Assessing and Identifying High-Impact Potential Climate Tech Start-ups

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I declare that this document is an original work of my own authorship and that it fulfils all the requirements of the Code of Conduct and Good Practices of the Universidade de Lisboa.

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Abstract

With the urgent threat facing humanity due to the climate emergency, decision-makers need tools to assess the future potential climate impact of emerging technologies. To understand the impact of these technologies two types of assessments were studied: GHG Footprint and GHG Impact. It became clear more work needs to be done on the GHG Impact side, so a detailed review of existing forward-looking GHG Impact frameworks is performed. Then a new methodology, combining two of the existing frameworks, to identify high-impact potential start-ups is introduced and implemented. This led to the identification of 39 high-impact potential climate tech start-ups out of a database of 30,000. Then an analysis of these start-ups was undertaken to understand their performance.

Keywords

Climate impact, climate tech, impact assessment, start-ups

Resumo

Com a ameaça latente que a humanidade enfrenta devido à emergência climática, os decisores precisam de ferramentas para avaliar o impacto climático potencial das tecnologias emergentes. Para entender o impacto dessas tecnologias, dois tipos de avaliações foram estudadas: "GHG Footprint" e "GHG Impact". É hoje claro que é necessário fazer um esforço adicional para diminuir o impacto dos gases de efeito de estufa (GEE), pelo que uma revisão detalhada das plataformas sobre o impacto dos GEE é realizada de forma prospectiva. Em seguida, uma nova metodologia, combinando duas das plataformas existentes, para identificar potenciais start-ups de alto impacto climático é introduzida e implementada. Isso levou à identificação de 39 "start-ups" de tecnologia climática de alto impacto a partir de um banco de dados de 30.000. Em seguida, uma análise dessas "start-ups" foi realizada para compreender o respetivo desempenho..

Palavras-chave

Impacto climático, tecnologia climática, avaliação de impacto, “start-ups”

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List of Abbreviations

AE	Avoided Emissions
BAU	Business-as-usual
Bn	Billion
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
EV	Electric Vehicle
ECT	Emerging Climate Technology
ERP	Emissions Reduction Potential
EGS	Enhanced geothermal system
EU	European Union
GtCO2eq	Global GHG emissions
GHG	Greenhouse gas
GVA	Gross-value added
NDCs	Nationally determined contributions

List of Software

Net0 Platform	The Market Intelligence Platform for Climate Tech.
CRANE Tool	Provider of a quantitative & qualitative output report about its greenhouse gas emissions reduction potential.
Google Collab	Colab is a free Jupyter notebook environment that runs entirely in the cloud.
Google Sheets	A spreadsheet program included as part of the free, web-based Google Docs Editors suite offered by Google.

Chapter 1

Introduction

This chapter gives a brief overview of the investigation. Before establishing work targets and original contributions, the scope and motivations are described. At the end of the chapter, the structure of the investigation is provided.

1.1 Overview

With the looming threat of the climate emergency, the importance of climate innovation is critical for the transition to a more sustainable economy. The Paris Agreement set the ambitious goal of limiting global temperature rise to well below 2°C and pursuing efforts to limit it to 1.5°C (IPCC, 2018). To avoid a serious disruption of human existence on the planet, it is critical to reach this goal. Under the terms of the Paris Agreement, 156 nations had submitted new or revised nationally determined contributions (NDCs) as of January 2022. An NDC is a climate action plan to cut emissions and adapt to climate impacts. Each Party to the Paris Agreement is required to establish an NDC and update it every five years. The new unconditional and conditional NDCs of these nations, if achieved, will result in an overall reduction in world emission levels by 2030 of around 3.8 and 3.9 Global GHG emissions (GtCO2eq), respectively, in comparison to the earlier NDCs as of October 2020. However, this total reduction must be about three times greater to be consistent with keeping global temperature increase to well below 2 °C, and even seven times greater for 1.5 °C (Michel G. J. den Elzen, 2022).

To achieve these targets, significant emissions reductions will be required. Firms must adopt more than just a business-as-usual approach, as potentially soon reducing their existing emissions will be required. New strategies led by businesses will be required to provide innovative and disruptive solutions that will significantly alter social behavior and rapidly result in total emissions reductions.

Companies that provide climate solutions rather than simply lowering their own emissions have contributed to many of today's most significant emission reductions. Renewable energy, electric vehicles, dematerialization, virtual meetings, and other examples have been driven by firms that provide solutions rather than by firms that reduce their own emissions. There are numerous opportunities in the Fourth Industrial Revolution (connectivity, novel materials, and innovative business models). This is not to say that a company's emissions are insignificant; rather, we will not be able to achieve a zero-carbon society unless all or most emissions are eliminated.

On the other hand, rapid emission reductions necessitate innovative solutions, which require a methodology capable of assessing the impact of avoided emissions from these solutions. These technologies have a new classification, called; Climate Tech. Climate Tech is defined as technologies that are explicitly focused on reducing greenhouse gas (GHG) emissions, or addressing the impacts of global warming (PWC, 2020). Climate tech applications can be grouped into three broad sector-agnostic groups—those that:

1. Directly mitigate or remove emissions
2. Help us to adapt to the impacts of climate change
3. Enhance our understanding of the climate.

Understanding the potential climate impact of emerging technologies provides key insights for policymakers, investors, and researchers (referred to as decision-makers for the remainder of this thesis) on where to allocate resources. Although climate technologies can be developed and scaled through different pathways this thesis focuses on the start-up commercialization process, as this has been a significant driver of innovation in the 21st century.

This thesis develops and implements a methodology for identifying the climate tech start-ups with the greatest impact potential regarding GHG emissions reductions/avoidance, to demonstrate how future impact assessments can be a valuable tool for decision-makers. The work presented utilizes data from leading organizations in the space of climate tech and impact assessments: Prime Coalition, Rho Impact, and Net Zero Insights. The aim is to bridge the gap between technology-specific assessments and an automated start-up assessment, creating a unified methodology that can be used at scale to identify start-ups with high potential impact.

1.2 Motivation and Contents

Analyzing emerging climate technologies and the associated start-ups developing them will help decision-makers allocate resources that will ultimately support the successful implementation and scaling of the companies. Ensuring the success of these start-ups can have a major influence on reaching net zero GHG emissions. Reaching net zero by 2050 requires further rapid deployment of available technologies as well as the widespread use of technologies that are not on the market yet ((IEA), 2021).

