IIIEE Theses 2019:25

Keepin' it Clean(tech)

Assessing South Africa's cleantech ecosystem to improve a framework for Cleantech Innovation and Entrepreneurship Ecosystems in Developing Countries

Rheanna Johnston

Supervisor:
Jonas Sonnenschein

Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, September 2019

iiiee
THE INTERNATIONAL INSTITUTE FOR
INDUSTRIAL ENVIRONMENTAL ECONOMICS

Published in 2019 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

ISSN 1401-9191

Acknowledgements

First and foremost, thank you to my UNIDO supervisor, Alois Mhlanga for making this research possible and for your confidence in me. Thank you also to Sunyoung Suh, for all of your support throughout this process and for all of the extra work you did to give me feedback.

Thank you also to the rest of the Vienna-UNIDO office including Tareq Emtairah, Nurzat Myrsalieva and Nick Dehod, and to the SARO office, Petro de Wet, Nikki Niebuhr and Conrad Kassier for making me feel welcome and for all of your help. An *especially big thank you* to Gerswynn McKuur for all of your support and input, for challenging me, and for putting up with all of my questions and constant hunt for adventure in South Africa.

Thanks also to Fynn, Paula and the other UNIDO interns for all your help (in and out of the office), the coffee breaks and the post-work river-basking. You made work feel like vacation.

An absolutely MASSIVE thank you to my supervisor Jonas. You sacrificed your summer holidays and always took the time to chat when I needed it, and you've probably read this thesis almost as many times as I did. I can't imagine a better thesis supervisor.

A big ol' shout out goes to my SED team – Silvia Guevara, Jamie Wylie, Xuan Xie, and supervisor Hakan Rodhe. You were truly the #dreamteam and without all of the work each of you did back in April, none of this would have been possible! And thank you also for all the help and advice you've given me since then – even when it wasn't your project anymore.
#ladsontour

Thank you, Jacob, for being the best, most supportive friend and roommate this past year and always sharing your pesto pasta,[1] sauerkraut and wise life advice – we do all turn into diamonds under pressure. Thanks Anja and Jon for being my chalk-buds, pun-muses and snack-consultants. And to my insti-study dates, Alexandra, Paulina and Felicia. Madison, you know what you did. <3

Love you mom and dad – sorry I didn't call you more. Kailex and Julian, thnx for the memes, the chocolate and sharing Spotify with me.

And finally, thanks so much to all of my amazing batchmates and friends (from Lund to Budapest to Vienna, Stockholm and Seattle!) who dropped everything to help me and distracted me all summer with the best adventures – exploring new cities, climbing in the park, wine-and-write evenings, longgg bike rides to go swimming, ice cream runs, innebundy, conversations about how best to #deletecapitalism, a prank or two, aperol spritz that was much too expensive, family road trips, and all the rest. You are the most inspiring group of people and you make it easy to stay in the fight. See you all tomorrow at the global climate strike.

[1] The real MVP.

Abstract

This thesis researched the Cleantech Innovation and Entrepreneurship Ecosystem (CIEE) of South Africa with the dual aim to improve and operationalise a conceptual framework as well as to identify areas for intervention in the specific case of South Africa. Supporting the growth of cleantech solutions in developing countries and emerging economies can be an important driver of inclusive and sustainable industrial development, resulting in economic, social and environmental benefits at the local level and supporting the achievement of global environmental and human development targets. To effectively support local cleantech, international development agencies such as UNIDO, and national stakeholders, need a method to assess national Cleantech Innovation and Entrepreneurship Ecosystems (CIEE) in order to identify barriers as well as best practices. This research has contributed to the research gap in this area and further developed a conceptual framework for assessing CIEEs and tested it in the specific case of South Africa's national cleantech ecosystem.

As a first step, the research operationalised the framework by adding indicators. This was followed by an extensive desktop review of South Africa's CIEE and field research including semi-structured interviews in South Africa. The analysis of the literature and the interview data resulted in an updated CIEE framework and the identification of the key barriers and strengths in South Africa's CIEE. Of particular note was the finding that understanding the ecosystem linkages, both at the level of the conceptual influences of the system as well as at the stakeholder level, is crucial for assessing a CIEE. A lack of coordination in stakeholder interactions was among the most significant barriers in South Africa's ecosystem. As a result, policy recommendations for supporting cleantech development in South Africa include 1) better coordination among stakeholders and alignment of targets and metrics; 2) expanding the access of rural and low-income communities to innovation and entrepreneurship services; and 3) focusing support on cleantech which helps to address key social and environmental issues in South Africa.

Keywords: Cleantech, Entrepreneurship, Innovation, Innovation Ecosystems, Entrepreneurial Ecosystems, Developing Countries, South Africa

Executive Summary

It is increasingly clear that meeting global climate targets and supporting human development goals will require us to adapt our current patterns of resource use, production and consumption. As our ever-rising emissions further commit us to significant changes to the climate systems which have thus far supported our economies, the creative ability of our societies to mitigate, adapt and develop resilient systems, technologies and communities becomes increasingly vital. Supporting cleantech innovation and entrepreneurship in developing countries is an important driver of inclusive and sustainable industrial development (ISID). The associated economic, social and environmental benefits of cleantech development can be felt both at the local level as well as in support of achieving global targets such as the Sustainable Development Goals and the Paris Climate Agreement. Consequently, in order to identify appropriate interventions and opportunities for support, international development organizations, such as the United Nations Industrial Development Organization (UNIDO), as well as national policy makers need to understand the existing national Cleantech Innovation and Entrepreneurship Ecosystem (CIEE).

However, there remains a significant knowledge gap in this area. According to a World Bank report "[t]here is limited empirical knowledge regarding the relationship between specific developing country contexts and the most effective instruments to promote clean technology industries" (infoDev, 2014, p. 79). Furthermore, although there are a variety of different existing frameworks indexing entrepreneurship or innovation globally, few focus on developing country contexts and instead tend to be more suited to OECD or developed countries (Budden, Murray, & Turskaya, 2019). Finally, existing frameworks do not combine the concepts of cleantech, innovation and entrepreneurship as a single ecosystem, but typically treat them separately, despite their overlaps and interdependencies. Yet although there is a lack of conceptual clarity, cleantech innovation programs are nonetheless run in many developing country contexts. One such initiative, the Global Cleantech Innovation Programme (GCIP), was first piloted by UNIDO in South Africa in 2011, and has since grown to include eight other countries, with the expectation of expansion to a further sixteen in the near future.

To facilitate the expansion of this programme and support assessment of the overlap between the innovation and entrepreneurship aspects of cleantech in the developing country context, research to define a CIEE was identified as necessary. The CIEE conceptual framework was therefore first developed in April 2019 by four students on behalf of UNIDO's Department of Energy and the Climate Technologies and Innovations division. Building on this previous work, this thesis tests this framework in the specific case of South Africa, with two main objectives:

- to provide an assessment of South Africa's CIEE;
- to identify improvements to further develop the conceptual theory of the framework.

By developing an assessment of South Africa's cleantech ecosystem using the CIEE framework to structure and assess the data collected, important gaps in the theory or additional considerations for the methodological approach could be identified. These gaps could then be addressed to produce an improved CIEE framework, while simultaneously supporting UNIDO's work.

Research question 1 begins by asking **[RQ1]** what is a suitable framework to assess the cleantech innovation and entrepreneurship ecosystem in a developing country context and how can it be operationalized? By then testing the existing theory in the case of South Africa, using the framework seeks to further answer the questions of **[RQ2]** what is the state of South Africa's CIEE? As well as **[RQ3]** what are significant barriers and drivers of cleantech development in

the national cleantech innovation and entrepreneurship ecosystem of South Africa? The subsequent results and learnings from the process of identifying key barriers and drivers in South Africa will then support answering the final question **[RQ4]** how can the CIEE framework be improved to accurately reflect the significant barriers and drivers in a national cleantech innovation and entrepreneurship ecosystem?

The thesis research began by operationalizing the CIEE framework through research and justification of indicators intended to assess each aspect. This was then followed by a case study of South Africa using both an extensive literature review as well as twenty semi-structure interviews with stakeholders. The literature review was conducted in order to find indicator data and information regarding each of the pillars in the CIEE framework to assess the strength of each pillar in the context of South Africa's national ecosystem. This was followed by a field mission to South Africa in order to conduct in-person interviews with key ecosystem stakeholders. During the interviews, data was collected using semi-structured interviews on which aspects of South Africa's cleantech ecosystem actors viewed as being the greatest barriers to cleantech development, as well as possible strengths. The interviews also provided individual stakeholder perspectives on the ecosystem more broadly.

The results of both the desktop review and the data collected in the interviews could then be compared to develop an assessment of South Africa's cleantech ecosystem and identify improvements to the CIEE framework. The results of this data collection identified two key improvements for the framework: 1) that indicators alone were not sufficient to address a topic as complex as a CIEE, and that the framework would be better served by focusing on answering key questions; and 2) that understanding the ecosystem linkages, both at the level of the conceptual influences of the system as well as at the stakeholder level, is crucial for assessing a CIEE. This led to the development of an updated CIEE framework. The newly proposed framework includes a series of questions for each pillar to guide the researcher to assess the most important aspects of each factor rather than rely on indicators alone. In addition, a new pillar, Ecosystem Linkages, was developed. This pillar consists of two sub-pillars, the 'Environment Linkages' (the conceptual, high-level influences) as well as the 'Stakeholder Linkages' (the interactions and relations between key actors) in the system. These aspects were included in order to capture how they contribute to the ecosystem's behaviour as a whole and influence the outcome of cleantech sector development.

Furthermore, the assessment of South Africa identified several key barriers, as well as strengths in the country's CIEE. A key barrier identified was a lack of communication between stakeholders and a misalignment of purpose and targets across different organizations. Additional important barriers identified included the significant degree of inequality, as well as difficulty commercializing cleantech solutions due largely to a lack of access to markets and a risk-averse environment (particularly regarding funding). Strengths of South Africa's CIEE included the existence of well-developed institutions and infrastructure overall, as well as a general motivation to support cleantech among a wide-range of actors who understand the benefits of the cleantech sector. Policy recommendations for addressing these barriers therefore include: improving coordination and alignment of goals among actors in the CIEE to better align support efforts, resources and timelines; improving rural access to innovation and entrepreneurship services to help address inequality, especially by taking advantage of existing agency infrastructure; and to focus on driving cleantech development that addresses key social and environmental problems in the country, thereby effectively identifying demand and maximizing both market access as well as the positive impacts of cleantech.

The resulting updated CIEE framework is intended to serve as a holistic and systems-thinking based approach to assessing a national cleantech ecosystem. The focus is on understanding, rather than measuring the system, and the framework attempts to cover a broad range of

influencing factors in a CIEE – many of which are difficult to measure – while also acknowledging that every country context will be different. In some ways this might limit the utility of the framework – an extensive and qualitative assessment of a CIEE may not always be feasible. Further research is therefore needed to explore options for operationalizing such a framework in a more quantitative way, such as by developing indicators to measure concepts like culture or stakeholder interactions. However, measuring some of the intangible concepts of a CIEE will likely always depend on some measure of subjectivity and it is worth considering whether a quantitative approach is the most appropriate method. In line with systems thinking, effective interventions depend on considering not just the elements in a system but also their interactions and purpose in order to identify the underlying causes, all of which may be significantly difficult to quantify. But by identifying the key influences and system behaviours which drive negative outcomes, interventions can be structured to shift undesired ecosystem behaviours into new patterns. An understanding of a CIEE that takes full advantage of a systems approach to assess influences and interactions, will better inform structuring interventions that can successfully drive long term change in a system and build a CIEE's capacity for sustainable, lasting growth.

Table of Contents

List of Figures

List of Tables

Abbreviations

CET – Community Education and Training

CIC – Climate Innovation Centre

CIEE – Cleantech Innovation and Entrepreneurship Ecosystem

CSIR – Centre for Scientific and Industrial Research

DBSA – Development Bank of Southern Africa

DEA – Department of Environmental Affairs

DHET – Department of Higher Education and Training

DOE – Department of Energy

dtic – Department of Trade, Industry and Competition

DUT – Durban University of Technology

GCII – Global Cleantech Innovation Index

GCIP – Global Cleantech Innovation Programme

GCIP-SA – Global Cleantech Innovation Programme South Africa

GDP – Gross Domestic Product

GEF – Global Environment Facility

GEM – Global Entrepreneurship Monitor

HEI – Higher Education Institutions

ICT – Information and Communications Technology

IDC – Industrial Development Corporation

II – Impact Investing

IP – Intellectual Property

IPP – Independent Power Producer

ISID – Inclusive and Sustainable Industrial Development

ISP – Incubation Support Programme

NCPC – National Cleaner Production Centre

NERSA – National Energy Regulator of South Africa

PDI – Previously Disadvantaged Individuals

PIF – Project Information Form

R&D – Research and Development

RE – Renewable Energy

REIPPP – Renewable Energy Independent Power Producer Programme

SA – South Africa

SABS – South African Bureau of Standards

SANEDI – South African National Energy Development Institute

SDG – Sustainable Development Goals

SED – Strategic Environmental Development

SEDA – Small Enterprise Development Agency

SEFA – Small Enterprise Finance Agency

SETA – Sector Education and Training Authority

SME – Small- and Medium-sized Enterprise

SPII – Support Programme for Industrial Innovation

TVET – Technical, Vocational, Educational & Training colleges

TIA –Technology Innovation Agency

UNFCCC – United Nations Framework Convention on Climate Change

UNIDO – United Nations Industrial Development Organization

VC – Venture Capital

WHO – World Health Organization

WRC – Water Research Council

ZA – South Africa

1 Introduction

The impacts of climate change are increasingly being felt around the globe – hotter, drier summers, increased flooding, dying coral reefs, disappearing glaciers. With these impacts come ever more difficult challenges such as more drought and forest fires, biodiversity loss, and decreased agricultural productivity, as well as risks to human health and livelihood, all of which will require us to adapt our current patterns of resource use, production and consumption. As our ever-rising emissions further commit us to significant changes to the climate which has thus far supported our economies, the ability of our societies to mitigate, adapt and develop resilient systems, technologies and communities becomes increasingly vital.

The latest IPCC (2018) report has given the global community about twelve years to take decisive action on mitigating greenhouse gas emissions (GHGs) in order to avoid catastrophic climate impacts. The report found that limiting global warming to 1.5C would require "rapid, far-reaching and unprecedented changes" in almost every sector, not to mention an increasing reliance on as yet unproven technologies should we allow global temperature to "overshoot" the 1.5C goal (IPCC, 2018). Meanwhile, world population is projected to grow to over 9 billion people by 2050 (World Bank, 2019b) while resource use is expected to double in the same period, effectively jeopardizing the achievement of the United Nation's Sustainable Development Goals (SDGs) if resource efficiency and materials use are not significantly improved (UNEP, 2017). As a result, developing new solutions that can advance economic and human welfare, yet do so in a manner that reduces environmental problems and supports a systemic economic transition to more sustainable patterns is crucial.

One important source of more sustainable and resilient systems and processes is the innovation of new and creative solutions to address these climate challenges and mitigate environmental problems. *Cleantech* is defined as a technology or process that leads to an increase in sustainability, in particular, reduced climate impacts and pollution, improved resource efficiency, or other environmental benefits (Xie et al, 2019). The innovation and subsequent entrepreneurship of cleaner technologies and solutions is an important driver of resource efficiency, GHG emissions reductions, and other environmental problem solving.

The development of cleaner and more efficient alternatives in almost every sector is considered a key element in driving sustainable industrialisation and economic development globally (UNEP, 2017; UNIDO, 2019). The SDGs set out a blueprint for working towards global sustainability by 2030 in order to improve global welfare and support achievement of global climate targets. Most of the SDG targets can be directly related to increased cleantech development, in particular Goal 9 (Industries, Innovation, and Infrastructure) as well as the United Nation's Industrial Development Organization's (UNIDO) mandate to promote inclusive and sustainable development (ISID). Goal 9 includes technological progress as fundamental for achieving "environmental objectives, such as increased resource and energy-efficiency" while "[e]conomic growth, social development and climate action are heavily dependent on investments in infrastructure, sustainable industrial development and technological progress" (UN SDGs, 2018). Furthermore, supporting the growth of cleantech start-ups and small and medium-sized enterprises (SMEs) is critical for encouraging sustainable development and poverty reduction as they are typically some of the largest job creators – SMEs account for 90% of global business and 50-60% of global employment (Sustainable Development Goals, 2019). Cleantech investment can not only contribute to creating jobs and fostering markets, but also has strong potential to create green jobs that are "more skilled, safer, and better paid" compared to jobs in other sectors (infoDev, 2014, p. 5). Continuing to drive growth in cleantech, particularly in developing countries, is therefore critical to improving global standards of living and reducing the wealth gap between developed and developing countries,

while also driving sustainability, reduced environmental footprints, and achievement of international climate goals.

1.1 Problem Definition

In order to drive cleantech development in developing countries, it is vital to understand how existing national innovation and entrepreneurship ecosystems impact the growth of cleantech. According to a World Bank report "[t]here is limited empirical knowledge regarding the relationship between specific developing country contexts and the most effective instruments to promote clean technology industries" (infoDev, 2014, p. 79). Although there are a variety of different existing frameworks indexing entrepreneurship or innovation globally, few focus on developing country contexts and instead tend to be more suited to OECD or developed countries (Budden et al., 2019). Most are also not intended to effectively "facilitate decision-making" (Budden et al., 2019) or provide a transparent oversight of the existing ecosystem. Furthermore, these frameworks do not combine the concepts of cleantech, innovation and entrepreneurship in an overarching ecosystem, but typically treat them separately, even when recognizing their overlaps and interdependencies. Thus, applying one of these frameworks may miss important aspects.

Despite this lack of conceptual clarity, cleantech support programmes are nonetheless run in a developing country context. Funded by the Global Environment Facility (GEF), and run by UNIDO, the Global Cleantech Innovation Program (GCIP) was set up in 2011 to foster innovation and entrepreneurship in order to "promote affordable and scalable solutions [that enable] partner countries to leapfrog to cleaner, more resilient economies" and effectively contribute to solving global challenges (GCIP, 2019). The GCIP was established as part of a project called "Greening the COP" in conjunction with the COP17 for the United Nations Framework Convention on Climate Change (UNFCCC) in Durban, South Africa (GCIP South Africa, 2018). As part of their mandate, GCIP seeks to promote cleantech 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 entrepreneurs"*
> (GCIP, 2019).

The GCIP aims specifically to foster cleantech ecosystems in developing countries through interventions based on partnerships with in-country organizations and actors. Currently it is active in 9 countries. However, these programs so far have been implemented mostly on a trial- or intuitive-basis (Xie et al, 2019). Although this has nevertheless been successful in some cases, according to Programme Coordinators in South Africa, Morocco and Turkey it has also made it difficult to assess the success of the programmes when an initial assessment baseline is lacking (Xie et al, 2019). The necessity of understanding the starting baseline and situation in a given context is essential not only for identifying barriers and meaningful interventions to support cleantech development but also for assessing progress. Furthermore, the GCIP programme is expected to expand into sixteen additional countries in the near-term. This expansion would be significantly facilitated by a more systematic method for assessment of the existing cleantech ecosystem in new partner countries. GCIP has therefore indicated a need for a framework which not only provides an academic justification but can also serve as a useful tool for identifying opportunities for interventions to support individuals as well as SMEs in commercializing environmental solutions.

In order to facilitate the expansion of the GCIP programme as well as to begin addressing the above-mentioned research gap, a research project was conducted by the author and three colleagues in April of 2019 to develop a framework designed specifically to assess the cleantech innovation and entrepreneurship ecosystem (CIEE) in developing countries (Xie et al, 2019). The CIEE framework provides the conceptual grounding for this thesis. However, Xie et al (2019) also concluded that there is a need to conduct further research to test the framework's conceptual theory, further develop the associated methodology, and contribute to the development of a practical tool. The aim of this thesis research is therefore to build on the framework's theory and contribute to the development of an associated methodology in order to eventually help produce a useful diagnostic tool for UNIDO to use in assessing future GCIP projects.

1.2 Research Question and Objectives

The overarching objective of this research is to drive the long-term sustainable development of cleantech innovation and entrepreneurship by SMEs in developing countries. To achieve this aim, the research has two main objectives:

- to provide an assessment of South Africa's CIEE;
- to identify improvements to further develop the conceptual theory of the framework.

By testing the CIEE framework and providing an appropriate assessment of South Africa's cleantech innovation and entrepreneurship ecosystem, this research contributes to the body of work on cleantech development. Further improvement of the CIEE framework will help facilitate the identification of weaknesses and opportunities for intervention by stakeholders in a CIEE.

The below research questions were chosen in order to address these two objectives of the research. By developing an assessment of South Africa's cleantech ecosystem using the CIEE framework to structure and assess the data collected, important gaps in the theory or considerations for the methodological approach could be identified. These gaps could then be addressed to produce an improved CIEE framework.[2]

Research question one begins by asking **[RQ1]** what is a suitable framework to assess the cleantech innovation and entrepreneurship ecosystem in a developing country context and how can it be operationalized? By then testing the previously developed CIEE theory in the case of South Africa using the framework, the research further seeks to answer the question of **[RQ2]** what is the state of South Africa's CIEE? As well as **[RQ3]** what are significant barriers and drivers of cleantech development in the national cleantech innovation and entrepreneurship ecosystem of South Africa? The subsequent results and learnings from the process of identifying key barriers and drivers in South Africa will then support answering the final question **[RQ4]** how can the CIEE framework be improved to accurately reflect the significant barriers and drivers in a national cleantech innovation and entrepreneurship ecosystem?

[2] At the same time, the research and data collected on South Africa's cleantech ecosystem could be developed into a useful report to support UNIDO's work in the country, primarily the implementation of a second phase of the GCIP-SA programme.

1.3 Scope and Limitations

The scope of this research is limited primarily to South Africa and specifically the testing of the CIEE framework in this context. The CIEE framework is quite broad and is intended to capture the different aspects of the cleantech ecosystem as well as the relationships between them. Furthermore, the definition of cleantech, for the purposes of the framework, is also kept deliberately broad in order to allow for new and innovative solutions in different forms. This broad scope of the research means that it will necessarily remain relatively high level in order to provide a useable assessment framework. The lack of depth was not deemed problematic however, as the main function of the tested framework is to identify general hotspots for intervention in the national ecosystem, rather than to provide detailed information for intervention in a small and restricted sub-aspect of the ecosystem.

The primary limitation of this research is therefore the complexity and broad scope of the project's aim. Because the intention was to produce a framework which can be applied in a broad variety of country contexts, but which simultaneously is being tested in a specific country context, there is an important balance between specificity and generalizability: on the one hand, it will be necessary to adopt a high-level approach for the framework in order to make it applicable to a broad range of developing country contexts. On the other hand, testing the framework in the specific case of South Africa, will almost certainly influence the further development of the framework and may limit the generalizability of the framework to further case studies. South Africa is a good test case (for reasons outlined in the case study, chapter 4) but it is nevertheless much more developed than many other countries in the global south (particularly as it is technically not classified as a "developing country"). When considering the wide range of variability between different country contexts, it is possible that the results of this research and the subsequent improvements to the framework may have been informed too much by the specific case of South Africa. The relevance or importance of certain factors may be very different in the context of another case. Further testing of the framework will therefore be needed, as well as further consideration to find the appropriate balance between generalizability and an appropriately specific degree of assessment.

It is also very important to note, that the aim of this research is to test the conceptual theory in the CIEE framework and whether it appropriately captures the most important aspects in a national cleantech ecosystem. It is beyond the scope of this project to develop the framework into a quantitative diagnostic tool. Instead this testing of the framework is intended to provide background and academic theory as to which aspects of a national ecosystem need to be assessed and included in such a tool. The outcomes of this research do not provide a tool for quantitatively measuring or ranking factors. Instead the research and the updated framework is intended to contribute to academic research on the theory of a cleantech innovation and entrepreneurship ecosystem and how to identify and understand the critical parts, as well as provide some preliminary policy recommendations to help inform short term interventions in South Africa. Further methodological limitations are discussed in chapter 2.4, while reflections on the research more broadly are discussed in chapter 6.

1.4 Ethical Considerations

Much of this research depends on qualitative assessments and interviews, which incorporate both the authors' own perspectives as well those of the individuals interviewed in South Africa, at UNIDO and in the cleantech sector. It is therefore important to keep in mind that the interviewees' and the researcher's biases or world-views might influence results. In particular, remaining aware of my own views is important when analysing or citing the outputs of semi-structured interviews as this depends significantly on my own interpretations. All interviewees

participated voluntarily and were informed of the dual purpose of the UNIDO mission as well as the aim of this research at the start of each interview.

Furthermore, because this research is conducted as an intern for UNIDO, it has also been important to keep in mind that although generally aligned, the results desired by UNIDO may not be fully identical to the objectives of academic research. In addition, the influence of UNIDO in identifying interviewees and resources has been recorded as much as possible in order to be transparent about the objectivity of the research. The nature of the internship also meant there was collaboration and discussion around different aspects of the research and methodology throughout the project, and informal input from UNIDO staff informed the project output.

1.5 Audience

The primary audience for this research is the UNIDO-GCIP team as well as national policy-makers interested in supporting the development of the cleantech ecosystem in their jurisdiction. The framework output is intended to serve as a diagnostic tool for decision-makers interested in supporting cleantech innovation and entrepreneurship and facilitate the assessment of the existing cleantech ecosystem at a national level in order to identify areas for support. The audience may therefore also be further expanded to academics, development NGOs, cleantech professionals and others who are interested in supporting the further development of national cleantech ecosystems.

1.6 Disposition

The following chapters begin by outlining the methodology used to conduct the research, including the methods of data collection, analysis and identified limitations. This is followed by a chapter describing the original CIEE framework as well as how it was operationalized with indicators, which together forms the conceptual basis of this research. The case study of South Africa is then introduced to provide both current country context as well as an overview of relevant UNIDO activities in the country which influenced the choice of case study. The results and analysis of the desktop review and the conducted interviews is presented in chapter 5 which concludes with a final assessment of the state of South Africa's CIEE. These results are discussed further in the following chapter to improve the CIEE framework, propose policy recommendations, and reflect on the broader implications and areas in need of further research. The final chapter closes with concluding thoughts and a call to continue development of this research into a tool for future use.

2 Methodology

2.1 Overview of Methodology

The conceptualization phase began with the work conducted by Xie et al (2019) for a project requested by UNIDO-GCIP. The aim of the project was to develop a framework for assessing the national ecosystem of cleantech entrepreneurship and innovation in the specific context of developing countries. A conceptual framework based on literature review and extensive interviews was developed by Silvia Guevara, Xuan Xie, Jamie Wylie and myself in April of 2019, as part of a student-consulting project for the Climate Technology and Innovation division within UNIDO's Department of Energy. This work resulted in the CIEE framework as well as recommendations to test this framework to further develop it into a useful tool.

In consultation with the needs of UNIDO, this thesis builds on the work of Xie et al to conduct the next research step and test the theory of the CIEE framework. The testing focuses on two parts: 1) whether it provides an assessment of the ecosystem which reflects the real-world circumstances and complexities in an appropriate manner (appropriateness); and 2) whether it provides information that helps to identify barriers and drivers in the ecosystem that could be supported through intervention (usefulness). By applying the conceptual framework as a case study, the research intends to provide an assessment of the cleantech innovation and entrepreneurship ecosystem in South Africa as well as test how the framework might be improved and further developed based on practical application to a specific case. Figure 2-1 below illustrates the research design process.

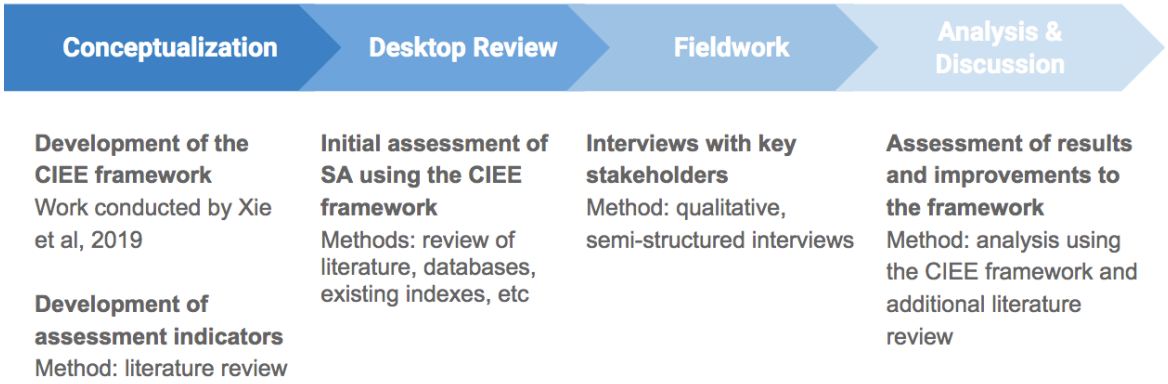


Figure 2-1: Research Design

The conceptualization phase built on the work done by the author and team and began with the first step of operationalizing the framework by selecting indicators for the framework's pillars. The inclusion of indicators was initially an important requirement by UNIDO. Although some suggested indicators had been identified by Xie et al., these were acknowledged as not being sufficient and that further indicators would need to be added to the framework.

After developing the framework's indicators, the 'Desktop Review' phase of the research began during which the conceptual framework was used to structure research on South Africa's cleantech ecosystem and the indicators used to find data. The primary aim was to develop an assessment of South Africa's cleantech ecosystem using the data which was available through the review of indicators from existing and available data sources. This review was intended to provide information regarding each of the pillars in the CIEE framework assess the strength of each pillar in the context of South Africa's national ecosystem.

The second phase of the research consisted of field work conducting in-person interviews with key ecosystem stakeholders. The initial aim of this phase was to validate the findings of the desktop review by interviewing stakeholders about each of the pillars using the key identified questions in the CIEE framework. However, due to the nature of the mission with UNIDO, it was not possible to structure the interviews in this way. Instead, data was collected using semi-structured interviews asking which areas of South Africa's cleantech ecosystem actors viewed as being the greatest barriers to cleantech development, as well as possible strengths. The interviews also provided individual stakeholder perspectives on the ecosystem more broadly.

The results of both the desktop review and the data collected in the interviews could then be compared to develop a more complete assessment of South Africa's cleantech ecosystem and identify improvements to the CIEE framework.

2.2 Research Methods -- Data Collection

The research was conducted based on data from literature review (both academic and grey literature) as well as qualitative interviews. Figure 2-2 below outlines the different sources and the topics for which the data was collected. The following sections provide additional detail.

	Academic Literature	Grey Literature (UN, World Bank, SA gov)	Existing Indexes & Frameworks	News & Media	Interviews with Stakeholders
Systems Thinking	✖				
UNIDO-GCIP		✖			✖
Indicator Selection & Methodology	✖	✖	✖		✖
Frameworks & Indexes	✖	✖	✖		✖
South Africa		✖	✖	✖	✖

Figure 2-2: Overview of data collected.

The leftmost column indicates the topic, while the top row indicates the data source type.

2.2.1 Literature Review

A review of available literature was conducted during three key phases of the research: in order to choose and justify the choice of indicators; to conduct the desktop assessment of South Africa's CIEE; and finally, to support the additions to the updated framework during the analysis and discussion.

