DEVELOPING COUNTRIES

6.1 Thematic dialogue

On 14 March 2018, the TEC, the GCF and the CTCN jointly held a thematic dialogue on climate technology incubators and accelerators. The event brought together global experts with the aim of:

- Identifying the role that climate technology incubators and accelerators play in supporting countries to achieve the Paris Agreement;
- Identifying how to enhance the impact of such incubators and accelerators, by considering success stories, good practices and lessons learned in their implementation around the world;
- Identifying opportunities for unlocking financing for climate technology incubators and accelerators in developing countries, and for enhancing the impact of related investment, including possible support from the GCF for such activities.

The event also sought to inform the secretariat of the GCF as it develops a request for proposals on climate technology incubators and accelerators for consideration by the GCF Board. It brought together 16 experts from around the world, including representatives from United Nations organizations, intergovernmental organizations, regional development banks, the private sector, incubators and accelerators, and government officials and entrepreneurs. The event was hosted by Ms. Claudia Octaviano Villasana, Chair of TEC, Ms. Carolina Fuentes, Head of Governance Affairs, GCF and Mr. Jukka Uosukainen, Director, CTCN. The UNFCCC Executive Secretary, Ms. Patricia Espinosa, also participated in the event. Further information on the event, including a recorded webcast and presentation slides, may be found at TT:CLEAR.[46]

46 http://unfccc.int/ttclear/events/2018_event2.

6.2 Key findings

The following key findings draw on the previous chapters of this paper and the interventions of the thematic dialogue (including panellist interventions, discussions between all participants, and the results of the dialogue's breakout groups).

1 A strong entrepreneurial ecosystem unlocks financing for incubators and accelerators

The entrepreneurial ecosystem is the supporting environment – the system of institutions, actors and linkages – in which entrepreneurs are embedded as they innovate. The system underpins and facilitates their activities and provides them with incentives, training, finance, networks and other kinds of support. A sound entrepreneurial ecosystem is fundamental for sustained entrepreneurial success, but strengthening it requires wide-ranging actions. Such systems in developing countries are often weak, underdeveloped and underperforming, affecting an entrepreneur's ability to innovate effectively. In such a context, incubators and accelerators also face significant difficulties in performing effectively.

Supporting a developing country in building and strengthening its entrepreneurial ecosystem enhances the effectiveness of its national innovation process and increases an entrepreneur's ability to innovate effectively. A strong ecosystem also unlocks finance, as it strengthens linkages between the private sector and entrepreneurs, and fosters greater awareness and capacity on both the supply and demand side. It also promote strong networks, opening up demand and delivery channels for climate technology solutions. While an ecosystem goes beyond providing support for climate technology, it is necessary for successful innovation.

Actions

There is a need to support developing countries in increasing their readiness for climate technology innovation. Actions include supporting a developing country to:

- Update national development and innovation strategies and align them with nationally determined contributions and national adaptation plans;
- Implement policies, standards, regulations and financial instruments that build markets and provide incentives for climate technology entrepreneurship in accordance with the above strategies;
- Facilitate private sector participation by undertaking business environment regulatory reform that increases the ease of doing business;
- Coordinate national entrepreneurial ecosystem activities and support related coordinating institutions;
- Deepen and broaden the pool of entrepreneurs through education and incentives (e.g. social protection that enables entrepreneurs to take risks);
- Strengthen the adaptive capacity of innovation actors through training and education programmes, including the professionals that manage incubators and accelerators;
- Increase and enhance access to the necessary infrastructure (e.g. IT connectivity);
- Strengthen and provide incentives for the development of enhanced linkages between the different actors in the ecosystem, including small and large firms, universities and government;
- Connect the national ecosystem to other national, regional and global ecosystems for accessing ideas, networks, knowledge and scaling opportunities (e.g. trade and investment policies);
- Encourage market development and stimulate demand by:
    - Strengthening linkages between incubators/accelerators and private sector financing;
    - Facilitating mission-based government procurement for climate technologies (noting that a credible process and a long-term focus are key to success on this). This may be especially relevant for climate technologies that are not commercially profitable on a broad scale;
    - Incentivizing behavioural change, including through education and awareness-raising activities.