With this in mind, understanding new technologies' development and commercialization process helps emphasize the decision-makers' role. Figure 1 illustrates the high technology adoption lifecycle combined with typical primary investors at the different stages. It reveals that investors are important stakeholders in accelerating the development of technology adoption, especially across the “valley of death”. A vast majority of the emerging climate technologies that will be discussed fall primarily into the first two stages: technology creation and market-focused business & product development.

Historically, low-carbon technologies have faced a critical funding gap during the validation and early deployment stages, causing technology development to stall (CDP, 2021). During this stage, technologies are ready for their first infrastructure projects, but they frequently struggle to attract project financing because their products are still expensive in comparison to fossil alternatives, and there is perceived technology risk. As a result, technologies stall in their price declines before reaching critical tipping points in market competitiveness that enable wide-scale adoption.

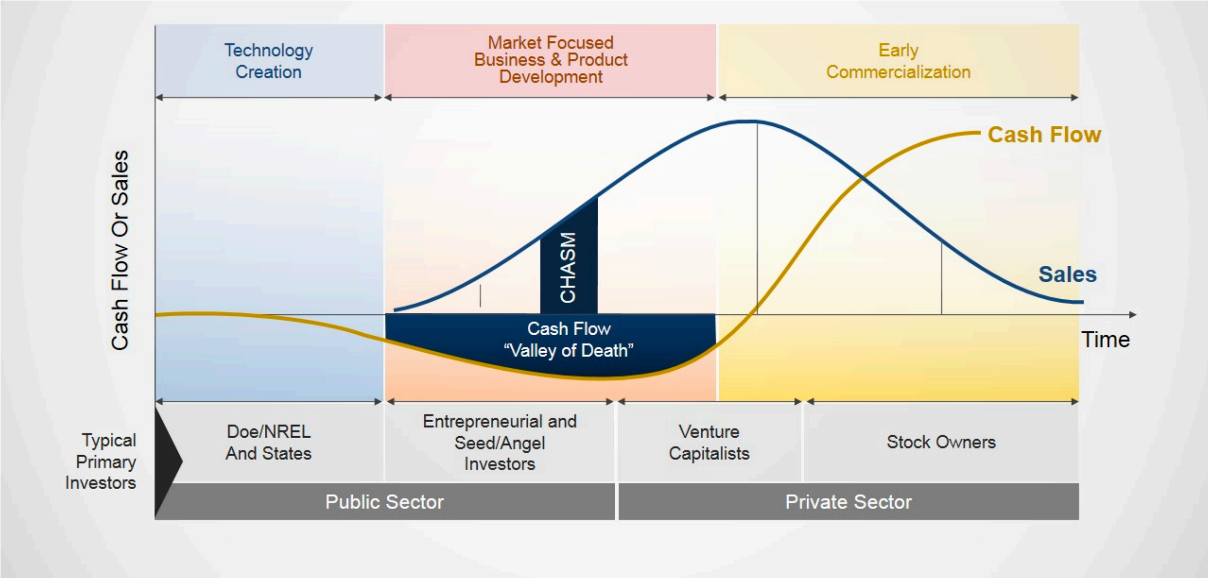

Figure 1: High technology adoption lifecycle (Moore, 2006).

Climate tech projects struggle to raise capital because there are no established markets for their products at a premium; thus, green products require subsidization to achieve market uptake at scale. To achieve widespread adoption of these products and technologies, the Green Premium must be reduced by bringing technologies to scale. Green Premium is defined as the difference between the final consumer price of a low-carbon solution and the final consumer price of the incumbent solution, all important terms are defined in Annex 1. Large infrastructure investments may lower the Green Premium of these products while increasing their cost-competitiveness with fossil fuel incumbents. Backward-looking analysis of clean technologies has empirically shown that greater deployment reduces the cost per unit, which encourages further deployment and drives an exponential decline in unit cost, particularly in the early stages (Kavlak, 2018).

Luckily, there seems to be a response to the urgent threat that climate change poses to humanity. Climate tech investments hit a record $60bn in 2021 (Net Zero Insights, 2022), up from <$2bn in 2010 (BloombergNEF, 2021). The effectiveness of those investment dollars in meeting the climate challenge is fundamentally dependent on decision-makers' ability to identify opportunities with the greatest potential for climate impact, such as risky and not-yet-fully-proven technologies, services, or business models that, if successful, could fundamentally change energy systems, industrial processes, or emissions-intensive goods. Given the variety of available solutions, decision-makers require robust and objective metrics for assessing the potential impact of various opportunities.

The frameworks with such metrics could benefit from greater consistency and transparency for widespread adoption by decision-makers. The existing frameworks are studied and analyzed in the first part of this thesis. While the findings suggest current progress is in the right direction, there is still much to do.

With rising GHG emissions levels that will cause catastrophic harm, accelerating high-impact solutions should be a critical element of the global climate strategy. This work is motivated by the need for decision-makers to provide the necessary resources for emerging climate technologies to have the most significant impact on emissions by reaching commercial scale in the future.

This thesis is composed of 5 chapters.

1. Chapter 1 – Introduction
    - Provides an overview and motivation of the work done.
2. Chapter 2 – State of the art
    - Introduction and analysis of existing impact measurement frameworks/assessments.
3. Chapter 3 – Theoretical development
    - Description of the methodology created and implemented to map emerging climate technologies.
4. Chapter 4 – Analysis of results
    - Detailed findings and insights of the highest impact potential start-ups
5. Chapter 5 – Conclusions
    - Summary of the work completed, limitations of the work, and aspects to be further developed.

The main goal of this thesis is to develop and implement a methodology for identifying high-impact potential climate tech start-ups.

Chapter 2
State of the art

This chapter introduces the topic addressed and an analysis of existing impact measurement frameworks/assessments.

2.1 GHG Emissions

Although there are many metrics when discussing impact, in the case of climate tech and this work, GHG emissions are the focus since they are the main driver of climate change. In this section, the importance of GHG emissions reductions is explained and a breakdown of their sources is provided to provide the rationale behind focusing on them.

2.1.1 Importance of GHG emissions

In 2018, the IPCC released a special report which states, human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C (IPCC, 2018). They indicated global warming is likely to reach 1.5°C between 2030 and 2052 if emissions continue to increase at the current rate. Global temperature rise is a result of the emissions of GHGs. The main GHGs to be concerned about are carbon dioxide (CO2), methane, and nitrous oxide. CO2 can last up to 1,000 years in the atmosphere, methane for about a decade, and nitrous oxide for about 120 years. Methane is 80 times more potent than CO2 in causing global warming over a 20-year period, while nitrous oxide is 280 times more potent (UN News, 2022). Since 1751, the world has emitted over 1.5 trillion tonnes of CO2 (Hannah Ritche, 2020).

