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CLEANTECH INNOVATION

Cluster Development Framework

GCIP
Global Cleantech innovation programme

Cleantech Group

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Acknowledgments

This document was produced as part of the UNIDO's Global Cleantech Innovation Programme (GCIP), supported by the Global Environment Facility (GEF). UNIDO would like to express its gratitude to the Cleantech Group for its key role in developing the present document in alignment with the objectives of GCIP.

UNIDO and the Cleantech Group extend their heartfelt appreciation to all individuals and institutions, organizations, private sector representatives and agencies that participated in interviews and took the time to provide inputs to and/or peer review this report, as well as the GCIP national project executing entities, partners and the GCIP-supported entrepreneurs and alumni.

Glossary

Accelerator
It is a structured cpacity building programme desgined to accelerate the growth of innovative cleantech startups and SMEs by strengthening their bsuiness models, enhancing theit market and invetsment readiness, connecting them with mentors, invetsors and ecosystem partners to enable the commercialization and sclaing of technologies.

Cleantech
A broad range of solutions (technologies, processes, services, business models, and their combinations) that lead to an increase in positive impact or a decrease in negative impact on climate change mitigation, transition to a low-emission economy, sustainable energy systems, and other dimensions of environmental sustainability. Climate technology, clean energy technology etc. are subsets of cleantech.

Cleantech Entrepreneurship Ecosystem
The network of entreprenuers, startups, support organizations, investors, policymakers, reserach instituions, corporations and other stakeholders that work together to enable the creation, growth, and scaling of cleantech enterprises.

Cleantech Innovation and Entrepreneurship Ecosystem (CIEE)
The network and interactions among innovation and entrepreneurship stakeholders and the social, economic and policy environment, and their combined influence on the development and commercialization of cleantech solutions.

Cleantech Innovation Ecosystem
The network of stakeholders, institutions, polciies, financing mechanisms, and support services that enable the creation, development, commercialization and scaling of innovative clean technologies as solutions.

Country/National Child Project
In the context of GEF, country-specific GCIP implementation project designed in line with the GCIP Global Programme, to address the maturity, priorities, and needs of the national cleantech innovation ecosystem.

Ecosystem
The wide range of stakeholders, factors and influences as well as the interactions between these. Can range from a low-level, small context such as city or community, to the high-level macro-view of whole countries or regions.

Entrepreneurship
Willingness and ability to turn an innovation into a profitable business model through identifying or creating a market opportunity.

Finalists
Selected group of semi-finalists advancing to the final stage of the accelerator and judging process.

GCIP Alums/Alumni
Entrepreneurs and companies that have successfully completed a GCIP accelerator cycle and remain engaged through the programme's alumni network.

GCIP Coordination Child Project

Global coordination project responsible for maintaining the GCIP methodology, ensuring consistency, and supporting collaboration across all national child projects.

Gender Mainstreaming / GEEW (Gender Equality and Empowerment of Women)

Cross-cutting activities ensuring equitable recruitment, participation, opportunities, and benefits for women and men throughout the programme.

Generalist Mentor

Experienced entrepreneur, investor, or cleantech professional providing overall business coaching and strategic guidance to participating startup and MSME teams. Generalist mentors may not invest in a mentee company during the competition cycle.

Global Accelerator

Global competition for innovators from developing, emerging, and transition economies without a national GCIP project, held after the national accelerators conclude.

Implementing Agency

In the context of GEF donor, the organization responsible for providing overall programme oversight, technical guidance and quality assurance throughout the implementation of the GCIP project. The Implementing Agency supports the NPEE, ensures compliance with project objectives and standards, and facilitates knowledge sharing and coordination across participating countries.

Innovation

The development of new, adapted, or alternative solutions and/or improvements to existing processes or addressing challenges.

Innovation Challenges

Mechanism for identifying demand-driven solutions to industrial climate and sustainability challenges by matching innovators with private-sector-defined market needs.

Investment Readiness

The degree to which a startup, product or solution is prepared to attract and secure external investment. It reflects the maturity of the venture, including a validated business model, scalable solution, capable team, financial planning and a compelling value proposition for investors.

Manufacturing Readiness Level (MRL)

A standardized scale used to assess the maturity of manufacturing processes, technologies, and production capabilities for a specific technology, component, or system. The MRL framework evaluates the readiness of manufacturing from initial concept and process development through stable, full-rate production, supporting the transition from innovation to commercial-scale manufacturing.

National Academy

Core component of the GCIP Accelerator, designed to equip participating entrepreneurs with the knowledge, skills and tools needed to strengthen their business models, validate their technologies and prepare for market growth and investment through expert-led workshops, mentoring and networking opportunities.

National Accelerator

Country-level platform and competition process that brings together national cleantech stakeholders and delivers the annual GCIP accelerator.

National Project Executing Entity (NPEE)

The institution/organization within the participating country that is responsible for the day-to-day implementation and execution of the national GCIP project. The PMU sits within the NPEE that manages the project implementation at the national level.

Post-Acceleration Support

Continued support for GCIP alumni focused on business growth, internationalization, partnership development, investment readiness, and access to finance.

Project Management Unit (PMU)

The operational unit responsible for the day-to-day management and implementation of the GCIP project. It coordinates project operations, stakeholder engagement, procurement, communications, training, mentoring and event delivery, ensuring the effective execution of national GCIP activities.

Proof of Concept (PoC)

An early demonstration that verifies the technical feasibility and potential effectiveness of an innovation, providing evidence that the proposed solution can successfully address the intended challenge.

Semi-finalists

Applicants selected from the pool of entrants to participate in the GCIP accelerator programme and receive structured support. Typically 15-25 nationally and 10-15 globally.

South-South and Triangular Industrial Cooperation (SSTIC)

A UNIDO-led cooperation approach that promotes the exchange of knowledge, technologies, expertise and resources among developing countries to advance inclusive and sustainable industrial development. Through triangular cooperation, these partnerships are further supported by developed countries or multilateral organizations to enhance their impact and scale.

Specialist Mentor

Subject-matter expert providing technical advice in a specific area, such as finance, marketing, engineering, legal affairs, or intellectual property.

Technology Readiness Level (TRL)

A standardized scale used to assess the maturity of a technology, from early-stage research to full commercial deployment. The TRL framework ranges from TRL 1 (basic principles observed) to TRL 9 (actual system proven in an operational environment) and is widely used to evaluate technological progress and readiness for commercialization.

Winners / Runners-up

Top-ranked finalists selected by the judging panel based on the programme's evaluation criteria.

Introduction

Purpose of this document

The United Nations Industrial Development Organization (UNIDO) is a specialized agency of the United Nations with a unique mandate to promote, dynamize and accelerate industrial development. The guiding principle of UNIDO's activities is low-emission, climate-resilient development. This means promoting policies, technologies and practices so that countries can take climate action and create millions of new, decent jobs. UNIDO sees innovation as key to mitigating and adapting to climate change.

Micro, small and medium-sized enterprises (MSMEs) form the backbone of the economy and generate a large share of economic value. Given the scale of climate mitigation and adaptation action needed, it is critical that MSMEs are supported to be part of the solutions, be it as entrepreneurs, in the context of small-scale industries and clusters or through their participation in regional and global value chains.

The **Global Cleantech Innovation Programme (GCIP)** of UNIDO, supported by the Global Environment Facility (GEF), aims to address the growing global demand for environmental sustainability and climate action by harnessing the potential of cleantech innovation and entrepreneurship. Through GCIP's theory of change, the programme seeks to empower innovative cleantech startups and MSMEs to make substantial contributions to climate mitigation. The goal is to achieve low-carbon development and stimulate job creation in priority sectors and systems.

Cleantech Group provides research, consulting, and events to catalyse opportunities for sustainable growth powered by innovation. Cleantech Group's Cleantech Ecosystem Building practice works with cities, regional administrations, national governments, NGOs and multilateral organizations to create the macro conditions for cleantech innovation to thrive. Cleantech startups face specific challenges as they scale, from long times to market, needs for testing equipment and demonstration opportunities, access to finance, talent, and the need to compete with lower-priced, higher polluting incumbent technologies. Effective cleantech ecosystems support startups to overcome these challenges, creating the conditions to bring more cleantech innovation to market and to scale it faster. The result is economic growth as well as climate impact.

This framework is part of GCIP activities which address **Cleantech Innovation and Entrepreneurship Ecosystem (CIEE)** strengthening and connectivity, implemented in partnership with the Cleantech Group. Through GCIP, UNIDO helps strengthen the capacity of national cleantech innovation and entrepreneurship ecosystems in the GCIP partner

countries, identifies synergies across these national ecosystems and facilitates knowledge exchange and partnership building among different CIEEs.

The purpose of this framework is to provide guidance to project executing entities (PEEs) in GCIP partner countries in defining, recommending and implementing activities to develop successful and inclusive regional innovation clusters that have the potential of fostering high-growth cleantech companies. The framework does this by analysing learnings from standout clusters globally to identify actions, success factors and milestones to replicate success.

Section 1 examines how clusters contribute to the growth of startups and scale-ups, outlines the distinctive characteristics of cleantech innovation clusters and highlights some of the key differences to generic innovation clusters.

Section 2 explores existing cluster activity in GCIP countries as well as national characteristics and priorities related to the development of cleantech sectors.

Section 3 focuses on standout cleantech innovation clusters at the global level. These clusters are located on different continents, are specialized in different sectors and have unique characteristics. Yet they share a common trait: a track record of success in creating cleantech startups and scale-ups.

Section 4 presents recommendations for establishing regional cleantech innovation clusters based on local advantages, characteristics and objectives, and outlines a set of activities to be carried out at the local, national and international level.

Methodology
General Approach

In this section, we describe our approach, sources used and other key inputs. A full list of sources is available in the appendix.

Mapping cluster activity in GCIP countries

For each GCIP partner country, information on key CIEE actors was collected and categorized according to location. The key actors were defined as universities and research institutions, risk capital investors, accelerators, incubators and hubs, government ministries, and startups and MSMEs. The results are presented through a heatmap to illustrate startup and MSME density by region. Universities, Entrepreneurial Support Organizations (ESOs) and Venture Capital (VC) investors in key cities are featured as well. ESOs encompass accelerators, incubators and hubs[1]. The following criteria for inclusion were applied:

- Startups and MSMEs that develop solutions to reduce emissions or optimize resource use in sectors such as energy and power, materials and chemicals, agriculture, transportation and the circular economy;
- Universities and research organizations engaged in basic science research, clean technologies, or deep tech (technology based on scientific advances including artificial intelligence, biotechnology, advanced materials or robotics);
- Risk capital investors specialized in cleantech investments, or generalist investors with a significant number of portfolio companies involved in cleantech activities;
- ESOs engaged in cleantech-specific programmes or cohorts, or that exclusively accelerate cleantech-related startups.

The maps in section II show existing cluster activity in GCIP countries. Cities that the GCIP team has identified as strategically important for future cleantech development are included as well.