As can be seen in Figure 2-2 above, the data collection to select indicators was done by reviewing academic literature, grey literature, and by looking at the indicators and methodologies used in other similar databases and frameworks such as the World Bank Open Data or the Global Entrepreneurship Monitor (GEM). Indicators were understood to be the data sets used to "translate physical and social science knowledge into manageable units of information" in order to facilitate decision-making and monitor the development of key goals (United Nations, 2001, p. 3). Although the framework developed by Xie et al (2019) included some initial indicators,

these were incomplete. At the request of UNIDO and in order to operationalize the framework, the thesis project therefore began by further developing and selecting a set of recommended indicators to complete the framework.

An extensive literature review was then conducted for the desktop review of South Africa, in which databases, news articles, government publications, and grey literature were consulted to find the relevant indicator data and any additional information for each pillar in the CIEE framework. This was primarily done by reviewing data from the World Bank's Open Data, other relevant frameworks (such as the GEM, Global Cleantech Innovation Index, Global Entrepreneurial Spirit Index (GESI), etc), reviewing UN documents and GCIP reports, searching national government websites and the websites of other stakeholders, and reading current news. Key words for searches were narrowed to 'South Africa' and structured around the framework's sub-pillars and indicators.

Finally, additional literature review was conducted to further develop the CIEE framework and build on the results discussed in Ch 5 and 6. Searches were done primarily through the Lund University library system using keywords such as systems theory, innovation systems, policy intervention in innovation systems, and the developing country context. Primarily the topics focused on systems theory and innovation systems as there was little literature found that looked at entrepreneurship systems. As it was beyond the scope of this research to conduct additional case studies to assess the relevance of findings, the additional literature was intended as a proxy to support key findings.

2.2.2 Interviews

Twenty interviews were conducted with country experts and stakeholders in a wide range of organizations, capacities and perspectives. These included government officials, non-profits, academics, and individuals engaged in innovation and entrepreneurship. The full list of interviewees can be found in Appendix II, though names and positions have been withheld to maintain confidentiality.

Most of the interviews were conducted in the Pretoria and Johannesburg region as part of a fieldwork mission to South Africa. Primarily these were in person though a few were also conducted via teleconference. The interviews conducted in South Africa were interviewees identified by UNIDO based on prior contact with the stakeholders through the first GCIP project. These interviews were also conducted in conjunction with UNIDO staff whose primary aim was to collect information in order to identify ecosystem needs and develop a second phase of the GCIP for South Africa. In order to balance this UNIDO influence, additional interviews were also conducted with other stakeholders that were identified independently once back in Sweden. This included some additional non-profits in the environmental and financial sector, as well as an academic from the GEM.

Although the initial intention was to develop the interview questions based on the *Key Question* identified for each sub-pillar in the CIEE framework, this was not possible due to the combined interviewing with UNIDO staff. To achieve both the research aims of the UNIDO project as well as those of the thesis, a qualitative semi-structured interview approach was used to collect information from interviewees. Each interviewee was asked to identify the top barriers, and if possible strengths, for cleantech innovation and entrepreneurship in South Africa's national ecosystem. Furthermore, the interviews were also used to understand the stakeholder's perspective and gain a broader understanding of the cleantech ecosystem in South Africa, collect further information on pillars, and validate the findings of the desktop review.

2.3 Methods for Data Analysis

The original framework was initially operationalized by considering the key question developed by Xie et al for each pillar: what information is needed in order to best answer this key question? To supplement this, a review of the World Bank's available indicator data, as well as indicators used in other similar indexes was conducted, and a UN 2001 guideline on sustainable development indicator selection and methodology was consulted as well. From these two aspects (each sub-pillar's key question and the academic/grey literature), the analysis developed an initial set of "ideal" indicators based on what kind of data sets would preferably be available for assessing the sub-pillar in question. However, the availability of datasets for certain indicators may vary due to "different national circumstances, capacities, and levels of development" which can significantly impact the utility and comparability of indicators (Green Growth Knowledge Platform, 2013, p. 3), while there are also further technical issues such as the source, continuity, delivery and reliability of data (United Nations, 2001, p. 25). This is of particular relevance for the developing country context, which tends to vary much more widely in terms of the availability of resources for compiling datasets.

As a result, because it was recognized that these ideal indicators may not be readily available, a secondary set of indicators, "identified available indicators" was put together based on the World Bank development indicators and the indicators from other indexes and reports such as the Global Entrepreneurship Monitor, Global Cleantech Innovation Index, Ease of Doing Business, Rule of Law Index, etc. These indicators were selected as datasets that could be proxies for the ideal identified indicators and make up the final 'Recommended Indicators' included in the conceptual framework's description in chapter 3 as well as the framework found in Appendix I. The final selection of indicators for the framework as applied to the South African context was therefore based on a combination of both the ideal and available indicators in order to maximize utility.

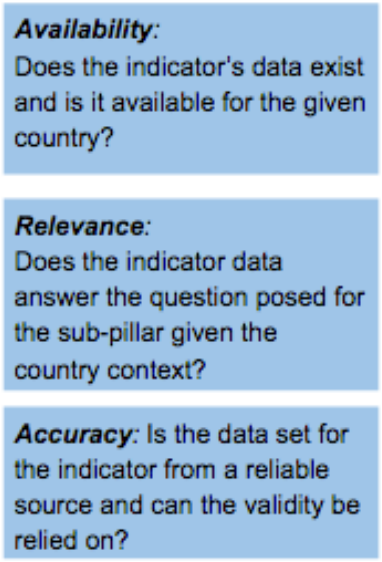


Figure 2-3: Definitions for three aspects of data quality
Source: Aspen Network of Development Entrepreneurs, 2013

The final choice of ideal and proxy indicators was based on analysis of these issues considering three aspects of quality taken from the OECD's framework for assessing data: *availability*, *relevance* and *accuracy* of the indicators chosen (Aspen Network of Development Entrepreneurs, 2013, p. 9). Figure 2-3 includes full definitions of these aspects. The intention was that the final Recommended Indicators would generally meet the three criteria for a wide-range of country contexts, but that proxy indicators could be selected should the framework user find that these ideal indicators did not meet the data quality criteria.

The next phase of the analysis consisted primarily of comparing the results from the desktop review with the results of the interviews in order to put together an assessment of South Africa's ecosystem. A synthesis matrix was used to organize the literature reviewed while the desktop review organized data by the sub-pillars in the framework. The analysis of the results of these findings was done on semi-qualitative basis using both the indicators but also subjective assessment of the additional context found.

The sub-pillars of the CIEE framework were used to categorize the outcomes of the interviews into key themes, by sorting statements that were relevant in answering key questions about the

pillars into areas of the framework. Interviews were also analysed by counting the total number of times the barriers and interactions were identified by different individuals. This data can be seen in Appendix II Table II-2.

2.4 Limitations to Methodology

The primary limitation to the methodology is its reliance on a very iterative and qualitative process. Some aspects of the initial research plan changed over time which meant that there was not always a clear separation between phases of research. There was a degree of overlap between the development of the indicators in the framework and the collection of data for the desktop review. It is therefore possible that this informed or influenced the selection of indicators as there was no clear separation between these two aspects of the research. As a result, some of the recommended indicators may have been chosen based on perceptions of availability and relevance in the South African context rather than a developing country context more broadly. In addition, due to the time constraints of the thesis period and the timing of the mission to South Africa, the data for the desktop review and the data from the interviews were collected and subsequently assessed at the same time. Efforts were made to keep the analysis between these two research phases as separate as possible, but it is possible that there was some cross-influencing between the themes identified in each area of research.

A further limitation is that the interviews were conducted primarily with stakeholders identified by UNIDO as well as with UNIDO staff. It is possible that this may have resulted in results geared towards the views or needs of UNIDO rather than a fully objective range of stakeholders. Interviewees may also have felt inclined to answer questions in a manner which would suit their needs in terms of expectations of support from UNIDO programmes. Interviewing with UNIDO staff, who had slightly different aims, also made it somewhat more difficult to focus questions purely on the ecosystem. A further limitation to the interviewees chosen was also that most were from government agencies and were based in and around Johannesburg and Pretoria in South Africa. Stakeholders from more rural, less well-served areas of the country are missing from the selection of interviewees, potentially leaving out an important perspective.

However, it was ultimately extremely beneficial to the research to work with UNIDO since this made it possible to get access to high-profile interviewees which would otherwise have been impossible, as well as to go on a mission to South Africa which facilitated first-hand learning and in-person interviews with stakeholders. The dual-focus of the interviews also ultimately did not pose too significant a challenge since there was significant overlap between the areas of interest.

Further reflection on research method and limitations to these findings are discussed in more detail in Chapter 6.4.

3 The Conceptual Framework: CIEE

3.1 The Cleantech Innovation and Entrepreneurship Ecosystem Framework

The conceptual basis of this thesis is the Cleantech Innovation and Entrepreneurship Ecosystem (CIEE) framework. The framework is largely the outcome of a previous research project (Xie, Guevara, Johnston, & Wylie, 2019) conducted in April, 2019. It is the focus of the testing in this thesis and was chosen because it provides a solid and well-researched conceptual basis for assessing South Africa's cleantech ecosystem. Furthermore, using it will allow for the identification of areas for improvement in order to contribute to the research gap and help meet the needs of UNIDO in supporting the sustainable development of cleantech in various countries.

A significant gap in the literature was identified for the specific intersection of three important concepts – cleantech, innovation and entrepreneurship (Xie et al., 2019). Although there are several existing frameworks or indexes used to map out innovation or entrepreneurship ecosystems (Ács, Szerb, & Lloyd, 2018), none address the specific overlap of all three concepts. This is important because although some factors may be relevant to both concepts, there are nonetheless some factors which are unique to just one. This might then be overlooked in a framework focusing on just one concept – for example, research institutions and funding for research activities are relevant for innovation but less so for entrepreneurship. Furthermore, though innovation and entrepreneurship were also found to be very interrelated and similarly influenced by many factors (Kline & Rosenberg, 2009; Xie et al., 2019), it is not the case that innovation always leads to entrepreneurship. This indicates that there are at least some factors which are unique to one or the other concept, justifying the identified research gap (Xie et al., 2019). The additional dimension of ecosystems, understood to be "the networks and interactions among stakeholders and the social, economic and policy environment, and their combined influence" (Xie et al., 2019, p. 9), was identified as a further important aspect for consideration.

Finally, the specific focus on the cleantech sector adds an additional aspect since it limits the scope of innovation and entrepreneurship activities to activities that have a net-positive impact on issues of environmental sustainability as well as a specific analysis of factors from an environmental lens. The combination of these two ecosystems – the ecosystem for innovation and the ecosystem for entrepreneurship – in combination with the focus on the cleantech sector, thus results in a new and presumably unique network of "interactions among innovation and entrepreneurship stakeholders and the social, economic and policy environment, and their combined influence on the development and commercialisation of cleantech solutions" (Xie et al., 2019, p. 10).

Furthermore, there are few (if any) existing frameworks or indexes designed to specifically assess the context of developing countries (Budden et al., 2019; Xie et al., 2019). Of course many of the factors influencing the growth of the cleantech sector in developing countries are likely also important in the context of developed countries – for example innovator/entrepreneurs' access to funding or information are generally accepted as key challenges in either case (Edquist, 2006; Pastakia, 2002; Xie et al., 2019). However, the degree of existing infrastructure available to facilitate this exchange of information or funding, and thus the challenges faced by entrepreneurs and innovators, will be significantly different where telecommunication, banking or market infrastructure are not well-developed (Xie et al., 2019). As well, it was particularly evident that this lack of consideration for different economic, political, physical and social

aspects was reflected in the types of indicators used in many existing frameworks or indexes (Xie et al., 2019). Often, the indicators were well-suited for OECD or Nordic countries but would prove either unavailable for many developing countries or would neglect important real-world complexities – such as a well-established informal sector, high prevalence of corruption or economic and social inequality (Xie et al., 2019).

The CIEE framework developed aims to address this gap in the knowledge and provide an assessment framework for the specific complexities of a national cleantech innovation and entrepreneurship ecosystem (CIEE) in the context of developing countries.

To address this research gap, a novel framework was developed by Xie et al. based on an extensive literature review and interviews with cleantech professionals, academics and UNIDO staff. The concept of a *Cleantech Innovation and Entrepreneurship Ecosystem* (CIEE) was thus defined by Xie et al. as follows:

"The network and interactions among innovation and entrepreneurship stakeholders and the social, economic and policy environment, and their combined influence on the development and commercialisation of cleantech solutions."

(Xie et al., 2019, p. 6)

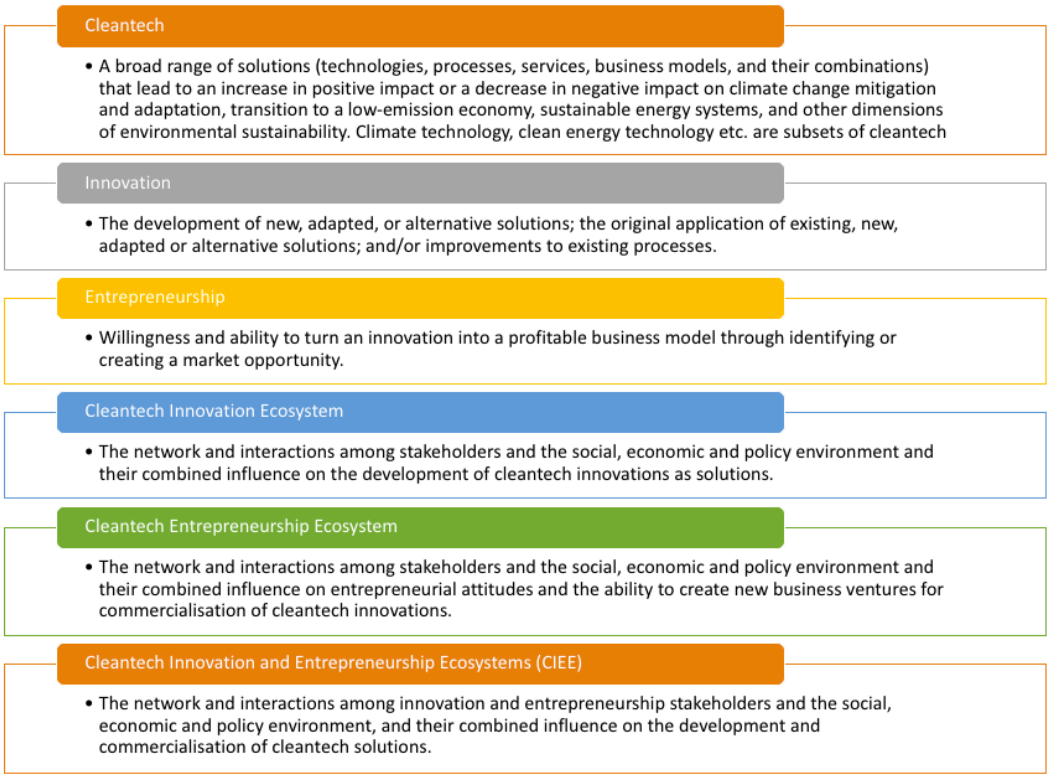


Figure 3-1: Key definitions for a CIEE
Source: Xie et al, 2019

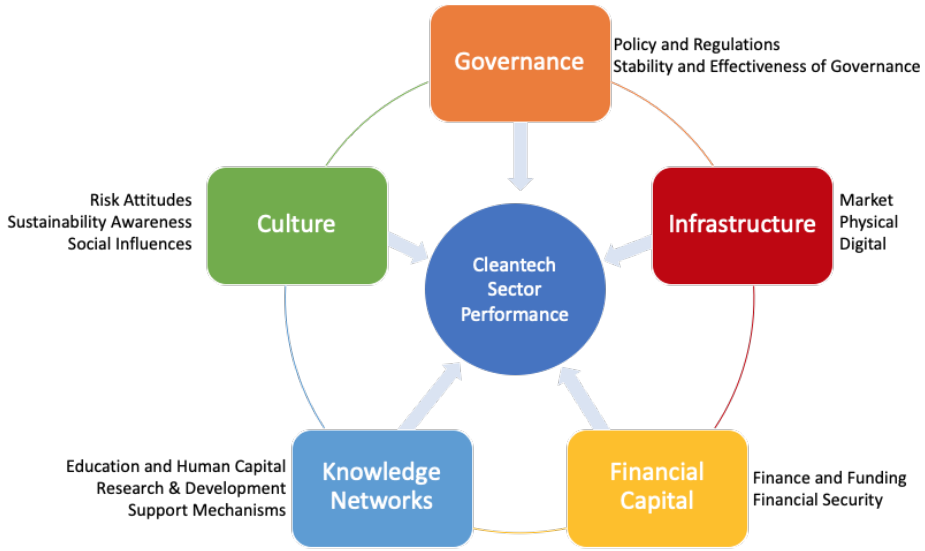


Figure 3-2: Cleantech Innovation and Entrepreneurship Ecosystem Framework
Source: Xie et al, 2019

The research developed a final framework which was presented to UNIDO. Figure 3-2, which provides an overview of the framework's six pillars, illustrates how the pillars of *Governance*, *Infrastructure, Financial Capital, Knowledge Networks* and *Culture* are factors of the final central pillar, *Cleantech Sector Performance*. Each of the five outer pillars is also made up of two to three sub-pillars. The framework developed included a key entry question for each pillar/sub-pillar which was intended to provide the starting point for assessing how each influences the CIEE.

The thesis is thus based on these definitions and conceptual framework. During the conceptualization phase of this thesis research a set of recommended indicators was also identified for each of the frameworks' sub-pillars in order to operationalize it. This framework is described in detail in the next section, Chapter 3.2, including the choice of indicators.

3.2 Key Pillars of the CIEE and their Indicators

This section provides an explanation and justification for the choice of each of the pillars and sub-pillars. The descriptions and justification for each of the pillars are based on the work conducted by Xie et al (2019) who synthesised the literature and conducted interviews and workshops with practitioners in the field of cleantech in a developing country context.

This section also describes how the CIEE framework was operationalised in this thesis by adding indicators for each of the pillars. A table with the overview of indicators can be found in Appendix I.

3.2.1 Governance

This pillar is intended to capture the strength and influence of a country's governance structure which sets the rules or the playing field with which individuals and businesses seeking to engage in cleantech innovation or entrepreneurship must engage. An enabling environment for CIEE should provide a stable regulatory environment that is predictable and transparent for all players, both new SMEs as well as larger companies or centres of innovation (Budden et al., 2019; Xie et al., 2019). Furthermore, policies and regulatory attitudes that incentivise cleantech development by internalising externalities of competing industries or providing incentives to invest in cleantech companies can significantly improve the rate of cleantech development (Cleantech Group & World Wide Fund, 2017; Xie et al., 2019). These conditions may vary

considerably from country to country as there are many policies or political structures which may support cleantech (UNCTAD, 2011), but the existence or lack of such policies and a stable environment are nevertheless an important factor.

Policy and Regulation

Policy is a key aspect of developing an ecosystem which supports cleantech innovation and entrepreneurship. Public policies are "major ingredients of national development strategies" and policies as well as their related institutions are key for all "processes of technological learning and economic coordination and change" (Lundvall, Joseph, Chaminade, & Vang, 2009, p. 24). Policies and regulations can either create incentives or pose barriers for cleantech innovation and entrepreneurship (Polzin, 2017; UNCTAD, 2011). They can present market signals that incentivize alternatives or open up market niches: for example, through the promotion or mandate of energy efficiency targets or by protecting patents encouraging the development of new SMEs and creating a pull for individuals to innovate and take to market new cleantech solutions. Furthermore, clean energy targets or ratification of international climate agreements may also have a significant impact as enabling policies (Pastakia, 2002). Alternatively, policies can artificially maintain old technology regimes through subsidies (Polzin, 2017), or even unintentionally create regulatory red tape for new cleantech. For example, testing procedures for pesticide licensing which applied to both chemical and non-chemical pesticides equally added significant costs for new cleantech businesses even though they were intended to protect the environment (Pastakia, 2002). Such policies can effectively create a regulatory, cost or market barrier for nascent cleantech.

Performance of this pillar should be assessed by answering the key question of whether the policy framework supports entrepreneurship and cleantech/sustainability innovation by individuals and SMEs? Several of the indicators that can be used to assess performance under this pillar attempt to identify and review the existence of key policy that would help to incentivize cleantech development, including: a commitment to the Paris Agreement and the strength of Nationally Determined Contributions (NDCs), existence of key energy efficiency and renewable energy policy as well as environmental regulations around pollution, existence and stringency of carbon pricing (as this can function as an important market signal), and policy incentives for small business development. In addition, the country's score in the World Economic Forum's Energy Transition Index and the existence of an agency mandated to manage cleantech development and specific cleantech sector targets, were also included in the framework as key measures of the policy environment. However, a key limitation of using pre-defined policy indicators is that there is no single ideal policy framework that could support an enabling CIEE. Therefore, a complementary qualitative assessment is needed to research the effectiveness of the respective policy regime in promoting cleantech.

Stability and Effectiveness of Governance

Policies and regulations are only as powerful as the ability to implement and enforce them, as well as the norms and institutions which are at their core (Budden et al., 2019, p. 6). Furthermore, the degree of trust individuals have in government institutions can also affect the ability or willingness of individuals to exercise their rights and engage in innovation and entrepreneurship activities or to feel confident in the success of such activities. Stable institutions with long-term mandates and consistent strategy to support sustainability or SME development are also more likely to be able to effectively and continuously work to improve these areas. The key question for this pillar begins by assessing whether the governance systems and institutions have a sufficient degree of stability to support cleantech innovation and entrepreneurship. Three indicators were chosen for this sub-pillar: the score on the Corruption Perceptions Index from Transparency International, the Rule of Law Index and the Strength of

Legal Rights index. These were primarily chosen because they are three readily available and recent data sources, each of which captures data on a range of important issues such as: bribery, legal protections for whistle blowers, perceptions of the degree of state capture (CPI); regulatory enforcement, civil and criminal justice (Rule of Law); and the strength of legal rights associated with "the degree to which collateral and bankruptcy laws protect" the rights of borrowers and lenders (World Bank, 2019d). Furthermore the CPI additionally uses interviews with country experts and business executives to capture the perceptions of individuals regarding corruption in the policy and business climate – making it a particularly relevant quantitative value capturing some of the qualitative aspects of the business and market aspects of a CIEE (Transparency International, 2018). Furthermore, all three sources are available for most countries with recent data sets available.

3.2.2 Infrastructure

The Infrastructure pillar seeks to identify whether the basic elements of physical, digital and market infrastructure exist and are sufficiently mature in the developing country ecosystem to support cleantech innovators and entrepreneurs. Infrastructure is key to an enabling CIEE as it "improves physical mobility of people and enables exchanges of information and knowledge locally and internationally" (UNCTAD, 2019, p. 7). While electrification, access to internet services or markets tend to be well developed in the global north as well as in emerging markets, they may not be as strong in the least developed countries. Yet besides ensuring basic living standards, access to infrastructure and services was identified as fundamental for driving innovation and research, knowledge sharing among actors, and the ability to do business in a country (Xie et al., 2019).

Market

The Mark pillar is intended to capture the degree to which market(s) exist and how well the ease of creating and taking business opportunities, long term operation, and other aspects of producing and selling goods or services is facilitated. This is a vital component of a healthy CIEE as it influences the availability of opportunities as well as the potential of individuals to start or operate a business through aspects such as stock markets (Mason & Brown, 2014), access to production and supply chains, existence (and degree) of consumer demand (Pastakia, 2002), banking infrastructure, existence (and degree of) the informal sector, and the degree of market liberalisation. Thus, this pillar seeks to answer the question of whether existing market infrastructure and systems facilitate the creation and operation of cleantech business ventures.

Multiple indicators were chosen for this pillar in order to cover this broad range of aspects including GDP growth rate and GDP per capita as starting points since these are broadly accepted indicators of economic development and are generally readily available. This is followed by the country's credit rating to provide assessment of the stock market which can be instrumental in allowing companies to go public rather than simply selling to larger multi-national companies (Mason & Brown, 2014, p. 9). The World Bank Ease of Doing Business ranking and Ease of Starting a Business rating as well as the World Economic Forum's Global Competitiveness Index provided useful compilations of information which also allow for a degree of comparison between countries to provide a potential benchmark.

These were further supplemented by individual indicators taken from the World Bank's database as this data is also readily accessible and available for most countries. Time required to start a business, Time to resolve insolvency (years), and Cost of business start-up procedures (as a percent of GNI per capita) were included to look at ease of or potential barriers to starting a business, while Exports of goods and services (as percent of GDP) is intended to help capture information regarding the degree of access to international markets. Informal employment was

included to assess the degree to a which the informal economy exists as this can significantly impact where or how an entrepreneur sees or is able to access opportunities.

Physical

Although often taken for granted in other entrepreneurship and innovation frameworks designed for more developed countries, physical infrastructure may not be as well developed or equally accessible in developing country contexts (Xie et al, 2019). Roads, access to basic utilities (water, electricity, heat), and public transport networks are key aspects of the CIEE as they are fundamental not only to human welfare (World Bank, 2019d) and meeting basic needs, but also facilitate business (UNCTAD, 2019) through aspects such as travel and freight delivery, operation and production, as well as the exchange of knowledge and goods. This pillar therefore begins by asking whether basic physical infrastructure to support doing business exists.

The percent of population with access to improved drinking water and sanitation facilities as well as the electrification rate (percent of population with access to electricity) were key indicators—the World Bank identifies access to electricity as a "clear and un-distorted indication of a country's energy poverty status " as well as crucial to human development, economic growth and community prosperity (World Bank, 2019d). Electricity is crucial for basic household activities as well as running a business, and it is also increasingly at the forefront of policies for human development and electrification programmes for decarbonization (World Bank, 2019d). The rate of electrification for rural areas was therefore included as well in order to identify potential gaps in access due to geographic distribution, while the indicator for Quality of Electricity supply was intended to capture qualitative aspects, such as consistency of access. Similarly clean water and sanitation are fundamental for human development and health with impacts such as " severe welfare losses – [including] wasted time, reduced productivity, ill health, impaired learning, environmental degradation and lost opportunities " (World Bank, 2019d). In addition Government Expenditure on Road and Transport was included to provide an indication of road infrastructure, while the World Bank's Logistics Performance Index was also included because it provides an overview of aspects such as customs clearance processes, quality of trade infrastructure like ports and railroads, and timeliness of shipments for example (World Bank, 2018a).

Digital

Digital infrastructure is key to an enabling CIEE because it facilitates accessing and exchanging information as well as doing business. Informations and communications technology (ICT) is considered a "critical" piece of necessary infrastructure as it has "the potential to contribute to the social, economic and environmental dimensions of development" as well as being relevant "to virtually all the SDGs" (UNCTAD, 2019, p. 7) including those relevant for cleantech growth. Access to internet services or telecommunications are generally well developed in high income and emerging economies and thus are often not included in other frameworks but may be only sporadically available (or even not at all) in the context of developing countries or remote rural regions. Technology infrastructure that facilitates innovation and knowledge sharing such as access to the internet, telecommunication technologies and networks, and online services can greatly simplify interactions and exchanges (UNCTAD, 2019) between CIEE factors and stakeholders. Assessing this pillar is based on asking whether individuals have access to communication technologies and infrastructure.

The percent of the population using internet was a primary indicator because internet services can be accessed from computers or mobile devices and offer "opportunities for economic growth, improved health, better service delivery, learning through distance education, and social

and cultural advances " (World Bank, 2019d). Mobile cellular subscriptions, fixed broadband subscriptions, and fixed telephone subscriptions were included in the index to provide a deeper assessment of the degree and quality of digital access. Mobile access in particular is overtaking fixed telephone subscriptions – especially in developing countries with rural areas, fixed lines are often more expensive, not available at all or require long waiting periods compared to mobile networks which are increasingly more widely available and of increasingly higher-quality networks with internet capabilities (International Telecommunication Union, 2017).

3.2.3 Financial Capital

Access to financial capital was one of the most frequently cited factors influencing innovation and entrepreneurship development (Xie et al., 2019). In particular, cleantech projects tend to be particularly capital-intensive due to their tech-intensive nature, so the availability and access to cash flow, especially during the commercialisation stage, is one of the key factors for cleantech start-up and SME survival (Budden et al., 2019; Mason & Brown, 2014; Xie et al., 2019). Healthy CIEEs must therefore have systems that allow innovators and entrepreneurs to access capital, whether through loans and credit, grants, tax breaks, or other financial support. Furthermore, it is important for individuals to have the financial security – either through income and savings or through social safety nets – in order to feel financially able to undertake economic risks.

Finance and Funding

This category encompasses the money available from venture capital, private or public grants, and crowdsourcing as well as capital that must be paid back such as public or private loans and access to credit. This can include capital invested in innovation or in entrepreneurship. It is broadly recognized in the literature and other frameworks that new projects require some form of external capital either as angel equity funding, venture capital (VC), debt or credit (Budden et al., 2019, p. 20), and that it is especially important that a "critical mass of seed and start-up investors " exist to provide financial support (Mason & Brown, 2014, p. 11). The World Bank estimates that "70% of formal SMEs in developing economies are … either unserved or underserved by the formal financial sector" (The World Bank Group, 2019). Readily available capital that is stable, with reasonable interest rates, and accessible to individuals is therefore not only crucial to facilitating but can also significantly incentivise cleantech innovation and entrepreneurship. This pillar therefore begins by asking whether individuals or SMEs can access capital for starting or expanding a business venture or commercialising an innovation.

Ideally the indicators for this sub-pillar would include data on the number of donor grants and cleantech-specific loans available, however during the course of the research and data collection it became clear that this information would likely not be available for many countries, and particularly developing ones. Therefore, the indicators selected (available primarily from the World Bank Development data which includes data for a wide range of countries) included: Lending interest rate (percent), Real interest rate (percent), Account ownership at a financial institution or with a mobile-money-service provider (percent of population ages 15+), Commercial bank branches (per 100,000 adults), Venture capital deals/bn PPP$ GDP, Microfinance gross loans (percent of GDP). These were selected in order to provide an initial assessment of the financial sector and the availability of financing but because data on actual availability of specific types of loans, grants or VC and impact investment is diffuse and difficult to find as a specific indicator, additional qualitative assessment will likely be necessary for this pillar.

Financial Security

In considering the importance of financial capital during the development of this framework, the security of finances for individuals appeared particularly important in the context of lower income countries. The willingness to engage in potentially risky financial behaviour or to take out loans to start a business may depend heavily on financial security and whether social safety nets exist to support an individual if their venture fails (Xie et al., 2019). Aspects of this pillar are also closely tied to the cultural context, particular in terms of risk-aversion, and there is potential for overlap between the two. However, this pillar can be measured comparatively well with quantitative data and is therefore included as its own sub-pillar by seeking to answer the question of whether individuals are financially able to take a business risk.

Indictors were therefore included which aim to provide an assessment of overall wealth and financial security: Unemployment rate (percent of population), Wealth inequality; GNI per capita, and GDP per capita. Furthermore the percent of the population living in multidimensional poverty according to the Human Development Report's definition[3] was included to consider non-monetary aspects of poverty which influence financial choices (United Nations Development Programme, 2018). Also included were the World Bank's indicator for Coverage of Social Safety Net Programmes which provides data on the percent of the population participating in programmes such as social pensions, child and disability benefits, food transfer or school food programmes, and other social assistance programmes (World Bank, 2019d); as well as the indicator for Adequacy of Social Safety Net Programmes which is measured as "total transfer amount received by the population participating in social safety net programs as a share of their total welfare " (World Bank, 2019d). These were included in order to provide a measure of how much individuals rely on safety net programmes to assess to what degree financial security might impact the CIEE.