To reach the climate goal of limiting average temperature rise to 2°C, many countries around the world are committing to Net Zero emissions targets. Reaching these targets will require efforts from every aspect of the economy: government policy, public and private companies, non-governmental organizations, universities, etc.

2.1.2 Breakdown by Sector

GHG emissions occur across many different aspects of economic activity. Figure 2 shows the breakdown of GHG emissions by economic sector for 2019. It reveals that Industry is the main source of emissions, accounting for 30% of all emissions worldwide. The great majority of the emissions from the production of electric power, came from the burning of coal. Combined emissions from land use, agriculture and waste made up 21%, followed by transportation (16%) and buildings (7%).

This breakdown demonstrates that a variety of sectors and processes contribute to global emissions. Meaning that there is no single, simple solution to address the challenge.

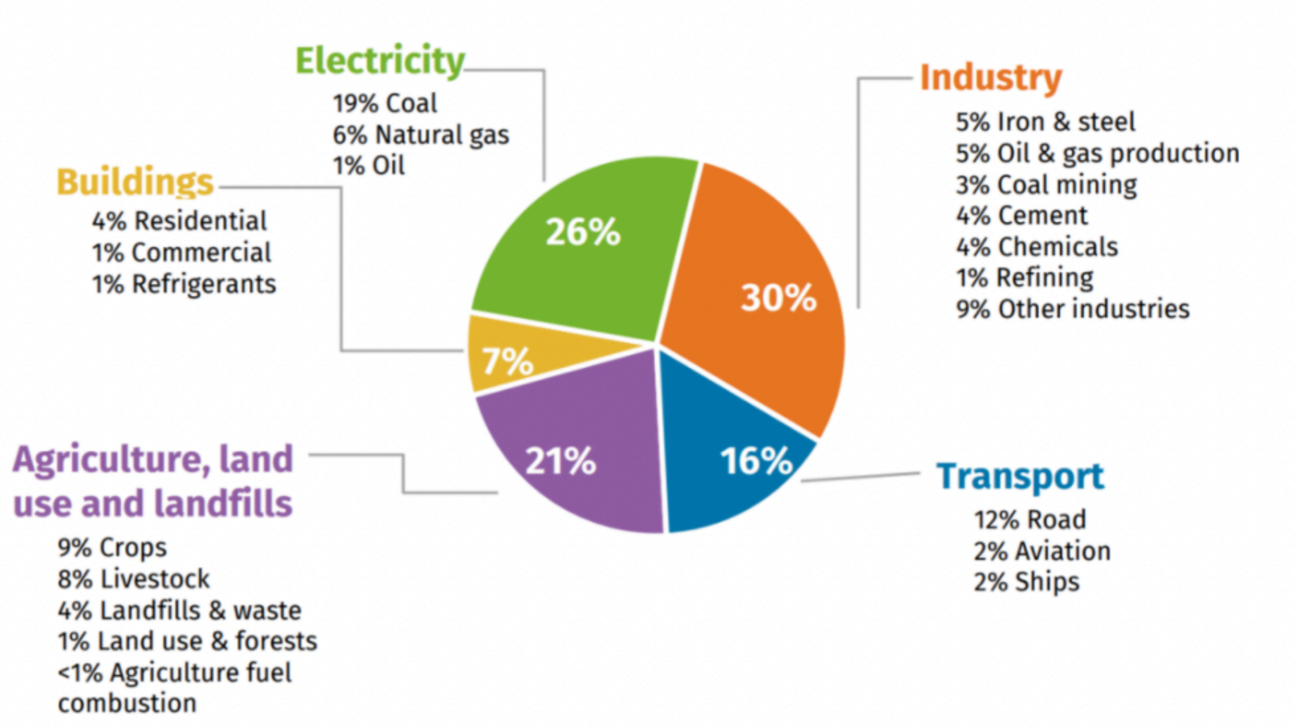

Figure 2: Global Greenhouse gas emissions by sector, 2019 (Rhodium Group, 2021).

2.1.3 Classifying GHG Emissions

To handle GHG emissions, there have emerged assessments that help stakeholders understand the situation. Two classifications of GHG assessments have been developed and are important to distinguish: GHG Footprint and GHG Impact (Project Frame, 2022).

The term GHG Footprint refers to actual outcomes in absolute numbers, such as GHG emissions. These figures are not relative to a baseline or status quo. Typically, they are concerned with Scope 1, 2, and 3 emissions. GHG Footprint assessments aim to understand the current and past number of GHG emissions that an individual, technology, or country has emitted. Generally speaking, a lower GHG Footprint is better (Project Frame, 2022).

On the other hand, the term GHG Impact refers to the planned or potential change brought about by an innovation in comparison to the status quo. Typically, it refers to an intended positive change, and the higher the GHG Impact the better (Project Frame, 2022).

When examining the landscape of frameworks aimed at assessing and reducing GHG emissions from specific activities, it became clear that GHG footprint assessment efforts are more developed and thus more widely used. This is likely due to the increased implementation of regulations requiring more disclosure from businesses regarding emissions. GHG footprint assessments are extremely helpful in understanding the impact of commercial and late-stage companies.

However, there is a need for GHG impact assessments in early-stage ventures that are actively developing technologies aimed at reducing emissions. Because the technology has not yet been scaled, these assessments help decision-makers understand the future potential impact of the technology, which in this case is more important than the current footprint.

Figure 3 shows the landscape of climate impact assessment tools for companies. It is not an exhausted figure of all the assessments that exist, but it demonstrates where there is a lack of development in the space.