The starting point for data collection was Cleantech Group's i3 database, which tracks around 45,000 cleantech startups, investors and accelerators globally, in addition to investment flows and key partnerships[2]. This information was supplemented with desk research and the results of the written questionnaires distributed to GCIP partner countries to gain a baseline understanding[3]. The baseline datasets were then shared with GCIP partner

1 The significance and contribution of these organizations to cleantech ecosystems is detailed in the Global Framework for Cleantech Ecosystem Actor Engagement.

2 i3 is Cleantech Group's proprietary database, established in 2002 to provide data and insights on cleantech innovation and investment deals for corporates, investors and startups. i3 tracks private investment of around 35,000 high-growth innovative startups globally.

3 The written questionnaire was developed by Cleantech Group with inputs from UNIDO's GCIP team and circulated to country PEEs, who were in charge of coordinating the collection of responses. The questionnaire, which included

country PEEs for validation. Additional information was collected from third parties where recommended by in-country PEEs. In applicable countries, alumni companies of previous GCIP accelerator programs were added to the dataset.

After incorporating all additional information provided by in-country representatives, datasets and maps were updated. Finally, the updated maps underwent another round of validation by GCIP partner country PEEs.

Additional information on national objectives, priority cleantech sectors and regions was collected directly by PEEs via email, video or voice call.

Identification and selection of standout clusters at the global level

Clusters use a variety of metrics to measure success, but their overarching objective is to create successful cleantech startups and scale-ups.

The purpose of ecosystem strengthening is to facilitate the growth of startups and MSMEs. In this document, we distinguish between startups and scale-ups. Startups are high-growth companies that develop innovative cleantech solutions. Scale-ups specifically refer to startups in later stages (Series B onwards)[4]. It is useful to treat scale-ups as a distinct category, namely (i) as an indicator of cluster maturity, since startups in successful clusters will eventually develop into scale-ups; and (ii) because scale-ups have specific support needs that differ from those of earlier stage companies[5].

Cluster success was evaluated using indicators such as the number of startups created, the number of scale-ups developed, total VC investment secured and investment per capita. The rationale for recognizing a cluster as a standout cluster is explained for each cluster featured in Section 3. The cluster output indicators were calculated using data from Cleantech Group's i3 database.

We also included clusters that have comparable challenges to those faced by GCIP partner countries, including the transition from oil and gas (Houston, Kazakhstan), the transition to renewable energy (Estonia, South Africa) and waste management (Chennai, Nigeria).

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questions on policy, stakeholders and cleantech ecosystem observations, was distributed to government officials and government agency representatives, university professors and other research leaders, cluster facilitators and other ecosystem actors. A full list of respondents to the questionnaire is included in the appendix.

4 The OECD-Eurostat Manual on Business Demography Statistics (2007) defines high-growth enterprises as those with an average annualized growth rate that is greater than 20 per cent per year over a 3-year period, and with 10 or more employees at the beginning of the observation period, where growth is measured by turnover or employment.

5 The different support needs based on the startup's stage of development and ecosystem maturity will be addressed in the Policy Strategy Framework.

Definition and characteristics of cleantech innovation clusters

The characteristics of innovation clusters and of cleantech innovation clusters were identified through desk research, drawing from internationally recognized academic and commercial literature. A full list of sources is available in the appendix.

Insights from standout clusters

We interviewed 17 cluster facilitators and startups via video call, phone call or in person. The respondents were selected because of their role as facilitators in standout cleantech innovation clusters or in startups created by or associated with standout clusters. A full list of respondents is included in the acknowledgements section. The insights gained were analysed in terms of their relevance at the local, national or international level and serve as the basis for the recommendations outlined in Section 4.

Executive Summary

Cleantech innovation clusters are localized cleantech ecosystems with a specific sector theme. Successful clusters leverage feedback loops and network effects to boost the success of individual innovators, so startups and MSMEs within the cluster grow faster than the market average. Innovation clusters are characterized by participating entities operating, collaborating and networking in close geographic proximity; multiple clusters with different thematic focuses may exist in close proximity to each other and may also interact with one another. Cluster success arises from the interactions between the actors within them, and these interactions produce synergies. Hence, there is no single blueprint for achieving cluster success. There are specific measures, however, that contribute to cluster development. This framework explains some of these measures and gives examples of how they have resulted in successful cluster development.

Cleantech innovation clusters have specific needs over and above generic innovation clusters. Because of the hardware-intensive, CAPEX-heavy nature of most cleantech solutions, cleantech innovation clusters must provide specific forms of support to enable startups and MSMEs within them to flourish. These include access to specialized technical and commercial talent, access to risk capital and debt finance providers with the expertise to evaluate technical solutions, and access to markets to allow for commercialization of new products and solutions.

Current cluster activity in GCIP partner countries is concentrated primarily around key cities. Startup and MSME density tends to be correlated with proximity to technical universities and ESOs. There are a few examples of sustainable or climate-focused venture capital funds in GCIP partner countries: most venture investment in cleantech companies originates from generalist funds. When formulating strategies for the development of cleantech innovation clusters, GCIP partner countries should consider national characteristics and objectives, and identify strategic regions for developing cleantech innovation clusters and cleantech priority sectors.

Standout clusters display distinct characteristics based on local advantages and circumstances. Cleantech innovation clusters are created in already existing innovation clusters, for example in Boston, USA. They can also develop from existing industries that are transitioning towards decarbonization, for example Green Tech Valley in Graz, Austria. Clusters located in areas with a high concentration of universities and research institutions often produce startups with a high incidence of intellectual property (IP). Clusters located in areas with a history of industrial activity may produce startups that capitalize on the existing knowledge and expertise, for example solid oxide fuel cell (SOFC) component startups located in former ceramic manufacturing centres. Clusters may also be included

in national strategic priorities, for example Singapore's food-tech cluster, which resulted from the government's prioritization of food security. In many successful clusters, a "cluster facilitator" played a critical role in driving its development by providing services to ecosystem actors and collaborating with the local authorities. These cluster facilitators may be NGOs, social enterprises or government bodies. This report analyses the insights gained from cluster facilitators in the standout clusters identified, as well as from the startups produced by those clusters.

Cluster facilitators can promote a range of activities at the local level to develop clusters. These activities include practical support for startups and MSMEs such as networking and providing information on funding and commercial opportunities, as well as advocacy activities at the municipal level, for example collaborating with mayors to boost demand for cleantech solutions or to promote smart regulations to reduce common obstacles to growth such as permitting processes.

National level programmes can create conditions that facilitate cluster development. These include education and immigration policies to ensure an adequate talent pool, streamlining administrative procedures to ease the bureaucratic load on young companies, and financial incentives such as tax breaks and grants. A stable policy and regulatory framework that embraces innovative solutions can generate long-term market signals that attract companies and investors, while national branding can enhance the country's reputation as an attractive place to live and do business in.

Successful clusters are connected with international networks. Cluster facilitators can facilitate the establishment of connections by sharing information on international opportunities and eligibility criteria with startups and MSMEs, and by attracting international programmes to operate in the region or country. Facilitators of successful clusters are also engaged in international cluster networks to exchange knowledge and best practices, and to establish connections between local startups and MSMEs with international markets where there is demand for their solutions.

I. How cleantech innovation clusters boost startup growth

In the context of this framework, clusters are defined as "local concentrations of cleantech activity, with a sector or subsector specialization." Cleantech subsectors include energy and power, transport and logistics, materials and chemicals, agriculture and food, and resources/ circular economy. Successful clusters leverage feedback loops and network effects to boost the success of individual innovators, so startups and MSMEs within the cluster can grow faster than their counterparts in the same market[6].

Innovation clusters consist of participating entities that operate, collaborate and network within close geographic proximity of each other. Clusters encompass the same actors as CIEEs, but while ecosystems include multiple sectors, each cluster is concentrated around one sector or subsector. **Figure 1** illustrates the key actors in a CIEE.

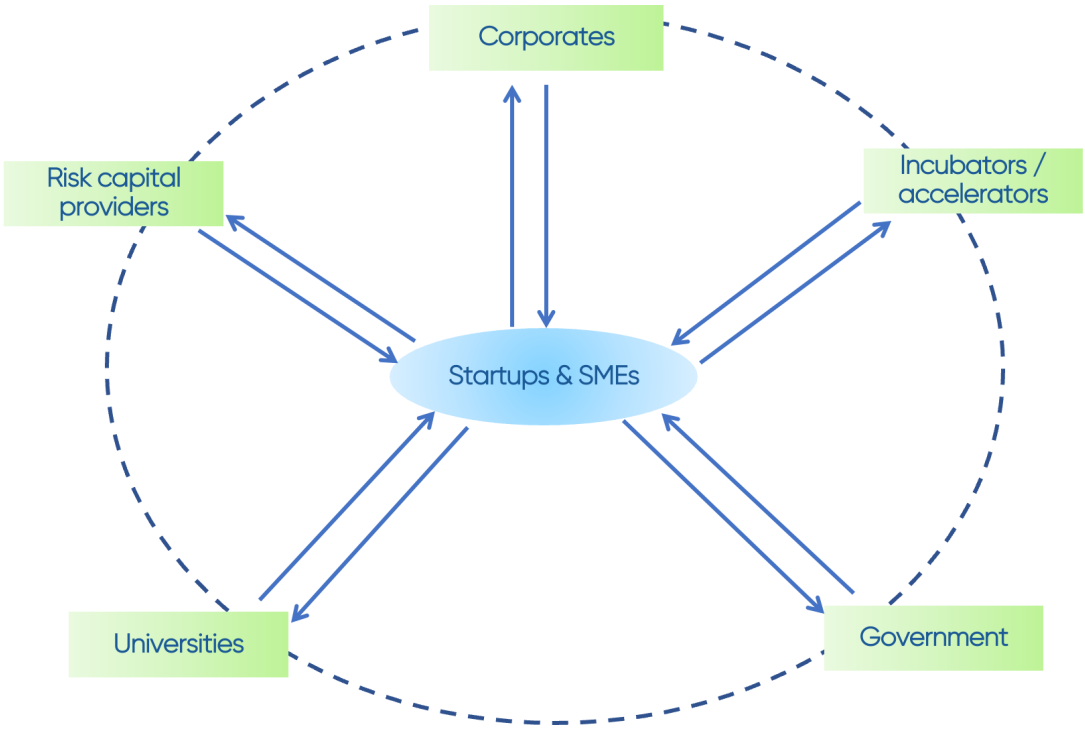


Figure 1: Actors in a CIEE

6 The Economist Intelligence Unit. (2016). Innovation clusters: Understanding life cycles. The Economist, 24.

These actors assume distinct roles in growing and developing the cluster: startups and MSMEs serve as the central focus of the cluster; the cluster's key objective is to enable them to scale faster and deliver solutions for climate impact. ESOs such as accelerators, certain government bodies and occasionally universities, play an important role in facilitating cluster development and contributing to the growth of startups. Other actors indirectly support the growth of startups, but are equally important, for instance by supplying risk capital, or as first customers or pilot partners to test solutions.