3.2.4 Knowledge Networks

To facilitate innovation and entrepreneurship in cleantech, the creation and flow of knowledge between individuals and organisations as well as the capacity of individuals to engage in such activities is crucial. A healthy ecosystem should facilitate the exchange of information between actors and support the development of skills and knowledge in the areas of technology, research, business and environmentalism in order to foster cleantech innovation and entrepreneurship (UNCTAD, 2019; Xie et al., 2019). This includes both avenues in the formal knowledge sectors (e.g. universities) as well as localized community knowledge sharing from informal networks

Education and Human Capital

An enabling CIEE needs trained, knowledgeable people with the capacity to innovate and create new cleantech businesses as well as provide skilled labour to existing cleantech(Ács et al., 2018; Herrington, Kew, & Mwanga, 2017; Xie et al., 2019). This pillar seeks to measure to what degree the ecosystem has individuals with the knowledge and capacity to devote time and energy to engaging in new enterprises by asking: do individuals with the capacity to engage in innovation and entrepreneurship exist in society? In particular " [h]uman capital depends on the quality of education, the level of educational attainment and employment in their fields " (Budden et al., 2019, p. 17) as well as demographic aspects (such as the share of young people remaining in the country after graduation).

[3] The Human Development Report defines multidimensional poverty by using indicators in three dimensions looking at health, education and standards of living. Deprivation in at least one third of these indicators is considered multidimensionally poor (United Nations Development Programme, 2018).

The indicators chosen therefore include percent of population in the Labour Force, total percent of the labour force in Unemployment, Compulsory years of education, Labour force with intermediate education (as percent of total working-age population with intermediate education), Skilled labour (percent of labour force), Government expenditure on education (as percent of government expenditure), and Net Migration. Again, these were chosen as a measure of the above-mentioned aspects because they are generally available and provide a basic assessment of the level of education, workforce and working population. In addition, an assessment of the number of universities and technical institutes is included as an indicator, ideally on a per capita basis but this could also be a more qualitative assessment depending on information available.

Research and Development

The availability of research institutions and the amount of research being done in formal institutions influences the potential of new innovations, technologies, and solutions to be developed – almost all of the other frameworks reviewed considered some measure of research and development (R&D) (Xie et al., 2019). Although innovation can also take place outside of formal institutions, strong research institutions as well as funding and support for research activities, are more easily measured than informal innovation sources. Furthermore, from the research conducted, they are also considered very strong drivers for increased development of innovation and cleantech solutions because they provide the knowledge and infrastructure needed to research, test and develop new ideas (Cleantech Group & World Wide Fund, 2017; Edquist, 2006). In particular, research dedicated to technology, engineering and sustainability can support increased cleantech development. For this reason, this pillar begins by asking whether there are research institutions and systems facilitating cleantech innovation.

Indicators such as the percent of tertiary graduates in science and technology, R&D expenditure (total as percent of GDP), number per capita of patents, total trademark applications, and number of fulltime employed (FTE) researchers were included as a measure of the amount of research activity being done. In addition, to focus on cleantech specifically, research institution pre-eminence according to the science journal *Nature*'s index[4] was included as it provides an important insight for quality and output of research in fields related to cleantech. As well the proportion of R&D expenditure in cleantech, climate and energy or environment related fields should be considered if that data is available.

Support Mechanisms

Support mechanisms are the final category in the Knowledge Networks pillar because they serve an important role in providing knowledge and access to resources for innovators and entrepreneurs as their ideas or businesses grow. Such access to information can be "almost as critical as business planning and skills training" (Herrington et al., 2017, p. 10). These sources of support can include community associations, innovation incubators and accelerators, business and industry associations, mentorship programmes or other similar mechanisms. Support mechanisms help an entrepreneur or innovator access information on buyer needs, technologies, logistics, and potential markets as well as to acquire technical or business skills and understand the relevant organisational structures (Mason & Brown, 2014, p. 13). Taking an

[4] The Nature Index "highlights the institutions and countries which dominated research in the natural sciences" including the areas of life sciences, chemistry, the physical sciences and Earth and environmental sciences (Nature Index, 2019a)

idea and commercialising it can be a challenging and confusing process, particularly if other ecosystem factors are not well developed, therefore networks which can facilitate overcoming these challenges are an important component of a healthy CIEE. Such support mechanisms can be either formal, institutionalised and/or government-run mechanisms, or they may come from informal sources. The sub-pillar therefor asks whether there are there institutions and support mechanisms which support entrepreneurs and innovators.

Indicators for this sub-pillar focus on determining Existence of entrepreneurship/innovation incubators and accelerators, Number of University/Industry research collaborations, Existence of cleantech industry organizations/associations, and the Number of programmes/incentives available for cleantech. Where possible the numbers as well as existence should be included however, the availability and easy access to such data may vary considerably depending on the degree of development of such organisations.

3.2.5 Culture

Culture is one of the most important factors influencing a CIEE in a developing country context and was widely cited particularly by interviewees but also in literature. In order for innovation and entrepreneurship to flourish, a level of risk acceptance and openness to new ideas is required, particularly one which is inclusive, open to sharing information and accepting of risk (Budden et al., 2019; Mason & Brown, 2014, p. 11). In addition, a certain level of awareness of environmental issues is needed both on the part of innovators and entrepreneurs as well as from consumers and markets (Pastakia, 2002). In interviews with current GCIP Programme Coordinators it was remarked that culture can be one of the biggest barriers to entrepreneurship and innovation even though the underlying reasons for this can vary significantly. For example, the Programme Coordinator from Morocco described how commercialising local cleantech innovations faced a cultural barrier because people had a greater degree of trust for non-Moroccan companies and were therefore more willing to pay a higher price for an outside product. Conversely, in the context of Pakistan, culture was also one of the biggest barriers for domestic cleantech development but in this case because Pakistani culture valued frugality and people preferred cheaper product alternatives from China.

Although difficult to quantify, this pillar will require extra attention and customisation when performing the initial assessment. The Culture pillar has been split into three sub-pillars intended to assess risk attitudes, the level of awareness of sustainability issues, as well as a third category to include other social factors (for example gender equity) which might be relevant in impacting the development of cleantech innovation or entrepreneurship

Risk Attitudes

Entrepreneurship and innovation require individuals to explore new opportunities and take risk. For this reason, the cultural acceptance of potential failure is an important measure as it may either hinder or support entrepreneurship and innovation of new ideas (Herrington et al., 2017). Additionally, the level of encouragement for risk taking through social narratives or norms, as well as acceptance of entrepreneurship as a career, or cultural perceptions of education may impact how likely individuals are to take risks and pursue entrepreneurial endeavours (Ács et al., 2018; Xie et al., 2019). To assess this pillar, the initial question asks: which cultural attitudes influence risk acceptance and perception of business opportunities.

The Global Entrepreneurship Monitor (GEM) was the primary source of indicators for this sub-pillar from which the following indicators were drawn: percent of population viewing Entrepreneurship as Desirable Career Choice, Media Attention for Entrepreneurship and the percent of the population engaged in Entrepreneurial Employment Activity were all sourced

from the GEM. In addition, the Entrepreneurial Spirit Index (GESI), developed as part of the 2017/2018 GEM report, was also included as a further indication of entrepreneurship attitudes. These were chosen as they are well-respected and researched sources based on country surveys. However, not all countries are represented in these indexes, so this information may not be readily available, and these indexes do not provide a complete understanding of which cultural aspects present barriers. Further assessment through country experts will therefore likely be necessary to understand how risk attitudes materialize in a country and how these might impact cleantech development.

Sustainability Awareness

In order for cleantech innovation to occur and be successfully commercialised, the level of awareness of environmental problems and sustainable alternatives is particularly relevant. Such awareness is important both in order to drive innovation of new sustainable solutions, technologies and process improvements as well as in order to ensure that consumers can recognise the added value of cleantech solutions and environmentally friendly alternatives(Xie et al., 2019). For example, in order to drive cleantech it is important to identify potential resistance from consumers to environmental products due to higher cost, or to solutions which require greater effort to implement, as this could impact consumption of a product (Pastakia, 2002). The successful commercialisation of cleantech therefore relies in particular on the ability of and degree to which society can recognise environmental problems and favour solutions. The question asked is therefore whether individuals in society are aware of sustainability issues such as climate change, recycling, air pollution, water scarcity, etc.

Quantifying environmental consciousness is a difficult factor, so the chosen indicators are proxies rather than perfect indications of awareness of sustainability issues. Annual exposure to particulate matter (PM2.5 levels), amount of protected wildlife areas (as a percent of total area), media narratives and number of environmental NGOs were included as proxies for the degree of visibility of pollution and conservation, as well as a measure of environmental engagement. In addition, NGO activity can be considered a proxy of civil society's engagement more generally which "can be instrumental in testing, promoting and diffusing innovations designed to benefit the most disadvantaged communities" which includes sustainability issues (UNCTAD, 2019, p. 6). Per capita CO2 emissions, GDP per unit of energy use, and total GHG emissions are indicators intended to provide information on the overall climate impacts of the country at the individual and national scale as climate issues are often related to cleantech. Share of electricity from renewable energy was included because "measurements of renewable energy penetration…[can] provide a valuable signpost for wider cleantech definition" (Sworder, Salge, & Van Soest, 2017, p. 47). The share of electricity from coal was included as an indicator for the degree of reliance on the dirtiest of fossil fuels and therefore possible resistance from incumbent industry to cleaner alternatives.

Social Influences

Many other social influences beyond risk attitudes and environmentalism can affect the health of CIEEs, especially in terms of the ability of individuals to engage in innovation and entrepreneurship activities. Particularly where certain groups have historically been disenfranchised (such as women, certain ethnicities and young people), such influences may affect access to resources and knowledge as well as how different stakeholders interact (Xie et al., 2019). Countries with "general attitudes towards exclusion of women, homosexuals, and immigrants" also tend to have poor performance when it comes to measures of development, indicating that social inclusion and cultural factors are important drivers of technological capabilities and innovation governance (Lundvall et al., 2009, p. 21). Other cultural aspects that

could be relevant include the degree of trust in society, the promotion of local small business and production, etc. This category is deliberately broad to capture a wide range of possible cultural aspects and asks whether that are any other factors that might impact the ability of individuals to interact with stakeholders and institutions or their ability to access knowledge and resources.

A measure of interpersonal trust is included because social trust is a key element of social capital and "a key contributor to" well-being including economic development (Ortiz-Ospina & Roser, 2019) in that it can facilitate exchange of information and resources among actors. According to Lundvall et al (2009, p. 18) where social cohesion and trust is strong, it is easier to engage in learning and "passing on elements of tacit knowledge" between individuals and generations, thus making trust and social capital crucial elements for reproducing and using intellectual capital.

Also included as suggested indicators were the Human Development Report's Gender Inequality index, percent of females employed with an advanced degree, the female to male total entrepreneurship ratio, and whether law mandates non-discrimination based on gender in hiring (from the World Bank indicators where 1=yes; 0=no). There is an emphasis on women's empowerment in these suggested indicators due to the UN's focus on gender mainstreaming and because there is a well-established link between women's education and employment, and overall economic growth. Female economic empowerment "boosts productivity, increases economic diversification and income equality" while organizational effectiveness, growth and performance have been shown to score higher with more women in positions of management (UN Women, 2018). Yet in about 40% of the world's economies "women's early stage entrepreneurial activity is half or less than half that of men" and they are far more likely to face disadvantages, such as lack of access to banking or internet services and disproportionate responsibility for unpaid household work (UN Women, 2018) as well as "lower levels of education (particularly in developing countries); lack of female role models in the business sector; fewer business-orientated networks in their communities; lack of capital and assets; lower status in society and a culturally-induced lack of assertiveness and confidence in their ability to succeed in business (Herrington et al., 2017, p. 31). Women are likely to be an underserved social group in almost all countries, so an assessment of the degree to which women are able to engage in innovation and entrepreneurial activities is an import aspect for determining the degree to which half of a country's population is actually able participate in the CIEE.

A further indicator focuses on youth as this is another area of interest for the UN. The total share of youth not in education, employment or training (as a percent of the total youth population) serves as a measure of youth unemployment. This can not only have damaging impacts on local communities but also demonstrates a lack of investment in human capital, and can potentially prevent "companies and countries from innovating and developing competitive advantages " (World Bank, 2019d), as well as indicating the potential need for intervention to support youth engagement with entrepreneurship. Finally, the existence of campaigns or incentives promoting local business or other similar initiatives is included as a way of measuring interest and focus on local products. This was incorporated based on anecdotes from project coordinators in GCIP countries that experienced cultural barriers to cleantech products due to perceptions of quality between local and imported goods and services.

3.2.6 Cleantech Sector Performance

The pillar for Cleantech Sector Performance is intended to provide an assessment of the degree to which the cleantech sector already exists as well as an initial baseline. A baseline of the cleantech sector will allow comparison with later assessments in order to track the development overtime of cleantech as well as the effectiveness of interventions implemented. According to

interviews conducted during Xie et al.'s research (2019), determining the initial level of cleantech is a key step in order to later assess the level of success of the GCIP programme. However, this can be very difficult depending on the degree of development of the sector, the ability to identify existing cleantech and defining or accurately measuring its impact. The pillar's assessment begins by asking whether there is a cleantech sector in this country, and to what degree the cleantech sector is already developed as well as how healthy this the existing cleantech sector may be.

Several of the recommended indicators are quite straightforward in attempting to assess degree of cleantech development, including the number of cleantech companies registered, amount of investment in the cleantech sector and amount of venture capital invested in cleantech, cleantech patents filed, and number of industry associations, physical clusters and economic initiatives supporting the cleantech industry (as a proportion of GDP). However, it is likely that many or even all of these indicators will not be available for a given country – even where cleantech is well developed there may not be a national registry or set definition of cleantech. In this case, data will need to be estimated or proxied either by looking at the number of companies in cleantech related sectors (such as renewable energy for example) or by starting with an assessment of whether such industry associations and cleantech investment exist at all (and omit the actual number). Additionally, the country's score in the Global Cleantech Innovation Index was included as an indicator, and although this can provide a useful overview of the potential for cleantech commercialisation, this score is only available for about 40 countries, most of which are not developing and may therefore have limited utility.

Several additional indicators included measure environmental or sustainable business practices, as these might indicate use or engagement with cleantech. These indicators include: number of B-corps certifications, number of impact investment firms, and ISO 14001 certifications. ISO 14001 is a global standard for certifying the Environmental Management Strategy (EMS) of organizations and has been documented as a "source of change that is beginning to make an impact" in terms of cleantech development and sustainable business strategies in emerging economies such as India (Pastakia, 2002, p. 102). Finally, the number of jobs in the renewable energy sector was also included as an indicator, because as noted in the section on Sustainability Awareness, the visibility and impact of renewable energy is considered a valuable signpost for cleantech development (Sworder et al., 2017).

4 Case study – South Africa

South Africa was chosen as the case study for this project based on its prior participation with UNIDO through the GCIP programme, as well as demonstrated government motivation to facilitate cleantech growth. In particular, a second phase of the GCIP is being explored for South Africa by request of the South African government. The below sections provide an overview of South Africa's current context with a focus on key current events as well as a brief overview of UNIDO's activity in the country so far.

4.1 Current Country Context

Although not technically a developing country, and in fact classified as an emerging economy, South Africa is nevertheless a relevant case study for this project due in large part to the extreme degree of inequality present. Subjected to the colonial system of apartheid until 1994 by the primarily British and Dutch-Boer colonists, the country only very recently began the process of integration. These entrenched systems have left a legacy of extreme inequality and South Africa is consequently one of the most unequal countries in the world. The predominantly black, majority of the population – the bottom 60% – hold an extreme minority of net wealth in the country, only 7% (World Bank, 2019c). While the minority, predominantly whites, make-up only 10% of the total population yet own 71% of the net wealth (World Bank, 2019c). One interviewee described this gap as effectively resulting in "two different worlds" within the same country: a highly modern first world country and a deeply poor, under-served developing nation. This division is sometimes referred to as the "first economy" and "second economy" (the dti, 2007).

Image 1: Map of South Africa, SA Venues, 2019

This divide is felt geographically as well, with some regions of the country being significantly wealthier with better access to services, jobs and basic utilities. A majority of farmland is owned by whites, while urban areas, which are made up of about 2/3 of the population include huge informal settlements that "lack the basic infrastructure for transportation, water, sanitation, or electricity" ("South Africa," 2019). Some of these urban spaces, known as townships, were set aside as segregated public housing during apartheid and were intended to house non-whites, but these areas continue to be underserved ("South Africa," 2019).

After the official end of apartheid and the first democratic elections in South Africa in the early 90s, subsequent administrations have made attempts to improve this extreme state of marginalization. One particularly important policy implemented is the Broad-Based Black Economic Empowerment (BBBEE) Act which was passed in 2003. The act is intended as a comprehensive programme to "advance economic transformation and enhance the economic participation of black people in the South African economy" (Dept of Trade & Industry, 2019). In other words, the intention is to effectively increase the number of black and minority individuals owning and controlling, as well as employed, in South Africa's economy (The Investment House, 2016). BBBEE established "Codes of Good Practice" which defined both

a generic "scorecard" or sets of criteria and measurement metrics for state and private entities as well as ones for specific economic sectors (the dti, 2007). The policy is controversial in South Africa and is criticized as ineffective by the major opposition party which argues that BBBEE has been used primarily to "enrich only a few politically connected elite" while failing to deliver economic inclusion for the majority of South Africa's black population (Phakathi, 2019). The current government and other sources however, argue that the BBBEE has nevertheless been effective in growing the black middle class and employment equity (Phakathi, 2019). In either case however, the policy remains important in the context of South Africa's CIEE – certification under the BBBEE scheme is mandatory for all public entities and companies listed on the Johannesburg Stock Exchange (JSE) and although technically not compulsory for private companies, many choose certification anyway (The Investment House, 2016). Thus, it remains an important policy influencing economic and business affairs throughout South Africa's economic and political landscape.

South Africa's inequality is also impacted by issues of corruption and state capture. Since the first democratic election in 1994, the African National Congress (ANC) won almost two-thirds of the vote[5] and has remained the dominant political party ever since ("South Africa," 2019). The last ANC president, Jacob Zuma was elected in 2009 amid controversy over corruption allegations. These resurfaced again in 2016 along with new charges having to do with mis-use of public funds, money laundering and racketeering resulting in several years of legal and constitutional back and forth ("South Africa," 2019). However, Zuma remained in power until February of this year when he was finally recalled by the ANC and replaced with Cyril Ramaphosa. Zuma's tenure was marked by significant corruption scandals and political controversies, chief among them the issue of state capture due to Zuma's close relationship with the Guptas, a family of business moguls who gained lucrative contracts as well as direct influence over political and regulatory decision-making under his administration (Arun, 2019). Although the results of the state capture caused the disappearance of tens of billions of rand in public money as well as significant damage to the reputation of the ANC and the political system, some argue that the scandal also demonstrated the strength of other institutions – including the independent media, the judicial system and civil society – which led to the eventual uncovering and "rescue" of the state (Arun, 2019). Although the ANC remains in power under Ramaphosa, there are some encouraging signs that the government is attempting to address corruption and state capture through a series of public trials and investigative commissions and measures for improved transparency (Transparency International, 2019).

South Africa has a federal government structure with the three branches of government divided among three different capitols – Pretoria is the seat of the executive, Cape Town the legislative seat, and Bloemfontein the seat of judicial power while Johannesburg is effectively the financial and commercial centre ("South Africa," 2019). The relatively weak federal state is divided into nine provinces: Gauteng, Limpopo, Mpumalanga, KwaZulu-Natal, Northwest Province, Free State, and the Western, Eastern and Northern Cape. These provincial legislatures have a significant degree of authority and can legislate on a range of issues including education, environment, and transport for example ("South Africa," 2019). The federal government meanwhile is split into several different departments with subordinate agencies – of particular relevance to the CIEE are the Department of Science and Innovation; Department of Trade, Industry and Competition; and the Department of Small Business Development. Due to the recent transfer of presidential power, many of these departments have been officially re-named or re-structured. However, this is so recent that these changes have not yet fully taken effect in

[5] This is due in large part to the ANC and Nelson Mandela's role in the anti-apartheid movement ("South Africa," 2019).

some cases. Further important departments, sub-agencies and the relevant restructuring is detailed in Table 4-1 below.

Table 4-1: Selected Departments & agencies of South Africa's national government

National Department	Former Name	Sub-Agencies
Dept of Environment, Forest and Fisheries (DEFF)	Department of Agriculture, Forestry and Fisheries incorporated into the Dept of Environmental Affairs (DEA)	
Dept Higher Education and Training (DHET)		
Dept of Mineral Resources and Energy (DMRE)	Merging of Dept of Mineral Resources and Dept of Energy	Dept of Energy (DOE)
		National Energy Regulator of South Africa (NERSA)
		South African National Energy Development Institute (SANEDI)
Dept of Science and Innovation (DSI)	Dept of Science and Technology (DST)	Technology Innovation Agency (TIA)
		Council for Scientific and Industrial Research (CSIR)
Dept of Public Enterprise (DPE)		Eskom
Dept of Small Business Development (DBSD)		Small Enterprise Development Agency (SEDA)
		Small Enterprise Finance Agency (SEFA)
Dept of Trade, Industry and Competition (The dtic)	Dept of Trade and Industry (DTI)	Industrial Development Corporation (IDC)
		South African Bureau of Standards (SABS)

Finally, cleantech is particularly relevant as South Africa is one of the most industrialized countries in Africa (Pariona, 2018) which means there is significant potential for industrial development and to implement cleantech solutions. The economy relies on several key sectors including agricultural production, natural resource extraction and manufacturing, and international tourism, as well as a well-developed financial services sector and access to intellectual capital (Pariona, 2018; "South Africa," 2019). In particular, the mining industry employs more individuals than any other sector in the country while the manufacturing sector, particularly in the automotive industry is significant as well, with both industries producing primarily for export (Pariona, 2018). This focus on resource extraction and manufacturing is an important aspect of the South African CIEE context as it poses both significant barriers – primarily due to the strength of the incumbent fossil fuel industry – as well as opportunities for cleantech to support resource efficiency, pollution mitigation and sustainable development.

4.2 GCIP and UNIDO Engagement in South Africa

After the initial GCIP pilot project in 2011 was deemed successful, UNIDO was asked to launch a full-scale project in 2014. The GCIP program has since functioned primarily as an accelerator program – hosting competitions, providing mentorship and training to entrepreneurs, providing funding through GEF, and establishing partnerships between private and public institutions in order to further support cleantech innovation and entrepreneurship activities in South Africa (GCIP South Africa, 2018). Due to the success of the pilot, the GCIP programme was also subsequently expanded to include seven other countries (Morocco, Turkey, Armenia, Pakistan, India, Malaysia, and Thailand) (GCIP, 2019). According to UNIDO, "the GCIP [South Africa] Project remains one of the best performers in terms of entrepreneurial innovations and the successful development of their business models" (GCIP South Africa, 2018, p. 2). Furthermore, the country has recently confirmed participation in a new phase of the GCIP to continue developing the cleantech innovation and entrepreneurship ecosystem.

As of 2018, the GCIP program was handed over to a local implementing agency, the Technology and Innovation Agency (TIA) to house and continue implementation of the GCIP program.

However, although a competition was run in 2018, as of writing in the summer of 2019, TIA has not yet begun planning for this year's annual competition. There was significant doubt among the stakeholders interviewed that TIA would have the sufficient drive and organizational capability to successfully run the program this year. Several actors also expressed concern that TIA has expanded the GCIP to also include innovative medical technology, which was seen by some as being beyond the scope of the original cleantech mandate

As a result, and in conjunction with the phase one GCIP's terminal evaluation, it was determined that additional support in South Africa's cleantech innovation ecosystem was needed. Consequently, a proposal for a second phase of the GCIP was submitted this year and received a funding endorsement from the GEF's focal point in South Africa, the Department of Environmental Affairs (DEA). The endorsement for the development of a Project Information Form (PIF) was further supported by the Department of Trade, Industry and Competition (dtic) as well as the Department of Science and Innovation (DSI). Key elements for the development of a PIF include engagement with key country stakeholders to further develop and understand the needs of a second project phase as well as to develop a better understanding of South Africa's cleantech ecosystem. South Africa was thus chosen as the case study for this research to support identification of where such support might be most effective.

5 Results and Analysis

The below sections present the findings and analysis of the two primary sources of data collection. First the indicator-based review of South Africa's CIEE is presented (5.1) followed by an analysis of key outcomes and limitations from the desktop review (5.2). Next, the results of the interviews are provided (5.3), again followed by an overview of the key outcomes and limitations (5.4). Finally, chapter 5.5 provides a synthesis of both data sources to present the final analysis of South Africa's CIEE.

5.1 Desktop Review of South Africa's CIEE

This chapter presents the findings from the indicator-based review of the pillars of South Africa's CIEE. This research was conducted using the CIEE framework identified in the conceptual framework section and the chosen indicators (Ch 3). Pillars were assessed and graded as *weak, moderate*, *strong* or *inconclusive*. Figure 5-1 below illustrates the four different categories used to grade each sub-pillar.

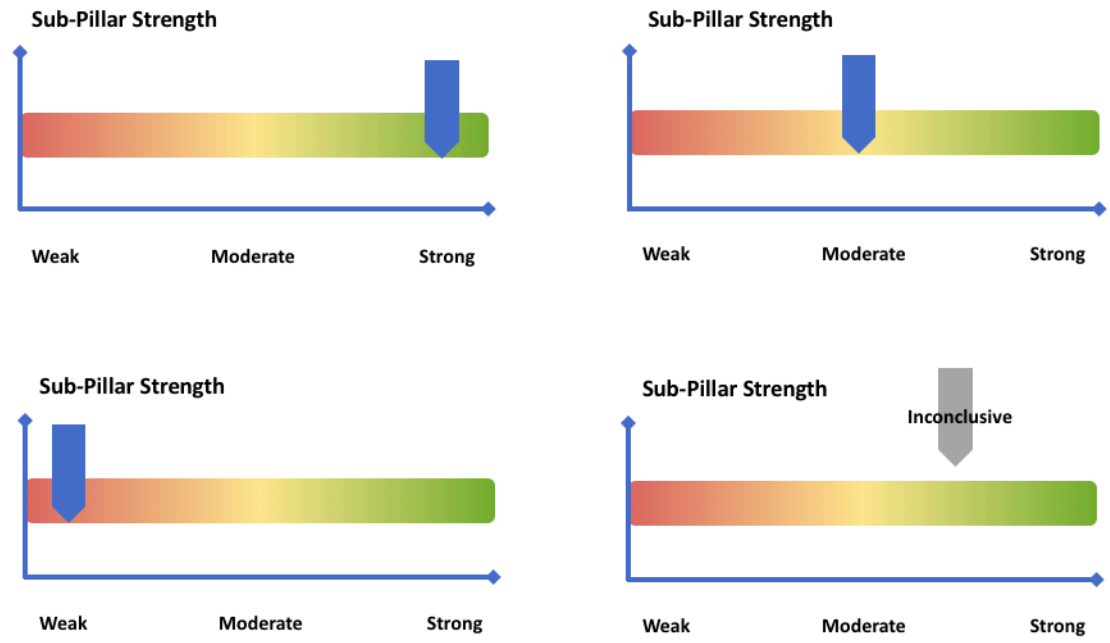
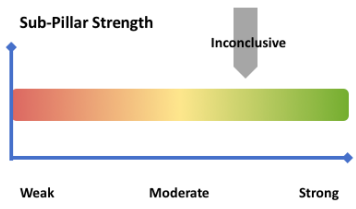


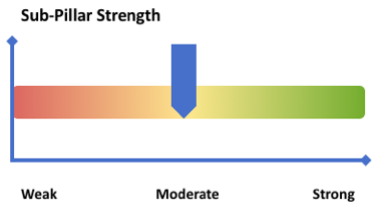
Figure 5-1: Grades used to assess sub-pillars
Based on the indicators and data collected in the desktop review each sub-pillar was graded on a scale of 'weak,' 'moderate,' and 'strong.' Where the indicator data was insufficient to provide a grade, a fourth grade of 'inconclusive' was used.

Assessment of the **Policy and Regulations** sub-pillar was inconclusive. Of the indicators in the framework, almost all of the key policies were present, including a commitment to the Paris Agreement, availability of renewable energy and energy efficiency policies (13 in force currently ("IEA-IRENA Joint Policies and Measures Database," 2018)) as well as incentives, existence of a national agency mandated to support cleantech (Department of Science and Technology, 2018; TIA, 2019) and even a recently passed carbon tax. However, deeper reading of the policies as well as an extremely low Energy Transition Score (114th out of 115 countries) indicated that though key policies were present there was room for concern about the stringency and actual effectiveness of implementation (World Economic Forum, 2019). For example, a review by Climate Action Tracker found that although South

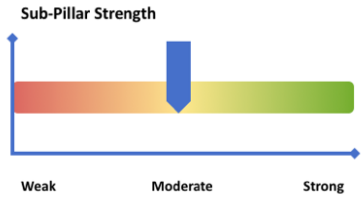


Africa's Nationally Determined Contributions (NDCs) for the Paris Agreement is one of the few which established absolute emissions reductions, the targets themselves were rated as "Highly Insufficient" because they would actually result in a 17-78% increase in emissions from 1990 levels by the year 2025 ("South Africa | Climate Action Tracker," 2019). Furthermore the recently passed carbon tax is unlikely to be very effective as it exempts about 60% of emissions from the base tax with further exemptions until 2022, effectively omitting about 95% of emissions from taxation ("South Africa | Climate Action Tracker," 2019), and although the price is set at a very moderate 120 Rand (about US$ 8.30) due to allowances, the effective rate of the tax is extremely low, between six to forty-eight South African Rand (Al Jazeera, 2019). In terms of environmental regulations, South Africa's Mandatory Emissions Standards (MES) are also extremely low, and allow for ten times the emissions of NO2 as compared to China or Japan, yet most of the old coal plants in South Africa do not even comply with these standards – as a result "Mpumalanga province is the global number one hotspot for NO2 emissions" (Greenpeace Africa, 2018). In addition, of the 13 renewable energy policies and measures identified by the IEA-IRENA, only one was highlighted as a key element of the renewable energy policy ("IEA-IRENA Joint Policies and Measures Database," 2018).

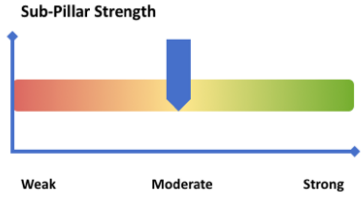
However, in terms of small business policies and incentives, there did appear to be a more robust framework. A compilation of resources put together by a local non-profit indicated the existence of several different incentives, programmes and funds that could be relevant for the small enterprise and cleantech sector such as the SEDA Technology Programme, an Incubation Support Programme (ISP), 12i tax incentive for more investment in manufacturing (particularly energy efficiency), or the Youth Technology and Innovation Fund (YTIF) (GreenCape SA, 2019b; SEDA, 2019). In addition, the existence of several agencies dedicated to small business such as the Department of Small Business Development, Small Enterprise Development Agency, and Small Enterprise Finance Agency appeared to indicate that there is support for entrepreneurs and SME development. However, again it appeared that the degree of engagement and robustness of these organizations and incentives was low, with this information being difficult to find and dispersed across government websites. Furthermore the Doing Business in South Africa report described the government policies and bureaucracy as being " among the lowest-performing factors in an assessment of South Africa's entrepreneurship environment " (World Bank, 2018b, p. 2). It was therefore not possible to determine the sub-pillar strength from the indicators.