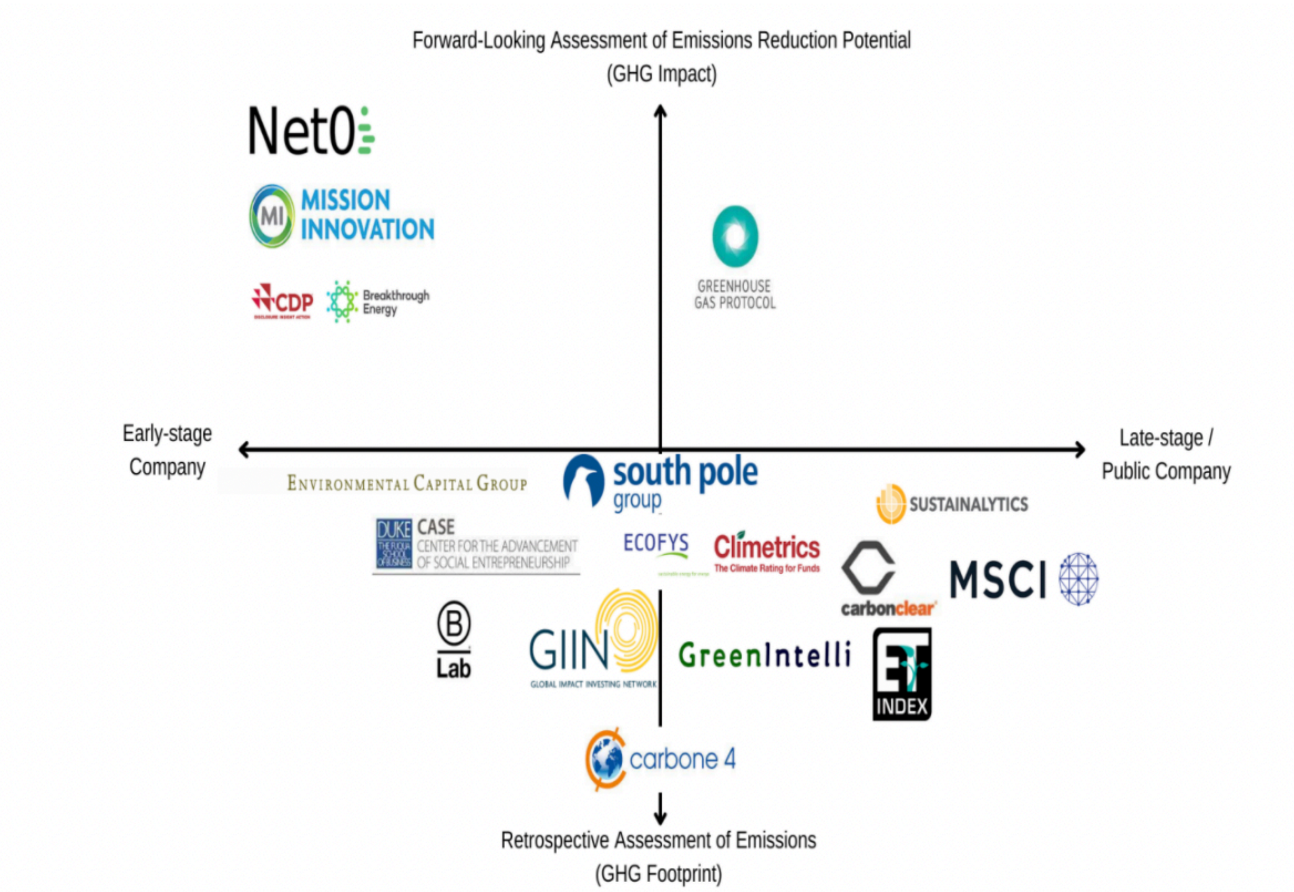

Figure 3: The landscape of climate impact assessment tools. Adapted from (PRIME Coalition, 2017).

The top left section of the figure is the area of interest in this thesis. It is important to note that Prime Coalition and Rho Impact's Emission Reduction Potential Framework is missing. Their framework is technology specific and is not applied directly to companies but is an important part of this thesis.

2.3 Assessments Overview

In this section we discuss the 5 GHG impact assessment frameworks that have been developed and that are seen in Figure 3:

1. Greenhouse Gas Protocol, Projects Accounting (World Resources Institute and World Business Council for Sustainable Development, 2005)

    a. **Summary**: The GHG Protocol for Project Accounting provides specific principles, concepts, and methods for quantifying and reporting GHG reductions i.e.the decreases in GHG emissions, or increases in removals and/or storage from climate change mitigation projects.

    b. **Comments:** The Greenhouse Gas Protocol's Project Accounting Framework is most likely the oldest methodology available. In 2004, the World Business Council for Sustainable Development and the World Resources Institute collaborated to create it. It serves as the foundation for many of today's methodologies and concepts that organizations use in their in-house methodologies. It outlines specific principles, concepts, and methods for quantifying GHG reductions. There is also an excellent glossary to help you quickly understand what they are saying.

2. Mission Innovation, Avoided Emissions (AE) Framework (Mission Innovation, 2020)

    a. **Summary:** The methodology provides a comparison of the greenhouse gas emissions from a business-as-usual (BAU) baseline scenario with those from a solution-enabled scenario to demonstrate the benefit of the solution to reduce overall system-level GHG emissions.

    b. **Comments:** The flexibility of this framework, which uses avoided emissions as a metric, is its main strength. When it comes to project or technology assessments, it fits in the center of the landscape. And it is because of this flexibility that the framework, or at least the steps within it, can guide you in evaluating either a specific company or a technology in general. One of the most important aspects is that you can assess the impact of early-stage or growth-stage technologies and companies.

3. Breakthrough Energy/CDP, Emerging Climate Technology (ECT) Framework (CDP & Breakthrough Energy, 2021)

    a. **Summary:** The ECT Framework articulates the estimation, monitoring and attribution of the environmental and financial impacts of investing in emerging climate technologies. Its purpose is to provide visibility on the important role ECT investments have in achieving the transition to a zero-carbon economy. By providing methods to quantify the positive impacts of ECT investments, the Framework aims to facilitate the creation of incentives to accelerate the deployment of emerging climate technologies. This in turn should help address the recognition gap of the positive externalities of ECT investments through ESG rating systems and sustainability claims.

    b. **Comments**: This methodology goes beyond quantification to address attribution, or how to assign credit for investing in emerging climate technologies. It was founded to direct capital toward the most promising climate-change technologies available. Other methodologies have not addressed this gap. Accounting, reporting, and verification of GHG reductions are still included in this methodology, but the ECT framework refers back to Mission Innovation's Avoided Emissions Framework for how to quantify impact.

4. Prime Coalition/NYSERDA/Rho Impact, Emissions Reduction Potential (ERP) Framework, CRANE (PRIME Coalition, 2017).

    a. **Summary:** CRANE provides rigorous, standardized, and transparent analysis of a technology's ability to reduce GHG emissions and allows users to view the estimated annual and cumulative emissions reduction potential (ERP) for innovative low-GHG technologies. Key results, calculations, assumptions, references, and data are provided as part of every output report. CRANE allows users to calculate multi-year ERP estimates and compare market penetration scenarios for technologies based on sector and sub-sector breakdowns.

    b. **Comments:** The emissions reduction potential framework developed by PRIME and NYSERDA is ideal for assessing new technology and the diffusion of technology to cover 100% of the market. So, when you look at, say, electric vehicles (EVs), you make broad assumptions about what the impact of EVs might be once they take over the world. They use an s-curve to calculate the adoption or diffusion rate. This makes it extremely useful for assessing the impact of new / early-stage technologies.