The Economist identifies six key factors that contribute to the long-term success of innovation clusters. These key factors include a skilled workforce, supportive policy frameworks, developed infrastructure, low cost of living, good quality of life to attract talent, and historically perceived as geographically desirable[7]. While these ingredients are necessary for a cluster to succeed, the interaction between the different factors is essential[8]. Hence, there is no distinct blueprint for creating a successful cluster: the trajectory of a cluster depends on geography, sectoral expertise, industrial history and culture, as well as the interactions between these factors. This report highlights the synergy of the key factors that underpin the success of standout clusters where growth opportunities for startups and MSMEs are abundant. Once the key factors start generating successes for the cluster, the momentum created within a region can lead to cities prioritizing cleantech innovation cluster development[9].

Due to the science-based CAPEX-intensive nature of cleantech solutions, the requirements and characteristics of cleantech innovation clusters differ significantly from those of generic innovation clusters. The Erasmus Centre for Entrepreneurship, Rotterdam, identifies three crucial factors for cleantech innovation ecosystems[10]. The first is access to talent: both technical expertise to develop cleantech products and solutions, and commercial expertise to market and sell these complex products and services. Capital providers also need technical expertise to evaluate new solutions and to gauge technical and market risk. They must also be open to collaborating with other investors to mitigate risk and to facilitate the hybrid funding mechanisms necessary to finance working capital needs for as-a-service business models, or plant investments needed to transition from commercial pilots to mass production. Finally, new cleantech solutions must identify a market. Here, government plays a pivotal role in establishing a supportive policy environment and in leveraging public procurement to create demand.

7 The Economist Intelligence Unit. (2016). Innovation clusters: Understanding life cycles. The Economist, 24.

8 Ibid.

9 Oyetunde, B. (2022, November 16). The booming Estonian cleantech ecosystem. Retrieved from e-Estonia: https://e-estonia.com/the-booming-estonian-cleantech-ecosystem/

10 Erasmus Centre for Entrepreneurship (November 2020). Study of the(cleantech) innovation ecosystem with a focus onGIST and SCALE-UP.

Figure 2 summarizes the specific needs of local cleantech innovation clusters.

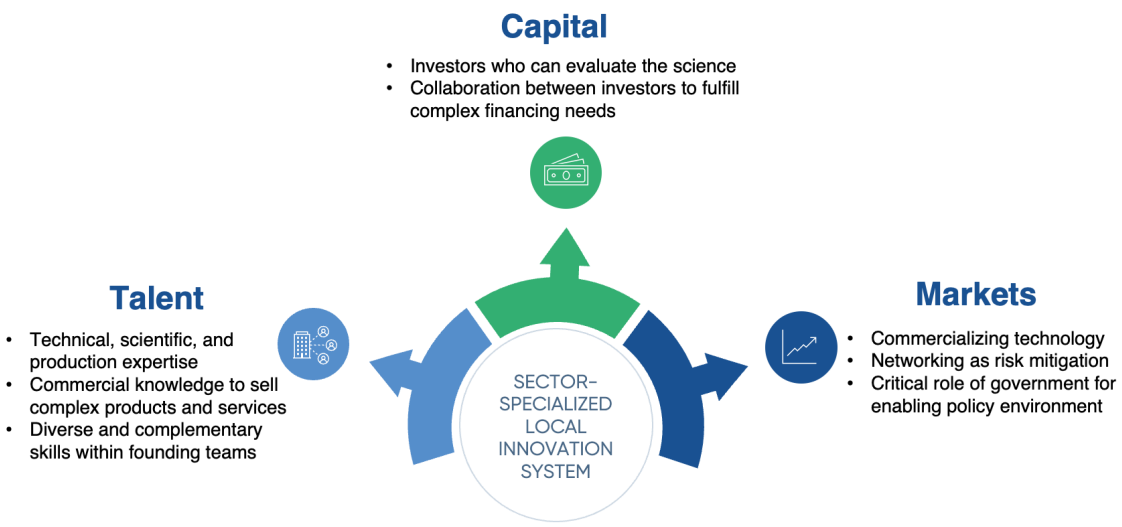


Figure 2: Specific needs of cleantech innovation clusters

Close interaction fosters an ecosystem that drives research and innovation initiatives, promotes the establishment of relationships and opens up opportunities, and encourages the establishment of favourable conditions for cleantech startups and MSMEs by influencing climate policy[11].

Cleantech innovation clusters have grown in recent years, capitalizing on increased access to concrete data on the cleantech sector, a range of funding opportunities, and increased possibilities for piloting technology[12]. Cleantech innovation clusters typically emerge in regions with engineering-focused education systems, substantial government funding for research and development, an emphasis on export markets and policies that encourage knowledge retention and prevent brain-drain by increasing repatriation and immigration[13]. Cleantech innovation clusters may emerge within existing innovation clusters, for example Boston, USA. They may also evolve from incumbent industries that are transitioning towards decarbonization, for example Green Tech Valley in Graz, Austria.

There is currently a global push for cleantech innovation in response to the need for climate mitigation, adaptation and resilience. For example, the growing demand for solutions to the global energy crisis is driving innovation in the energy sector. Cities that provide favourable conditions for cleantech innovation play a crucial role in enabling the establishment of startups that focus on energy efficiency, clean energy production and

11 Oyetunde, B. (2022, November 16). The booming Estonian cleantech ecosystem. Retrieved from e-Estonia: https://e-estonia.com/the-booming-estonian-cleantech-ecosystem/

12 Ibid.

13 The Economist Intelligence Unit. (2016). Innovation clusters: Understanding life cycles. The Economist, 24.

storage, as well as green buildings and construction materials[14].

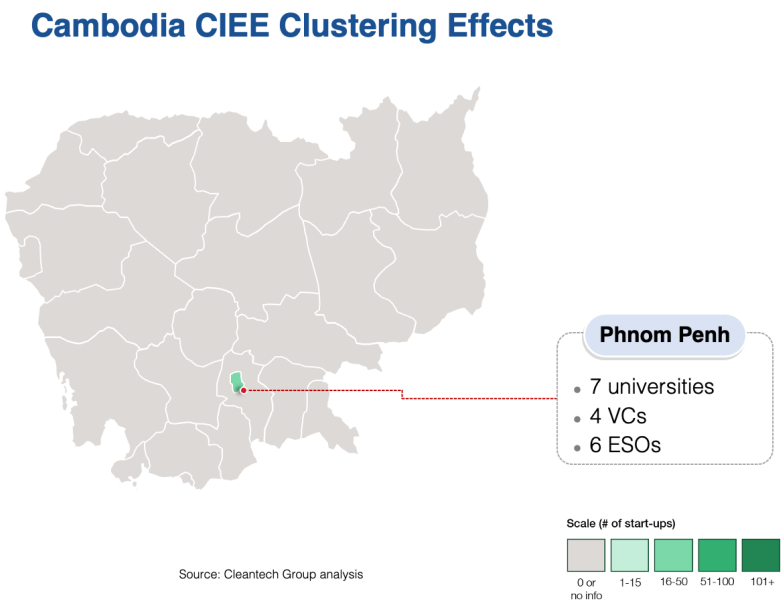
The purpose of this report is to identify the key characteristics of cleantech innovation clusters that can be replicated in GCIP partner countries to develop their own cleantech innovation clusters at the municipal level.

14 Oyetunde, B. (2022, November 16). The booming Estonian cleantech ecosystem. Retrieved from e-Estonia: https://e-estonia.com/the-booming-estonian-cleantech-ecosystem/

II. Existing cluster activity in GCIP countries

This section analyses current cluster initiatives in GCIP partner countries, and explores the plans for future development of cluster activities in specific regions and sectors.

Cambodia



Current activity

Cambodia's cleantech startup and MSME activity is concentrated in the country's capital and most populous city, Phnom Penh, which is home to seven universities, six ESOs, and four VC firms that specialize in cleantech investments.

There is a growing recognition of the importance of cleantech and green technologies. The key sectors of current activity include water solutions, energy efficiency, renewable energy and associated technologies, biomass, recycling of agricultural waste and alternatives to plastic.

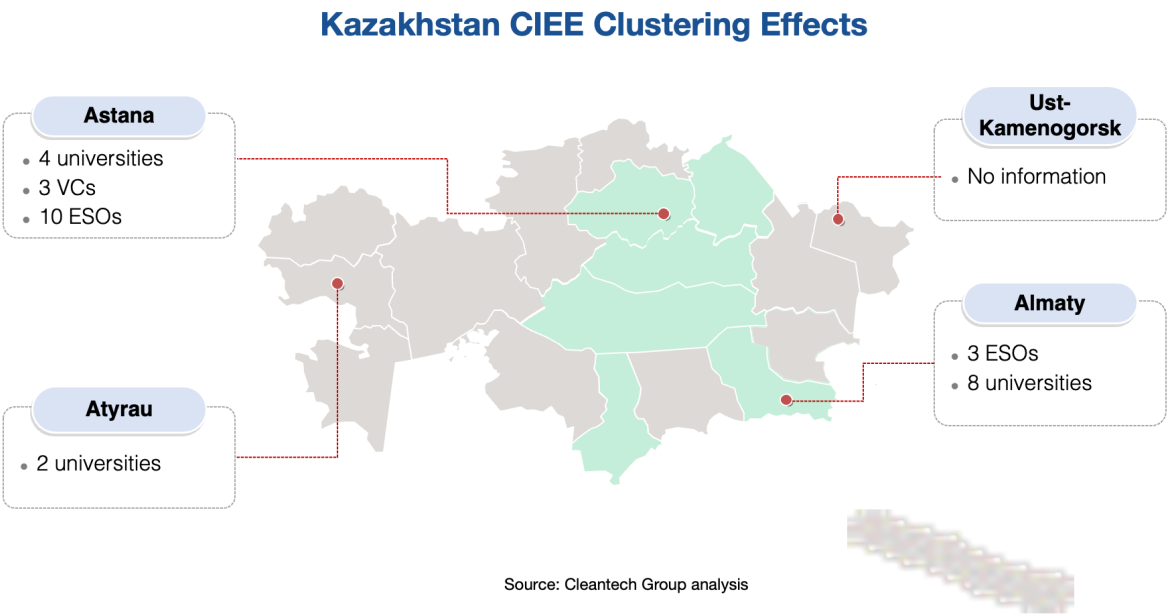
Objectives for cleantech development

Cambodia has established a series of national objectives for cleantech development, as outlined in its National Strategic Plan on Green Growth 2013–2030. The country's focus lies in the efficient use of natural resources, environmental sustainability, the creation of green jobs, the adoption of green technology, and economic reform, placing more

emphasis on green incentives and green investment. Moreover, Cambodia published its Industrial Development Policy 2015–2025 aiming to transform and modernize Cambodia's industrial structure from a labour-intensive to a skill-based economy by 2025, by promoting a conducive business environment, developing infrastructure and logistics, building a skilled workforce, and promoting innovation and technology adoption.

The CIEE would benefit from stronger links between ecosystem actors and improved access to grant and equity funding for early-stage ventures.