The sub-pillar for **Stability and Effectiveness of Governance** appeared moderate in strength, neither particularly strong nor particularly weak. Although the indicators did show some level of corruption (43/100 for Corruption Transparency (Transparency International, 2018) and some weak areas in the Rule of Law index (World Justice Project, 2019)) the strength of legal rights index was moderate (5/12). South Africa's score for corruption has not changed over the years, yet there are recent indicators that perhaps things may be improving – new President Cyril Ramaphosa has been taking additional steps to improve transparency including establishing the Zondo Commission to investigate state capture and a second commission to address corruption in tax administration (Transparency International, 2019). In addition the recently announced break-up of corrupt and failing state enterprises such as the country's only utility, Eskom also seems to indicate at least some level of improvement (National Treasury Republic of South Africa, 2019). The legal framework is also regarded as robust and the judicial branch in particular is perceived as strong and independent (Arun, 2019; OECD, 2017b). Thus, this particular pillar was certainly not strong, but neither did it appear to present a significant barrier for cleantech development.



Market Infrastructure was one of the only pillars for which data was available for all the chosen indicators, however the results were mixed resulting in a grade of 'moderate.' Annual GDP growth rate has been declining since 2011to a present rate of 1.32% according to World Bank data, while 'time required to start a business' was very high at 40 days[6] and 'time required to resolve insolvency' was indicated to take two years[7] (World Bank, 2019d). On the other hand, cost of business start-up procedures was very low at 0.2% of GNI per capita, and global rankings in the Ease of Doing Business and Ease of Starting a Business report both had mediocre rankings (World Bank, 2019a). The 2018 Ease of Doing Business country report for South Africa stated that South Africa's economy is "globally positioned, sophisticated and diversified " (World Bank, 2018b, p. 2) yet also found a wide range of variation between geographic regions. The country's credit rating was classified at a Baa3 level with a stable outlook by the international rating agency Moody's in 2018, however, this was the only one of the three main agencies that did not downgrade the country, Fitch and S&P having graded South Africa at sub-investment grade in 2017 (Cronje, 2019). As of July 2019, Fitch graded South Africa at BB+ with a negative outlook (Trading Economics, 2019). This grading technically puts South Africa in a risky position since a third downgrade would result in South Africa's rejection from the World Government Bond Index, negatively effecting investment potential in the country (Cronje, 2019). As a result, the indicators seemed to show that although developed enough to ensure data availability, trends overtime, and the existence of relatively established and international market, there nevertheless appear to be areas for improving overall confidence and engagement in the market.

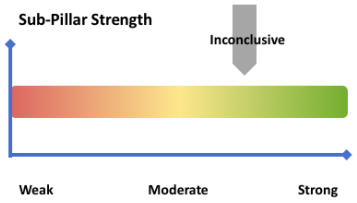


The sub-pillars for **Physical** and **Digital Infrastructure** were both moderate and did not indicate significant weakness relative to other pillars. Access to drinking water/sanitation facilities and electricity were both at about 80% of the population, while mobile cellular subscriptions were also quite high, with many people having multiple phones (156 subscriptions per 100 people). There was no data readily available for assessing the quality of the electricity supply, but access of rural populations to electricity was significantly lower (67.9%) and internet use was also quite low with only about half the population using the internet (56.2%). The wide gap between access to electricity for the total percent of the population (at 84.2%) compared to the significantly lower rate of access for rural areas (67.9% according to 2016 data (World Bank, 2019d)) appears to be reflective of the high degree of inequality in the country and the existence of the huge gap between the "first" and "second" economy. This was further reflected by the Doing Business report for South Africa which identified a gap of nearly 40% for electricity access between geographic regions, effectively putting "them worlds apart " (World Bank, 2018b, p. 5). As a result, the access to electricity services might be quite good in some regions but could also be a significant barrier in others. The Logistics and Competitiveness Index score was also moderate – South Africa was well above average for the region (Sub-Saharan Africa) and though still somewhat behind high-performers like Germany or the US, it was nevertheless relatively on par in each indicator category and appears to have stayed consistent over the years (2007-2018) (World Bank, 2018a). Government spending in these areas appeared grouped under "Economic Regulation and Infrastructure" and was at 101.3 billion R according to a 2019 budget review (National Treasury

[6] Compared to 8 days in Germany and 5.6 days in the United States for example (World Bank, 2019d).

[7] About twice the time as needed in the US or Germany (World Bank, 2019d).

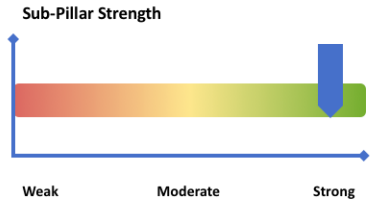
Republic of South Africa, 2019, p. iv) Although the data did indicate that there were certainly areas for improving access to key infrastructure, particularly in terms of equality, it also did not appear significantly weak.



The **Finance and Funding** pillar was also inconclusive as it was difficult to assess –the indicators chosen did not appear very representative of day to day realities. The World Bank (2019d) indicator for lending interest rate ("bank rate that usually meets the short- and medium-term financing needs of the private sector") was quite high at 10.4% which would likely make access to loans for new enterprises unappealing without a high degree of certainty of success. The real interest rate ("bank rate that usually meets the short- and medium-term financing needs of the private sector") and an indicator of demand for credit) was moderate however, at 4.6% according to the most recent data year 2017 (World Bank, 2019d). Account ownership at a financial institution or with a mobile-money-service provider (percent of population ages 15+) was at almost 70% which seems relatively robust and commercial bank branches (per 100,000 adults) also appeared accessible at 10.4 compared to other countries[8] (World Bank, 2019d). There was no data available for amount of venture capital deals or microfinance gross loans, however the MicroFinance South Africa association indicated that about 1100 microfinance credit providers are registered in the country (MFSA, 2019), while GreenCape and Silicon Cape, both non-profits, list a number of existing venture capital firms (GreenCape SA, 2019a; Silicon Cape Initiative, 2018). This appears to indicate that these resources are available. Finally, the Ease of Getting Credit score for the country was at 60 out of 100 and the percent of adults covered by a credit bureau was about 67%, both of which appear moderate. However, additional assessment by the 2017 GEM report for South Africa found that entrepreneurs were "almost three times more likely to exit their businesses because of problems accessing finance, compared to the average for entrepreneurs in efficiency- driven economies" and that "access to finance is a significant constraint for early-stage entrepreneurs in South Africa" (Herrington et al., 2017, p. 7). As a result, the strength of this sub-pillar could not be determined.

The most significant aspect of the **Financial Security** sub-pillar was the very high degree of unemployment and inequality in the country. At almost 27% unemployment and with one of the most extreme gaps in wealth equality in the world, the assessment of this pillar indicates significant weakness. Furthermore because of the high degree of inequality, some of the other indicators, such as GNI per capita or GDP per capita became much less reliable as accurate representations of average values. The indicators for the degree of coverage of social safety nets was also quite low, with the most recent data (2010) indicating that only about 61% of the population was covered. It is also difficult to determine how these issues, particularly unemployment, are actually impacting the degree of innovation/entrepreneurship. In theory, high unemployment could drive entrepreneurship on the basis of need, as individuals seek other opportunities to generate income. Yet entrepreneurial intentions appear to have dropped since 2013 and are less than half of the average for other efficiency driven economies (Herrington et al., 2017, p. 7) indicating that perhaps the CIEE is not adequately enabling on some other level, therefore discouraging potential entrepreneurs. Financial Security was therefore identified as a pillar of significant weakness.

[8] Such as Germany at 12.9 and Sweden at 16.2 (World Bank, 2019d).



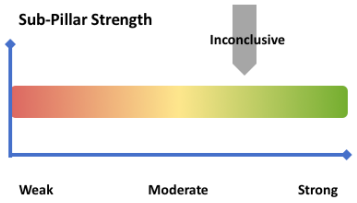
Based on the indicators, the **Education and Human Capital** sub-pillar was graded 'strong.' There did not appear to be a significant barrier in terms of education as a majority of the population had an intermediate education (over 65%, compromising upper secondary or post-secondary non-tertiary education (World Bank, 2019d)), and there were a number of post-school education and training institutions such as universities, colleges and technical institutes. At a total of 487 (Department of Higher Education and Training, 2018; National Government of South Africa, 2019) the availability of higher education institutions appeared robust. Education is compulsory for nine years and migration also did not seem to be a significant factor (300,000 people in net migration). Current education expenditure was at 18.7% of government expenditure as of 2017 (World Bank, 2019d) and of that, R36.5 billion went to higher education and training during the 2016/17 fiscal year, an increase of R2.2 billion from the previous year (Department of Higher Education and Training, 2018). This included Higher Education Institutions (HEIs) such as universities, Technical and Vocational Education and Training (TVET) colleges, Community Education and Training (CET) colleges as well as private colleges. High unemployment was a negative factor and a 2017 OECD report found that "[i]mproving equity and quality of education would boost human capital accumulation and reduce the high levels of inequality" (OECD, 2017a, p. 289). There appears to be at least one university in each of the nine provinces, and 2016 statistics by the DHET found that the majority of higher education graduates were in Science Engineering and Technology (29.1%) or in Business and Management (27.8%) (Department of Higher Education and Training, 2018) which indicates engagement with these topics. As a result, this was again a pillar which probably could be strengthened but seemed strong overall.

The **Research and Development** sub-pillar was found to be 'moderate.' Only 0.05% of GDP was spent on R&D in 2015/16 (Centre for Science, Technology and Innovation Indicators, 2017) and the number of per capita patents (728 ("South Africa Patent applications by residents," 2019)) and total trademark applications (26,251) seemed low (World Bank, 2019d). Of that, only about 6.4% of proportional R&D expenditure went to Environment/Environment Related areas in the year 2015/16 (Centre for Science, Technology and Innovation Indicators, 2017, p. 9). Although this seems low, or it is at least difficult to determine how meaningful this number really is, it is significant to note that funding for the specific area of environment-related R&D is being tracked – indicates the intention to support and develop research in this area. The science journal *Nature* tracks the total research outputs (published articles) authored by individuals from the country in the areas of Life Sciences, Physical Sciences, Chemistry, and Earth & Environmental Sciences, as well as by institutions and found that South African researchers led or co-authored 319 articles, primarily from Stellenbosch University and the University of Capetown[9] (Nature Index, 2019b). Compared to other developed countries this is not very high,[10] but it was similar to other emerging economies indicating that South Africa's research institutions are on par in terms of outputs. The number of full-time employed researchers (51877 FTE/mn pop) and percent of tertiary education graduates in science and engineering (18.49% in 2016 (UNESCO Institute for

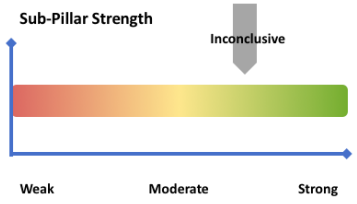
[9] Both these universities are located in the wealthier province of Western Cape, appearing again to indicate a degree of disparity in access to quality research institutions in the country.

[10] Such as such as Sweden with 1619 or Germany with 8360 articles, while emerging economies such as Colombia with 202 or Pakistan with 153 articles (Nature Index, 2019b).

Statistics, 2019)) similarly seemed to indicate that the research field was doing well. More useful however, was the GEM report which indicated that 'R&D Transfer' was very low and one of South Africa's weakest aspects. This indicates that although R&D is well supported, there remains a degree of disconnect in moving this research out of research institutes. As a result, it appeared that this sub-pillar could likely use additional re-enforcement and was graded 'moderate.'



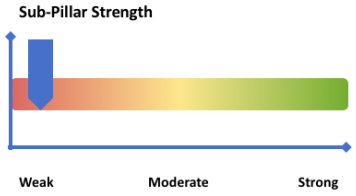
Data available for the **Support Mechanisms** sub-pillar (assessed as inconclusive), was not easily accessible through obvious sources, such as government resources, particularly in terms of any quantitative data such as the number of incubators, clusters or university and industry research collaboration. Moreover, although it was clear that incubators and accelerators beyond just GCIP did exist, it was also very difficult to gain any oversight on how many exist or who ran them – this information was scattered across various websites belonging to both government agencies, private sector and non-profit entities. Such scattered and dispersed resources mean individuals will have a much harder time looking for or learning about support mechanisms. The GEM South Africa report had similar findings in a 2016 survey which found that only 25% of the adult population were aware of the Small Enterprise Development Agency (SEDA), one of the key government agencies for entrepreneurship and enterprise development (Herrington et al., 2017, p. 9). This number only became slightly higher when narrowed to entrepreneurs, with only 38% "indicating that they were familiar with SEDA's offerings and services" (Herrington et al., 2017, p. 9). One source identified 255 organizations with some kind of support programmes for entrepreneurship in Gauteng,[11] most of which provided non-financial support focused on employment generation (55%) due to the high degree of unemployment in South Africa (ANDE, 2018). Of these support mechanisms in Gauteng however, 63% of programmes operated in Sandton, the wealthiest part of Johannesburg, while only 13% operated in the lower income township of Soweto (ANDE, 2018). This indicates at least some degree of barrier in terms of accessibility for lower income communities. As well further research was needed to determine whether this pattern is similar in the rest of the country or how many of these programmes are relevant for cleantech. The research on this pillar overall suffered from a lack of clarity regarding where to go to find these resources. Thus, this sub-pillar was identified as needing significant additional research to better determine the strength or weakness of the pillar.



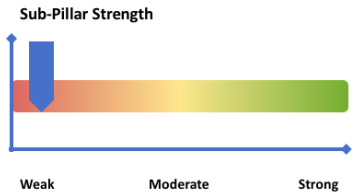
The review of data concerning **Risk Attitudes** was also inconclusive. The indicator for 'Media Attention for Entrepreneurship' taken from the Global Entrepreneurship Monitor's (GEM, 2017) indicators showed that SA had a higher than average score (74.2) compared to the regional average, while just over 69% of those surveyed indicated that they thought entrepreneurship was a good career path, which was higher than the global average. GEM (2018) also found that the rate of 'Perceived Opportunities' was very high and on par with the global average, while 'Total early-stage Entrepreneurial Activity' was also quite high. However, the percent of the population engaged in entrepreneurial activity was only at 0.5% (GEM, 2018) and they found that the entrepreneurial culture in South Africa is a key area that needs to be addressed (GEM, 2017). The 'Entrepreneurial Spirit Index' for the country was also quite low at -0.2% (GEM, 2018).

[11] A province of South Africa and considered the "economic hub" of the country as it contains the capital of Pretoria as well as the city of Johannesburg.

Meanwhile, the Global Cleantech Innovation Index found that the "country lacks a… good entrepreneurial culture" (GCII, 2017, p. 39). The indicators and report data for this sub-pillar seemed to contradict each other, resulting in a grade of 'inconclusive.'



Sustainability Awareness was assessed as 'weak.' Indicators for exposure to pollution were high, while land conservation and the share of renewable electricity generation versus coal power were very low. Mean annual exposure to PM2.5 (in micrograms per cubic meter) exceeded WHO guidelines by more than twice the amount recommended, while the percent of population exposed to levels above WHO guidelines was at 100% according to 2017 data (World Bank, 2019d). PM2.5 exposure appears to be declining somewhat, as have emissions of CO2 (metric tons) per capita while GDP per unit of energy has also been trending up. However, total CO2 emissions have been trending up ("South Africa | Climate Action Tracker," 2019) and the total percent of protected area also declined from about 13% in 2016 to just over 10% in 2018 (World Bank, 2019d). Share of electricity from renewable energy (excluding hydropower) was also at only 1.9% while electricity generation from coal was at 92.7% in 2015 (World Bank, 2019d) which indicates such a high reliance on coal power that cleantech alternatives are unlikely to be broadly available and might face serious resistance from incumbent industry. Media narratives in one source were described as having been nearly non-existent or at least very much side-lined (Joubert, 2018) though the desktop review of climate issues in South Africa resulted in several news articles that appeared to cover climate issues.[12] Finally, a search of the Department of Social Development's non-profit organization (NPO) database (2019) only found about 500 out of 215,308 registered non-profits that had "climate," "environment," or "sustainable" in their name, which seems to indicate that there is not very much activity by non-profits in the sustainability field.[13] The indicator results were thus graded as 'weak.'

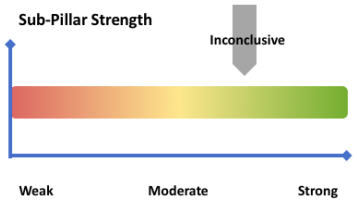


The key **Social Factors** identified for the South African context included black communities, youth and women. These were identified in part with consultation with UNIDO staff, as well as through the focus paid to these groups on government websites and reports. In terms of gender, South Africa seems to be doing fairly well in addressing inequality – non-discrimination in hiring based on gender is mandated by law, while the percent of females employed with advanced degrees was at 79% in 2018, and the total female/male entrepreneurship ratio was found to be .69 in 2017 by the GEM (Herrington et al., 2017; World Bank, 2019d). Although the GEM report for South Africa did find that men continue to be more likely to engage in entrepreneurship, it also found that "the widening of the gender gap noted in 2015 has been reversed, and South Africa once again shows a healthy level of gender parity in terms of entrepreneurial involvement" (Herrington et al., 2017, p. 31). The same report also found an increase in "opportunity-motivated entrepreneurship" among Black South Africans, who make up about three-quarters of the entrepreneurial population as of 2016 (Herrington et al., 2017) which also appears to indicate a positive trend in engagement with previously disenfranchised groups. However, the high degree of inequality in the country and the continued divide between white and black South Africans as well as the government

[12] The finding of many news articles on climate issues was likely influenced by the research topic and search terms used rather than an objective review of such coverage. A thorough analysis of this aspect would require additional research to better understand this indicator objectively.

[13] This may be due to search terms used however that might miss organizations not having these keywords in the name. More time and a better searchable database might yield different results.

focus through policies like BBBEE on previously disenfranchised individuals (PDIs) indicates that this issue is by no means resolved and continues to be a very central issue in the South African CIEE. Regarding youth dynamics as well, the most recent data for the percent of children in employment (between the ages of 7-14) was only available for 1999 which seemed too old to be reliable, while the share of youth not in education, employment or training (as a total percent of youth population) was relatively high at 31.6% according to 2018 figures (World Bank, 2019d). This would indicate that increasing youth engagement in innovation and entrepreneurship programs should be a continued focus. Finally, the indicator for interpersonal trust was also quite low, with only about 23.5% of the population agreeing with the statement "most people can be trusted" according to a 2014 survey (Ortiz-Ospina & Roser, 2019). The sub-pillar was therefore assessed as weak due to the high prevalence of these social issues.



Finally, the **Cleantech Sector Performance** pillar was also quite difficult to assess, primarily because data for some of the indicators was not available and was therefore graded inconclusive. South Africa did not appear to have a national registry of cleantech companies, nor could an accounting of investment in the cleantech sector, number of cleantech industry associations and clusters, or data on venture capital and survival rate of cleantech companies be found. However there was available data for some of the other indicators – the number of certified B Corps was only at 8 ("Directory | Certified B Corporation," 2019) while there were 1230 current ISO 14001 certifications (ISO Technical Committee 9, 2019). The OECD database for Patent Indicators had data available for South Africa and found that in 2015, 14.53% of technology patents were environment-related technologies, the majority of which were in "climate change mitigation technologies related to energy generation, transmission or distribution" (OECD, 2019). The number of renewable energy jobs was also tracked by IRENA, who recorded 42,900 jobs in the renewable energy sector, the majority of which were in solar photovoltaic (IRENA, 2019). Finally the Global Cleantech Innovation Index (GCII) ranked South Africa at position 31 out of a total of 40 countries with a score below the global average in terms of inputs and outputs of cleantech innovation (Sworder et al., 2017). This low assessment was due primarily to a lack of "evidence of emerging cleantech, especially shown in the low number of filed cleantech-related patents and low showing of successful cleantech start-ups" and a low score in the category of commercialised cleantech (Sworder et al., 2017, p. 39).[14] As a result, although there appears to be a nascent cleantech industry, the strength of this pillar was 'inconclusive' based on the indicators.

5.2 Key outcomes and limitations of the Desktop Review

Of the 14 sub-pillars, there were several which were identified to be weak or inconclusive and in need of additional research. Seen in Figure 5-2 below, these included the sub-pillar for Policy and Regulations, Financial Capital, the sub-pillars for Research and Development and Support Mechanisms, as well as the three Culture sub-pillars, and finally pillar for the Cleantech Sector. In particular, it was difficult to determine from the indicators to what degree the existence of certain factors (such as a policy or support mechanism) actually facilitated cleantech innovation and entrepreneurship. The desktop research also struggled due to the fragmentation of

[14] The GCII ranking includes a wide range of countries (from Nordic frontrunners like Sweden and Denmark to emerging economies like Brazil or Indonesia, so ranking of South Africa on this scale is perhaps not ideal for assessing this pillar in the context of developing countries.

information across multiple agencies and actors in the ecosystem – in terms of understanding actor roles and where to find certain resources, such as funding or incubators, there appeared to be very limited transparency and even conflicting information. The full table of sub-pillars, indicators and the indicator data can be found in Appendix I.

Areas identified for further research:

- Policy and Regulations
- Financial Capital
- Knowledge Networks
  - Research & Development
  - Support Mechanisms
- Culture pillars
  - Risk Attitudes
  - Sustainability Awareness
  - Social Influences
- Cleantech Sector

Figure 5-2: Areas for further research in South Africa's CIEE

Overall the desktop review was quite useful for developing an overview and high-level understanding of the South African CIEE. It was also a useful deep dive into the current events and key issues facing the country currently, which are undoubtedly important for understanding and assessing the cleantech ecosystem. However, there were also some key shortcomings to the desktop review – it was quite time-consuming to collect data for all of the indicators, and it was not always clear what significance individual indicators had. The indicators only became meaningful in the context of broader research or other published data which were able to provide context for the individual statistics. For example, an indicator providing share of government spending for a sector like 'Education' or 'R&D' was relatively meaningless in that it provides no indication on its own of whether this is a sufficient amount and whether that money is being spent effectively. Instead additional context, assessment by third parties or at least comparison to government spending in other sectors or countries, was needed in order to draw any kind of conclusion. A further limitation was that the data was not always available or accessible, which meant it was necessary to either skip that indicator or use available data to find a proxy. This could be quite time consuming as well since it became very easy to get bogged down looking for the required additional research.

Furthermore, although the indicators were initially included to serve as an objective and quantitative data point, the overall process of interpreting these data points relied on additional context and drawing conclusions based on individual assessment of the pillar overall. The limitations of the indicator approach are further discussed in chapter 6.1.1.

As a result, the review of the indicators became comprehensive desktop review of available data and reports, for which the indicators themselves were a guideline. Rather than the framework's indicators alone producing results, ultimately it was the whole process – both collection of indicator data as well as the reading of reports, indexes, news articles, government websites and other sources – that resulted in an initial assessment or even more broadly, an impression, of the pillars and where additional research or follow up would be needed.

5.3 Stakeholder Interviews on South Africa's CIEE

Interviewees were asked to identify the most significant barriers for cleantech innovation and entrepreneurship from their perspective. From these conversations, several key themes emerged regarding particular barriers which were repeated by multiple interviewees. Figure 5-3 below sorts the barriers identified by interviewees according to the framework's themes as well as the additional theme of Ecosystem Interactions. Under each theme there were multiple sub-themes which add up to total number of times the pillar was identified as a barrier. In addition, some

of the interviews also provided additional nuance for certain aspects based on their specific perspective.

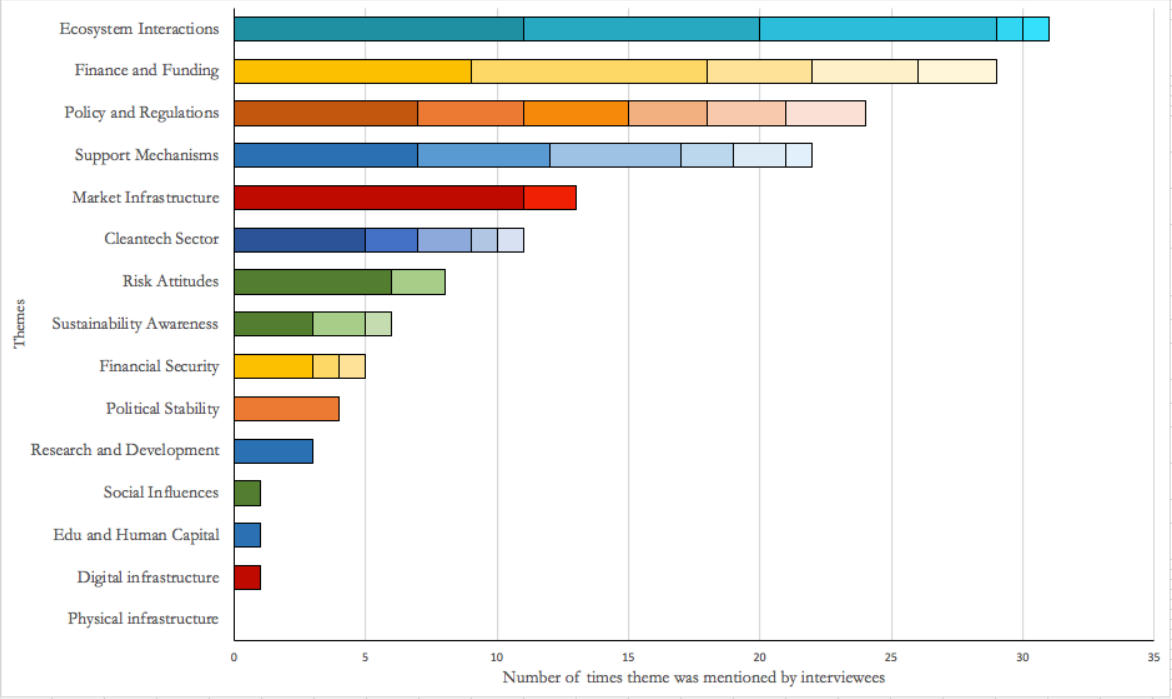


Figure 5-3: Key barriers in South Africa's CIEE as identified in the interviews

Results of the interviews were sorted into the framework's pillars as well as the additionally identified category of the Ecosystem Interactions. The x-axis corresponds to the total number of times each theme was mentioned by interviewees. The barriers were further sorted into sub-themes within each of the categories and are indicated by the colors in each bar – some sub-themes were identified more often as key barriers. The table of the data can be found in Appendix II.

A key theme that emerged was that the innovation ecosystem in SA is well-developed but very fragmented with no single actor having a thorough overview of existing actors and programmes. The issue of coordination and lack of oversight was repeated by a majority of interviewees (11 of 20) and was one of the most commonly mentioned barriers. This was a problem that seemed to be an issue no matter where in the ecosystem an individual was – whether for someone working at TIA, running a cleantech incubator or an individual seeking to commercialise an idea. According to several of the individuals interviewed, this led to a significant amount of overlap in some areas and yet left gaps in others, resulting in an overall inefficient ecosystem in which finding information for both individuals and organizations was exceedingly difficult. Similarly, 9 of the interviewees expressed the view that this problem was compounded by a misalignment of targets and that better coordination of metrics for measurement was needed, while 9 out of 20 also found that the purposes or goals of different actors in the system were not aligned, leading to further problems of coordination.

Views regarding adequacy of amount of funding were mixed – some actors, such as the individual(s) from the NCPC and Climate Innovation Centre, as well as one of the interviewed entrepreneurs, felt that there was a need for more funding in the system overall, while others, such as the interviewee from the DTI, a former SEDA employee and GCIP mentor, as well as the other entrepreneur interviewed, felt that there is enough funding already in the system, and

that the focus should be on better utilisation of existing funding. Still others (including the interviewees from dtic, SEDA, WRC, and Impact Investment South Africa) indicated that they felt there was a lot of funding but perhaps there could be more within particular areas, such as for commercialization or longer-term projects specifically. Yet there was strong consensus among these interviewees that *access* to funding and knowing where to *find* funding was the biggest barrier – 9 out of 20 found that there was a lack of access to funding, while only 4 indicated a need for more funding, and 3 found that existing funding was not effectively utilized. As well, multiple actors (9 of 20) mentioned that the innovation and entrepreneurship ecosystem overall, particularly in terms of funding, was very risk-averse when it came to supporting innovations that require longer turn-around time and are newer, less tested, and more disruptive. This applied not only to banks for example, but also to other agencies or donors, which resulted in little private sector engagement according to the interviewee from TIA. It was also repeated that this risk aversion was due in large part to the funding system as well as the targets and incentives provided, which incentivize short term projects with a quick turn around and which quickly provide jobs – cleantech projects however, can take up to five years or longer to develop a product according to several interviewees (NCPC, GreenCape, TIA), mainly due to hardware and technical needs, and generally don't produce a lot of jobs. It was suggested that this problem could possibly be mitigated with better technology validation and re-evaluation of investment strategies and metrics.

Several interviewees (7 of 20) also identified a gap between incubator and accelerator programmes supporting projects and then having support mechanisms to help these projects actually get to commercialization. In particular, finding the first few paying clients was identified as a difficult step that could use additional support, especially in terms of helping individuals to network and find partners or clients. Several interviewed actors (CIC, dtic, Eskom) indicated that establishing a better pipeline – that is some manner of tracking or publicising current up-and-coming enterprises – as well as coordination between industry needs and research/innovation centres might facilitate better access for innovators and/or entrepreneurs to find markets, as well as facilitate industry to find solutions. Along with the lack of oversight, the issue of accessing markets and finding a buyer was the other most commonly cited barrier with 11 out of the 20 interviewees indicating that access to markets and clients to commercialize cleantech solutions was very difficult.

Furthermore, although most interviewees indicated that there generally are relevant policies and/or incentives in place for clean energy, energy efficiency and small business, there was less consensus about how well implemented these truly are and to what degree they are effective. Policy was one of the most frequently mentioned areas that could be strengthened although the sub-reasons for this varied, including: inadequate policy or policy that was missing from the regime (4/20), ineffective policy that was not translating into intended outcomes (7/20), relevant support policy that exists but is not well implemented (3/20), and an overall incoherence or conflict within the policy regime as a whole (4/20). Three of the interviewees also found that cleantech needed to be better prioritized within the policy regime, and three more found that the policy and bureaucratic processes were too slow to effectively facilitate cleantech development. Regarding policy coherence, one actor (GreenCape) pointed out that many policies are simply out-dated and require significant overhaul to be become relevant.

Further key takeaways from interviews included:

• Several actors, particularly government agencies (dtic, DST, SEDA, DOE and Eskom) identified several similar areas of interest for cleantech innovation, including energy efficiency, water issues, and grid stabilization technologies as well as industries to replace coal in mining- and power-plant-towns. These areas were repeatedly indicated as areas of priority for innovation that would benefit South African communities and industry.

• Job creation was a high priority for many actors due to high unemployment in South Africa, particularly with a focus on previously disadvantaged individuals (women, black communities, and youth).

• Cleantech as a sector needs further development – there is currently no registry of cleantech companies or oversight of the cleantech sector. This would be facilitated by more coordination and communication among key actors to determine goals and metrics to measure progress.

• There was a general sense (even where this was not directly stated by interviewees) that the actors in the ecosystem overall are well-intentioned and that there is a strong desire to support cleantech innovation and entrepreneurship. However, there are resource, time and implementation barriers in the day-to-day implementation of these objectives and programmes, particularly within government agencies.

From the interviews conducted, observations were collected regarding the fourteen factor sub-pillars in the CIEE. In addition, three key areas that were not part of the original CIEE framework were also identified as key factors due to the high degree of repetition. Table II-2 in Appendix II provides a summary these findings by CIEE framework sub-pillars. Appendix II also contains a table (Table II-2) of the themes and how many interviewees indicated specific sub-themes as barriers.