5. Net Zero Insights, Net0 Score (Net Zero Insights, 2022).

    a. **Summary:** The Net0 Score is conceived to be a means to quickly identify the most impactful organizations. Ranging from the lowest impact 0 to the highest impact 1, the score measures the opportunity to reduce CO2eq emissions from the organization's development. The score is computed as the weighted average of six factors, capturing both macro- and micro-economic aspects.

    b. **Comments:** The Net0 Score is still a Minimum Viable Product, the score represents the first attempt of Net Zero Insights to measure the climate impact of start-ups. The score's main advantage is its ability to be applied at scale to thousands of start-ups at the same time. It is lacking on technology-specific data related directly to emissions. Additionally, parts of it are only designed for European companies, so it needs to be developed further to work with universal indexes.

2.4 Assessments Comparison

A result of studying the landscape of existing impact methodologies is the comparison based on 5 metrics, seen in Table 1. The five assessments are analyzed based on the users, the applicability, specific characteristics, topics not covered, and the ability to be scaled on large scale.

The user applicability is an important aspect of any assessment that aims to be used widely. Most of the assessments are designed for the full range of decision-makers, except the GHG Protocol which is focused only for companies and investors. When looking at the applicability of the assessments, there is a range across the assessments. None of the assessments covers all the possible applications: projects, early-stage company or tech, growth stage company or tech, or late-stage company or tech. The characteristics described give insights into the approach of the assessments. It's clear the characteristics are all unique and that the coverage varies significantly. Thus, also included in the comparison are the topics not covered by each assessment. Here it is seen that no assessment is fully complete as they lack topics from attribution/technology adoption to specific company impact. The last aspect for comparison is the ability to be done at scale or in other words automated. In this regard, the Net Zero Insights assessment is the only one capable of assessing thousands of companies in an automated way. The rest require calculations to be done one by one. It is also important to note that the ERP assessment from Prime/NYSERDA has led to the development of CRANE, a free tool to do ERP assessments.

Overall, it was discovered that numerous frameworks are available to assist investors and entrepreneurs in quantifying and communicating their impact, from scope 1 and 2 emissions to forward and backward-looking impact assessment. However, a maze of jargon and 200-page volumes can make it challenging for new decision-makers to manage. With billions of dollars in private capital now flowing into early climate tech, decision-makers are interested and need support to direct capital to solutions with the greatest potential to support the change our world needs. Lastly, reliable data and tools are crucial. Even though many approaches are brilliant and strong, the inputs are crucial. Any methodology's outcome will only be as good as the data it uses. Since this is a rapidly evolving space the need for such assessments may increase rapidly, especially if and when regulations call for increased information regarding emissions.

The work explained in Chapter 3 of this thesis builds off the ERP assessment from Prime/NYSERDA and the Net0 Score from Net Zero Insights. Therefore, these two assessment methodologies are detailed further.

Table 1: Comparison of Impact Methodologies, adapted from (Project Frame, 2022).

Assessments	Who should use	Applicability	Characteristic	Topics Not Covered	Can be done at scale
GHG Protocol	Companies / Investors	Specific Project	Provides specific guidelines at project level	Attribution / Technology adoption	NO
Mission Innovation	Companies / Investors / Policy Makers	Growth to late stage company or tech	Flexible - can be modified for planned or potential approach	Technology adoption	NO
Breakthrough /CDP	Companies / Project Finance Investors / Policy Makers	Early stage tech / project	Covers catalyzed emissions / attribution	Looks to Mission Innovation for emissions reduction methodolog y	NO
Prime/NYSER DA	Companies / Investors / Policy Makers	Early stage tech	Market view Potential Impact approach	Specific company impact	NO
Net Zero Insights	Companies / Investors / Policy Makers	Early to late stage company	Market view and dependent on database classifications.	Technology emissions reduction	YES

2.5 ERP Assessment Methodology

The goal of the ERP methodology is to provide metrics to assess early-stage companies based on their potential to mitigate GHG emissions in the future based on the products they develop and sell. Therefore, assessing ERP requires estimates of product effects and anticipated product deployment across the timeframe specified in the Emissions Reduction Potential estimate.

Equation 1 shows a simplified formula that merely considers future product deployment and product impacts. This equation is for a timeframe of 30 years and provides an easy way to understand how the ERP calculation works.

Equation 1: ERP simplified formula (PRIME Coalition, 2017).

$$
\begin{aligned}
&Emissions\ Reduction\ Potential \\
&\quad = (Total\ system\ emissions\ in\ scenario\ without\ the\ new\ venture's\ product \\
&\quad - total\ system\ emissions\ in\ scenario\ with\ the\ new\ venture's\ product) \\
&\quad = \sum_{year=1}^{year=30} Estimated\ Units\ of\ Product\ Sold\ in\ year\ y \\
&\quad * Estimated\ Greenhouse\ Gas\ Reductions\ due\ to\ Products\ Sold\ in\ year\ y]
\end{aligned}
$$

To be able to estimate the "total system emissions in a scenario with the new venture's product" requires looking far into the future and thus handling systemic uncertainties. Three main uncertainties have been identified are (PRIME Coalition, 2017):

1. The future evolution of the venture's product impacts;
2. The scalability of the venture's product; and
3. The pace of growth in the deployment of the venture's product.

Figure 4 provides a visual representation of how the uncertainties impact the calculations. Prime/NYSERDA provides the following tips for handling the uncertainties (PRIME Coalition, 2017).

- Consistency: use the same assumptions in all assessments of common companies.
- Transparency: detail and communicate key assumptions.
- Conservatism: when forced to make simplifying assumptions, attempt to make conservative assumptions.
- Averages: When establishing base-case ERP assessments, use average values for certain key variables in these cases.
- Extremes: in addition to estimating base-case ERPs using averages, strive to calculate ERPs under best and worst cases.
- Magnitude: attempt to identify the minimum viable information required to adequately assess a company's impact.