Kazakhstan



Current activity

Cleantech startup and MSME activity in Kazakhstan is mostly concentrated in Almaty and Astana, with ESOs also primarily located in these two cities. Astana has four VC firms that focus on cleantech investments. The country is home to several scientific universities and research institutes; the most significant ones in terms of cleantech-related output are included in the map. In general, most of the country's clean technology innovations are imported.

Key sectors for startup activity include renewable energy, energy efficiency and waste management.

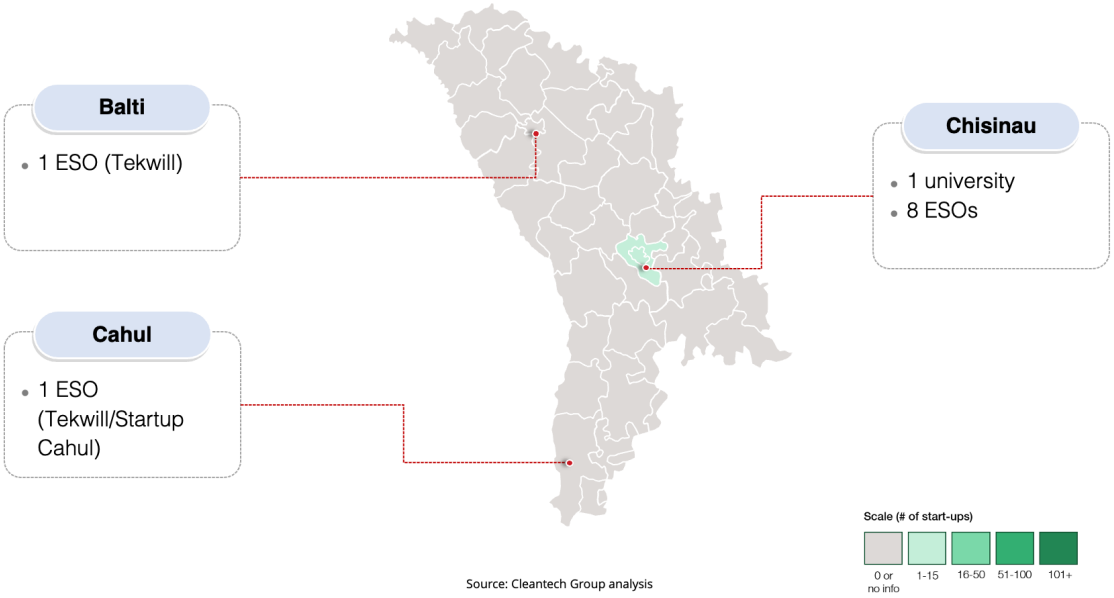
Objectives for cleantech development

Ust-Kamenogorsk and Atyrau have been identified as priority regions for cleantech development. Kazakhstan's PEE, the International Green Technologies and Investments Center (IGTIC), has identified nine cities that are transitioning from economic reliance on

oil and gas or heavy industry. IGTIC is conducting technology brokerage activities in these areas, with the goal of connecting industrial incumbents with innovative startups which provide relevant cleantech solutions to help these industries decarbonize. Another of Kazakhstan's national objectives is to increase the share of renewable energy generation from the current three per cent to 15 per cent.

Republic of Moldova

Republic of Moldova CIEE Clustering Effects



Source: Cleantech Group analysis

Current activity

The existing cleantech activity in the Republic of Moldova is concentrated in and around the capital, Chisinau, which is home to one university and eight cleantech-focused ESOs. The most important cleantech-specific ESO in the Republic of Moldova, Tekwill, also has branches in Cahul and Balti. The Republic of Moldova recently passed a law which aims to streamline the university and research ecosystem. The Republic of Moldova's national credit risk hinders access to financial mechanisms that could support cleantech innovation. There is currently no legislation in place to support risk capital, resulting in the absence of VC firms.

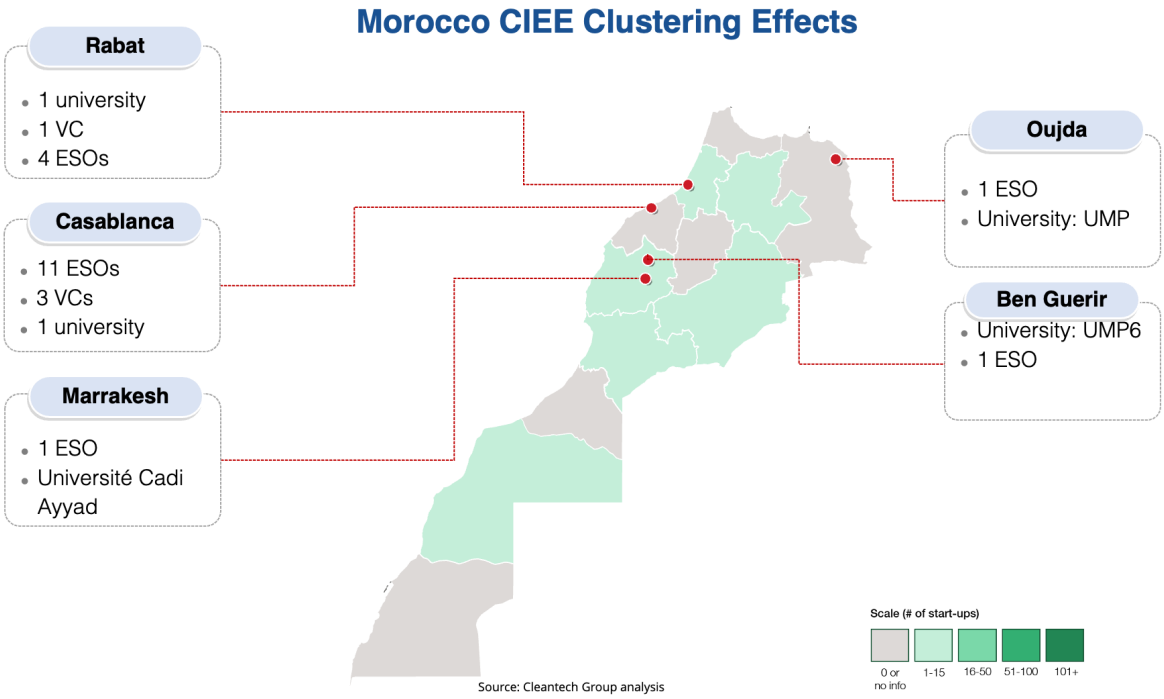
Key sectors for startup innovation include farmers' marketplaces, energy storage solutions, and solar technologies.

Objectives for cleantech development

The priority sectors for cleantech development are energy efficiency and renewable energy. Balti and Cahul have been identified as priority regions for cleantech innovation

development.

Morocco



Current activity

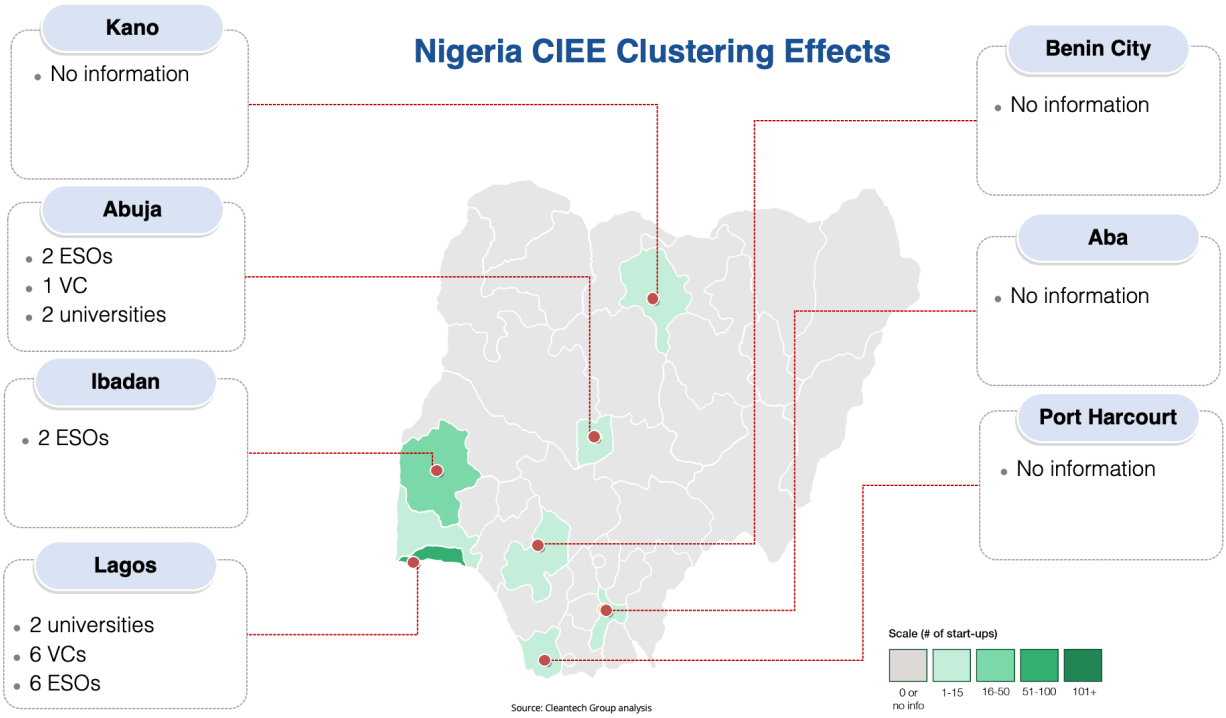
Cleantech innovation activity in Morocco is scattered across Rabat, Casablanca, Marrakesh and Ben Guerir. Several national universities are engaged in cleantech-related research. Rabat and Casablanca jointly have four VC firms that invest in cleantech startups. Lack of access to technology can be a barrier to cluster development in the country's remote regions. Key sectors for startup innovation include irrigation technologies, farming robotics, energy services, solar technologies and waste management and recovery.

Objectives for cleantech development

Oujda has been identified as a priority region for future cleantech development; the region is currently home to Mohamed First University (UMP) and one cleantech-related ESO, but startup activity in the region is relatively low.

The priority sectors include smart farming, innovations addressing water scarcity, green buildings, renewable energy and tourism. Morocco welcomes around 10 million tourists annually, and reducing the tourism sector's environmental impact is a priority. Cleantech solutions also have the potential to reduce the environmental impact in other sectors such as textiles (concentrated in Casablanca and Tangiers), automotive (Northern Morocco), food processing and fisheries.

Nigeria



Current activity

Cleantech innovation activity in Nigeria is scattered across the country with the highest concentration of cleantech startups and ESOs in Lagos (over 70 startups) and Abuja (20 startups), followed by Port Harcourt, Aba, Benin City, Ibadan and Kano (less than 10 startups each).