In addition to the above actions, the TEC, in collaboration with the CTCN, could:

- Develop tools and methodologies for countries to map and define the quality of their innovation systems (building on existing initiatives);
- Develop indicators to measure the success of support for innovation efforts;

- Collect and disseminate good practices, both at the country and sectoral levels, on strengthening the entrepreneurial ecosystem;
- Develop further understanding on the role of climate technology incubation in facilitating the implementation of the Paris Agreement;
- Identify new models of climate technology incubators and accelerators which may respond to the specific context and needs of developing countries;
- Analyse the role of government procurement in strengthening climate technology incubators and accelerators.

Furthermore, the CTCN could:[47]

- Support developing countries at their request to:
  - Strengthen their enabling frameworks and the capacity of coordinating institutions;
  - Develop innovation elements of funding proposals;
  - Engage stakeholders and facilitate twinning arrangements for climate technology entrepreneurship;
- Share best practices and tools from network and technical assistance interventions.

47 These actions were developed at a CTCN expert meeting held in February 2018. These were included as part of the outcomes of the breakout group at the thematic dialogue.

2 Crowding in private finance helps to transform ideas into solutions

Enhanced provision of public and private financing for climate technology entrepreneurship is greatly needed. It would enlarge the pool of entrepreneurs and facilitate the development, scaling up and market penetration of climate technology solutions that replace high-emitting and non-resilient incumbents. Globally, private funding for investment in the development and demonstration of climate technologies is scarce. And this is most pronounced in developing countries. There is a multitude of reasons for this.

Firstly, climate technologies can take a long time to mature and are often capital intensive. It can take more than 10 years for such a technology to reach profitability at scale. For this reason, most investors don't want to lock in an investment in such a sector when other low-capital alternatives exist that could provide quicker returns. Secondly, technology development is inherently risky. Learning from failure is an important part of innovation as entrepreneurs push technology and market limits in search of new solutions. While such risk is not unique to climate technologies, it compounds the challenges faced in climate technology innovation. This high risk makes such investment unattractive to many investors. In developed countries, venture capitalists and angel investors have filled this gap, but in developing countries this has not generally occurred. Thirdly, entrepreneurs in developing countries, especially those from the poorest communities, often face challenges in accessing low-cost capital. Fourthly, uncertainty in implementing climate policies that shape the markets for climate technologies leads to uncertainty of the benefits of undertaking related entrepreneurship.

Together, these reasons highlight why entrepreneurs in developing countries have limited access to capital for the development and demonstration of climate technologies. They particularly lack access to non-dilutive low-cost capital and financial instruments that they could use to leverage loans and private capital. And this is particularly the case for low-income entrepreneurs. Public funding and effective financial instruments are crucial as many developing countries have little or no venture capital. Enhanced provision of suitable public and private financing for such efforts is greatly needed. Care will need to be taken in designing such financial instruments, however, as subsidized bank loans can put pressure on entrepreneurs to generate cash flow earlier than desired and thus inhibit the innovation process.

Actions

There is a need to support developing countries in crowding in private finance, thus increasing access to finance for entrepreneurs. Actions include supporting a developing country to:

- Develop financial instruments that reduce the risk and opportunity cost for local public and private financial institutions to invest in the development and demonstration of climate technologies. For public institutions, such products might underwrite the risks of local bank loans by providing performance guarantees, driving down the interest rate for entrepreneurs and the buyers of the technology. For private institutions, products might crowd in private financiers with expertise in technology investment. Products might include first-loss tranches and blended finance, especially for the broader diffusion of a technology;
- Facilitate the provision of 'patient' capital with long payback periods for climate technology start-ups with high capital expenditure;
- Facilitate access to foreign exchange for entrepreneurs to purchase technologies not available in local markets that they need for developing their solution on an economically viable scale;
- Educate investors (such as angel investors and venture capitalists) on the nature of climate technology development (e.g. long payback times, type of market demand and broader benefits and returns);
- Educate public funders on how private investors think about investments.