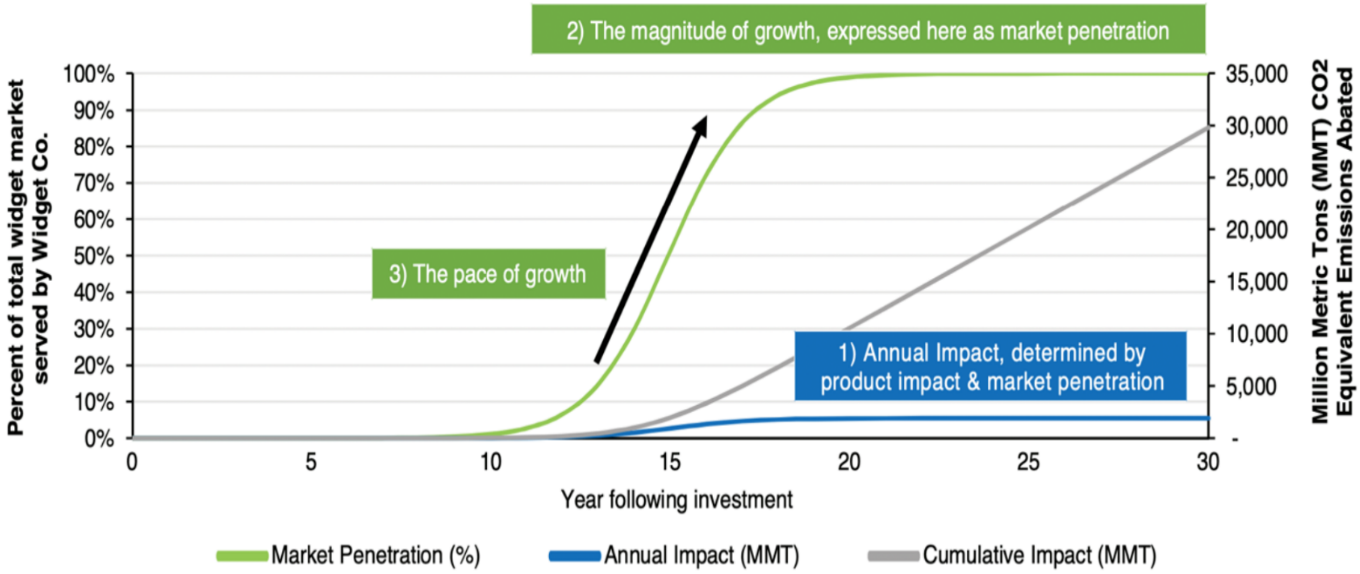

Figure 4: Illustration of ERP systemic uncertainties (PRIME Coalition, 2017).

In reality, the calculations involved are quite complex, so for Assessing ERP when looking at companies pre-investment Prime/NYSERDA has created a 5 step process (PRIME Coalition, 2017):

Step 1: Estimate the emissions of the product displaced.

- Identify the data source for assessing the product impact, using a full lifecycle impact where possible.
- Project the product impact over the timespan of the ERP calculation (i.e. 30 years).
- Translate displace product impacts into units of business success for the new venture.

Step 2: Estimate additionality.

There are four broad types of impacts that a product may have that must be included in an analysis of additionality. A new product may:

1. Improve the performance (e.g. efficiency or lifetime) of a GHG-emitting product;
2. Improve the performance of an existing low GHG product;
3. Increase the deployment of an existing low GHG product;
4. Introduce a new low GHG product into a market without existing low GHG products.

Step 3: Estimate the emissions of the venture's product & emissions reduced by products sold.

- Use the same procedures as Step1 to estimate the emissions of the venture's product, per unit of product sold.
- Calculate the GHG reductions due to Product Sold by subtracting the GHG emissions of the venture's product from the GHG emissions of the product displaced.

Step 4: Estimate Potential Product Deployment

- Estimate the parameters for a standard market penetration model and forecast penetration over the ERP period.
- Adopt a market forecast for the market in question from a recognized forecasting agency.

Step 5: Put it all together to create and ERP estimate.

- Multiply annual emissions reduced from products sold by annual estimates of product sales.
- Sum annual values over the ERP period to create a cumulative value: the Emissions Reduction Potential.

Although the ERP methodology provides clear steps for performing a climate impact assessment, it is still a time-intensive process. Therefore in 2019, NYSERDA, the John D., and Catherine T. MacArthur Foundation, and Massachusetts Clean Energy Center supported Prime and three additional development partners – Greenometry, Rho AI, and Clean Energy Trust – built a tool that makes the methodology available to anyone that might want to consider climate impact in their decision making: CRANE

The CRANE tool is a free online software to make ERP assessments based on different inputs from the user and in-built projections. Below are the details of the required inputs (CRANE, 2022).

Required Inputs

From the User

- The geographic scope of analysis - This is the geographic region that you expect to adopt your technology. Most of the CRANE technology models are global, but some are specific to certain regions, i.e. North America.
- The time horizon of analysis - This is the start and end point for the analysis. CRANE restricts the analysis projections to a maximum of 2060 for the final year of the analysis.
- Technology area selection - This includes identifying the most appropriate technology model in CRANE. Sometimes technologies that do not at first seem like a direct fit can be modified appropriately for reasonable analysis.
- Projected market penetration - CRANE provides default values for projected market penetration. CRANE currently does not support projected unit sales as a direct input, so some conversation may be necessary to reach the appropriate input units. The units are always a percentage of the target market.
- Key physical performance metrics or targets - This is a commonly used performance metric for the specific technology, such as fuel efficiency improvement or percent energy savings. CRANE provides default values for an expected similar technology, but this will likely need to be updated if the analysis is for a specific company’s technology.
- Current hypothesis around impact potential (i.e. mechanism of mitigating or avoiding emissions.

From CRANE

- Total Market and target market projection(s)
- Corresponding industry emissions projection(s)
- Key performance metrics and/or GHG intensity of incumbent technologies (i.e. those which are expected to be displaced by solution)

From these inputs the software performs the calculations and provides the following outputs:

Key Outputs

- Estimate of range of cumulative GHG emissions reduction potential to the end year.
- Estimate of the annual GHG emissions reduction potential per company to the end year.

The team behind CRANE has identified around 200 emerging climate technologies for which they have built in the results for them. To demonstrate what this looks like, here an example is provided for the technology: CO2-based enhanced geothermal system (EGS).

EGS can access geothermal energy in areas without natural reservoirs. Super-critical CO2 may be injected, instead of water, into a man-made reservoir in hot rock, then used to drive a steam turbine to generate electricity. Some CO2 would remain underground to maintain the man-made reservoir.