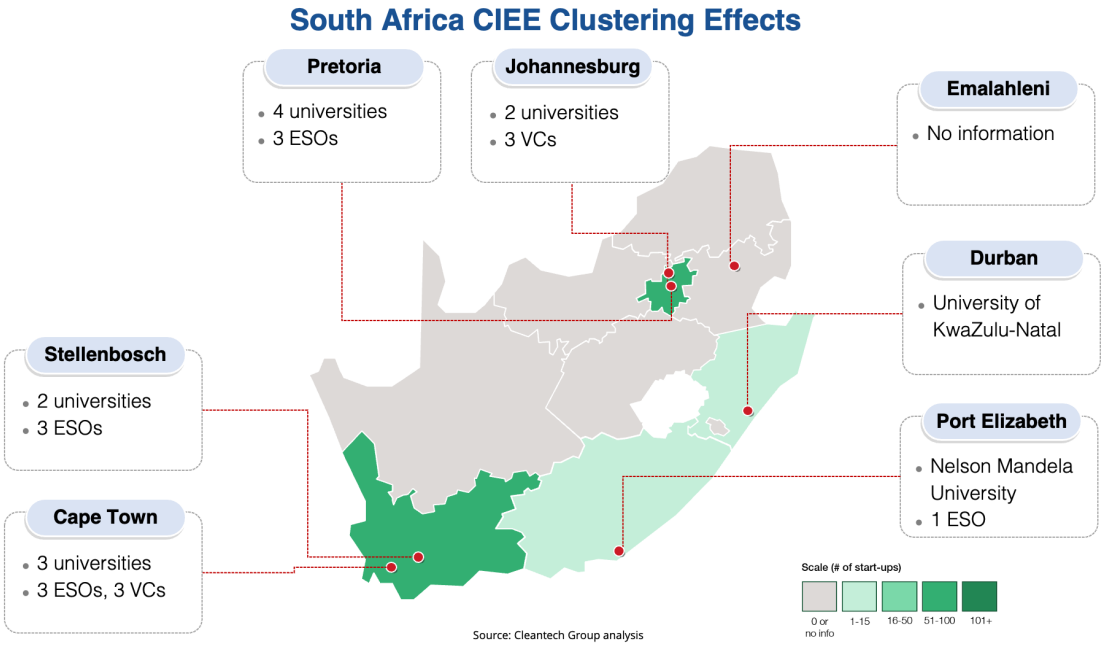
Key sectors for startup innovation include food marketplaces and delivery services, food processing, renewable energy, energy storage and services, e-mobility and waste management.

Objectives for cleantech development

Nigeria's Federal Ministry of Innovation, Science and Technology conducted a technology needs assessment, which identified agriculture, energy and industry as crucial sectors for development. Other priority areas for cleantech solutions include clean water and waste management. Furthermore, efforts are required to raise public awareness of the benefits of climate or environmental projects.

Six ministry hubs aim to support regional development. Regional competitive advantages will drive cluster activity in the North, South and West.

South Africa



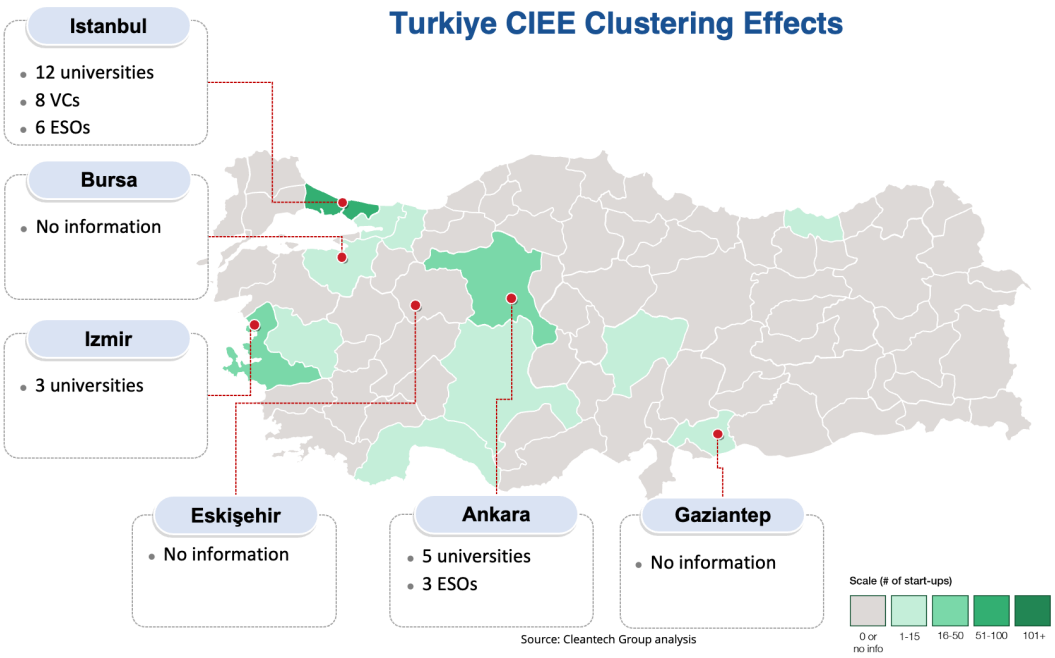
Current activity

South Africa's cleantech innovation activity is mainly centred in the Western Cape province, which includes Cape Town and Stellenbosch, as well as in the Gauteng province, which includes Pretoria and Johannesburg. The University of Stellenbosch supports alternative protein and sustainable food innovators with a maker space and test market storefronts. Major ESOs and universities with cleantech activities are concentrated in these cities. Durban and Port Elizabeth also house several universities and startups. A total of six VC firms specializing in cleantech investments are located in Cape Town and Johannesburg. Key sectors for startup innovation include agricultural robotics, robotics for spatial analysis, renewable energy, water solutions, waste management, e-mobility and electric vehicle (EV) charging.

Objectives for cleantech development

South Africa's Technology Innovation Agency (TIA) has identified nine rural and isolated regions that have significant innovation potential but limited means to facilitate startup and MSME growth. With adequate support, these regions could play a more active role in developing cleantech innovation. South Africa's national cleantech development objectives are in line with UNIDO key focus areas.

Türkiye



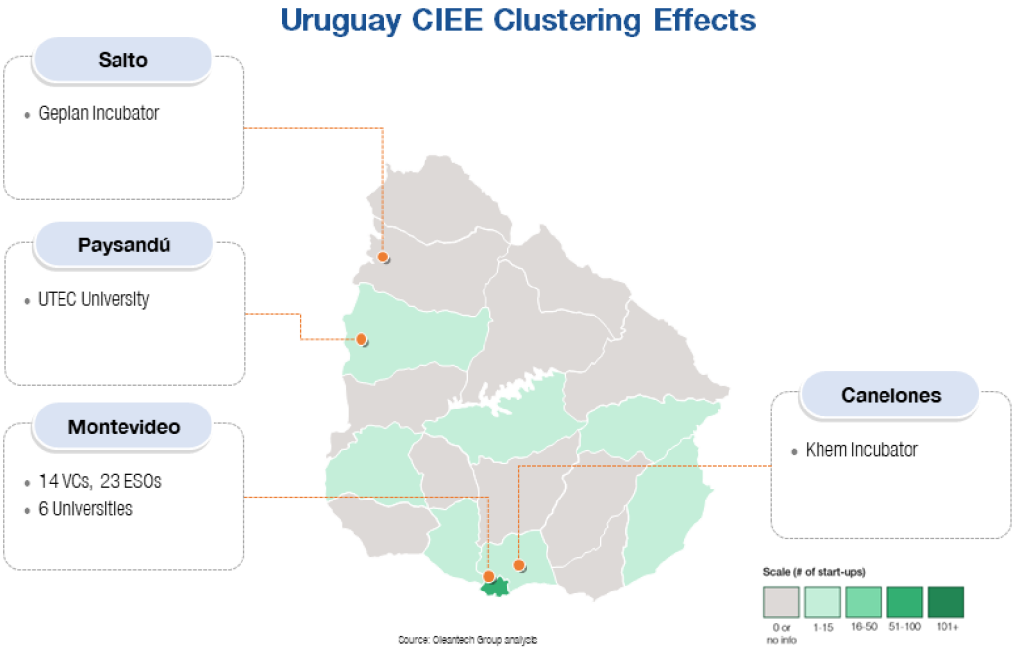
Current activity

Cleantech innovation activity is scattered across Türkiye. The highest concentration of startups is located in its largest city and main economic hub, Istanbul, with over 80 startups and three VC firms specializing in cleantech, followed by Izmir (20 startups) and Ankara (37 startups). Risk capital opportunities are increasing in Türkiye, although most funds are generalist and invest in cleantech ventures as opportunities arise. Ankara and Istanbul are home to ESOs and major universities involved in cleantech activities, while private research and development activity is concentrated in Istanbul, Tekirdağ, Ankara, Kocaeli, Bursa and Izmir. Key sectors for startup innovation include indoor farming, agricultural robotics, waste management and recycling solutions, wastewater treatment and energy services.

Objectives for cleantech development

All regions are eligible for GCIP accelerator programmes; however, Izmir, Gaziantep and Eskisehir have been identified as priority regions for the development of cleantech innovation clusters. The priority sectors for cleantech development in Türkiye include energy, waste management, circular economy, sustainable agriculture, transport and logistics. The country also has high potential to further develop its renewable energy generation capabilities. The goals for sustainable agriculture include sustainable irrigation systems and the use of renewable energy in agriculture. Türkiye has identified sectors with high potential demand for cleantech solutions. These include transportation, especially cement transportation, agriculture, housing, energy, manufacturing including automotive, consumer electronics, food and chemicals, textiles and healthcare.

Uruguay



Current activity

Cleantech innovation activity in Uruguay is concentrated in its capital, Montevideo, with several active ESOs and VC firms. A small concentration of startups is also located in the Canelones, Durazno, Paysandú, Rocha, San Jose, Soriano, and Treinta y Tres regions.

Key sectors for startup innovation include agriculture robotics, food tech, energy services and waste solutions.

Objectives for cleantech development

The priority sectors for cleantech development in Uruguay are agriculture and energy. The country aims to leverage its high percentage of renewable electricity generation to develop secondary industries including green hydrogen production and other power-to-X solutions.

III. Global standout cleantech innovation clusters

The following cities host standout cleantech innovation clusters based on the success metrics defined in the methodology and on characteristics that can be replicated for cities in the GCIP countries.

Boston, Massachusetts, USA

Boston is located in the northeast of the United States, in close proximity to and in the same time zone as other major U.S. cities such as New York City and Washington, D.C. The Greater Boston Area encompasses the surrounding suburbs, including Somerville and Cambridge, which are home to several world-renowned universities, and many of the country's largest biotech and tech companies.

The access to research facilities in the Boston area opens the door to many sectors. The most noteworthy cleantech innovations are taking place in electric grid energy storage, electric vehicle batteries and charging, energy efficiency software and monitoring, agriculture, solar and renewable energy, air and water quality, as well as research and manufacturing for climate[15].

Massachusetts has the highest concentration of colleges and universities in the country, including Harvard University and Massachusetts Institute of Technology (MIT). Consequently, the state has the highest percentage of college-educated adults[16]. The state's investments in education and technology research has catalysed the expansion of Boston's cleantech sector and attracted graduates to participate in its growth. At the municipal level, the mayors of Somerville, Boston and Cambridge have focused on modernizing outdated infrastructure into hubs for cleantech innovation. Greentown Labs, a renowned cleantech ESO, repurposed a warehouse in Cambridge into its first site for emerging founders to share space and equipment to create prototypes[17].