5.4 Key outcomes and limitations of Stakeholder Interviews

The key barriers identified by the stakeholders interviewed were:

- Difficult or ineffective coordination and a lack of oversight as to which actors were responsible or active in different areas of support along the commercialisation value chain (11 of 20)
- This problem was compounded by a misalignment of targets and a need for better coordination of metrics for measurement (9 of 20)
- The purposes or goals of different actors in the system were not aligned (9 of 20)
- There is a lack of access to funding (9 of 20) in the CIEE even though funding does seem to be available.
- The innovation and entrepreneurship ecosystem overall seems to be very risk-averse when it came to funding or investing in new, innovative and untested cleantech (9 of 20).
- Accessing markets and finding a buyer for cleantech solutions is a key barrier for commercialising cleantech (11 of 20).

The interviews were very helpful in developing an insight into the underlying causes of the above-mentioned barriers and how many of these issues come from the influence of other problems. However, the interviews were also limited in that they relied very much on the perspectives of single individuals within the organizations mentioned. Most were from organizations based in Pretoria and Johannesburg, which are two of South Africa's most well-developed urban centres, with well-developed infrastructure, the home of the financial sector, and many government agencies. Furthermore, the majority enjoyed a wealthier and more privileged position with good jobs or positions of relative power and standing. This means that the cross-section of interviewees may be missing important perspectives from more rural and low-income communities as well as from a broader range of geographic locations. For example,

physical and digital infrastructure, although two important sub-pillars of the infrastructure category, were not identified as barriers to CIEE by the interviewees. The desktop review however, identified problems with a history of rolling black outs and uncertainty over the future of the country's monopolizing utility, Eskom, which would appear to make these relevant issues. Instead, more nuanced problems seemed to be perceived as the key barriers – interactions between agencies and even interpersonal dynamics within and between organizations.

In a sense, this might indicate that South Africa is too developed for the framework because these basic issues are no longer key problems. However, based on the limited cross-section of interviewees, instead it may be that the issue of access to electricity was not a problem encountered by the individuals interviewed. None of the interviewees represented rural areas or the poorest demographic, which unfortunately continues to experience problems with access to electricity, clean water, increased crime rates and issues of food security according to the desktop review.

5.5 Synthesis Assessment of South Africa's CIEE

Generally, there was a relatively strong degree of overlap between the qualitative descriptions of different factors provided by interviewees, as well as the findings from the framework desktop review. However, the interviews undoubtedly provided a deeper and more nuanced view of several factors – such as policy environment and funding – as well as drew attention to the very important aspect of interactions between these different factors and actors. The additional themes around ecosystem interactions, purpose of the ecosystem and issues of metrics or targets were all not sufficiently captured in the original CIEE framework yet were clearly very important in the case of South Africa. Overall then, the conceptual theory in the framework seemed to do a good job capturing the barriers in South Africa's ecosystem, but is missing consideration of the linkages in the ecosystem.

As indicated in chapter 1 there were two key elements of testing the framework:

1) whether it provides an assessment of the ecosystem which reflects the real-world circumstances and complexities in an appropriate manner (appropriateness); and
2) whether it provides information that helps to identify barriers and drivers in the ecosystem that could be supported with interventions (usefulness).

In comparing the interviews and the results of the desktop review the appropriateness of the framework seemed relatively high, although with the important limitation of interactions in the ecosystem, which appears to be an important addition to the framework. Overall though, the findings from the desktop review seemed to reflect the findings from the interviews and vice versa. For example, policy in the desktop review was inconclusive because it was difficult to assess the effectiveness of the policies even though the relevant policies existed within the regime. This matched the findings of the interviews which similarly found the policy regime to be ineffective. The lack of cleantech sector data was also mirrored in the lack of oversight of the sector among interviewees, while education and human capital was graded as a strong pillar and was not really mentioned as a barrier. The results of the framework's assessment of Market infrastructure, which was graded as moderate due to the mixed results of the indicators, also aligned with the interviews since it was not the markets itself but rather the access which was identified as a barrier.

More accurately though, it seems that both methods of data collection provided valuable insights that the other method may have missed – for example the indicators picked up on the high degree of inequality while the interviews provided more nuance for understanding the

effectiveness of the policy regime. This would appear to make a strong case that both methods together are needed to provide a robust, thorough and appropriate assessment.

Regarding the usefulness of the framework, the results would appear to echo the above: for the most part the framework certainly helped provide information to identify key barriers and strengths in the ecosystem, but again the aspect of ecosystem links and purpose of different actors was missing.

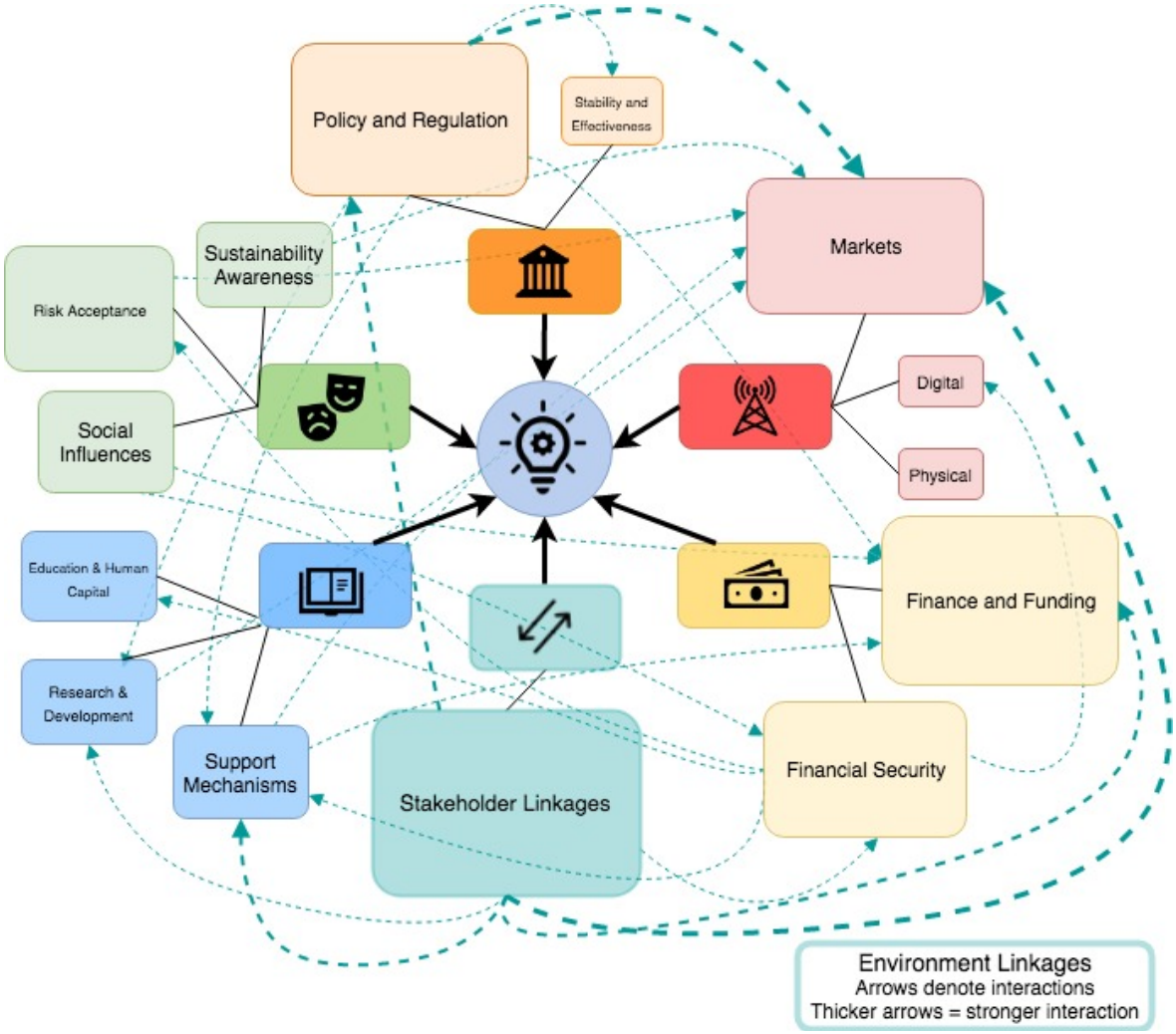


Figure 5-4: South Africa's CIEE
The figure is intended to be illustrative of the complexity of South Africa's CIEE based on the data from the desktop review and interviews. The size of the boxes denotes degree of significance of a pillar as a barrier, while the arrows indicate interactions between aspects. Thickness of arrows denotes significance of the interaction. The figure is purely meant to be illustrative of the complexity of the ecosystem and does not capture all of the interactions.

Figure 5-4 above visualizes the assessment of South Africa's CIEE. Based on the improved CIEE framework, the sub-pillars or factors in the ecosystem are compared relative to each other based on a combined synthesis of interviews and the desktop review. The size of the sub-pillars indicates significance of the factor as a barrier in the CIEE. The dotted arrows reflect key ecosystem interactions and thicker arrows represent stronger interactions. As can be seen in the web, no single pillar is barrier by itself. Instead, barriers identified in one pillar were linked to barriers or factors in other pillars. Figure 5-4 is intended to be illustrative of the complexity of

the CIEE and highlights some of the key aspects and interconnections, rather than explicitly capturing all of the results described in previous sections.

The below section provides a synthesis of the results in order to answer research question two regarding the state of South Africa's ecosystem, as well as to help identify the barriers and strengths in the CIEE to answer the third research question.

5.5.1 Key Ecosystem Factors

The key barrier in South Africa's ecosystem is the **Ecosystem Linkages** pillar, due to a lack of interactions between actors in the ecosystem. The interviews conducted in particular identified this barrier, however even the desktop review found that it was difficult to find information about available support mechanisms. Most of the pillars themselves are relatively strong and much of the necessary resources in terms of funding, research, infrastructure and even intention to support cleantech, appear to exist. However, because these pieces are scattered across different agencies and organizations and there appears to be little practical communication between actors, individuals who seek to engage in cleantech entrepreneurship and innovation encounter significant barriers due to a lack of transparency, a high degree of bureaucracy and red-tape, as well as confusing and unintuitive processes. This results in difficulties getting funding from different sources to reach eligible projects, connecting innovators with potential clients, and an inefficient allocation of time and resources where different actors are providing the same services. These aspects also result in increased difficulties measuring the progress of development of the cleantech sector. According to interviewees relevant agencies within the ecosystem may mis-direct projects to the wrong organizations, or entrepreneurs finish one accelerator programme only to realize they are not sure where to go next. This also results in duplication of efforts by multiple organizations and agencies – many of which provide the same services – which results in double funding some support roles while leaving gaps elsewhere. In addition, interviewees also suggested that besides adding difficulty for individuals and organizations to find information or resources, available funding is therefore not being effectively targeted.

Without effective collaboration between actors, there is also a lack of alignment as to the purpose or goal of cleantech innovation and entrepreneurship. Some actors in the system, such as the Small Enterprise Development Agency (SEDA), have a mandate which views entrepreneurship as vital for growing jobs and thus measures its programmes, including cleantech initiatives, based on the number of jobs created. Other actors, for example the Industrial Development Corporation (IDC) or the Department of Trade, Industry and Competition (dtic), view cleantech as a source of new solutions for industry; while some NGOs like GreenCape or research institutes want to see impactful and disruptive clean technologies developed. In theory, cleantech can be all of these things. However, different goals and a lack of communication among different actors leads to ineffective or patchy support in the ecosystem. For instance, the Climate Innovation Center (CIC),[15] was set up with a pre-commercialization phase for projects of only a year – this timeframe was originally designed for IT start-ups, but these can generally be developed much faster than cleantech due to their lower material and technical needs. Similarly, Invotech[16] faces requirements to spend only 3 months on the incubation period for projects, at which point the project is expected to have a full business and achieve a turnover of R40,000 within the first quarter. These projects are then expected to exit the program after 18 months. Though these targets are considered "unscientific

[15] A cleantech incubator based in Gauteng.

[16] An innovation and business incubator based out of the Durban University of Technology.

and uncalculated" by one interviewee, the Invotech team is pushed to meet these goals in order to receive continued funding from SEDA. As a result, cleantech companies are exited from the support program before they are ready, potentially jeopardizing commercialization and success of the project. The GreenCape interviewee as well as a former GCIP-mentor and SEDA employee, also identified disincentives created by these metrics and targets – either because "bad" ideas are facilitated by a programme in order to meet targets (but effectively waste resources as they may not be viable ideas) or because progress is measured based on what the agency does (such as the number of projects assessed or registrations filled out) rather than by the success or progress of the participants. This was linked to SEDA's mandate to drive job growth and enterprise development. Yet this goal may come at the expense of effective cleantech support due to a lack of understanding that cleantech likely requires more time and funding than other sectors.

These missing or weak ecosystem linkages also impact the strength of the **Market Infrastructure** pillar. Incubators and support programmes are often limited in their capacity to support a project along the full value chain – for example the CIC does not cover ideation and prototyping and focuses on scaling up the business, while Invotech supports primarily the ideation phase. An area that appears to be a significant gap in the ecosystem is thus the commercialization phase, and particularly support to help cleantech enterprises find clients and a market. It is difficult however, to fully assess the degree of this gap due to the lack of oversight in the ecosystem. Several actors also expressed the view that better coordination between these support organizations and industry partners could help develop these markets – providing the pipeline development or creating linkages between industry and corporate needs for innovative tech solutions could help commercialize technologies. Similarly, more targeted research and development, as well as better coordination between research institutes and industry or private sector partners could help innovative research commercialize. One actor expressed the view that though there is a lot of good research conducted in South Africa, nothing is being done with it. This was similar to the results of the **Research & Development** sub-pillar, which also found aspects such as funding for R&D or research employment to be fairly strong, but which was weakened by a very low indicator for Research Transfer. Better collaboration between innovators and private sector parties would therefore help facilitate cleantech access to markets. Important to keep in mind however is that incumbent industry may also present a barrier. The interviewee from the GEM pointed out that the South African retail market for example, is dominated by three or four companies, while there are also several state-owned enterprises with monopolies (such as electricity utility Eskom). Although well-established industry can be a useful partner for commercializing cleantech, dominant industry players may also make it difficult for small companies to compete or may present barriers to commercializing more disruptive and competitive types of technology.

Market infrastructure was also identified as a barrier due to a generally low level of **Sustainability Awareness**. Cleantech products on the market must compete with existing products, and South African consumers were described as unwilling to pay a "green premium." Consumption of "sustainable" or "green" products is not a significant market in South Africa, and one actor indicated that only Greenside (a suburb of Johannesburg) and Capetown were areas with "a real green attitude." The interviewee from the DOE also pointed out that the huge gap in wealth significantly impacts the willingness and ability of individuals to be green consumers. A lack of strong media narratives as well as well-enforced pollution regulations and climate action, no doubt contribute to a weak awareness of environmental issues. As a result, cleantech products must work even harder to reduce cost-barriers and differentiate their products, as well as face a well-entrenched incumbent industry. However, environmental awareness seems to be improving and several actors also expressed positivity regarding the development of more eco-conscious consumers. In particular, key issues such as water efficiency due to increased drought periods, air pollution from coal, and the advantages of

renewable energy to stabilize an unreliable electricity grid seem to be encouraging signs of a general shift in attitudes. Continuing to support environmental education and raise awareness of how consumer choices and actions can impact sustainable development thus remains important for further driving the innovation and uptake of cleantech solutions.

Finance and Funding was also an area that was not weak in itself but appears negatively impacted by other factors. Although there was some disagreement, many actors indicated that there is sufficient funding in the system to support cleantech. However, often finding the funding is difficult because there is little oversight of relevant funders in the ecosystem. Seed funding for example was described by the CIC interviewee as "catalytic" for cleantech projects but that it is hard to find and takes a long time to receive. Furthermore, the lack of transparency and duplication of different services by multiple actors, led to the conclusion that the funding which does exist may be poorly used. This is further compounded by the issue of misaligned targets and requirements placed on implementing agencies – the interviewee from GreenCape again pointed out that many funding agencies (such as SEDA) have too many requirements for implementing partners. Excessive reporting requirements for example, can drain resources that would be better spent directly on projects. A further factor impacting the funding environment, is the high degree of risk aversion, especially in the financial community. Several actors described barriers due to a financial system which prioritized investing in projects with short timelines, predictable returns and measurable impact. Cleantech however, generally requires a longer timeframe to develop and get a return on investment, and the more innovative or potentially disruptive the technology, the riskier the investment. Impact investing and venture capital are not yet well developed in South Africa (according to the interviewee from Impact Investing South Africa), while traditional banks were described by the interviewee from GEM as relying on asset-based assessments for providing loans rather than risk-based assessments. This effectively incentivizes existing businesses rather than innovative ones without collateral or history. Driving investment in green projects to help demonstrate to funders that the risks of such projects is mis-priced, was identified as an important action by the GreenCape interviewee.

A further key factor, which also impacts as well as is impacted by several of the others, was the **Policy and Regulations** sub-pillar. There was substantial consensus from both the desktop review and the interviews that although relevant policies exist, they seem to either be poorly implemented, not stringent enough, or ineffective due to a lack of overall policy coherence. The indicators for political commitment to climate change mitigation, such as NDC goals under the Paris Agreement or carbon pricing, were met based on the indicators. Yet when further assessed, the actual commitments of these policies are mediocre or even missing altogether. The desktop review found that South Africa's NDCs were found to be "Highly Insufficient" ("South Africa | Climate Action Tracker," 2019) and the effective price of the carbon tax is only a few rand, matching interview findings – the interviewee from the dtic stated that "South Africa likes to brag about taking a leading role in climate negotiations, but implementation is lacking." Several examples were described in the interviews, such as an Eskom interviewee who recounted the following conflicting policy: The Department of Environmental Affairs (DEA) mandates carbon emission reductions, yet the DTI levies a significant import tax on electric vehicles; while Eskom is required to comply with emission reduction standards, yet the DOE allocates all of the available renewable energy connections to independent power producers (IPPs). Similarly, mandatory emission standards which are not complied with and an electricity sector with 92.7% of electricity generation from coal (2015 data, (World Bank, 2019b)) do not present persuasive arguments that South Africa is taking climate mitigation seriously. An interviewee engaged in climate activism in South Africa, also described a very disappointing renewable energy policy – although incentives for REIPP exist, grid connections are capped at an extremely low amount, effectively limiting the expansion of renewable energy by independent producers. Specific subsidies for cleantech or sustainable agriculture were also seemingly missing according to one interviewee as well as the desktop review. The influence of incumbent industry and labour

unions keen on maintaining the status quo were described by a few actors as at least in some part responsible for this lack of effective climate action.

Policy also seemed to be an issue in other regulatory areas. Public procurement was specifically mentioned several times as a barrier – regulatory barriers as well as the risk aversion discussed above, limit the potential of public entities to be markets for cleantech. From the DOE's perspective for example, cleantech must be commercially viable and affordable before it can be procured from a regulatory perspective. The interviewee from the dtic also mentioned that banks often insist on procurement from established producers rather than cleantech start-ups – again reflecting risk aversion to new and innovative technologies which may lack credibility. Yet according to interviewees from the CIC, dtic, and the DSI, public procurement could be a significant market for new technologies and better regulations to help prioritise cleantech innovations could be very helpful in providing market access. The need for policy changes around education standards, unbundling of Eskom (to address the issue of who can generate electricity), bureaucratic red-tape for starting a business, labour laws which make firing individuals difficult and increased policy support for social innovation were all also mentioned as necessary policy updates. As a result, the policy environment overall could be strengthened—as the GreenCape interviewee put it, systemic policy reform is required not necessarily because the changes are contested, but rather because many policies are outdated or no longer reflect current priorities.

The final key influence, and perhaps the most complex in the ecosystem, is the extreme degree of inequality, categorized under the **Financial Security** pillar. Although rarely explicitly mentioned as a barrier by interviewees, the desktop review flagged the extreme wealth gap and this issue was often implicit in the issues discussed by stakeholders. For example, it was reflected in the difficulty of expanding the GCIP program to rural areas. Interviewees from GreenCape, GEM, NCPC, Invotech as well as one of the entrepreneurs all indicated that expanding programme access and resources to rural areas would be very difficult. The DOE and Eskom interviewees also touched on the issue of inequality in their assessment of the affordability of sustainable technologies (such as EVs), energy security and electricity prices, as well as socio-economic issues tied to the coal industry. The mandates of government agencies focused on addressing job growth and empowering youth, women and black communities as well as the lack of sustainability-oriented consumers all reflect the deep divide between the two different worlds in the country. The socio-economic realities of this huge wealth gap and high degree of unemployment are thus an underlying factor for many (if not all) of the other factors and should be kept in mind when developing support programmes.

The intersection of these factors, as well as the others not explicitly discussed here, are all influences on **Cleantech Sector Performance** in South Africa. It appears that a strength of South Africa's CIEE is the existence of many well-established institutions, an awareness of the benefits of cleantech development among ecosystem actors, and a stated intention to support cleantech innovators and entrepreneurs. However, the cleantech sector itself remains obscure and not well-defined. For example, there is no real oversight of current or developing cleantech projects and no single agency or resource which functions as a comprehensive repository of resources or effectively tracks the development of the cleantech sector. There is thus a need to better align intentions with results and actions across the ecosystem to overcome barriers and effectively drive cleantech uptake.

6 Discussion

There were several important realizations that came from applying the framework in a practical context, rather than as a purely academic theory. These considerations are discussed further below in chapter 6.1, as well as how they were subsequently addressed in the updated CIEE framework presented in 6.2. Chapter 6.3 also presents the policy recommendations for South Africa, and chapter 6.4 and 6.5 conclude with reflections on the research methodology as well as remaining limitations and areas for further research.

6.1 Improving the CIEE Framework

6.1.1 Are Indicators Adequate?

The first key issue identified was the amount of time it took to track down indicator data for all of the pillars. Consultation with UNIDO staff during the project was initially very focused on incorporating "Recommended Indicators" into the framework. The initial thinking was that this qualitative data would lend validity to the framework. However, once the recommended indicators had been chosen and the desktop review completed it became clear that the indicators were far less helpful than expected, not only because they were time consuming and required some kind of further context to really make sense, but also because they may actually guide the user to look at specific data sets rather than the actual aspects of a CIEE. Including indicators, even if only recommended, may guide the user to focus on that particular data, rather than thinking about the context of a country and getting the unique information needed to assess each pillar. Furthermore, identifying indicators in these types of frameworks, particularly in a UN context, may also create an inappropriate focus on a specific type of dataset. UNIDO staff later noted that indicators can become "trending" even when that data may not actually be an ideal measure of the issue at hand, leading to misleading or unnecessary data collection.

At first this seemed to indicate that cutting down the framework in some way – perhaps by cutting out indicators could be useful. However, although a qualitative assessment based on interviews no doubt provides important nuance, it may nevertheless miss important aspects for two reasons: 1) the type of actors interviewed will influence the type of answers given which may result in some things being omitted; and 2) even where a thorough cross-section of stakeholders is interviewed, it is possible that some issues may be forgotten or overlooked either by accident, due to personal bias, or because they seem too obvious a problem. South Africa's deep degree of inequality is almost certainly an important aspect of the CIEE and an underlying influence of other barriers. Yet it was not indicated as a key problem by interviewees, most likely because it is taken for granted. From the outside perspective, relying on only the interviews might have resulted in overlooking this very important influence on the CIEE and any intervention measures taken.

To avoid this problem, or at least mitigate it, after consultation with UNIDO staff the framework was refocused to centre around the "Key Questions" for each sub-pillar. Rather than focus on the indicators – which can be viewed as the potential answers to the question of how strong a pillar is – the framework was reworked to focus on a set of questions that would allow the user to best assess the pillar and instead search for whatever relevant data is needed to answer this question. The recommended indicators for this sub-pillar were still left in the framework for reference.

An example can be seen in Table 6-1, and the final Key Questions and Sub-Questions for each sub-pillar can be found in Appendix III.

Table 6-1: Example of updated framework

Key questions, sub-questions and recommended indicators for the Policy and Regulations sub-pillar

Sub-Pillar	Key Question	Sub-Questions	Recommended Indicators
Policy and Regulations	Does the policy framework support entrepreneurship and cleantech/sustainability innovation and SMEs?	To what degree does the policy framework support entrepreneurship? Innovation? Cleantech and/or sustainability? - Which policies are in place and what are their main objectives? Which policies are under development and what are their main objectives?	NDC Commitment (Paris Agreement) Key Energy Policy (Cleantech Friendly policies): Energy Efficiency, Renewable energy, Environmental regulation Carbon Pricing Energy Transition Index Score Existence of Cleantech specific regulations and/or targets Small business regulation/policy and SME incentives Existence of National Agency mandated for cleantech
		Are there any policies (or lack of policies) which seem to pose barriers to the cleantech ecosystem? Are there policies which seem to work particularly well?	
		Is the policy support for cleantech (for example regarding energy efficiency, renewable energy, climate policy) sufficient? Is it well-implemented? - Do the policies in these sectors effectively drive renewable energy growth, uptake of energy efficiency, or achievement of climate targets? - Do policies in these sectors effectively drive resource efficiency?	
		Is the policy support for entrepreneurship and SMEs sufficient? Is it well-implemented? - Do the policies in these sectors effectively help incentivise and grow entrepreneurship and small-business? - Are individuals in the ecosystem aware of and using the support?	
		Are existing policies in climate/energy/environment and small business support considered efficient and/or well-implemented? Do they incentivize cleantech innovation and entrepreneurship?	

6.1.2 Systems Approach

Although there was a significant degree of overlap between the pillars outlined in the CIEE framework and the types of issues identified by the individuals interviewed, there was also a clear limitation to the original framework in that it failed to adequately address the issue of interactions within the ecosystem. Although this overall lack of clarity was identified to a small degree in the desktop review for the Support Mechanisms sub-pillar and the definitions developed for the original framework intended to capture these interactions (Xie et al., 2019), it was clear that the framework did not do so to a sufficient degree when comparing the results of the desktop review with the barrier most often indicated by interviewees.

Systems theory defines a system as consisting of three parts: elements, interconnections and the ultimate function, or purpose, of the system (Meadows & Wright, 2008). What makes a system

unique is that it is more than the sum of its parts and its structure is also the source of its behaviour (Meadows & Wright, 2008). Assessing only the pieces of a system is not sufficient to capture the behaviour of the whole. Similarly, a national innovation ecosystem "encompasses relationships within and between organizations, institutions and socio-economic structures " (UNCTAD, 2019, p. 2). These connections and relationships between actors are vital in an innovation system and "it is precisely the link between firms and entrepreneurship and others actors in the system which is missing in many developing countries" (UNCTAD, 2019, p. 6). This can be expanded to apply to a CIEE as well, in that it is an ecosystem as a whole, whose various elements as well as their structure and interactions produce a given cleantech outcome, rather than any single factor alone.

SYSTEM: a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviors, often classified as its "function" or "purpose."

Figure 6-1: Definition of a System
Source: Meadows and Wright, 2008, p.188

Similar to a biological ecosystem with biotic (living organisms) and abiotic (physical environment) factors that interact to produce the full system (Jackson, 2011; Margalef, 1968), there appear to be two types of interconnections in a CIEE. There are actual information flows, which are primarily in the form of communication or knowledge exchange between stakeholders in the ecosystem such as government agencies, research institutes, funding bodies, support mechanisms and other organizations. But there are also less tangible interactions, which are made up of the interactions between concepts or factors in the ecosystem and how they influence each other. There are thus two identified types of linkages in a CIEE system:

1. specific actors (key stakeholders or organizations); as well as
2. the conceptual factors identified by the CIEE framework's pillars.

The third important part of a system is its purpose. Although the purpose of a system can often be the least obvious or most difficult aspect to identify it is often the "most crucial determinant of a system's behaviour " (Meadows & Wright, 2008, p. 16). Edquist argues that a system of innovation for example, has the purpose of "pursu[ing] innovation processes, i.e. to develop, diffuse and use innovations" (Edquist, 2006, p. 182). In theory, one might argue that the purpose of a CIEE is similarly obvious: the development and commercialisation of cleantech solutions. However, the wide range of actors – governments, agencies, non-profits, businesses, individuals, etc – involved in a national CIEE can often mean that a stated purpose does not always translate into effective purpose. As Meadows argues, the purpose of a system should therefore be "deduced from behaviour, not stated goals" (Meadows & Wright, 2008, p. 14). In the context of CIEE in developing countries, where different individuals, organizations and governments are all engaging with cleantech for different reasons, it may be particularly relevant to consider to what degree the stated purpose of actors is reflected in behaviour and how this impacts cleantech development. Support of the cleantech ecosystem may be done for a variety of different purposes which may vary from country to country as well as between actors in the national ecosystem. Desire for economic growth, ambitions to meet climate targets or grow local resilience, as well as to enhance political or personal gain may all be reasons to promote CIEE or engage with international support actors such as UNIDO. But the reasons for supporting cleantech may also impact the ultimate behaviour and success of the CIEE by influencing how institutions and actors develop and implement policies, metrics, or engage in business. The assessment of a CIEE using a systems approach needs to therefore evaluate each of these parts: elements, interactions and purposes.

In a biological ecosystem, the functioning of the ecosystem generally works to maintain a stable equilibrium state in which system behaviour maintains certain patterns, populations or nutrient flows through positive and negative feedback loops (Jackson, 2011). In an innovation system,

the existence of such feedback loops make it a dynamic system, in which elements can reinforce interactions positively or result in barriers blocking important processes (Lundvall, 2016). Understanding the feedback loops in a given system is important for understanding the system and how to manage it. Meadows and Wright (2008, p. 40) point out for example that where maintaining a stock-balancing feedback loop is desired, the goal of the feedback loop must be set appropriately "otherwise the feedback process will fall short of or exceed the target for the stock," echoing the importance of appropriate target-setting. Similarly, they argue that "systems with similar feed-back structures [will] produce similar dynamic behaviours" (Meadows & Wright, 2008, p. 50) which in turn is relevant for comparing national CIEE's across countries. Identifying similar feedback loops in different countries could help to inform selecting relevant interventions. Relatedly, the resilience or ability of a system "to survive and persist within a variable environment" (Meadows & Wright, 2008, p. 76) and to either overcome or return to the patterns dictated by feedback loops may lead to either positive or undesired outcomes. The resilience and adaptability of a system must therefore be reinforced into positive behaviours – such as reinforcing the capability to learn (Lundvall et al., 2009) – while negative aspects are identified and mitigated.

Applying systems thinking to the development of the CIEE framework has several important consequences, not only because it requires assessing the linkages and purpose of the system but also because this will ultimately impact the development of programmatic interventions. As Meadows and Wright argue, once we recognize the interactions between factors in a system "we can begin to understand how systems work, what makes them produce poor results, and how to shift them into better behaviour patterns " (Meadows & Wright, 2008, p. 1).

According to the systems approach, there are several key areas in which to intervene in a system to change its behaviour. Four of the areas identified by Meadows and Wright (2008) seem particularly relevant based on the learnings from the South Africa case:

1. Information flows: the structure of who does or does not have access to information
2. Rules: the incentives, punishments, and constraints on actors in the system. These could be understood as policies but also informal cultural or social norms.
3. Goals: the purpose or function of the system
4. Paradigms: the mindset out of which the system (its goals, structure, rules, delays and parameters) arises

Information flows between actors and stakeholders in the case of South Africa, were a key identified barrier. Improving communication and coordination between actors would improve information flows and help to change the system's behaviour. The rules, which include policies as well as cultural norms were also an identified barrier in South Africa's ecosystem – policies did not effectively translate into the desired outcomes while a culture of risk aversion in society as well as the financial sector reduced investment in cleantech. The different goals and misaligned targets or purposes of different institutions and actors in the system also resulted in ineffective coordination between actors and a system which does not produce the desired results. The overall paradigms in the system – for example what cleantech is for and how it can develop, the underlying economic principles of growth through consumption, definitions of sustainable development, etc – may all influence the types of interactions and expectations of actors.