Key Assumptions that are the inputs in CRANE:

- The reference scenario (i.e. projections for a world in which the new technology has not been deployed) uses data from **IEA ETP 2017 RTS** model.
- Geographic scope of analysis and markets is **Global** and covers the years **2023** to **2050.**
- **Total Available Market:** Gross electricity generation
- The new technology is expected to displace **100%** of the target market's+ incumbent technology by year **2050**.
- The target market and incumbent high-GHG technology currently serving it is **Gross electricity generation from coal, oil, and natural gas** and has a GHG intensity of **0.84 MMtCO2e/TWh** in year **2023**, ending with a GHG intensity of **0.72 MMtCO2e/TWh** in year **2050**.
- The established market and incumbent clean technology currently serving it is **Geothermal electricity generation** which has a GHG intensity of **0.1 MMtCO2e/TWh** in year **2023**, ending with a GHG intensity of **0.1 MMtCO2e/TWh** in year **2050**.
- By year **2050**, **0%** of the new technology's adoption is expected to displace the incumbent clean technology in the established market **(Geothermal electricity generation)**.

- The new technology is expected to have a GHG intensity of **-3.9 MMtCO2e/TWh** beginning in year **2023** and **-3.9 MMtCO2e/TWh** by year **2050**. This value cannot be modified by the user at this time.
- As modeled, the new technology adoption cannot exceed the projected target market size, including in cases where the target market is expected to decline over time.
- The new technology provides a 1:1 replacement for each **TWh** in the target market and, if applicable, the established market.

The main results provided to the users are the Annual Emissions Reduction Potential, seen in Figure 5, and the Cumulative Emissions Reduction Potential, seen in Figure 6.

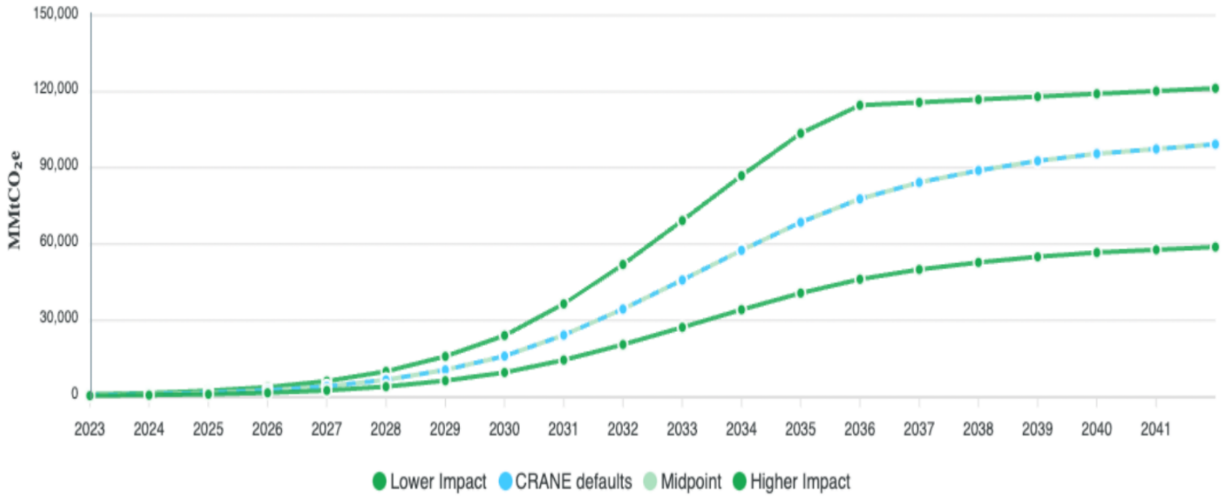

Figure 5: Annual Emissions Reduction Potential of EGS (CRANE, 2022).

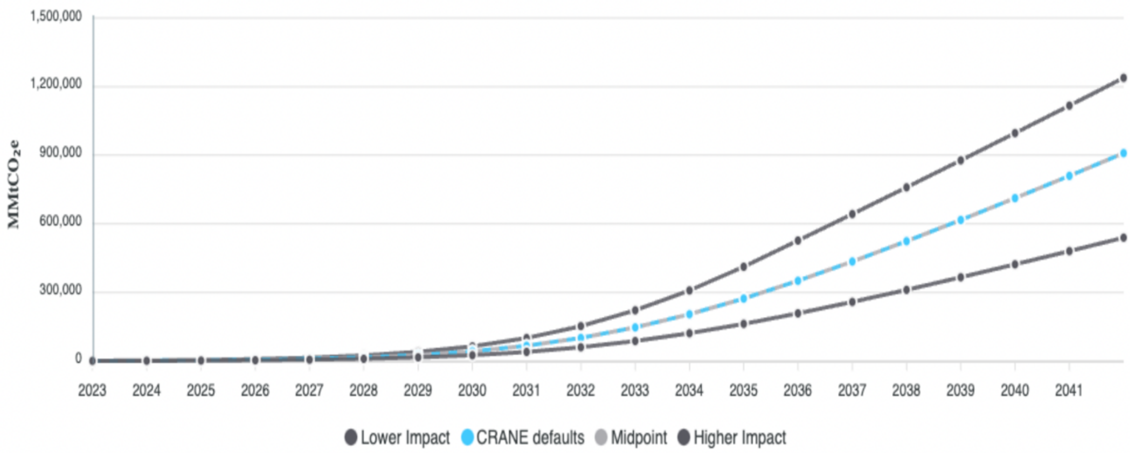

Figure 6: Cumulative Emissions Reduction Potential of EGS (CRANE, 2022).

As seen in the figures the results are given in MMTCO2e which means million metric tons CO2 equivalent, which is a standard metric. To prove context on it, the total U.S.

emissions for 2019 totaled 6,558 MMTCO2e (Center for Climate and Energy Solutions, 2021).

2.6 Net0 Score

The Net Zero Insight's Climate Model (CM) gives a score (between 0 and 1) to each company on the Net Zero Insight platform. This score acts as an assessment of the positive environmental impact that a start-up has. Hence, the higher a company's CM score, the more climate impact they have.

The score is computed as the weighted average of six factors, capturing both macro- and micro-economic aspects (Net Zero Insights, 2022):

1. **Eco-innovation index**: developed by the European Commission, the index measures the performance of only European Union (EU) Member States on environmental innovation.
2. **GVA by sector and country:** the Gross Value Added (GVA) by sector and country measures the economic market opportunity in which an organization is operating.
3. **CO2 emissions by sector and country:** the total addressable CO2 emissions by sector and country that an organization can target to reduce.
4. **Development stage**: a proxy measuring the development maturity of an organization derived from the funds raised, founding date, number of employees, patents, and such.
5. **Activity sector**: each activity sector is ranked by CO2 emissions. Organizations targeting more emitting sectors rank higher.
6. **Technology developed**: each climate technology is ranked by its potential to reduce CO2 emissions. Organizations developing more impactful technologies rank higher.