15 Unis, S. (2022, November 6). Navigating the Boston CleanTech Startup Scene - Who to Know, Where to Go. Retrieved from Startup Boston: https://www.startupbos.org/post/navigating-the-boston- cleantech-startup-scene-who-to-know-where-to-go

16 Carapezza, K. (2017, August 9). Why Massachusetts Leads Nation In College Attainment. Retrieved from WGBH News: http://blogs.wgbh.org/on-campus/2017/8/9/why-massachusetts-leads-nation- college-attainment/#:~:text=JM%3A%20 Massachusetts%20has%20some%20advantages,also%20 focused%20on%20workforce%20education.

17 Greentown Labs. (2023). Here's how they unintentionally founded North America's largest climatetech incubator. Retrieved from Greentown Labs: https://greentownlabs.com/about/history/

The ESO has established a dedicated programme for minority founders to address equity disparities within the industry. Furthermore, the city's top industries, which include higher education, healthcare, and financial services, generate a high concentration of wealth. Ultimately, the key elements contributing to Boston's success as a cleantech innovation cluster are its robust network of investors, committed industry partners and a diverse talent pool to draw on.

Boston is a cluster with the highest density of investment in cleantech innovation at over USD 4 billion invested over the last three years. The cluster counts 495 startups and scale-ups.

Successful startups created by the Boston cluster

florrent designs and builds high energy density ultracapacitators to work with electrical grids. It aims to address bottlenecks in the transition to renewable energies, electric vehicles and net-zero buildings. florrent's mission is a just transition to renewable and equitable energy systems while generating, storing and using renewable energy with a hybrid system of its ultracapacitators to supplement conventional battery systems for grid electrification. The company has partnerships with research institutions including the University of Massachusetts, the University of Washington and Oregon State University. florrent is affiliated with the network and incubator Greentown Labs, the accelerator CleanTech Open and the biomass supplier, Genoverde Biosciences.

Mori develops an edible, silk-derived biomaterial coating that extends the shelf life of perishable foods. Its biotechnology extends the shelf life of fruits and vegetables by up to 50 per cent, reducing food waste by one-third annually. The company's impact extends beyond contributing to the food supply chain, but also reduces the need for single-use plastic packaging. Mori was featured as a 'Cleantech 50 to Watch' company in 2019 and recognized as a 'Global Cleantech 100' company in 2023[18].

Houston, Texas, USA

Historically, Houston has been the energy capital of the world, known as a hub of the oil and gas industry. As the world shifts towards renewable energy sources and reduces its reliance on fossil fuels, Houston is poised to emerge as a model of how cities can successfully transition towards net zero goals. Consequently, the largest cleantech incubator in North America, Greentown Labs, is expanding its operations from Boston to Houston. Both cities have access to capital, including investors, project financing for startups and corporate partnerships.

18 Cleantech Group. (2023, January 30). Mori. Retrieved from i3 Connect: https://i3connect.com/ company/mori

What sets Houston apart is the presence of many entrepreneurs originating from corporations rather than universities. Houston's mayor is a co-chair of a bipartisan network of 450 U.S. mayors known as Climate Mayors, who are committed to a science-based, community-driven reduction of greenhouse gas emissions[19].

In addition to Houston's focus on renewable energy, other cleantech sectors include materials and chemicals, resources and environment.

Over USD 1.9 billion has been invested in the last three years, and 116 startups and 21 scale-ups have been established in Houston.

Successful startups created by the Houston cluster

Sunnova offers a solar and EV bundle for residential energy and power storage. Founded in 2010, the company became publicly traded in 2019. Sunnova has formed strategic partnerships to provide competitive and affordable solar solutions across the U.S.
The company has raised USD 1.341 billion in equity capital.

Sage Geosystems provides geothermal energy and offers a geothermal modelling tool, GeoTwin. The company aims to make geothermal energy both scalable and affordable by leveraging existing oilfield technologies and equipment. Founded in 2020, the company is now widely available commercially.

Helsinki, Finland

While Helsinki may be a comparably small city, it is ranked among the world's top 25 most innovative cities by the World Economic Forum. A key success factor is the high number of university students and researchers engaged in this cluster. Over one-third of the population holds a university degree. Finland is ranked number one in Europe for digital fluency and availability of cutting-edge technologies. Finland also ranks prominently for its progressive climate policies. It fosters innovation through a supportive culture and forward-looking regulations while government initiatives encourage open data for environmental, transportation and health data[20].

These factors fuel a highly skilled talent pool for the cleantech sector and a conducive operating environment. The public sector readily participates in pilot programmes, thus becoming an early adopter of new technologies.

19 Vargas, J. (2020, June 16). North America's Largest Cleantech Incubator Expanding to Houston in 2021. Retrieved from Greater Houston Partnership: https://www.houston.org/news/north-americas- largest-cleantech-incubator-expanding-houston-2021

20 What makes Helsinki one of the most innovative cities in the world? (2022, November 10). Retrieved from Helsinki Partners: https://www.helsinkipartners.com/article/what-makes-helsinki- one-of-the-most-innovative-cities-in-the-world/#:~:text=Finland's%20capital%20is%20fertile%20 ground,innovative%20cities%20in%20the%20world

The close collaboration between corporations, startups and universities drives innovation in the cluster, which has produced at least four unicorns as of 2021[21].

There are 68 startups and 7 scaleups in Helsinki. Innovators have received investments of over USD 1.495 billion over the last three years. Key sectors for cleantech innovation in Helsinki include energy, materials and transportation.

Successful startups created by the Helsinki cluster

Carbo Culture removes CO_2 from the atmosphere. The technology converts CO_2 from decomposing plants into biochar that can be stored for up to 1,000 years. Additionally, the company produces carbon credits, and the process of converting plants to biochar emits usable heat. The company recently announced collaborations with technology companies, has received grant funding, and won the European Innovation Council's EU Accelerator Award.

Norsepower produces its patented rotor sail technology, which uses wind to improve the fuel efficiency of large shipping vessels. Founded in 2012, the company has been at the forefront of transforming naval technology to transition ocean transportation towards zero carbon emissions. The company has raised over USD 20 million through development partnerships, pilot projects, and international corporates to expand commercialization in domestic and international markets.

Stockholm, Sweden

Stockholm has evolved organically into an impact hub centred around innovation-driven companies. The city hosts several accelerators which are partly funded by the city to drive innovation and provide cleantech-focused coaching for new businesses. Sweden's major car manufacturer, Volvo, is based in Stockholm, and the city is therefore investing resources in the battery storage and cleantech transportation sector. Many startups here focus on electrifying different modes of transport including bikes, cars, boats and even trucks. There is a robust investment community in Stockholm, including former entrepreneurs who have successfully scaled and established startups in other sectors, which seek local investment opportunities.

Because of this, regional startups look to Stockholm's investor network for VC funding. Sweden is considered a leader in climate-friendly policies. Stockholm hosts over 143 cleantech startups and 11 scale ups. Innovators have raised over USD 22.5 billion in funding over the last three years.

21 O'Sullivan, J. (2021, June 29). Helsinki-based startups now worth a combined EUR 25.2 billion. Retrieved from Good News from Finland: https://www.goodnewsfinland.com/helsinki-based-startups- now-worth-a-combined-eur-25-2-billion/#:~:text=Furthermore%2C%20there%20are%20eight%20 high,functional%20city%20in%20the%20world

Successful startups created by the Stockholm cluster

Volta Trucks delivers full-electric trucks to help cities reduce harmful emissions. The company collaborates closely with utilities companies, large corporations and EV charging infrastructure providers. Volta Trucks was founded in 2017 in Sweden but has leveraged international networks to grow: the company has received seed funding from U.S. VC investors, conducts research and development (R&D) activities in the UK to tap into local technical expertise, and has a commercial presence in France, capitalizing on the favourable market conditions for its products. Along with developing and marketing electric truck technology, the company runs Volta Academy, a training programme for technicians and drivers to learn how to operate these vehicles.

Northvolt develops battery storage technology and infrastructure solutions. The company is building the world's first and largest battery factory akin to a semiconductor foundry. Founded in 2015, Northvolt has now achieved widespread commercial availability and has over 250 employees. It has partnerships with multiple leading automotive brands; many have provided investment. Northvolt has also received financing from the European Investment Bank. It is headquartered in Stockholm and has a research partnership with the University of Gothenburg. Its first production site was established in Skelleftea, thus boosting regional employment while remaining part of Stockholm's ecosystem.

Tallinn, Estonia

Estonia's capital city provides an ideal environment for startups to thrive. Its culture fosters and encourages positive attitudes towards startups and businesses. The quality of life in Tallin is high coupled with low costs of living. The population is proficient in English, the international language of business, which attracts international talent from other ecosystems[22].

Tallinn's cleantech innovation cluster has its roots in the success of the information and communication technology (ICT) sector. Cleantech companies began to emerge around 2010, and the early success stories revolved around ICT-based solutions. Over time, hardware-based companies gained traction. The cluster has excelled in the renewable energy and energy storage sectors, driven by a need to decarbonize the highly polluting oil shale-based energy sector. Over the last ten years, Tallin has made significant strides as a cleantech innovation cluster capitalizing on the momentum of existing startups and attracting investments for new ventures, resulting in the emergence of the exceptional scale-up, Skeleton Technologies. The city has 34 startups and five scale-ups with substantial investment per enterprise totalling over USD 2.1 billion over the last three years.

22 Why Estonia? (2022, November). Retrieved from Startup Estonia: https://startupestonia.ee/why- estonia

Successful startups created by the Tallinn cluster

Skeleton Technologies specializes in graphene-based ultracapacitor energy storage solutions. The company has entered the growth equity phase after securing USD 171.4 million in equity capital. Skeleton Technologies has achieved a global reach through partnerships with Shell, Marubeni, Wrightbus, Medcom and Sumitomo Corporation.

Thinnect aims to minimize the energy consumption of buildings by ensuring optimal indoor climate. Thinnect has raised over USD 5 million for technology development. The company has a presence in over 30 countries on around 8,000 devices. The startup is a spinout of Defendec, which developed and patented the technology. The purpose of establishing Thinnect was to exploit the technology's benefits for everyday use, which was initially built for the defence sector.

Cambridge, United Kingdom

Cambridge is one of the oldest cleantech innovation clusters in the UK, and one of the largest in Europe. The innovation landscape in the Cambridge area tends to be highly research-driven, with intellectual property (IP) contributions by the University of Cambridge, the University of Anglia and Cranfield University. The cluster initially started as an information technology (IT) and life sciences centre before tapping into cleantech: the key sectors include energy systems management, grid services, materials science and built environment.

The cluster has created at least 12 cleantech scale-ups and attracted USD 660 million in investments over the last three years. Startups from the Cambridge area have a valuation premium of GBP 2-5 million (USD 2.4-6 million) at the pre-seed stage, distinguishing them from startups from other regions in the UK.