An important limitation to interventions in systems is that there is no single or "optimal structure" for a well-performing system (Markard & Truffer, 2008, p. 601). Every ecosystem is unique and "an approach which simply seeks to duplicate other ecosystems is therefore inappropriate and likely to fail" (Mason & Brown, 2014, p. 9). Instead, policy intervention should take a holistic approach and consider how it can support the system's ability for "self-steering" and enhance "adaptation and learning" by choosing an intervention that allows the

system to obtain and use information which leads to changing behaviour (Stewart & Ayres, 2001, p. 89). Lundvall et al (2009, p. 19) argue that generalized theories or drawing lesson from individual case studies is unlikely to be appropriate given the significant diversity of national, regional and sectoral systems. Instead perhaps the best, "intermediary" approach would be grouping countries into "families" based on commonalities of underlying system structure so that in this way best practices could be identified and drawn on with less room for error due to overgeneralization (Lundvall et al., 2009, p. 19).

Incorporating this systems approach into an updated framework may therefore help to capture these aspects of a CIEE. The addition helps to better meet the definition of a CIEE developed by Xie et al (2019, p. 6) which includes the "network and interactions among innovation and entrepreneurship stakeholders" as well as "the social, economic and policy environment, and their combined influence on the development" of the cleantech sector. Finally, a more holistic systems approach will also help to design effective interventions that address critical feedback loops in a CIEE and direct the system into behavioural patterns which support cleantech growth.

6.2 An updated Framework – CIEE 2.0

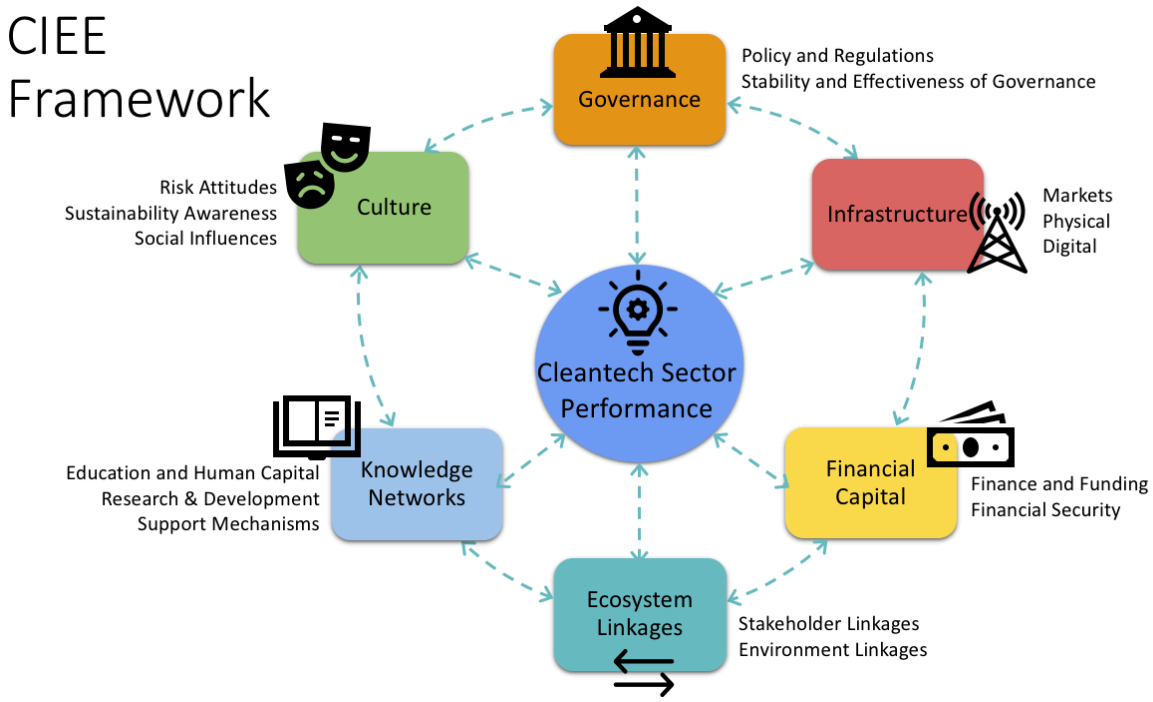


Figure 6-2: Updated CIEE Framework 2.0
Source: own elaboration based on Xie et al, 2019

As can be seen in Figure 6-2, the proposed addition to the framework is a new pillar – Ecosystem Linkages. Based on the learning from the case study as well as the literature reviewed, this new pillar has two sub-pillars, the Stakeholder Linkages as well as the Environment Linkages. Furthermore, the arrows in the figure represent the potential for interaction between pillars as well as their influences on Cleantech Sector Performance. Although difficult to quantify with few quantitative indicators identified for this pillar (this pillar will likely rely primarily on interviews or surveys for data collection), understanding the interactions between factors, not

just the factors themselves, was determined to be crucial to understanding the functioning of the ecosystem. This pillar is further defined below in section 6.2.1.

In addition, although the recommended indicators identified in section 3.2 were left in the framework, in the updated framework the focus of assessment was moved from finding the data for the indicators, to answering a key set of questions. The indicators included in the framework are potentially still relevant and they may help guide the user to find datasets for answering the questions. However, based on the discussion in chapter 6.1.1, answering a set of questions is designed to assess the important aspects of each sub-pillar, and better focus assessment on the unique country context at hand.

6.2.1 Ecosystem Linkages – a new pillar

As with a biological ecosystem, the interactions between both living and non-living aspects of the environment influence how the ecosystem functions. In the same way, a CIEE is made up of both living aspects (stakeholders, actors, individuals, etc) as well as non-living environmental aspects (cultural or social norms, perceptions of institutional roles or purpose, conceptual influences, etc). The interactions between stakeholders – "the content, intensity and quality" of their relations (Fraunhofer ISI, 2012, p. 9) – may be a key barrier or driver for cleantech development because the communication, transparency and implementation of support mechanisms, targets, policies and day-to-day interactions with individuals in the ecosystem depend on these actors. The deeper conceptual factors in the ecosystem may similarly present barriers or drivers – aspects such as cultural norms around entrepreneurship, the level of sustainability awareness, inequality or perceptions of political legitimacy may be underlying causes for the ultimate outcomes of the CIEE. As a result, even where individual pillars in the framework may be considered well-developed, these two levels of interaction may nevertheless impact how and to what degree cleantech development is actually supported. Understanding these linkages between pillars and actors in the CIEE will allow the user to develop a more holistic understanding of the CIEE and help identify behavioural barriers in the system that could be shifted to move the ecosystem towards better patterns. By incorporating an assessment of the strength of the connections between the ecosystem factors, barriers resulting from how factors, influences, and stakeholders interact can be identified and considered when developing interventions.

Environment Linkages

The environment linkages are the high-level or conceptual factors in a CIEE. These can be understood as the interactions between the pillars and sub-pillars in the framework. Assessment of this sub-pillar will depend primarily on the results of findings in the other pillars through the desktop review as well as by interviewing individuals to understand why identified barriers (and strengths) may exist in the system. This assessment may consider important feedback loops in the system that might affect the system's outputs. In innovation systems, feedback loops are understood to be elements that can reinforce interactions positively or result in barriers blocking important processes (Lundvall, 2016). Understanding the feedback loops is important for understanding the system and how to manage it. Assessment may also look at the resilience of a system, or its ability "to survive and persist within a variable environment" (Meadows & Wright, 2008, p. 76) and to either overcome or return to the patterns dictated by feedback loops. Finally, the assessment of Environment Linkages should also consider the broad paradigms or theories underlying how and why the national innovation and entrepreneurship ecosystem is supporting cleantech development – how do well-accepted concepts (such as economic growth, development or sustainability) play a role in the system?

Key question: How and to what degree do the factors in the ecosystem influence each other?
Sub-question:

- What are the underlying influences for key barriers? Key Strengths?
- Where are positive feedback loops in the ecosystem?
- Where are negative feedback loops in the ecosystem?
- How resilient is the system?
    - To what degree are behavioral patterns entrenched in the system?
- What appear to be the broad paradigms or goals driving system behavior?

Stakeholder Linkages

Part of the linkages in an ecosystem rely on the communication and interaction of key stakeholders. The interactions between players in the CIEE impact the basic day-to-day realities that individuals and organizations face when innovating or engaging in entrepreneurship. These stakeholders are responsible for functions such as the implementation of policies and programmes, coordination of support mechanisms, transfer of information, decisions regarding which projects to fund or support, directing individuals to the right resources, and making funding decisions. Cleantech in particular involves a wide range of stakeholders due to the nature of its value chain which includes the stages of innovation, demonstration, commercialisation and diffusion (Polzin, 2017). As a result, even where pillars may be well-developed these interactions may nevertheless influence outcomes.

Relevant stakeholders may include "students, faculty, staff, industry researchers, [and] industry representatives" as well as institutions or organizations such as universities and other educational institutions (technical or business schools), "business firms, venture capitalists (VC), industry university research institutes, federal or industrial supported Centers of Excellence, and state and/or local economic development and business assistance organizations [or] funding agencies" (Jackson, 2011, p. 2). Political actors, non-profit organizations and international development organizations such as UNIDO are also important stakeholders. Important aspects to consider are existing relationships between stakeholders, how the various purposes or goals of actors are aligned, what kind of metrics different actors are using, and how these translate into outcomes.

Key Question: How and to what degree do the stakeholders in the ecosystem interact and how does this impact cleantech development?
Sub-questions:

- Who are key stakeholders in the ecosystem?
- Is there a stated relationship between key stakeholders?
    - To what degree does this relationship translate into outcomes?
- To what degree do actors in the ecosystem interact and collaborate?
    - How do relationships between institutions manifest as linkages?
        - Consider: the formal and informal interactions of government agencies (local and national), industry, research institutes and researchers, non-profits, environmental organizations, entrepreneurs, investors and markets, consumers, etc.
- How do the mandates or purposes of different actors compare?
    - Is there broad alignment? Misalignment?
    - What kind of targets or metrics do different agencies have for measuring progress? Measuring impact?

- Is there sufficient communication/cooperation between actors to help individuals overcome barriers to turning an innovation into a business? To commercializing a business?
- Are there sufficient linkages and interactions between pillars and relevant actors (including government, private sector, non-profit, and individuals) to facilitate innovation and entrepreneurship?

6.3 Policy Recommendations for Improving South Africa's CIEE

The individual barriers that seem to be key in South Africa's CIEE have been highlighted in Figure 6-3 below. However, in line with the ecosystem approach these barriers were very much a result of the interaction of other factors. The extreme degree of inequality was an underlying influence for risk aversion, how and what kind of targets are being set, and the difficulty accessing markets. Similarly, the ineffective or uncoordinated communication between key actors influenced the general misalignment of targets and the translation of policies into effective outcomes, as well as the weak accessibility of markets. These were further compounded by a low degree of sustainability awareness and a general culture of risk aversion.

However, South Africa's ecosystem did exhibit strengths in the existence of fairly strong and well-established institutions and an ecosystem with relatively robust infrastructure overall. As well, there appears to be a strong understanding among actors as to the benefits of cleantech and thus a stated intention to support its development. South Africa seems to have the necessary infrastructure and resources to facilitate cleantech, but it is the access to, and coordination between these aspects which appears missing and which consequently hinders effective growth of the cleantech sector through innovation and entrepreneurship.

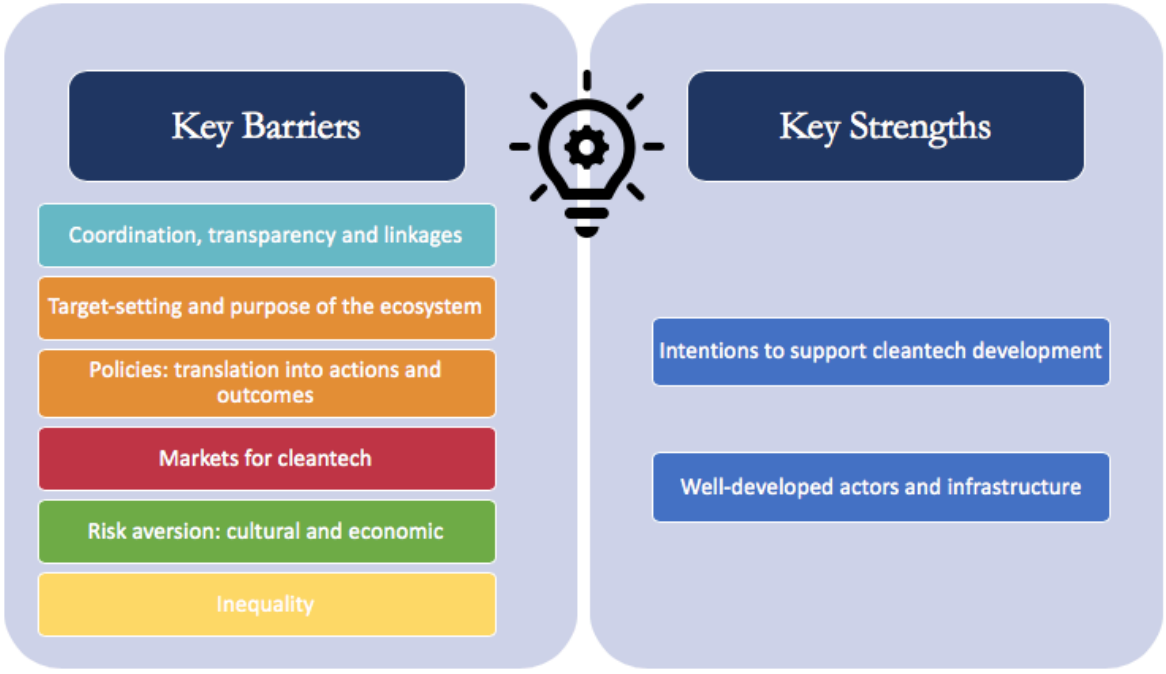


Figure 6-3: Key barriers and strengths in South Africa's CIEE

The assessment of the cleantech ecosystem in South Africa resulted in the following suggestions for UNIDO and national stakeholders to consider when structuring interventions, including the second phase of the GCIP programme.

6.3.1 Better alignment of practices

A more coordinated alignment of practices, primarily including purpose, target-setting and monitoring among actors and organisations would improve transparency and cooperation. A lack of coordination between actors in the ecosystem and a lack of alignment in terms of what stakeholders in the ecosystem are trying to achieve was a barrier. Improved alignment could be facilitated by better cooperation and partnerships between stakeholders in the ecosystem as well. For example, increased partnership between research institutes and cleantech incubators and industry or other private sector actors could help to accelerate cleantech commercialisation by involving private investments and simultaneously finding an initial market for solutions (Polzin, 2017). Further assessment and alignment of how impact is measured and what the intended impact of cleantech is in South Africa, also needs to be better defined, while consideration for the longer timelines for cleantech projects is needed. Cleantech projects can take up to five years or longer to develop a product according to several interviewees (NCPC, GreenCape, TIA), mainly due to hardware and technical needs, and generally don't produce a lot of jobs. However, the timelines and metrics of many support programmes do not take this into account. This problem falls into the trap identified by Meadows and Wright (2008, p. 140) of seeking the wrong goal, where "indicators of satisfaction of the rules" are defined inaccurately and therefore produce an undesired result. Success of programmes can be improved by setting goals that reflect the real and "desired welfare of the system" (i.e. the successful commercialisation of cleantech projects) and accurately differentiate between the "effort" and the "result" (i.e. the number of cleantech projects successfully commercialised, rather than the number of projects that participated in an accelerator) (Meadows & Wright, 2008, p. 140). It was suggested that this problem could possibly be mitigated with better technology validation and a re-evaluation of investment strategies and metrics. Particularly, key stakeholders such as SEDA and other funders should reconsider targets to focus less on short term job growth and instead look at the long term benefits that cleantech can offer, even though returns may be more limited in the immediate term.

6.3.2 Improve rural access to services

In large part a consequence of the significant inequality in the country, rural and low-income communities struggle to access resources as easily as wealthier or urban areas. Partly this is due to a lack of infrastructure (such as electricity, reliable buses, internet services) but it is also due to a lack of reach as existing support services do not have the funding or bandwidth to expand services to more remote areas. One approach that could facilitate the reach of a programme such as a second GCIP or other similar support mechanism would be increased partnerships between locally based organizations and larger cleantech organizations. For example, SEDA already has offices located in municipalities across South Africa. By partnering with SEDA to base resources or staff in their offices, other cleantech development organizations such as GCIP, the National Cleaner Production Centre or universities could take advantage of this existing infrastructure and resources to help engage a broader range of entrepreneurs and innovators throughout the country. By bringing services to a wider range of South Africans, inequality could be at least partly addressed by facilitating local capacity building and expanding access to the resources as well as benefits associated with cleantech to more communities. Entrepreneurs and innovators could be supported in their own communities, making it significantly easier for them to access mentorship, funding and other tools as well as potentially localizing positive impacts like new business, knowledge transfer or jobs. Facilitating access to

local innovation could also lead to new and innovative solutions that solve different problems – local innovators could contribute to solving local problems for affected communities using indigenous or alternative approaches that might not be found in urban centres or universities.

6.3.3 Focus on Key Issues

Promoting cleantech development focused on providing solutions for key sectors or environmental issues in South Africa would help to ensure markets and thus the commercialisation of cleantech. A variety of key issues were identified in the interviews including: energy efficiency, grid stabilization technologies, water scarcity and drought, waste and circular resource use, and a need for industries to replace coal in mining- and power-plant-towns. By focusing support on identified problems and effectively identifying the demand support for cleantech would be much better targeted. Not only would this help to better ensure the existence of markets for the developed cleantech solutions, but the impact of cleantech projects in South Africa could potentially be increased as well. For example, developing an alternative industry to replace the social and economic role of coal, could also have a significant climate impact by reducing the influence of the fossil fuel industry in South Africa, incentivizing renewable energy and consequently reducing the GHG impact of an electricity sector that is nearly 93% generation from coal. By focusing on key issues in need of cleantech solutions, clients and markets for new technologies may more easily be found while the positive impacts of cleantech for sustainable and inclusive development could be significantly increased.

6.4 Research on CIEE

6.4.1 Reflections on research methodology

Although the research provided many useful insights and a thorough assessment of South Africa's CIEE, there were nevertheless some remaining limitations.

An important limitation to this research is the qualitative and subjective nature of the framework and the assessment of South Africa. In the desktop review, although indicators were used to assess the pillars, weighting these different indicators to determine the strength of a single pillar was qualitative and depended on the researcher's interpretation of the indicators and the sources reviewed. Similarly, although the results of the interviews were categorized using the framework pillars, the interviewees were not asked a single set of questions, so the semi-structured nature of the interviews is again open to some interpretation. The overall analysis of South Africa's CIEE based on the combination of the desktop review and the interviews, was also done based on the researcher's interpretation of the data rather than on an a more objective quantitative assessment. Although the research conducted provided valuable insights and data overall, the ultimately qualitative nature of these results likely makes them difficult to reproduce.

A further difficulty was finding a balance between a simple and easy to use framework and a more complex, yet comprehensive and thorough one. The many sub-pillars and questions developed for the framework are long and time-consuming, which perhaps makes the framework unwieldy and complex. However, considering the complexities of a CIEE, and the unique contexts of different countries with vastly different systems, cutting the framework in order to simplify it would potentially compromise the validity and reliability of results. Though perhaps a little simpler to use, key aspects might be missing in a reduced framework. The final framework therefore retained the size and coverage of aspects in order to maintain its integrity.

It was beyond the scope and time available for this research to develop a robust method for quantitatively weighting the indicators in the desktop review or to develop a method for

measuring the ecosystem factors in a more quantitative manner. Partly this is a problem of being able to measure such complex concepts as culture or the degree of interactions between two organizations. Clearly there is a need for "quality indicators that reflect the quality of relationships such as trust" or social capital, and which are able to provide information from which to improve a system, for example about "what is learnt in… interactions between organizations" (Lundvall et al., 2009, p. 19). This need for more research is discussed further in chapter 6.5.

Another consideration is that it was clear from applying the framework in the case of South Africa, that some significant barriers, may not however be factors which are suitable for intervention, at least not directly. For example, the issue of inequality in South Africa is incredibly significant. A persuasive argument can be made that it impacts all factors in the CIEE. But this is a difficult finding to present to an organization such as UNIDO or even a policy maker within the country as this is not an easy issue to address. However, although the framework may result in identifying factors which are not candidates for programmatic intervention, this is nonetheless in line with the systems thinking. Even though "there are intrinsic institutional limits to what the policy making bodies" can do within their policy domains, it is often precisely these areas beyond their scope that "shape a large part of the so called 'framework' conditions" or ecosystem factors that impact the development of cleantech (UNCTAD, 2019, p. 8). Decision-makers must understand the entire system (as much as is possible) in order to construct effective interventions. A programme for South Africa may not be able to directly address inequality, however an intervention which seeks to encourage innovation or entrepreneurship (for instance through an accelerator) must nevertheless consider how inequality might impact the ability of individuals to participate. Understanding how the whole, holistic ecosystem works, is key to shifting it towards the desired patterns and results. By understanding the whole system – even the parts which seem too difficult to change – solutions can be found which avoid applying a band-aid to the problem, but rather contribute to meaningful and positive change over the long term.

6.4.2 Putting the CIEE Framework into use

Based on the experiences applying the original CIEE framework in the case of South Africa, an updated research and assessment approach is suggested as well. The approach for using the framework consists primarily of a three-step process outlined in Figure 6-4 below. This approach should be further refined to incorporate additional research on which stakeholders should be interviewed as well as how best to design a robust method of surveying interviewees.

As discussed above in chapter 6.4.1, there are benefits and drawbacks of both the chosen methods of data collection: indicators and interviews. This led to the conclusion that a combined approach would best mitigate drawbacks and maximize benefits. The recommended indicators should be assessed for availability, relevance and accuracy, and proxy indicators could be selected where the framework user finds that these ideal indicators did not meet the data quality criteria. In addition, a well-designed survey rather than semi-structure interviews, would also better lend itself to providing more quantitative data. Although beyond the scope of this research project, these findings were incorporated into an updated proposed methodology for the framework that should be further refined by the application of survey and research design as well as quantitative data analysis methods.

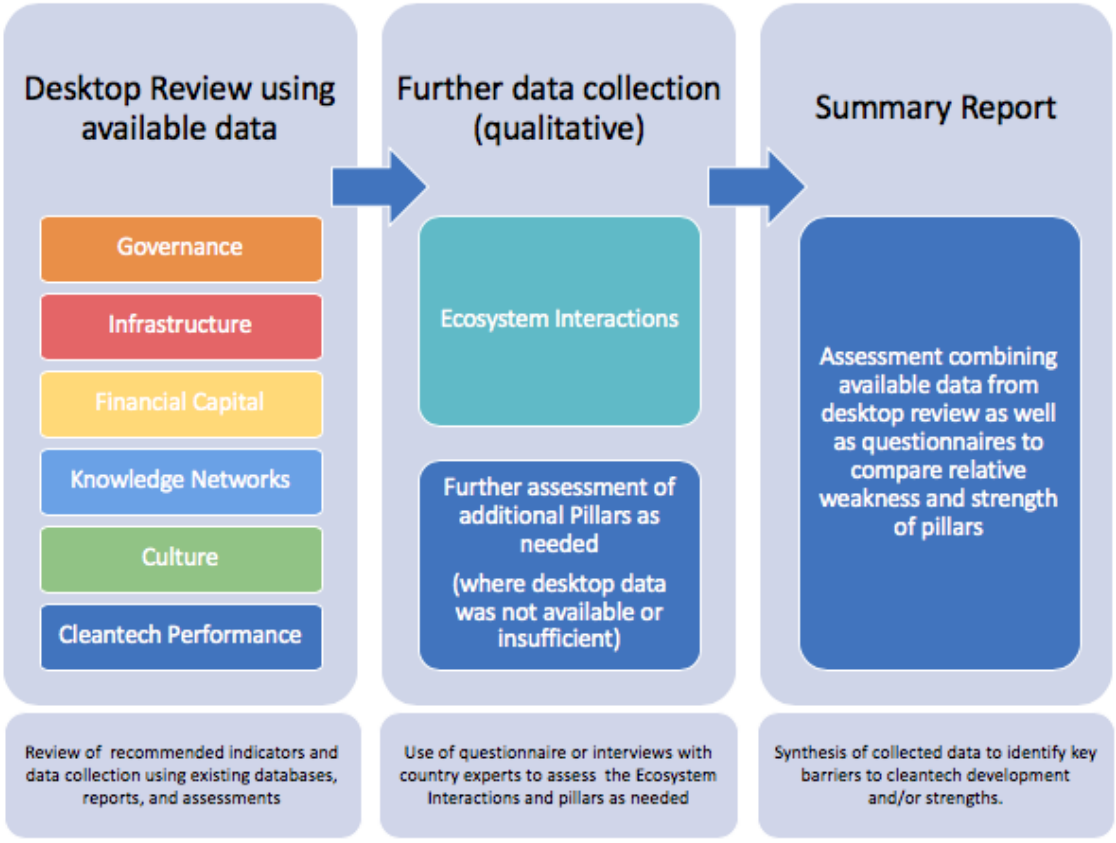


Figure 6-4: Proposed approach for applying the updated CIEE framework

6.5 Further Research

Based on the reflections in chapter 6.4, a key area for further research is developing a more robust and replicable method to quantitatively assess the collected data. For example, how do you measure the strength of each pillar based on the indicators or the data collected to answer the key questions? According to Lundvall (2009, p. 12) research on innovation systems needs to develop "new tools and indicators" to capture these difficult yet influential aspects of an ecosystem such as "social capital" or "generalized trust." Whether it is empirical data on the number of research publications or the slippery and difficult influence of cultural risk aversion or institutional legitimacy, assessment must capture the influence of both factors. In theory, a weight assigned to each question or indicator could be an obvious approach and similar methods are found in many existing frameworks. However, the primary limitation of such an approach is that different aspects of different pillars may be more or less important within different contexts. Assigning a weight to a given aspect of the CIEE may ultimately result in a less accurate analysis due to the wide degree of variation between different countries. There is no single "blueprint for managing innovation systems that can be replicated between countries" and the relative importance of different aspects in the ecosystem will depend on context, rather than a one-size-fits all approach (UNCTAD, 2019, p. 4). Furthermore, the qualitative nature of the answers for the key questions and sub-questions of each pillar will also make it difficult to apply a weighting or point-based system. Most frameworks that apply this method use a yes or no approach to questions (yes=1, no=0), but measuring the "degree of" or the "level of effectiveness" of different aspects is not well suited to such an approach. More research would therefore need to be done, particularly using case studies of developing and emerging economies, to determine which pillars might be most significant in a CIEE in order to weight the pillars accordingly. Further development of the framework methodology would be needed

if the end goal is a diagnostic and quantitative tool. Caution should be exercised however, as it is possible that a quantitative tool will not be as thorough or able to appropriately capture the specific and unique context of different countries. Even where more quantitative methods might be developed, some level of subjectivity will likely be inevitable. It may be worth considering whether the traditional paradigm of evidence-based policy making which relies so heavily on quantitative assessment is the best approach for assessing such a complex concept.

Further case studies would also provide additional data to confirm the validity of the underlying conceptual theory in the CIEE framework that was originally developed by Xie et al and expanded during this project. Testing the framework in the context of South Africa may have biased the conceptual theory in that some of the additions – for example the addition of ecosystem linkages which were found to be particularly important in the context of South Africa – was over stated. Conducting further research to further validate the framework is therefore necessary.

It is also worth noting that the framework in its current state does not provide solutions to the barriers it identifies. As Budden et al (2019, p. 9) point out, the many indexes and rankings for innovation and entrepreneurship which exist mean that although decision-makers are "presented with ever more information on which to base decisions" there is still little "guidance on how to assess [these indexes/rankings] or determine the most appropriate measures for their ecosystem or program/policy interventions." Similarly, the CIEE framework developed is intended to provide an understanding of the ecosystem assessed and help the user identify the systemic behaviour underlying the key barriers (or strengths) in the ecosystem. However, the user or other relevant decision-maker will still need to apply their own discretion and creativity to identify the key feedback loops and develop an appropriate and effective intervention based on this information. As Budden (2019) says, there is little guidance for this next step of turning these findings into practice. Further research on how to evaluate feedback loops and identify solutions and interventions as well as how to incorporate these into an assessment approach is therefore needed.

A further consideration is scoping a CIEE to the national level, which some argue may not be the most appropriate scope (Lundvall et al., 2009). Due to the influences of globalization, knowledge and economies are shared beyond national boundaries, while regional differences in countries, especially in terms of access to key resources may be more significant than those found between countries (Lundvall et al., 2009). For example, the extreme degree of inequality in South Africa and the differences in access to resources and infrastructure between Johannesburg – as the financial centre of the country, with a wealthier population and some of the best schools – and some of the other much poorer regions is a good example of this problem. The extreme between the wealthy, well-developed first economy and the impoverished, underserved second economy – the two worlds in South Africa – makes it very difficult to draw conclusions that are generally applicable. The problems faced by a white entrepreneur living in the Sandton district of Johannesburg, will be extremely different from those faced by a black entrepreneur living in a rural village in the province of Eastern Cape. Although the framework is intended to be general and assess the high-level national ecosystem, it is relevant to consider to what degree assessment at the national level can accurately capture such regional and local differences. Assessing a country on the national level when there may be such a degree of geographic or regional inequality may be limited in portraying an accurate picture of on-the-ground realities, particularly for individuals in the system. Further research to explore applying the CIEE framework at the regional level for instance, could be particularly useful or relevant for countries with such large geographic or regional disparities.

Finally, it is also worth considering to what degree broadly accepted definitions of "economic development," "sustainable development" or other similar concepts play a role in assessing, and

subsequently intervening, to support cleantech development. As mentioned, the purpose of an ecosystem influences the outcomes or results of the systems behaviour. The ideologies underlying these concepts at every level in a CIEE, from local to international, will therefore inform the outcomes and impact of cleantech development. An organization such as UNIDO is driven by practical concerns as well as the demands of its member states and funders. They may therefore be driven to look for quantitative outcomes or apply classical market ideologies because this is what is demanded of them, even when this may not be the best approach. For example, Lundvall (2009, p. 18) points out that economic development measured by classical metrics like the ability of markets to allocate resources may miss the point – "growth in material assets is not equivalent with growth in welfare and well-being." Instead, economic development should be about "supporting competence-building among people and capacity-building in organizations" (Lundvall et al., 2009, p. 16). Yet in innovation literature "few attempts have been made to link innovation with the specific needs of developing countries, such as poverty reduction" (Lundvall et al., 2009, p. 20), while the dominant paradigms in international development work remain focused on GDP growth and consumption as a measure of welfare. Even among the SDGs themselves, there are tensions between the end goal of sustainable development and achieving environmental and human development goals; and continuing to drive economic growth (Lim, Søgaard Jørgensen, & Wyborn, 2018). If cleantech development is truly to help achieve climate goals, reduce resource consumption, improve environmental impacts, and help build the welfare and well-being of communities in developing countries, then perhaps these underlying ideologies, or system purposes, at a global scale need to be re-evaluated.