3 New incubation models should aim for financial sustainability

Most current incubators and accelerators are not financially self-sufficient. It is estimated that fewer than five accelerators worldwide support themselves on revenue generated from equity in their successes. Generally, incubators and accelerators support themselves via a variety of sources. These include the government, international sponsorship, private investment and revenue from equity. Each incubator or accelerator will use a different combination, but for those in developing countries typically the first two sources are prevalent, which means they often remain dependent upon continued public support. The incubators and accelerators that support themselves are often part of a seed fund, consulting company or think tank that offers incubation as one of its services.

Furthermore, current incubator and accelerator models might not be the best fit for developing countries. For instance, the current accelerator model is based on supporting start-ups in ICT in the Silicon Valley, which has one of the strongest entrepreneurial ecosystems in the world. This model might need to evolve to effectively support climate technologies, with regard to both time scale and types of financing. The current accelerator model, generally a short three- to six-month burst of entrepreneurial support with the aim of achieving venture capital at the end, might not lend itself to climate technology development in developing countries. The model might also need to evolve to respond to challenging local market conditions in developing countries. Here entrepreneurs often encounter a lack of local manufacturing capability and weak integration into global value chains. Furthermore, the model might need to evolve to support the development of climate technologies that have limited (or no) commercial profitability but may play an important role in addressing climate change. Thus, incubators and accelerators in developing countries need to work, think and operate contextually.

To address these challenges, new models of incubators and accelerators are arising in developing countries. For instance, in order to address the need for financial sustainability, new incubators and accelerators are being co-created by public and private financial institutions with a value proposition for a broader range of actors. To address market challenges, new models are evolving that focus on creating linkages with supply chains and markets for the products. In this way, they are taking on the role of a market incubator, working to support not only technology development but also the connection of technology solutions to market users. Finally, new models are considering incubators and accelerators as local intermediary institutions that contribute to strengthening the entrepreneurial ecosystem within which they exist. If designed correctly, these new models could have a significant and long-lasting effect on climate technology innovation efforts.

Actions

There is a need to support developing countries in developing sustainable and impactful climate technology incubators and accelerators. Actions include:

- Supporting the international community in piloting new incubator and accelerator models for developing country contexts. Such models might take into greater account the diverse needs of entrepreneurs and technology users in relation to differing cultural contexts, local communities, income levels and gender considerations. They might focus on being an effective local intermediary institution that plays a leadership, coordination and advocacy role for developing the entrepreneurial ecosystem. They could also focus on market incubation, working to connect entrepreneurs to local and cross-border markets for supply and demand;
- Supporting the strengthening of global networks for learning, mentoring and exchanging good practices on climate technology incubators and accelerators in developing countries;
- Supporting a developing country to introduce incentives that encourage well-functioning existing incubators and accelerators to expand into climate technology markets instead of establishing new incubators;
- Encouraging the creation of multi-country incubators and accelerators that draw on a larger pool of entrepreneurs, financial providers, supply chains and potential markets. Encourage their co-creation with the participation of public and private financiers.

7 CONCLUSIONS

Technology entrepreneurship can play a key role in supporting technological transformations, economic growth and sustainable development. How can climate technology entrepreneurship best be supported to accelerate and scale-up the development and transfer of technologies for mitigating and adapting to climate change? This paper explored the role of incubators and accelerators in this regard.

Both incubators and accelerators aim to support the start-up of new ventures. However, this paper has highlighted that they are distinct in terms of their origins, operational models, and strengths and weaknesses. While there are more than 7,000 incubators and 300 accelerators in the world, it is estimated that just 69 are considered to have a focus on climate technology. And only 25 of these are in developing countries. In the context of the need to speed up and scale up climate technology innovation, the global community needs to find ways to address this low number.

In that context, this paper has highlighted three key challenges that need to be overcome and are thus key opportunities for the international community as it seeks to support developing countries to accelerate their low-emission and climate resilient development, namely: supporting the strengthening of entrepreneurial ecosystem in developing countries; finding ways to crowd-in private finance for earlier stage climate technology development; and supporting the development of new incubation models. The TEC, the GCF and the CTCN look forward to working with developing countries to harness these opportunities.

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