Successful startups created by the Cambridge cluster

Paragraf produces graphene-based electronic devices including biosensors with applications in precision farming and food toxicity testing, among others. It has also developed graphene- based 2D transistors which can reduce the energy footprint of computer data centres. The company received early funding from Cambridge Enterprise, a spinout facility that is part of the University of Cambridge. In February 2022, it raised USD 60 million in funding from the UK government's Future Fund and the U.S. strategic defence investor In-Q-Tel to accelerate production and market launch.

Nujira produces advanced chips that improve the energy efficiency of wireless transmitters, reducing heat dissipation and energy consumption. The company was founded in 2002, and received initial financing from local funds including Cambridge Angels, Cambridge Capital Group and Cambridge Gateway Fund, raising later funding rounds from national

and international investors. Nujira was acquired by Qualcomm in 2015.

Graz, Austria

Graz, also known as the Green Tech Valley, has a rich history of industrial manufacturing. Over 100 years of fostering innovation has paved the way for Graz to emerge as a pioneer in cleantech during the 1970s and 80s. The city hosts 14 scientific centres of excellence, which means it has an above average research and development ratio. A culture of innovation has attracted over 800 entrepreneurs to Graz who have founded over 60 startups. Moreover, there is a high concentration of global technology leaders, with 20 such corporations located within a one-hour drive of the city centre. Consequently, there is a high level of employment in this region, as well as notable opportunities for collaboration between startups and corporate partners. Around 75-80 per cent of startups in Graz export their products and services. This high export ratio has manifested the Green Tech Valley's international recognition as a leading cluster of cleantech innovation.

The cluster's origins trace back to 1998 when it initially was a loose network of companies. It eventually incorporated as a public-private organization and now has 300 members. It was initially focused on steel production, but transformed its plants into machinery for recycling, renewable energy, solar thermal collectors and hydropower stations during the steel crisis in the 1980s. Graz now specializes in climate protection, circular economy and recycling, green heat, green hydrogen and electrification sectors.

There are 56 startups and six scale-ups in Graz. The combined turnover of companies in this cluster has tripled over the last ten years, and the number of total employees has doubled.

Successful startups created by the Graz cluster

Arteria Technologies provides digital infrastructure solutions to optimize heating networks. The benefits of their technology include energy efficiency, cost savings and reduced CO2 emissions. Customers can digitize old plans for heating networks to improve data management. Data visualizations present temperature projections or sales forecasts. Companies can use these insights to share relevant information with customers, while collecting valuable customer data. The software can be applied worldwide with minor adjustments. At present, the company is expanding to the German-speaking market, as well as Belgium (Brussels) and Finland.

Botres Global GmbH builds and operates bio-refineries to convert organic waste into clean energy, clean water, fertilizer and protein-rich feed and food. Over the last ten years, the company has implemented biorefineries across Europe, the U.S., Asia and Australia. The biorefinery and demonstration plant in Austria was built between 2008–2012; its total investment and operational costs totalled approximately USD 3.7 million. Botres Global's

project to establish 20 biorefineries in Australia raised USD 25 million in the second stage of funding.

Valencia, Spain

Valencia's cleantech sector initially emerged from a group of renewable energy companies. Collaboration between the mayors of over 100 cities and the invested commitment of universities, investors and the government expanded the scope of the city's cleantech industry. This has given rise to healthy cross-sector collaboration between entrepreneurs. The city's first cleantech accelerator, Avaesen, has produced 275 companies since 2014, most of which continue to operate today. The city has witnessed relatively rapid growth as a cleantech innovation cluster due to the deliberate coordination efforts between mayors, chief executive officers (CEOs) of large companies raising awareness of this sector and creating opportunities for entrepreneurs to create cleantech solutions. Valencia's success as a cluster is attributable to its ability to adapt and diversify into new sectors, building the ecosystem from within through participatory leadership, a bottom-up approach to scaling, and attracting VC funding through targeted partnerships in the region.

Spain has a high population density, top universities, a high national gross domestic product (GDP), and attracts international talent due to its high quality of life and relatively low cost of living. The level of connectivity between Spain's cities is high, marked by extensive infrastructure and a shared interest in exchanging knowledge. Madrid and Murcia are looking to Valencia to develop their own cleantech innovation clusters. Valencia has attracted over USD 23 million in funding for its startups in the last three years.

Successful startups created by the Valencia cluster

Zeleros has created the world's fastest land transportation system for automated electric intercity travel. Their hyperloop capsules carry 50-200 passengers per vehicle with zero emissions, reaching top speeds of 1,000 km/h. The company aims to deploy the infrastructure globally by 2050. The company was initially founded by a team of engineering students from the University of Valencia, who won SpaceX's Hyperloop Design Weekend challenge in Texas, USA. Their early investments originated from accelerators such as Climate-KIC, Lanzadera and Plug and Play, as well as angel investments.

ClimateTrade provides carbon offset solutions using a blockchain platform. The company has raised USD 9.1 million in seed funding as of January 2022 from investors such as the Valencia-based cleantech VC firm, Zubi Capital. ClimateTrade also established a joint venture partnership with Planetwatch to issue carbon credits and catalyse sustainable, carbon emission reduction plans.

Chennai, Tamil Nadu, India

Chennai is a leader in cleantech innovation in the South Asia region. The city's high population density, coupled with India's high GDP and strong ties to international markets, contributes to its success. The many universities in the region produce a highly skilled technical workforce. India recently announced initiatives to increase its clean energy infrastructure, including reduced tariffs to lower the barriers to technological innovations. Regionally, there is a push among clean energy sector stakeholders to adopt solar after the Tamil Nadu government introduced higher tariffs, leading to increased energy costs. Key cleantech sectors emerging from Chennai include agriculture and food, enabling technologies, energy and power, and resources and waste management.

Chennai has many centres and labs that foster industries such as life sciences, high-tech and robotics, and cleantech. Government funding is available at the federal, state, and municipal level. Accelerators in the region host events and offer awards, connect startups with lab space for prototyping, connect entrepreneurs with local and global markets, and provide mentoring for business, finance and technical support.

The city has attracted over USD 310 million in funding over the last three years. Chennai has 42 startups.

Successful startups created by the Chennai cluster

Sea6 Energy has pioneered the world's first ocean operating system, a platform designed to harness the ocean's boundless potential. The technology can be used for ocean farming, ocean bioprocessing, and the development of solutions in the food fuel and feed sectors. Together with its partner Novozymes, Sea6 Energy produces biofuel from seaweed. In August 2022, the company raised Series B funding totalling USD 18.5 million in equity capital.

Tan 90 seeks to provide farmers with cost-effective and energy efficient cold storage solutions. Since introducing a 40-litre portable, solar-powered cold storage system for the transportation of milk sachets in 2019, the company has expanded to other cold chain markets including vegetables, fruits, meat and fish. Tan 90 was part of the Clean Energy International Incubation Centre incubation and acceleration programme in 2020.

Singapore, Republic of Singapore

Singapore is cementing its position as Asia's leading cleantech innovation cluster. Surging energy demands in the region are driving the clean energy sector's growth. Singapore has attracted investments in R&D and its workforce possesses technical expertise in engineering and project development. The national market is well-connected and places

a strong emphasis on public-private partnerships to stimulate innovation. The city state is giving rise to startups focused on grid communication, data analytics, renewable energy solutions and waste management[23].

The city has become a regional hub for hosting events for Asia's cleantech leaders. Singapore is an attractive business location due to its international population, highly educated workforce, mild climate, and U.S.-friendly time zone. The city has established specialized technology parks and positioned itself as a centre of commerce for multinational corporations seeking to expand to Asian markets.

Singapore is home to 224 startups and 21 scale-ups, attracting over USD 2.8 billion in investments over the last three years.

Successful startups created by the Singapore cluster

EcoWorth Tech has commercialized a carbon fibre aerogel technology with waste-to-worth uses for industrial wastewater treatment and oil and gas refinement. This technology converts waste materials into usable products. The company was developed at Nanyang Technical University and has received awards and recognition as a leading cleantech company in Asia. The founders previously worked for multinational companies before pursuing this entrepreneurial venture.

Singrow is an urban farming and architecture technology company that has developed vertical farming systems. Their proprietary seedlings and patented growth practices allow farmers to produce high quality crops at higher yields in a climate-controlled environment. The company has raised USD 10 million in seed funding and plans to expand beyond Singapore across Asia and the Middle East.

23 Cleantech Group. (2023, January 30). Data - Singapore. Retrieved from i3 Connect: https://i3connect.com/company?country=Singapore&filtered=done

IV. Steps for building successful cleantech innovation clusters in GCIP countries

This section outlines practical measures PEEs can implement at the local and national level to develop local cluster activity while leveraging their unique strengths. We interviewed accelerators, cluster managers and startups from the standout clusters identified in Section 3, as well as other clusters globally. The key takeaway is that all clusters are distinct, and each has its own unique trajectory, building on local resources, its industrial past and available knowledge and talent pools.

We also found that leading clusters are plugging into international networks and connecting their startups with international opportunities from an early stage. We include suggestions for enhancing international connectivity as well.

Local and regional measures

Helping founders navigate support opportunities

Increasing founders' understanding of environmental policies and cleantech initiatives in the cluster is crucial. The most successful founders typically possess a good understanding of how these factors relate to the city's existing industries, available resources and culture. Cluster leaders can provide valuable information to startups about available programmes and opportunities. Since eligibility depends on the startup's stage of development, among others, startups need help understanding which opportunities may align best with their specific needs.

Facilitating connections between actors in the cluster

Facilitators in successful clusters actively promote partnerships and information exchange that facilitate knowledge sharing and increased collaboration between companies within a cluster. Green Tech Valley in Austria, for example, regularly organizes events where startup founders have the opportunity to meet peers and share experiences and insights. A founder who faces a problem is likely to find a solution from someone in the group

who has experienced a similar problem. Some facilitators provide a physical space where startups and other companies can convene. The Techstars Cities of the Future accelerator in Turin, Italy, hosts startups in glass-walled offices for increased visibility. The space features a long table (instead of many small ones) to promote discussions between all participants over lunch.

Creating specific initiatives to promote the involvement of women, youth and other underrepresented groups

Women, youth and minority founders face a significant disparity in funding and support in the cleantech industry. These underrepresented groups require dedicated opportunities to increase their presence in leadership roles, on boards of directors, and within VC firms to alter the current status quo. ESOs play a pivotal role in breaking down these barriers to ensure equitable representation of such groups at the local level. ESOs in Toronto and Boston have created 'Women in Cleantech' accelerators and accelerators specifically targeting startups led by minority founders. A government-funded initiative in New Zealand allocates resources to indigenous Māori entrepreneurs, ensuring that investments are both culturally and financially impactful. Universities support young founders by providing resources for R&D, access to funding opportunities, business development strategies, and incubators.

Choosing locations in proximity to technical universities and research organizations

Innovation thrives in highly collaborative ecosystems that incorporate universities, local labs and platforms for exchanging ideas with other startups. Close proximity to technical universities and research institutions focused on cleantech innovation and entrepreneurship opportunities for students create a high number of successful startups. To foster collaboration within the industry, some ESOs measure success by assessing the quality and size of events that bring together cleantech companies as well as the number of flagship projects initiated within the cluster. The strategic location of ESOs is also crucial. The City of Toronto recently launched a cleantech innovation cluster mapping initiative to improve coalition building between ESOs and universities and corporations.