7 Conclusions

It is becoming increasingly clear that global issues of climate mitigation and adaptation as well as resource use and consumption, will come to dominate the environmental and social issues of the 21st century. Cleantech – solutions that lead to an increase in positive environmental benefits or reduce negative impacts – can be an important means of addressing these challenges. Particularly for developing countries, cleantech innovation and entrepreneurship can enable inclusive and sustainable industrial development by building local capabilities and enabling innovation of their own development pathways in response to economic, environmental and social issues (UNCTAD, 2019).

Supporting cleantech is thus a growing area of interest among national and international policy makers and is increasingly being favoured to help meet growing demand for more sustainable industry. However, in order to implement effective strategies and support the growth of the cleantech sector in developing countries, assessing a country's national ecosystem for barriers and drivers is a critical first step. Targeted interventions with impact will rely on the appropriate assessment of existing systems that identify aspects which may support or hinder cleantech innovation and entrepreneurship. Yet a knowledge gap remains – practitioners are missing a framework which incorporates the factors integral to an innovation system as well as for an entrepreneurship system, and which focuses on the cleantech sector and the specific context of developing countries.

The aim of this research was to contribute to this identified knowledge gap and test the previously developed CIEE framework by applying it to the case study of South Africa. As a result, the research was able to meet its objectives and provide an assessment of South Africa's cleantech ecosystem as well as identify improvements to further develop the conceptual theory of the CIEE. This was done by asking four research questions.

Research question one [RQ1] asked what a suitable framework for assessing the cleantech innovation and entrepreneurship ecosystem might be, as well as how this could be operationalized. After consultation with UNIDO, the framework was initially operationalized by reviewing and recommending indicators for each of the framework's pillars. This approach to the framework was then used to answer research question two [RQ2] and three [RQ3] by using the framework and the indicators as well as interviews conducted in the field, to assess the state of South Africa's cleantech ecosystem and identify the significant barriers and strengths for cleantech development. The results of the use of indicators to operationalize the framework demonstrated that indicators may not be sufficient to provide an appropriate assessment without further contextualization and a much higher than anticipated degree of subjectivity. In addition, the comparison of results from the desktop review and the interviews, also determined that the conceptual theory did not sufficiently capture the importance of ecosystem interactions. In the case of South Africa, one of the key barriers was a lack of communication between stakeholders and a misalignment of purpose and targets across different organizations which particularly informed this finding. Policy recommendations for South Africa therefore included improving coordination and alignment of goals among actors in the CIEE; improving rural access to innovation and entrepreneurship services to help address inequality; and focus on driving cleantech development that addresses key social and environmental problems in the country.

These outcomes subsequently led to answering the fourth research question [RQ4]: how to improve the CIEE framework to accurately identify the drivers and barriers in a national ecosystem for cleantech? Based on the outcomes detailed above, the key improvements to the framework were twofold: shifting from an indicator-based approach to one that instead focuses

on answering key questions for each sub-pillar; and the addition of an 'Ecosystem Linkages' pillar to incorporate assessment of interactions between actors, organizations and individuals (stakeholder linkages) as well as the interacting influences of conceptual factors in the ecosystem (environment linkages).

The resulting updated CIEE framework is intended to serve as a holistic and systems-thinking based approach to assessing a national cleantech ecosystem. The focus is on understanding, rather than measuring the system, and it attempts to cover a broad range of influencing factors in a CIEE – many of which are difficult to measure – while also acknowledging that every country context will be different. No two countries will have the same CIEE and the assessment and identification of interventions to support cleantech should be wary of overgeneralizing or comparing contexts.

In some ways this might limit the utility of the framework – an extensive and qualitative assessment of a CIEE may not always be feasible. Particularly for organizations such as UNIDO or national policy makers, availability of resources or time may limit the practicality of such an in-depth assessment. Further research is needed to explore options for operationalizing such a framework in a more quantitative way, such as developing indicators to measure concepts like culture or stakeholder interactions. However, measuring some of the intangible concepts of a CIEE will likely depend on some measure of subjectivity regardless of method. It is thus also worth questioning whether the traditional paradigm of decision-making based so heavily on numbers is an appropriate approach when assessing a concept as complex as a CIEE. In line with systems thinking, effective interventions depend on considering not just the elements in a system but also their interactions and purpose in order to identify the underlying causes, all of which may be significantly difficult to quantify. But by identifying the key influences, interventions can be structured to shift undesired ecosystem behaviours into new patterns and address root causes. In this way, interventions can successfully drive long term change in a system and build a CIEE's capacity for sustainable, lasting growth.

Cleantech development can not only support mitigation and adaptation to global environmental problems, but also foster the growth of jobs and social welfare by tapping into local knowledge, facilitating creative problem solving and building the economies and resilience of local communities. The research conducted aims to contribute to the innovation of cleantech and the entrepreneurial development of new mitigative and adaptive solutions through development of the CIEE framework. It is the hope that further work will be done to develop the conceptual theory into a holistic and useful diagnostic tool for decision-makers to support environmental problem-solving at both the global as well as the local level.

Bibliography

Ács, Z., Szerb, L., & Lloyd, A. (2018). *The Global Entrepreneurship and Development Institute: Global Entrepreneurship Index*. Retrieved from Global Entrepreneurship and Development Institute website: https://thegedi.org/2018-global-entrepreneurship-index/

Al Jazeera. (2019, May 27). Coal-hungry South Africa introduces carbon tax. *Al Jazeera*. Retrieved from https://www.aljazeera.com/news/2019/05/coal-hungry-south-africa-introduces-carbon-tax-190527113256102.html

ANDE. (2018). Gauteng 2018 | Ecosystem Snapshots. Retrieved September 5, 2019, from Aspen Network of Development Entrepreneurs website: https://ecosystems.andeglobal.org/snapshot/gauteng/2018/

Arun, N. (2019, July 15). Zuma, the Guptas, and the sale of South Africa. *BBC News*. Retrieved from https://www.bbc.com/news/world-africa-48980964

Aspen Network of Development Entrepreneurs. (2013). *Entrepreneurial Ecosystem Diagnostic Toolkit*. Retrieved from https://assets.aspeninstitute.org/content/uploads/files/content/docs/pubs/FINAL%20Ecosystem%20Toolkit%20Draft_print%20version.pdf

Budden, P., Murray, F., & Turskaya, A. (2019, February). *A systematic MIT approach for assessing "innovation-driven entrepreneurship" in ecosystems*. MIT's Laboratory for Innovation Science & Policy.

Centre for Science, Technology and Innovation Indicators. (2017). *SOUTH AFRICAN NATIONAL SURVEY OF RESEARCH AND EXPERIMENTAL DEVELOPMENT | Statistical Report: 2015/16* [Statistical Report]. Retrieved from Human Sciences Research Council SA on behalf of the Department of Science and Technology website: https://www.gov.za/sites/default/files/gcis_document/201803/sa-rd-survey-statistical-report-2015-16.pdf

Cleantech Group, & World Wide Fund. (2017). *Global Cleantech Innovation Index 2017*.

Cronje, J. (2019, March 30). Moody's again skips rating review of SA's sovereign debt. Retrieved July 17, 2019, from Fin24 website: https://www.fin24.com/Economy/moodys-again-skips-rating-action-on-sas-sovereign-debt-20190330

Department of Higher Education and Training. (2018). *Statistics on Post-School Educaton and Training in South Africa: 2016*. Retrieved from Department of Higher Education and Training SA website: http://www.dhet.gov.za/Research%20Coordination%20Monitoring%20and%20Evaluation/6_DHET%20Stats%20Report_04%20April%202018.pdf

Department of Science and Technology. (2018). *Department of Science and Technology Annual Report 2017/2018* (No. Vote No. 30). Retrieved from Department of Science and Technology Republic of South Africa website: https://www.gov.za/sites/default/files/gcis_document/201810/dstannualreport.pdf

Department of Social Development. (2019). NPO Register. Retrieved July 30, 2019, from Department of Social Development Republic of South Africa website: http://www.npo.gov.za/PublicNpo/Npo

Dept of Trade & Industry. (2019). Economic Empowerment. Retrieved July 26, 2019, from the dti | Department: Trade & Industry Republic of South Africa website: http://www.thedti.gov.za/economic_empowerment/bee.jsp

Directory | Certified B Corporation. (2019). Retrieved July 31, 2019, from Certified B Corporation website: https://bcorporation.eu/directory?search=&industry=&country=South%20Africa&state=&city=

Edquist, C. (2006). *Systems of Innovation: Perspectives and Challenges*. https://doi.org/10.1093/oxfordhb/9780199286805.003.0007

Fraunhofer ISI. (2012). *Innovation Systems Revisited | Experiences from 40 years of Fraunhofer ISI research*. Stuttgart: Fraunhofer Institute for Systems and Innovation Research.

GCIP. (2019). Global Cleantech Innovation Programme | UNIDO. Retrieved May 19, 2019, from United Nations Industrial Development Organization website: https://www.unido.org/our-focus-safeguarding-environment-clean-energy-access-productive-use-climate-policies-and-networks/global-cleantech-innovation-programme

GCIP South Africa. (2018). *GCIP SA Commemorative Book 2014-2017*. Retrieved from Technology Innovation Agency South Africa website: http://southafrica.cleantechopen.org/wp-content/uploads/2017/11/GCIP-SA-Commemorative-Book-2014-2017.pdf

GEM. (2017). GEM Economy Profile & Policy Brief South Africa. Retrieved July 30, 2019, from GEM Global Entrepreneurship Monitor website: https://www.gemconsortium.org

GEM. (2018). *Global Report 2017/2018*. Babson College, Maryland: Global Entrepreneurship Monitor.

Green Growth Knowledge Platform. (2013). *Moving towards a Common Approach on Green Growth Indicators | A Green Growth Knowledge Platform Scoping Paper*. Presented at the 2nd Annual GGKP Conference, Paris, France. Retrieved from http://www.greengrowthknowledge.org/sites/default/files/downloads/resource/GGKP%20Moving%20towards%20a%20Common%20Approach%20on%20Green%20Growth%20Indicators.pdf

GreenCape SA. (2019a). Green Finance Database. Retrieved July 27, 2019, from GreenCape website: https://www.greencape.co.za/content/focusarea/green-finance-databases

GreenCape SA. (2019b). *Incentives Information Booklet*. Retrieved from GreenCape South Africa website: https://www.greencape.co.za/assets/Uploads/Government-Funding-and-Incentive-Booklet.pdf

Greenpeace Africa. (2018, October 29). New satellite data reveals the world's largest air pollution hotspot is Mpumalanga, South Africa. Retrieved July 17, 2019, from Greenpeace Africa website: https://www.greenpeace.org/africa/en/press/4202/new-satellite-data-reveals-the-worlds-largest-air-pollution-hotspot-is-mpumalanga-south-africa/

Herrington, M., Kew, P., & Mwanga, A. (2017). *Global Entrepreneurship Monitor |South Africa Report 2016/2017 | Can Small Business Survive in South Africa?* Retrieved from Global Entrepreneurship Monitor website: https://drive.google.com/drive/u/0/folders/1_snQyZ0FGLWB3fAgevMIYNptSQZJH3hn

IEA-IRENA Joint Policies and Measures Database. (2018). Retrieved July 17, 2019, from International Energy Agency website: https://www.iea.org/policiesandmeasures/renewableenergy/?country=South%20Africa

infoDev. (2014). *Building Competitive Green Industries: The Climate and Clean Technology Opportunity for Developing Countries*. Retrieved from World Bank website: https://www.infodev.org/infodev-files/green-industries.pdf

International Telecommunication Union. (2017). *Measuring the Information Society Report 2017* (No. Volume 1). Retrieved from International Telecommunication Union website: http://handle.itu.int/11.1002/pub/80f52533-en

IPCC. (2018, October 8). Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments. Retrieved March 9, 2019, from IPCC website: https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

IRENA. (2019). Data and Statistics—IRENA REsource. Retrieved July 31, 2019, from International Renewable Energy Agency website: http://resourceirena.irena.org/gateway/dashboard/?topic=7&subTopic=10

ISO Technical Committee 9. (2019). ISO Survey of certifications to management system standards—Full results. Retrieved July 31, 2019, from International Organization for Standardization website: https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1

Jackson, D. (2011). *What is an Innovation Ecosystem?* Retrieved from National Science Foundation website: http://erc-assoc.org/sites/default/files/topics/policy_studies/DJackson_Innovation%20Ecosystem_03-15-11.pdf

Joubert, L. (2018, December 4). Why doesn't the media talk about climate change? Retrieved July 30, 2019, from Energy Transition | The Global Energiewende website: https://energytransition.org/2018/12/why-doesnt-media-talk-about-climate-change/

Kline, S. J., & Rosenberg, N. (2009). An Overview of Innovation. In N. Rosenberg, *Studies on Science and the Innovation Process* (pp. 173–203). https://doi.org/10.1142/9789814273596_0009

Lim, M., Søgaard Jørgensen, P., & Wyborn, C. (2018). Reframing the sustainable development goals to achieve sustainable development in the Anthropocene—A systems approach. *Ecology and Society*, *23*(3). https://doi.org/10.5751/ES-10182-230322

Lundvall, B.-Å. (2016). *The learning economy and the economics of hope*. London ; New York, NY: Anthem Press.

Lundvall, B.-Å., Joseph, K. J., Chaminade, C., & Vang, J. (Eds.). (2009). *Handbook of innovation systems and developing countries: Building domestic capabilities in a global setting*. Cheltenham, Glos, UK ; Northamption, MA, USA: Edward Elgar.

Margalef, R. (1968). *Perspectives in Ecological Theory*. Chicago, USA: University of Chicago Press.

Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research Policy*, *37*(4), 596–615. https://doi.org/10.1016/j.respol.2008.01.004

Mason, C., & Brown, R. (2014, January). *ENTREPRENEURIAL ECOSYSTEMS AND GROWTH ORIENTED ENTREPRENEURSHIP*. Presented at the Background paper prepared for the workshop organised by the OECD LEED Programme and the Dutch Ministry of Economic Affairs, The Hague, Netherlands.

Meadows, D. H., & Wright, D. (2008). *Thinking in systems: A primer*. White River Junction, Vt: Chelsea Green Pub.

MFSA. (2019). MicroFinance South Africa. Retrieved July 27, 2019, from MFSA website: https://www.mfsa.net/whoweare

National Government of South Africa. (2019). Universities of South Africa. Retrieved September 19, 2019, from National Government of South Africa website: https://nationalgovernment.co.za/units/type/11/university

National Treasury Republic of South Africa. (2019, February 20). *Budget Review 2019*. Retrieved from http://www.treasury.gov.za/documents/national%20budget/2019/review/FullBR.pdf

Nature Index. (2019a). 2019 tables | Nature Index. Retrieved September 18, 2019, from Nature Index website: https://www.natureindex.com/annual-tables/2019

Nature Index. (2019b). South Africa | Country outputs. Retrieved July 30, 2019, from Nature Index website: https://www.natureindex.com/country-outputs/south-africa

OECD. (2017a). *ECONOMIC POLICY REFORMS 2017: Going for Growth South Africa*. OECD.

OECD. (2017b). *OECD Economic Surveys: South Africa 2017*. https://doi.org/10.1787/eco_surveys-zaf-2017-en

OECD. (2019). Patent indicators. Retrieved July 31, 2019, from OECD.Stat website: https://stats.oecd.org/Index.aspx?DataSetCode=PAT_IND

Ortiz-Ospina, E., & Roser, M. (2019). Trust. Retrieved July 24, 2019, from Our World in Data website: https://ourworldindata.org/trust

Pariona, A. (2018). The Biggest Industries In South Africa. Retrieved July 26, 2019, from WorldAtlas website: https://www.worldatlas.com/articles/the-biggest-industries-in-south-africa.html

Pastakia, A. (2002). Assessing Ecopreneurship in the Context of a Developing Country: The Case of India. *Greener Management International*, *Volume 38*, pp 93-108. https://doi.org/10.9774/GLEAF.3062.2002.su.00010

Phakathi, B. (2019). Cyril Ramaphosa says B-BBEE will be strengthened not scrapped. *Business Day*. Retrieved from https://www.businesslive.co.za/bd/national/2019-07-18-cyril-ramaphosa-says-b-bbee-will-be-strengthened-not-scrapped/

Polzin, F. (2017). Mobilizing private finance for low-carbon innovation – A systematic review of barriers and solutions. *Renewable and Sustainable Energy Reviews*, *77*, 525–535. https://doi.org/10.1016/j.rser.2017.04.007

SEDA. (2019). Seda Technology Programme. Retrieved September 19, 2019, from Small Enterprise Development Agency website: http://www.seda.org.za/Programmes/Pages/Home.aspx

Silicon Cape Initiative. (2018). Venture Capital Investors. Retrieved July 27, 2019, from Silicon Cape Initiative website: https://www.siliconcape.com/resources/venture-capital-investors/

South Africa. (2019). In *Encyclopaedia Britannica*. Retrieved from https://www.britannica.com/place/South-Africa

South Africa | Climate Action Tracker. (2019). Retrieved July 17, 2019, from Climate Action Tracker website: https://climateactiontracker.org/countries/south-africa/

South Africa Map. (2019). Retrieved July 25, 2019, from SA Venues website: https://www.sa-venues.com/maps/south-africa.htm

South Africa Patent applications by residents. (2019). Retrieved September 19, 2019, from The Global Economy website: https://www.theglobaleconomy.com/South-Africa/Patent_applications_by_residents/

Stewart, J., & Ayres, R. (2001). Systems Theory and Policy Practice: An Exploration. *Policy Sciences*, *34*(1), 79.

Sustainable Development Goals. (2019). Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation. Retrieved June 6, 2019, from United Nations Sustainable Development Goals website: https://www.un.org/sustainabledevelopment/infrastructure-industrialization/

Sworder, C., Salge, L., & Van Soest, H. (2017). *The Global Cleantech Innovation Index 2017*. Retrieved from WWF and Cleantech Group website: https://wwf.fi/mediabank/9906.pdf

the dti. (2007). *BACKGROUND TO, INTENTION & APPLICATION OF THE CODES OF GOOD PRACTICE*. Retrieved from http://www.thedti.gov.za/economic_empowerment/docs/Inside.pdf

The Investment House. (2016). What Is BBBEE? *Entrepreneur Magazine*. Retrieved from https://www.entrepreneurmag.co.za/advice/doing-business-in-sa/bee/what-is-bbbee/

The World Bank Group. (2019). Getting Credit—Why it Matters. Retrieved July 23, 2019, from Doing Business | Meauring Business Regulations website: https://www.doingbusiness.org/en/data/exploretopics/getting-credit/why-matters

TIA. (2019). Technology Innovation Agency. Retrieved September 19, 2019, from Technology Innovation Agency website: https://www.tia.org.za/

Trading Economics. (2019). South Africa—Credit Rating. Retrieved September 19, 2019, from Trading Economics website: https://tradingeconomics.com/south-africa/rating

Transparency International. (2018). Corruption Perceptions Index 2018. Retrieved July 20, 2019, from Www.transparency.org website: https://www.transparency.org/cpi2018

Transparency International. (2019, January). Sub-Saharan Africa: Undemocratic regimes undermine anti-corruption efforts. Retrieved July 17, 2019, from Www.transparency.org website: https://www.transparency.org/news/feature/cpi2018-subsaharan-africa-regional-analysis

UN SDGs. (2018). *SDG Goal 9 | INDUSTRY, INNOVATION AND INFRASTRUCTURE: WHY IT MATTERS*. Retrieved from https://www.un.org/sustainabledevelopment/wp-content/uploads/2018/09/Goal-9.pdf

UN Women. (2018). Facts and Figures: Economic Empowerment. Retrieved July 24, 2019, from UN Women website: http://www.unwomen.org/what-we-do/economic-empowerment/facts-and-figures

UNCTAD. (2011). *A Framework for Science, Technology and Innovation Policy Reviews: Helping countries leverage knowledge and innovation for development* (No. UNCTAD/DTL/STICT/2011/7; p. 53). Switzerland: United Nations Conference on Trade and Development.

UNCTAD. (2019). *A Framework for Science, Technology and Innovation Policy Reviews: Harnessing Innovation for Sustainable Development* (No. UNCTAD/DTL/STICT/2019/4; p. 53). Geneva: United Nations Conference on Trade and Development.

UNEP. (2017). With resource use expected to double by 2050, better natural resource use essential for a pollution-free planet. Retrieved May 18, 2019, from United Nations Environment Programme website: http://www.unenvironment.org/news-and-stories/press-release/resource-use-expected-double-2050-better-natural-resource-use

UNESCO Institute for Statistics. (2019). UIS Statistics. Retrieved September 19, 2019, from UIS Statistics website: http://data.uis.unesco.org/#

UNIDO. (2019). 2030 Agenda and the SDGs. Retrieved from United Nations Industrial Development Organization website: https://www.unido.org/who-we-are/unido-sustainable-development-goals

United Nations (Ed.). (2001). *Indicators of sustainable development: Guidelines and methodologies* (2nd ed). New York: United Nations.

United Nations Development Programme. (2018). The 2018 Global Multidimensional Poverty Index (MPI). Retrieved July 23, 2019, from United Nations Development Programme Human Development Reports website: http://hdr.undp.org/en/2018-MPI

World Bank. (2018a). Country Score Card: South Africa 2018 | Logistics Performance Index. Retrieved July 18, 2019, from https://lpi.worldbank.org/international/scorecard/radar/254/C/ZAF/2018/C/DEU/2007/C/USA/2007/R/SSA/2018

World Bank. (2018b). *Doing Business in South Africa Report 2018*. Retrieved from World Bank website: https://www.doingbusiness.org/content/dam/doingBusiness/media/Subnational-Reports/DB18_South-Africa.pdf

World Bank. (2019a). Ease of Doing Business in South Africa. Retrieved September 19, 2019, from World Bank Doing Business website: https://www.doingbusiness.org/en/data/exploreeconomies

World Bank. (2019b). Population estimates and projections | DataBank. Retrieved May 19, 2019, from The World Bank website: https://databank.worldbank.org/data/reports.aspx?source=health-nutrition-and-population-statistics:-population-estimates-and-projections

World Bank. (2019c). South Africa Overview [Text/HTML]. Retrieved May 18, 2019, from The World Bank in South Africa website: http://www.worldbank.org/en/country/southafrica/overview

World Bank. (2019d). World Bank Open Data. Retrieved July 20, 2019, from The World Bank Data website: https://data.worldbank.org/indicator/IC.LGL.CRED.XQ

World Economic Forum. (2019). *Fostering Effective Energy Transition 2019 edition*. Retrieved from http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_2019.pdf

World Justice Project. (2019). Rule of Law Index 2018-2019 South Africa. Retrieved September 19, 2019, from WJP Rule of Law Index website: http://data.worldjusticeproject.org/#/groups/ZAF

Xie, X., Guevara, S., Johnston, R., & Wylie, J. (2019). *Assessing Cleantech Innovation and Entrepreneurship Ecosystems in Developing Countries—Client Report for UNIDO-GCIP* [SED]. IIIEE, Lund University.

Appendix I – CIEE Framework with data for South Africa

The below framework is the version developed in April by Xuan Xie, Silvia Guevara, Jamie Wylie and Rheanna Johnston. The indicators in the framework were chosen as part of this thesis work to operationalize it. Data was collected for the case study of South Africa and is included in the below.

	Key Question	Ideal Indicators	Identified Available Indicators	South Africa	Source
Policy and Regulations	Does the policy framework support entrepreneurship and cleantech/sustainability innovation and SMEs?		NDC Commitment (Paris)	Yes	"Highly Insufficient" Climate Tracker, South Africa 2019
			Key Energy Policy (Cleantech Friendly policies)	Renewable Energy Independent Power Producer Programme (REIPPP) (replaced the Feed-in Tariff program) Integrated Resource Electricity Plan 2010-2030 National Energy Act (2008)	IEA-IRENA Joint Policies and Measures Database, 2018

			Energy Efficiency Regulations		Various Sources National Energy Regulator of South Africa under Department of Mineral Resources and Energy National Energy Regulatory Act 2005 -- established juristic authority to make decisions regarding electricity, piped-gas and piped petroleum industries South African National Energy Development Institute (SANEDI): "advance innovation of clean energy solutions and rational energy use, which effectively supports South Africa's national energy objectives and the transition towards a sustainable low-carbon energy future"
			RE regulations		Various Sources SANEDI --> RECORD, REEEP, and WASA programmes for RE development
			Env Regulations		Greenpeace, 2018
		Review of Legislation/Policy: Are there specific policies which pose incentives or barriers for improving cleantech development and entrepreneurship?	Carbon Pricing	Yes, Carbon tax	Al Jazeera, 2019
			Energy Transition Index Score	114/115	World Economic Forum, 2019

			Cleantech Regulations/Targets	Technology Innovation Act (Act 26 of 2008)	Department of Science and Technology, 2018
			Small business regulation/policy	Yes	Various Sources, SEDA, 2019, Greencap SA, 2019b
			Existence of SME and Investment incentives and funds	Incubation Support Programme (ISP); Support Programme for Industrial Innovation (SPII); 12i tax incentive; Greencape incentives booklet	Greencape SA, 2019b
			Existence of National Agency mandated for cleantech	Yes: Technology Innovation Agency	TIA, 2019
			Number of clean energy related policies in force	~13	IEA/IRENA Joint Policies and Measures Database, 2018
Political Stability	Do the governance systems and institutions effectively support an environment in which to pursue cleantech innovation and entrepreneurship?	Corruption Perceptions Index (Transparency international)	Corruption Transparency Intl	43/100	Transparency Intl, 2018
		International Rule of Law index	Rule of Law Index	0.58 overall score, 47/126 global rank	World Justice Project, 2018
		Peaceful transfer of Power	Strength of legal rights index (0=weak to 12=strong)	5 (2018)	Open Data World Bank. 2019
Market Infrastructure	Do existing market infrastructure and systems facilitate the creation and operation of cleantech business ventures?	Ease of doing business report	Annual GDP growth rate	1.32%	Open Data World Bank. 2019
		World Economic Forum Global Competitiveness Report	Credit Rating	Baa3 Stable (Moody's, 2018)	Trading Economics, 2019

			GDP per capita, current US$	6151.1 (2017)	Open Data World Bank. 2019
			World Bank Ease of doing business Ranking	82/190 (2019)	World Bank Doing Business, 2019
			World Bank Starting a Business Rating	131/190 (2017)	GEM 2017/2018 report
			World Economic Forum Global Competitiveness	67/140 (2018)	WEF Global Competitiveness Report 2018
			Time required to start a business	40 days (2018)	Open Data World Bank. 2019
			Time to resolve insolvency (years)	2	Open Data World Bank. 2019
			Informal employment (% of total non-agricultural employment)	35.2% (2018)	Open Data World Bank. 2019
			Cost of business start-up procedures (% of GNI per capita)	0.2% (2018)	Open Data World Bank. 2019
			Exports of goods and services (% of GDP)	29.8% (2017)	Open Data World Bank. 2019
Physical infrastructure	Is there basic physical infrastructure to support doing business?	Electrification Rate (% of pop)	People using safely managed sanitation services (% of population)		
		Gov expenditure on road/transport	Electrification Rate (% of pop)	85% (2013)	Open Data World Bank. 2019
		Water sanitation rate	Quality of Electricity Supply		N/A
		Logistics Performance Index	Gov expenditure on road/transport	101.3 R billion for "Economic Regulation and Infrastructure	National Treasury Republic of South Africa, 2019
		Household Electricity Prices	Logistics Performance index	3.38 (2018)	Logistics Performance Index, 2018

		Transportation Infrastructure (distance traveled per capita by mode of transport)	Rural Population with access to electricity	67.9% (2016)	World Bank, 2019
Digital infrastructure	Do individuals have access to communication technologies and infrastructure?	% Household Access to Internet	Individuals using the internet (% of population)	56.2% (2017)	Open Data World Bank. 2019
		Percent of population with access to Mobile Networks	Percent of population with access to Mobile Networks		
		Amount of Gov services available online	Mobile cellular subscriptions (per 100 people)	156	Open Data World Bank. 2019
		ICT access and use	Fixed broadband subscriptions (per 100 people)	2.0 (2017)	Open Data World Bank. 2019
			Fixed telephone subscriptions (per 100 people)	8.5 (2017)	Open Data World Bank. 2019
			ICT access and use	N/A	
Finance and Funding	Can individuals or SMEs access capital for starting or expanding a business venture or commercialising an innovation?	Interest Rates	Lending interest rate (%)	10.4% (2017)	Open Data World Bank. 2019
		Amount of donor grants for cleantech	Real interest rate (%)	4.6% (2017)	Open Data World Bank. 2019
		Number of microfinance institutions	Account ownership at a financial institution or with a mobile-money-service provider (% of population ages 15+)	69.2% (2017)	Open Data World Bank. 2019
		Number of financial institutions	Commercial bank branches (per 100,000 adults)	10.4 (2017)	Open Data World Bank. 2019
		Availability of cleantech-specific loans	Venture capital deals/bn PPP$ GDP	N/A	

		Amount of donor grants for cleantech	Microfinance gross loans, % GDP	gross loans not available but 1100 microfinance offerers	MFSA, 2019
			Credit bureau or credit registry coverage % of adults	67.30%	World Bank Doing Business South Africa, 2019
		Number of venture capital firms	Ease of getting Credit	60	World Bank Doing Business South Africa, 2019
Financial Security	Are individuals financially able to take a business risk?	Adequacy and coverage of social safety nets	Unemployment rate	26.9% (2018)	Open Data World Bank. 2019
		Number of people per capita with a bank account	Wealth inequality	top 1% own 70.9% of the nation's wealth; bottom 60% control 7%	South Africa Overview, World Bank, 2019c
		Number of people below the poverty line	GNI per capita	5430 US$ (2017)	Open Data World Bank. 2019
		GNI per capita (HDI)	Population in multidimensional poverty, headcount (%)	8.2% (2015)	United Nations Development Project 2018
		Average income v. cost of living	Adequacy of social safety net programs (% of total welfare of beneficiary households)	29.37%	Open Data World Bank. 2019
		Degree of Inequality	Coverage of social safety net programs (% of population)	78.6% (2014)	Open Data World Bank. 2019
			GDP per capita, PPP (current international $)	13526.2$ (2017)	Open Data World Bank. 2019
Edu and Human Capital	Do individuals with the capacity to engage in innovation and entrepreneurship exist in society?	% of population in the labor force	Labor Force (% of population)	56% (2018)	Open Data World Bank. 2019
		Number per capita of scientific and technical publications	Unemployment, total (% of total labor force) (national estimate)	26.9% (2018)	Open Data World Bank. 2019

		Number per capita of universities, research institutes and technical schools		N/A	
		Number of graduates in business, science/engineering and sustainability	Compulsory years of education	9 (2017)	Open Data World Bank. 2019
		Jobs in low-carbon industries	Labor force with intermediate education (% of total working-age population with intermediate education)	68% (2018)	Open Data World Bank. 2019
		Skilled labour (% of labour force)	Skilled labour (% of labour force)		
		Youth Employment Rate	Government expenditure on education, total (% of government expenditure)	18.7% (2017)	Open Data World Bank. 2019
		Per capita number of universities/institutes	Net Migration	300,000 (2017)	Open Data World Bank. 2019
			Number per capita of universities	19 universities, 7 universities of technology, 9 community colleges/training colleges, 50 TVET (technical, vocational, educational & training colleges)	National Government of South Africa, 2019
Research and Development	Are there research institutions and systems	Number of Researchers in R&D	Number per capita of patents	728 patent applications by residents (2017)	South Africa: Patent applications by residents, The Global Economy, 2019

	facilitating cleantech innovation?	Number per capita of patents	R&D expenditure as % of GDP	0.05% (% of GDP by sector, Government)	Centre for Science, Technology and Innovation Indicators, 2017
		R&D expenditure as % of GDP	Trademark applications, total	26,251 (2017)	Open Data World Bank. 2019
		Government R&D expenditure in innovation	Research institutions prominence index (Nature)	Article count: 318 (131 in physical sciences, 72 in earth and environmental sciences)	Nature Index, 2019
		Government R&D expenditure in cleantech innovation	Researchers, FTE/mn pop	51 877 (2015/16, total number)	Centre for Science, Technology and Innovation Indicators, 2017
			Scientific & technical articles/bn PPP$ GDP	N/A	
			Citable documents H index	N/A	
			Graduates in science & engineering (percent in tertiary education)	18.49% (2016)	UNESCO Institute for Statistics, 2019
			Proportional RD expenditure in environment/environment related	6.4% (2015/2016)	Centre for Science, Technology and Innovation Indicators, 2017
Support Mechanisms	Are there institutions and support mechanisms which support entrepreneurs and innovators?	Number of Cleantech Industry Organisations	State of cluster development	N/A	
		Number of Incubators and Accelerators in the Region	Existence of entrepreneurship/innovation incubators and accelerators	Yes	Various Sources. Innovation Hub, SEED, Sector Education and Training Authority (SETA)
		Number of participants in incubators	University/Industry research collaboration	N/A	
		Existence of youth entrepreneurship programmes	Existence of cleantech industry organizations/associations	Yes	Various Sources. GreenCape, Climate Innovation Center, NCPC

			Number of programmes/incentives for cleantech	5 (4 specifically, 1 which includes coverage fur green industries projects)	GreenCape SA 2019b
Risk Attitudes	Which cultural attitudes influence risk acceptance and perception of business opportunities?	Existence of media narratives	Entrepreneurship as Desirable Career Choice	69.36	GEM, 2017/2018
		Global Entrepreneurship Index	Media Attention for Entrepreneurship	74.2 (2016)	GEM, 2017/2018
			Entrepreneurial Spirit Index (GESI)	-0.2	GEM, 2017/2018
			Entrepreneurial Employment Activity (GEM) percent of population engaged	0.50%	GEM, 2017/2018
Sustainability Awareness	Are individuals in society aware of sustainability issues? For example: climate change, recycling, air pollution, water scarcity, etc	Existence of public awareness programs educating on sustainability	PM2.5 levels, mean annual exposure	25.1 micrograms per cubic meter (2017)	Open Data World Bank. 2019
		Exposure to climate or env issues via pollution or env risk issues	CO2 per capita	8.98 metric tons per capita (2014)	Open Data World Bank. 2019
		Exposure to climate or env issues via media	Protected Area as % of total area	10.3% (2017)	Open Data World Bank. 2019
			Total Emissions of GHGs	575 MtCO2	Climate Tracker, 2019
			Share of electricity from RE	1.9% (2015)	Open Data World Bank. 2019
			Share of Electricity from Coal	92.7% (2015)	Open Data World Bank. 2019
			GDP/unit of energy use (PPP $ per kg of oil equivalent)	4.86 (2014)	Open Data World Bank. 2019
			Media narratives		Joubert, 2018

			Number of Env NGOs	~500 out of 215,308 registered Non-profits	Department of Social Development, 2019
Social Influences	Are there any other factors that might impact individual ability to interact with stakeholders and institutions or the ability for individuals to access knowledge and resources? For example: Gender, youth, etc.	Level of individualism vs. communitarianism	Gender Inequality Index	0.389 (2017) global rank = 90	United Nations Development Project 2018
		Gender equality (Gender Inequality Index)	Children in employment, total (% of children ages 7-14)	27.7% (1999)	Open Data World Bank. 2019
		Social Trust	Share of youth not in education, employment or training, total (% of youth population)	31.6% (2018)	Open Data World Bank. 2019
		Gender balance in STEM	Law mandates nondiscrimination based on gender in hiring (1=yes; 0=no)	1	Open Data World Bank. 2019
		Number of programs promoting local businesses	Females employed w/advanced degrees, %.	79% (2018)	Open Data World Bank. 2019
			Female/Male Total Entrepreneurship ratio	0.69 (2017)	GEM, 2017/2018
			Existence of programs promoting local business	?	Not on gov website (https://www.gov.za/about-government/government-programmes/projects-and-campaigns) but heard of Proudly South Africa
			Interpersonal Trust	23.51% (2014)	Open Data World Bank. 2019
Cleantech Sector	Is there a cleantech sector in this country?	Survival Rate of Cleantech startups at 3 and 5 years	Survival rate of businesses	N/A	

	To what degree is the cleantech sector already developed? How healthy is the existing cleantech sector?	Amount of investment in cleantech sector	Global Cleantech Innovation Index	31 in overall ranking	GCII, 2017 (Sworder et al, 2017)
		Ownership Rate of Cleantech Startups	Number of Cleantech companies	N/A	
		Employment rate of cleantech firms	Number of B corps	8	Directory Certified B-Corporation 2019
		Number of Cleantech companies that are operating under license	Amount of cleantech sector investment		
		Number of B Corps	Number of impact investment firms	N/A	
		Number of cleantech patents (OECD)	Cleantech patents (OECD)	Percent of technology patens in environment-related tech: 14.53% (2015)	OECD, 2019
		Number of impact investor firms present in country	Numbers of jobs in RE sector	42,900 jobs in renewable energy employment	IRENA, 2019
			Number of industry associations, physical clusters and economic initiatives supporting the cleantech industry as a proportion of GDP (PPP)	N/A	
			Amount of venture capital invested in cleantech companies as a proportion of GDP (PPP)	N/A	
			ISO 14001 certifications	1230	ISO Technical Committee 9, 2019

			Development of environment related technologies, percent of all technologies	14.53 (2015)	OECD, 2019
			Development of environment related technologies, inventions per capita	0.97 (2015)	OECD, 2019

Appendix II - Interview Data

Table II-1 Interviews conducted. Names and positions of individuals were withheld to maintain confidentiality.

Interview	Type of Stakeholder	Organization	Date	Format
1	Environmental Non-Profit	Climate Activist	5/23/19	video call and in person
2	Cleantech Sector	National Cleaner Production Center (NCPC)	7/1/19	in person
3	Research Institution	Center for Scientific and Industrial Research (CSIR)	7/1/19	in person
4	Government Agency	Department of Science and Innovation (DSI, formerly DST)	7/1/19	in person
5	Entrepreneur	GCIP-SA Alumni	July 3rd	call
6	Research Institution	Water Research Commission (WRC)	July 2nd	in person
7	Finance Sector	Development Bank of Southern Africa (DBSA)	July 2nd	in person
8	Government Agency	Department of Energy	July 2nd	in person
9	Public Utility	Eskom	July 3rd	in person
10	Support Mechanism	Climate Innovation Center (CIC)	July 3rd	in person
11	Government Agency	Technology Innovation Agency (TIA)	July 4th	in person
12	Support Mechanism	InvoTech, Durban University of Technology	July 4th	video call
13	Private Sector	Growth Point	July 4th	phone call
14	Government Agency	Small Enterprise Development Agency (SEDA)	July 5th	in person

15	Government Agency	Department of Trade, Industry and Competition (dtic)	July 5th	in person
16	Entrepreneur	GCIP-alumni, mentor and trainer	July 5th	call
17	Cleantech Sector; Non-profit	GreenCape	July 12th	video call
18	Government Agency	Small Enterprise Development Agency (SEDA)		*Not conducted by author. This interview was conducted by Rebecca Gunning, UNIDO-consultant, who provided a de-brief and notes.
19	Academic	Global Entrepreneurship Monitor (GEM) special report for South Africa	July 16th	video call
20	Finance Sector	Impact Investing South Africa	July 18th	call

Table II-2 Interview responses. Interviews were analysed using the following key themes.

THEMES	Barrier Sub-themes (without interactions) as frequency of response												Total
FRAMEWORK													
Policy and Regulations	Policy not adequate	4	Policy not effective	7	Policy not well-implemented	3	Policy incoherent	4	Need to better prioritize cleantech	3	Processes too slow	3	24
Political Stability	Institutions not stable enough	4											4
Market Infrastructure	Accessing markets and finding a buyer	11			cleantech not aligned with market demands	2							13

Physical infrastructure													0
Digital infrastructure	internet access not always available	1											1
Finance and Funding	lack of access to funding	9	Risk averse in terms of providing funding, therefore accessing is difficult	9	cleantech funding has different requirements	4	use of existing funding is inadequate	3	more funding needed	4			29
Financial Security	Rural access to services is lacking	3	cleantech not a solution to unemployment	1	insufficient safety nets	1							5
Edu and Human Capital	low quality of education	1											1
Research and Development	R&D uptake is lacking	3											3
Support Mechanisms	lack of business skills	5	lack of support in commercialization step	7	need more incubators	2	longterm support needed	2	tech support is unique/more difficult	1	need to improve incubator practices	5	22
Risk Attitudes	Risk Aversion: Funding and investment	6	Low risk acceptance among individuals	2									8
Sustainability Awareness	consumer/household awareness is lacking	2	affordability of eco products is kay	3	awareness of sustainability is increasing	1							6
Social Influences	not enough consumption of local products	1											1
Cleantech Sector	no oversigh/registry of industry	1	competition with incumbent industry	2	cleantech interest is increasing	5	no well developed cleantech	1	access to cleantech products and programmes is improving	2			11

							industry currently						
NON-FRAMEWORK													
Ecosystem Interactions	Oversight: who is doing what?	11											31
Purpose/Alignment in ecosystem	Intentions are good	1	Overall purpose is not aligned	9									
Measurement/Targets	Measuring and targets need to be better/coordinated	9	Timelines are not right for cleantech	1									

Table II-3: Summary of key findings from interviews

THEMES	Summary of Key Interview Findings
FRAMEWORK	
Policy and Regulations	- In some cases, policy exists but even where it does it does not seem to be stringent enough or well-implemented. Although for example, some clean energy incentives exist, they are not well marketed and/or are insufficient (for example grid connections for IPP are capped at an extremely low capacity). There is also a general misalignment between stated policy goals on climate and the reality of implementation and taking action (particularly due to an incumbent coal industry). - Similarly, some viewed IPR legislation as sufficient, others felt more was needed to protect disruptive ideas or clarify the process around IP depending on their role in the ecosystem. - SME and investment incentives exist but it remains unclear how successful they have been/are. In addition, the regulatory environment was seen as too slow and complicated by several actors (for example registering a business should be easier)

Political Stability	- The stability of institutions post-election was more important than anticipated: corruption exists but was not mentioned as a significant barrier. Instead, much more uncertainty was created in the ecosystem by re-structuring and renaming departments and changing their personnel or strategy as a result of the new administrations' efforts.
Market Infrastructure	- Market infrastructure itself appeared to be sufficient but access to these markets was the barrier. This issue is linked to fragmentation of the ecosystem generally as it was difficult for individuals to take the step of going from prototype to commercialized product. - Better facilitation of commercialization of projects is needed – as an individual, how do you get clients and enter an established market? General sense that this was a barrier, or at least was an area that could be significantly strengthened. - There is cause for concern about whether "green"-oriented markets exist to a level which is sufficient for cleantech to find a robust market. This is linked to weakness in the degree of sustainability awareness.
Physical infrastructure	
Digital infrastructure	
Finance and Funding	- Thoughts on sufficiency of funding were mixed: some actors felt there is enough in the ecosystem, others felt there could be more. - Private-sector and government interaction was considered low, with need for improvement - Finding funding and knowing which agencies have funding available for which stage in the process appeared to be the bigger problem - Funders in the system are also seen as being risk-averse with targets/investment objectives that are not very compatible with cleantech projects, primarily due to the long turn around and capital intensive nature of many cleantech projects.
Financial Security	- High degree of unemployment is relevant but it is unclear whether it is a driver or a barrier for entrepreneurship - Current cleantech sector entrepreneurship is unlikely to be a good driver of job creation though - Existing social safety net may be insufficient to support risk-taking
Edu and Human Capital	- General sense that business skills were lacking among entrepreneurs, but not sure if this can be linked to general/higher education specifically. - This area was not mentioned much
Research and Development	- Quality R&D is being done but there appear to be barriers in taking this research further. Better collaboration between institutional research and

	outside/other ecosystem actors is needed. - Improving the interactions between academic/research institutes and partners in industry could help to take ideas further, from prototype to commercialization, by ensuring there is a market
Support Mechanisms	- Support mechanisms exist but in a fragmented and uncoordinated way - No single actor has oversight of what others are doing or what is missing in the ecosystem - There is very limited coordination or cooperation between actors, both within the same space as well as throughout the commercialisation value chain - Need for better publicizing/marketing of existing opportunities for entrepreneurial support, especially in rural areas. Much of the existing opportunity seems clustered in Gauteng or Western Cape. - Multiple actors indicated that further help is needed to successfully take projects to commercialization (post-accelerator/incubator support to find clients and markets) as well as a better process for exiting “bad” ideas.
Risk Attitudes	- Although entrepreneurial attitudes among individuals was not indicated as being a significant problem, the system overall, and particularly the funding system, was described as being very risk-averse. Government agencies and private sector funders, like banks, are seen as being reluctant to invest in or support (such as through procurement) untested technologies which limits the growth potential of new cleantech, particularly the more disruptive it is. - Fear of failure was a potentially important barrier for entrepreneurship
Sustainability Awareness	- Awareness of energy efficiency (EE) issues was described as quite high/active (driven primarily by issues of electricity access), as well as concern for water efficiency. But other sustainability issues appeared less often in conversation. - There is not yet a strong green market. Cost competitiveness of clean tech is crucial to capture any market share, which may be a significant barrier. - Incumbent industry, and especially socio-economic issues related to coal, are still big players in society. - There is a split between society: industry and high-income areas are more aware of sustainability issues. But there is disagreement about the degree to which industry is taking cleaner measures seriously. - Increasing trend towards more sustainability due to health risks and increasing awareness.
Social Influences	- Almost all interviewees mentioned a focus on Previously Disadvantaged Individuals (PDIs): women, black communities, and youth - Strongly reflected in the mandate of government agencies - Not enough consumption of domestic products. Consumers seem to prefer international products, and though there is an initiative for government procurement of local goods, this is not widely implemented.

Cleantech Sector	- Overview of the cleantech sector is lacking, and it is unclear to what degree a cleantech "sector" really exists (for example, there is no national registry of cleantech companies or patents) - Green/clean trend in industry is growing and there does seem to be significant (or at least increasing) interest in cleantech in industry and the private sector - Barriers due to the strength of the incumbent industry - Need for better organization/coordination among actors in the ecosystem to better support cleantech
NON-FRAMEWORK	
Ecosystem Interactions	- Essentially a consensus that the biggest barrier in the CIEE is the lack of oversight and coordination between actors in the ecosystem. - The ecosystem lacks effective coordination between players - both those in the same space (for example: different incubators doing the same things) as well as along the value chain (how or who can help at different stages (ideation to commercialization) and how to do this hand-off) - Better transparency and cooperation are needed to allow for effective cleantech development
Purpose/Alignment in ecosystem	- Actors lack coordination regarding the overall purpose in driving cleantech development (Is the goal: job creation? solving climate change? personal opportunity? industrial solutions? economic growth? Etc.) - Better alignment of purpose, or at least an understanding of what other actors perceive as the purpose, would improve communication and interaction between actors - Divide between the type of cleantech being driven: a focus on supporting smaller innovations (less new, maybe have been done somewhere before) with a quick return on investment and which quickly produce jobs; or longer term more disruptive and risky projects that may have more environmental and disruptive impact? - The unfamiliarity with the purpose of other actors also means there is a disconnect in understanding what kind of key issues different actors and individuals engaged in cleantech development face.
Measurement/Targets	- Lack of purpose translates into a lack of appropriate target setting and a lack of effective measuring of progress - Alignment or conversation is needed to decide which projects are worthwhile, how to assess impact, and how actors should measure progress

Appendix III - Updated CIEE Framework

The below table is the fully updated CIEE framework developed as a result of this thesis project. It incorporates the new addition of the Ecosystem Linkages pillar as well as the new sub-questions developed and the recommended indicators which were maintained.

Sub-Pillar	Key Question	Sub-Questions	Recommended Indicators
Policy and Regulations	Does the policy framework support entrepreneurship and cleantech/sustainability innovation and SMEs?	To what degree does the policy framework support entrepreneurship? Innovation? Cleantech and/or sustainability? - Which policies are in place and what are their main objectives? Which policies are under development and what are their main objectives?	NDC Commitment (Paris Agreement) Key Energy Policy (Cleantech Friendly policies): Energy Efficiency, Renewable energy, Environmental regulation Carbon Pricing Energy Transition Index Score Existence of Cleantech specific regulations and/or targets Small business regulation/policy and SME incentives Existence of National Agency mandated for cleantech
		Are there any policies (or lack of policies) which seem to pose barriers to the cleantech ecosystem? Are there policies which seem to work particularly well?	
		Is the policy support for cleantech (for example regarding energy efficiency, renewable energy, climate policy) sufficient? Is it well-implemented? - Do the policies in these sectors effectively drive renewable energy growth, uptake of energy efficiency, or achievement of climate targets?	
		Is the policy support for entrepreneurship and SMEs sufficient? Is it well-implemented? - Do the policies in these sectors effectively help incentivise and grow entrepreneurship and small-business? - Are individuals in the ecosystem aware of and using the support?	
		Are existing policies in climate/energy and small business support considered efficient and/or well-implemented? Do they incentivize cleantech innovation and entrepreneurship?	
Political Stability	Do the governance systems and institutions effectively support an environment in which to pursue cleantech	Do institutions have the capacity and resources to facilitate entrepreneurship and innovation?	Corruption Perceptions Index Rule of Law Index Strength of Legal Rights Index
		To what degree are institutions perceived as stable and reliable for the purposes of starting a business or expanding a business?	

	innovation and entrepreneurship?	Is the regulatory and policy environment consistent enough to allow for predictability of business risks by investors, entrepreneurs and innovators?	
		Is the institutional environment perceived as fair for settlement of disputes, insolvency, or protection of investments?	
		Is there alignment between the policy framework and implementation by institutions on key policy issues related to SMEs, innovation and sustainability?	
		Is the enforcement of civil and criminal justice perceived as just?	
		Are there barriers due to corruption, state capture, human rights abuses or similar?	
Market Infrastructure	Do existing market infrastructure and systems facilitate the creation and operation of cleantech business ventures?	Is market infrastructure supportive of entrepreneurship and innovation, particularly for investment in and commercialization of new cleantech solutions? - Do financing mechanisms exist? - How stable are financial markets?	GDP growth rate and GDP per capita Credit Rating World Bank Ease of Doing Business and Ease of Starting a Business WEF Global Competitiveness Index Time required to start a business Time to resolve insolvency Cost of Business Start-Up Procedures (GNI per capita) Exports of goods and services (% of GDP) Share of Informal Employment (% of total non-agricultural employment)
		Is the market developed enough to accept new businesses? - How developed is consumer demand? - How developed is existing industry?	
		To what degree does the informal sector influence new or existing SME development?	
		To what degree is the market easily accessible for new businesses? - How easy is starting a business? - How easy is resolving insolvency?	
		To what degree does the level of market development facilitate business expansion?	
		What is the degree of development of consumerism and how might this influence long term commercialization of new products/services?	
		What is the level of availability of local/domestic investment? Foreign investment?	
		What is the degree of influence and role of foreign markets?	

Physical infrastructure	Is there basic physical infrastructure to support doing business?	Are people able to count on basic needs (energy, water, transport) consistently being met for themselves and their business? - How developed is electrification? - How developed is access to clean water? - How developed are waste management services? - How developed are road and transport networks? - Are there significant differences in availability of infrastructure between rural and urban areas? Other geographic barriers?	Access to improved drinking water and sanitation facilities (% of pop.) Electrification rate (% of pop.) Electrification rate rural areas Quality of electricity supply Existence of waste management service Government expenditure on Road and Transport World Bank Logistics Performance Index
		Can they access and take advantage of existing infrastructure for the purposes of entrepreneurship or innovation?	
		How difficult is it to access new electrification or water hook-ups for new businesses?	
		To what degree do waste management services meet the needs of businesses?	
		Are transportation systems sufficient to facilitate transfer of goods and services? For cities? For rural areas? For both? - Is public transport available? Safe and reliable?	
		Are there any significant physical transportation barriers (for people or goods/services) that might limit small businesses?	
		Are there any other significant physical infrastructure barriers (for people or goods/services) that might limit small businesses?	
Digital infrastructure	Do individuals have adequate access to communication technologies and infrastructure?	What is the degree of access to internet services? - For urban areas? Rural areas?	Internet use (% of pop.) Mobile network access (% of pop.) Mobile cellular subscriptions (per 100) Fixed broadband subscriptions (per 100) Fixed telephone subscriptions (per 100) Amount of government services available online
		What is the degree of availability of important services online? - This may include things like: technical data, business services, sustainability knowledge, support mechanisms, or other services	
		Can existing telecommunications infrastructure be accessed? - How reliable is it? - How affordable is it for most individuals?	
		Are telecommunications and internet infrastructure sufficient to support entrepreneurs and innovators in accessing	

		information? Starting a business? In commercializing their products?	
Finance and Funding	Can individuals or SMEs access capital for starting or expanding a business venture or commercialising an innovation?	How easily can individuals or SMEs access capital for starting or expanding a business venture or commercializing an innovation?	Lending interest rate (%) Real interest rate (%) Account ownership at a financial institute or a mobile-money-service provider (% o f pop. Age 15+) Commercial bank branches (per 100,000 adults) Venture capital deals/bn PPP$ GDP Microfinance gross loans (% of GDP) Credit bureau or credit registry coverage (% of adults) Availability of cleantech specific loans and grants (public sector) Availability of SME/innovation specific loans and grants (public sector)
		How much capital is available for entrepreneurs/innovators? - Is this capital stable and consistently available?	
		Are there significant barriers for accessing capital? - Do interest rates pose a barrier? - Other accessibility issues?	
		What types of funding resources are available? - How well developed is the banking system? - Does venture capital exist? To what degree? - Does impact investing exist? To what degree? - How developed is crowd-funding?	
		Is public funding, in the form of grants and loans, available for cleantech? SMEs? Innovation? - How much financing is disbursed and/or received? - How often are these instruments used?	
		To what degree is the access to available capital communicated to indivduals/SMEs? - How aware of where to find funding are individuals?	
Financial Security	Are individuals financially able to take a business risk and to what degree do socioeconomic factors influence entrepreneurship and innovation?	Are people's basic incomes meeting their needs so that they can feel safe/empowered to engage in potentially risky new business or spend time not working? - To what degree do average wages allow individuals to meet basic needs? - Are wages stable and can individuals count on consistency of wages?	Unemployment (% of pop.) Wealth inequality GNI per capita and GDP per capita Human Development Report's Multidimensional poverty (% of pop.) Coverage of Social Safety Net programmes Adequacy of Social Safety Net programmes
		How might employment rates or wage levels impact the ability of individuals to engage in entrepreneurship? - Do most people have stable, living-wage jobs? - How much unemployment is there?	
		To what degree do social safety nets offer support for individuals engaging in business risks? - Do they offer a fall back support if a business fails?	

		Are individuals/households able to save money in order to support themselves while starting a new business?	
		To what degree does wealth inequality exist? - How might this impact other factors?	
		To what degree does poverty exist? - How might this impact other factors?	
Edu and Human Capital	Do individuals with the capacity to engage in innovation and entrepreneurship exist in society?	Is there a sufficient population with the capacity to engage in cleantech entrepreneurship or innovation?	Labour force (% of pop.) Unemployment (% of labour force) Compulsory years of education Labour force with intermediate education (% of total working-age population) Skilled labour (% labour force) Government expenditure on education (% of gov expenditure Net migration Number of universities and technical institutes
		To what degree does the education system support entrepreneurship and innovation? - How does public education address science and technology; business skills; sustainability?	
		How well-developed is the public education sector? - How well funded is the sector? - How many: universities? Technical institutes? Community learning centers?	
		Do individuals have alternate access to further education on business, technical, and sustainability topics? - Availability of online or distance learning? - Availability and accessibility of public libraries? Research data bases?	
		To what degree does the population have skills in business? Technical skills? Sustainability knowledge/mindset? - What is the average degree of education in these fields? - How much of the population is pursuing secondary or tertiary education in these fields?	
		Are there demographic influences that might impact human capital ("brain drain," high youth migration, etc)?	
Research and Development	Are there research institutions and systems facilitating cleantech innovation?	To what degree are the research institutions and systems facilitating cleantech innovation? - How much research is being done? - How many patents and trademark applications are produced? - How prominent or well-regarded are research institutes? - How many people are employed in research activities?	Tertiary graduates in science and technology (% of tertiary degree graduates R&D expenditure (total % of GDP) Number per capita of patents Total trademark applications

		To what degree are research institutions producing new research and innovations? - How much of this research is cleantech/sustainability related?	Number of full time employed (FTE) researchers (per mn of population) Research institution prominence Share of R&D expenditure in cleantech, climate, energy and/or environment Scientific and technical articles (per bn PPP$ GDP) Citable documents H index
		Are research institutions sufficiently funded? - How much government expenditure goes to support R&D?	
		What role does industry play in supporting or funding R&D?	
		What role do universities play in supporting R&D?	
		Is there an incentive for institutions to focus on cleantech issues? - Do institutes with a cleantech focus or mandate exist?	
		Is research from institutions and universities accessible to innovators and entrepreneurs?	
Support Mechanisms	Are there institutions and support mechanisms which support entrepreneurs and innovators?	To what degree do support mechanisms facilitate access to information for entrepreneurs and innovators?	Existence of entrepreneurship/innovation incubators and accelerators Number of university/industry research collaborations Existence of cleantech industry organizations/associations Number of programmes and incentives for cleantech State of cluster development
		Do incubators, accelerators and mentorship programmes for new businesses and innovation exist? - How well-developed are they? - How well used are they? - How accessible are they?	
		How much industry and university collaboration is there?	
		Do business and industry networks for cleantech exist? - How robust are they? - How visible and accessible are they? - How do they interact with other institutions?	
		Are there specific support programmes and incentives for cleantech?	
		Is there sufficient communication/cooperation between actors to help individuals overcome barriers to turning an innovation into a business? To commercializing a business?	
		To what degree is there cooperation between individuals, innovators/researchers, and funding mechanisms? - How transparent is this cooperation?	
Risk Attitudes	Which cultural attitudes influence risk acceptance and	What kind of cultural attitudes around risk acceptance and perception of business opportunities exist?	Entrepreneurship viewed as a desirable career choice (% of population)

	perception of business opportunities?	- How do these attitudes influence entrepreneurship? Innovation? - Are these attitudes barriers or enablers?	Media attention for entrepreneurship Entrepreneurial employment activity (% of pop.) Entrepreneurial Spirit Index (GESI)
		Are individuals in society empowered to engage in entrepreneurship? In innovation?	
		What kind of social norms or narratives around entrepreneurship and innovation exist in society?	
		What are the social perceptions of entrepreneurship as a career choice?	
		How much risk associated with starting a business or pursuing an innovation do individuals perceive?	
		How much business opportunity in society do individuals perceive?	
Sustainability Awareness	Are individuals in society aware of sustainability issues? For example: climate change, recycling, air pollution, water scarcity, etc	How aware are individuals/communities about sustainability issues and the role they can play? - Are there public awareness programmes educating the public on sustainability? (i.e. recycling programmes, energy efficiency or water-saving campaigns) - How much exposure to pollution do individuals face? (especially more visible pollution such as air pollution)	Mean annual exposer to particulate matter (PM2.5) Amount of protected wildlife areas (% of total area) Media narratives Number of environmental NGOs Per capita CO2 emissions GDP per unit of energy use Total national GHG emissions Share of electricity from RE and Coal (% of total electricity mix)
		To what degree is awareness of environmental issues prevalent? - How is this reflected in media narratives? - In civil society? - In the mandates of public sector agencies? - In the private sector?	
		What kinds of environmental issues might be most prevalent (i.e. energy efficient, water/drought, air pollution, disease/health risks, waste, etc)? - Can cleantech help address these?	
Social Influences	Are there any other factors that might impact individual ability to interact with stakeholders and institutions or the ability for individuals to access knowledge and	Are there other social influences that might pose a barrier or opportunity for entrepreneurship or innovation in cleantech?	Degree of social trust Gender Inequality Index (HDR) Percent of females employed with advanced degree Female to male total entrepreneurship ratio
		To what degree are minority groups (such as women and youth) empowered to engage in new business? - Is society accepting of these individuals in positions of business ownership and leadership?	

	resources? For example: Gender, youth, etc.	To what degree are women and other minority groups able to access knowledge, funding and other services required to start a new business? - Do these individuals face additional barriers?	Law mandates non-discrimination based on gender Total share of youth not in education, employment or training (% of total youth pop.) Children in employment (total % of children ages 7-14) Existence of campaigns or incentives promoting local
		Are there any existing programs/policies targeted to support women, youth, other minority entrepreneurs and innovators?	
		What kinds of attitudes exist in society around social trust? Individualism? - How community oriented are individuals in society? Does this impact entrepreneurship?	
		What kinds of attitudes exist around supporting local business? - Are there any campaigns (government or NGO) promoting local businesses?	
Stakeholder Linkages	How and to what degree do the stakeholders in the ecosystem interact and how does this impact cleantech development?	Who are key stakeholders in the ecosystem?	Degree of inter-agency cooperation and alignment (number of partnerships) Degree of alignment in agency mandates Number of public-private partnerships
		Is there a stated relationship between key stakeholders? - To what degree does this relationship translate into outcomes?	
		To what degree do actors in the ecosystem interact and collaborate? - How do relationships between institutions manifest as linkages? Consider: the formal and informal interactions of government agencies (local and national), industry, research institutes and researchers, non-profits, environmental organizations, entrepreneurs, investors and markets, consumers, etc.	
		How do the mandates or purposes of different actors compare? - Is there broad alignment? Misalignment? - What kind of targets or metrics do different agencies have for measuring progress? Measuring impact?	
		Is there sufficient communication/cooperation between actors to help individuals overcome barriers to turning an innovation into a business? To commercializing a business?	
		Are there sufficient linkages and interactions between pillars and relevant actors (including government, private sector,	

		non-profit, and individuals) to facilitate innovation and entrepreneurship?	
Environment Linkages	How and to what degree do the factors in the ecosystem influence each other?	What are the underlying influences for key barriers? Key Strengths?	Policy coherence, Ease of access identifying resources for entrepreneurship and innovation,
		Where are positive feedback loops in the ecosystem?	
		Where are negative feedback loops in the ecosystem?	
		How resilient is the system? - To what degree are behavioral patterns entrenched in the system?	
		What appear to be the broad paradigms or goals driving system behavior?	
Cleantech Sector	Does a cleantech sector exist and to what degree is it already developed?	What is the health or what is the level of development of the existing cleantech sector?	Number of registered cleantech companies (or existence of a cleantech registry) Amount of investment in the cleantech sector Amount of venture capital invested in cleantech Number of cleantech patents filed Number of industry associations, physical clusters, and economic initiatives for cleantech Global Cleantech Innovation Index score Number of B-corps certifications Number of impact investment firms Number of ISO 14001 certifications Number of jobs in RE sector
		How many cleantech companies exist currently? - Are these registered as cleantech companies?	
		Are there any cleantech industry associations?	
		How much investment specifically in cleantech is there?	
		How many programmes or initiatives are there for cleantech specifically?	