Involving mayors and CEOs of local companies to match demand with solutions

Cities can become early adopters of cleantech solutions and set an example using green public procurement. Cluster facilitators can help raise awareness among municipal staff about potential solutions available to them and can connect purchasing teams with CEOs of companies that offer suitable solutions. Avaesen in Valencia, Spain, has built strong partnerships with many local municipalities through such initiatives. Where there is demand for a solution that does not yet exist, Avaesen collaborates with local startups to

co-create one. The proceeds from this service provide an important revenue stream and help support other cluster activities.

Working with local administration for smarter regulation

Startups typically operate with minimal staff and limited resources, so founders try to identify the most straightforward path toward growth. Agile and fast processes for permitting, funding, building and operating a manufacturing site are therefore essential. In Valencia, ESOs have created working groups to analyse current regulations, advocate to position cleantech, share experiences, and discuss entrepreneurial and innovation opportunities.

Working with local administration to promote liveability to attract talent

A supportive cleantech policy, liveability and a city's culture hold particular value. Support from municipal leaders not only unlocks more resources for cleantech entrepreneurs, but also creates brand awareness and enhances the city's reputation to attract talent and investment. Small cities that host technical universities, receive local government support, and have a corporate presence may be attractive to national and international talent and investment pools due to their low cost of living and quality infrastructure. Valencia is one such example of a smaller city that is attracting talent from Madrid (1.5-hour high speed rail trip to the historic coastal city) to join its growing cleantech sector. Spearheaded by the accelerator Avaesen, Valencia's growth strategy mirrors that of a startup, starting small with limited resources but pursuing a specific strategy focused on scaling what works. With a supportive mayor, increased access to public funding, and a rebranding of Valencia from a historic tourist destination to a modern cleantech innovation hub, a higher number of students are choosing to stay in the city after launching their startups, and in turn, attract more talent to the cluster.

Pursuing a clear strategy for cluster development

To improve agility and productivity, successful clusters pursue a clear strategy for development. For example, Graz, Austria successfully converted its traditional steel industry into cleantech. When the cluster started, it had a research, economic, renewable energy and environmental strategy.

Challenges

Cluster development faces many challenges at the local level. Silos exist between the municipal government, research institutions and industry within clusters. Breaking down these silos is possible by regularly organizing events for these key actors to convene and establish partnerships.

Supply chain logistics may delay and impede progress in certain regions. MSMEs can address these challenges by maintaining transparency for investors and buyers about funding constraints and supply chain delays on production schedules. If VC funding within the cluster is limited, entrepreneurs may explore external investment avenues, where they may not have strong connections. Applying to accelerators and for grant funding is time consuming and can be complicated, leading founders to forgo certain local opportunities.

The availability of talent to work on the highly specialized technology being developed by startups and MSMEs is another concern. The technologies being developed in the cleantech sector fall within highly specialized niches and only a small talent pool usually possesses the necessary skills. Attracting new talent from the region or internationally may be challenging due to fierce competition for the relevant skillsets and the restrictive immigration and work permit policies. Establishing an education system that integrates science and technology education from primary school through university will improve the population's digital and technical literacy. Creating more favourable immigration and work permit policies would increase possibilities for startups to recruit international talent and attract a more technically skilled workforce to the cluster.

National actions and conditions

Creating a culture of innovation and favourable attitudes towards cleantech

The key factors for success lie in national attitudes towards cleantech innovation and a culture of integrating sustainability and business. In Estonia, for example, an entrepreneur can easily establish a new company online within just 15 minutes, and complete tax returns in three minutes. Furthermore, Estonia retains no corporate income tax. Estonia's educational system incorporates computer science and technology education starting from primary school, which lays the foundation for a highly technology-literate population. The government's advanced online tools facilitate close collaboration between startups and the government to help them grow with minimal barriers. Such factors reduce obstacles to establishing a business and encourage innovation.

Providing stable market signals

Setting long-term policy interventions and delivering on targets provides the market the

stability it needs for companies to develop strategies and business models, and confidence for investors to finance those business models. Finland is known for its stable government, which decreases perceived risks for investors and carbon credit customers to confidently invest in the country's ventures.

Enabling close collaboration between government and innovators

Strong support and close ties with government ministries are pivotal for success. Founders familiar with national policies and government programmes can tap into resources and drive the national push for cleantech companies. Countries such as Finland, where the Ministry of the Environment and the Ministry of the Economy provide programmes and grant funding, create a positive national branding that supports companies entering export markets. Visibility is a challenge for startups, but a positive national branding increases international visibility for small businesses.

Becoming a leader in the global push for cleantech innovation

The global energy crisis has prompted many countries to drive renewable energy solutions. Government can play a pivotal role in reducing costs and improving market conditions for cleantech innovation. Collaboration across different cities in the country facilitates the sharing of information and expertise. Online tools for sharing information and building coalitions foster innovation in the market and attract VC investors to the clusters. This encourages a bottom-up approach to the dissemination of innovation to national and regional policymakers.

Challenges

Challenges at the national level include reliance on international markets for essential components of the value chain. Luxembourg, for example, is dependent on energy imports from Germany and France. With global oil and gas supplies depleting, Luxembourg must focus on scaling up renewable wind energy production to meet 70 per cent of domestic demand.

Another barrier are regulations that are not designed to be innovation-conducive. The energy sector in Austria is overregulated; access to data requires formal agreements resulting in substantial barriers for the cleantech industry. Recognizing the need to respond to climate targets and prioritizing a clean energy transition, countries can strive to reduce bureaucratic hurdles to cleantech innovation and allocate additional resources to cleantech entrepreneurs.
Yet another challenge is the lack of consistent exchanges and networking events at the national level, especially for the sourcing of talent. Employees with relevant technical

skills are often difficult to find within the country. However, it is also difficult to source talent internationally because labour laws restrict the hiring of foreign employees. ESOs can host events and facilitate networking opportunities at the national level, while also establishing accelerator and incubator programmes for students graduating from local universities to stay in the cluster and establish cleantech enterprises.

Some countries make less domestic funding available than others. When innovators do not receive support from government institutions, they may attempt to tap into international networks for financing. Scaling up to mass production can be challenging for many cleantech startups because they encounter difficulties in securing financing for manufacturing plants. If governments are unable to provide funding to grow the cleantech sector, they can introduce initiatives to attract international VC and debt funding and expose innovators to opportunities in export markets as an alternative.

Leveraging international networks

Success Factors

Joining international cluster networks

Network organizations such as the International Cleantech Network[24] provide opportunities for managers of different clusters around the world to exchange knowledge and best practices, and to create international connections that generate both new business opportunities and value for their cluster members. Many leading clusters are linked with other clusters internationally.

Expanding the talent search globally to address the local and national shortage of skilled labour

Resources at the international level can offset challenges at the local and national levels. Many clusters with high-growth innovators that lack sufficient talent supply at the national or local level must expand their talent search. Networking websites such as LinkedIn play an important role for startups and MSMEs to source talent. As previously mentioned, favourable immigration policies are essential for this strategy to succeed.

Aligning with internationally agreed targets for climate impact

International agreements such as the Paris Agreement have spurred legislation to support startups aligned with the Sustainable Development Goals (SDGs) and Fit for 55 targets. The European Union (EU) has been a leader in this regard. The EU offers non-dilutive

24 International Cleantech Network. (2022). Retrieved from International Cleantech Network: https://internationalcleantechnetwork.com/

public funding, has created the European Innovation Council, and provides opportunities for EU-based R&D. Europe also has a wide network of VC and private equity firms. The EU was the first to introduce funding schemes for renewable energy and offer incentives for solar and thermal technologies in the 1990s. Of the approximately 7,000 clusters globally, 3,000 are located in the EU. One in four jobs in the EU is linked to a cluster. International market trends such as EVs, hydrogen and renewable energy have helped the market gain traction. Paris serves as an example of a city that has emerged as a leader for catalysing its cleantech market following a diesel ban in response to global pressures.

Advertising international events online and establishing networks

International events and funding are easily accessible online, simplifying the process of connecting to international VC funding sources. Many global networks for cleantech already exist. ESOs that operate in the carbon removal industry can collaborate with competitors and collectively push the global policy agenda in favour of this industry. The International Cleantech Network (ICN) facilitates many connections across the top cleantech innovation clusters worldwide. The clusters receive financing from ICN, convene once a year, create mechanisms for establishing cluster working groups, engage in service exchanges, and benefit from complimentary services as network members. Many networking opportunities exist for connected companies. International events provide a platform for participants to discuss cleantech-related topics from different business perspectives.

Promoting international funding opportunities

International innovation grants are crucial for newly developing clusters. International non-governmental organizations (NGOs) such as the World Economic Forum, the World Bank and GIZ provide grants to finance pilot initiatives. By leveraging international NGOs, startups have access to global partnership opportunities and open data on the cleantech industry to identify opportunities. Many opportunities exist to access private equity from international VCs and pilot projects with international corporations and foreign governments.

Challenges

The cleantech sector faces significant pressure to deliver solutions for climate mitigation, adaptation and resilience. One common challenge experienced by cleantech clusters is securing funding for pilot projects which may entail long waiting times for profitability. Global competitors, benefiting from increased funding from international sources, inevitably scale up faster. International NGOs, multinational companies and international VC firms can help bridge funding gaps that arise at the national and local level.

Women and minority founders often encounter higher barriers to entry than non-minority, male founders. These challenges are difficult to address on a global scale and are

primarily rooted in high costs associated with technical education, limited opportunities to participate in training due to family commitments, difficulties in accessing funding, persistence of workplace biases and a lack of mentorship. These barriers for women and minority entrepreneurs often result in limited access to official financial resources and diminished chances of securing competitive funding. To address these funding disparities, providers of funding should re-evaluate gender- and minority-biases to eliminate regulatory constraints, complex loan application procedures, and high interest rates, which discourage and exclude these groups. Addressing these efforts at the local level can take the form of specialized scholarships, incubators and accelerators designed to include these groups.

Geopolitics and their repercussions currently represent major challenges for innovators. Energy prices have skyrocketed due to the war in Ukraine and inflation is putting pressure on supply chains and other costs of doing business. While governments are under pressure to respond quickly, they can consider ways to transition away from dependence on critical inputs, and to formulate measures that will enable innovative startups in the country to take advantage of new areas of demand for cleantech solutions.

Conclusions

The GCIP Pillar 2's Cluster Development Framework leverages insights from leading global cleantech innovation clusters to derive best practices for strengthening national cleantech ecosystems. PEEs in the GCIP partner countries have defined the national priorities for cleantech innovation. With the national priorities outlined, PEEs can use this framework to replicate success factors from leading clusters and implement activities to develop regional innovation clusters with high-growth cleantech companies in their own countries.

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Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 1 26026-0

www.unido.org

unido@unido.org

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