Each of the components of the model is in the range (0,1). The final score is computed as the weighted average of the components, where the component Stage gets the highest weight (because Stage is directly related to the start-up's level of development, while all the other components are with somewhat indirect data). In the case that there is missing data for any of the components, the climate score is computed as the weighted average of the components for which data is available.

The climate model consists of the following 3 steps:

1. **Data collection:**

- For each European country in the Net Zero Insights database, the CO2 emissions and GVA were collected for each of the 16-1 challenges (except V12-"Other") defined by Net Zero Insight's meaning: 49 countries * 15 challenges = 735 data points.
- The eco-index data was collected using an eco-index with the maximum number of countries possible (currently only European).
- From the SQL database, the model takes company data from different tables. The data necessary is: company_id, company stage, company size (#of employees), and company country.

2. **Data manipulation**: all of the input data for the climate model is normalized:
    a. Eco-index - min-max normalization between 0 and 1.
    b. Tags and challenges climate impact – min-max normalization, where:
        i. Tags have values of (0, 0.25, 0.5, 0.75, 1)
        ii. challenges were aligned hierarchically and normalized, so that Energy=1, Financial services=0, e.g. Agriculture=0.93
    c. Company Stage: min-max normalization w/ values (0, 0.25, 0.5, 0.75, 1)
    d. **CO2 and GVA**: A sigmoid function was applied to each CO2 and GVA twice:
        iii. To create a logistic distribution of the data by the challenges.
        iv. To create a logistic distribution by the countries.
        v. The mean of the two sigmoids was taken for each CO2/GVA
3. **Computation of Climate score**: the weighted average of all components is computed for the final score.

The following data might be missing for a company:

a. no challenges or tags are assigned to a company.
b. no country data (if the company is outside the EU).
c. No Stage assigned (very few companies without a stage).

In case some of this data is missing, the score is still computed, but the weights of the available data are recomputed to still sum up to 1.

On the Net Zero Platform, the Net0 Score is automatically computed for every start-up. Figure 7 is an example of how the score is provided on the company profile pages.

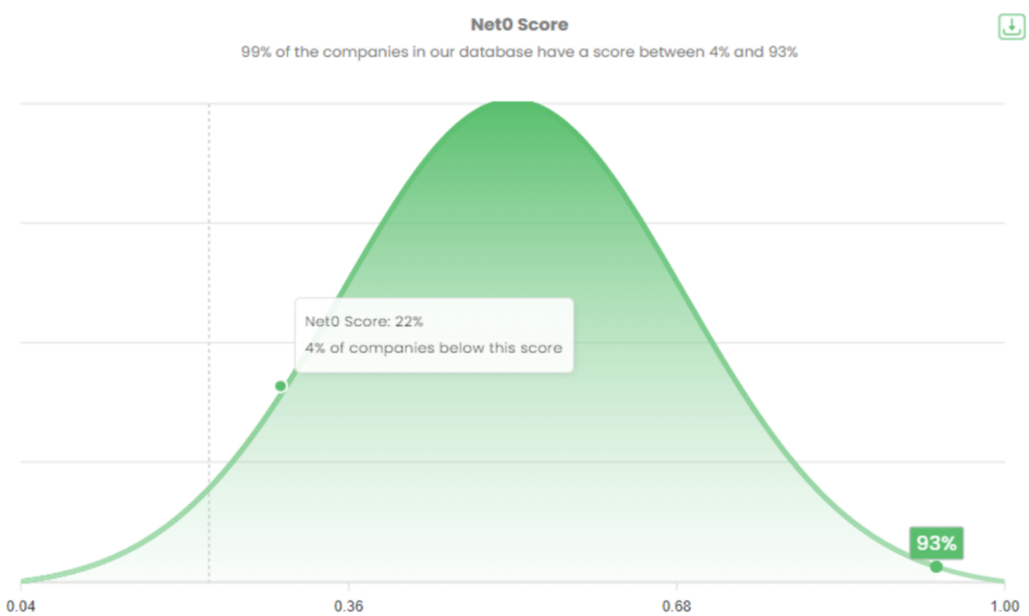

Figure 7: Net0 Score Example.

Chapter 3
Development

This chapter provides a theoretical development and methodology of the analysis to be done.

3.1 Methodology

The thesis aims to answer the question: how can the ERP assessment methodology be combined with the Net0 Platform to provide insights on the potential impact of the climate tech start-ups and their related sectors?

To answer this question, the following steps were taken to first understand which emerging technologies have the greatest potential impact, then to match the technologies with the start-ups on the Net0 Platform, and finally to combine the ERP results and the Net0 Score to identify a list of start-ups with high impact potential. This is to demonstrate how combing the two assessments can be used for down selection – a process for narrowing from many companies to a smaller subset of potential targets- based on potential climate impact (PRIME Coalition, 2017).

1. CRANE technologies
    a. Data collection
    b. Data analysis
2. Tech to Start-up Matching
    a. Research tech
    b. Create keywords list
    c. Create Matching criteria
    d. Run Matching script
    e. Review matches
    f. Repeat for different technology

3.1.1 CRANE Technologies

Data Collection

The team behind CRANE identified over 200 low-emission emerging climate technologies across a range of different sectors: Agriculture, Buildings, Carbon Dioxide Removal, Electricity, Manufacturing, Telecommunication, and Transportation. The full list of technologies can be seen in Annex 2. For each technology, they implemented the ERP methodology and the results of all the calculations were provided for this study, similar to the example of EGS. An important assumption for each calculation is the time frame and market penetration rates. The timeframe was 30 years, and the market penetration rates were 100% by 2050.

Data Analysis

Looking into the data provided there were two main takeaways. First, as seen in Figure 8, the Electricity category contains the largest number of technologies with a share of 30.4%. Then when comparing this breakdown with the breakdown of emissions in Figure 2, it's clear they do not match.

Figure 9 combines Figures 2 and 8, revealing that electricity and buildings are the only sectors that have a higher percentage of start-ups than emissions. The sector with the highest percentage difference is industry, with an 11% difference. Since the industry has the largest percentage of emissions this is an area of significant opportunity for innovation. However, since coal has the largest single percentage, it was decided to limit the scope of the analysis, by only focusing on the electricity technologies.

Secondly, it is possible to sort the technologies by ERP. Table 2 shows the electricity start-ups sorted by their ERP mean value in 2050. This number illustrates 100% market penetration and therefore is the upper limit on the emissions reduction potential of each technology in a single year. It is purely used here as a metric for comparison between technologies.

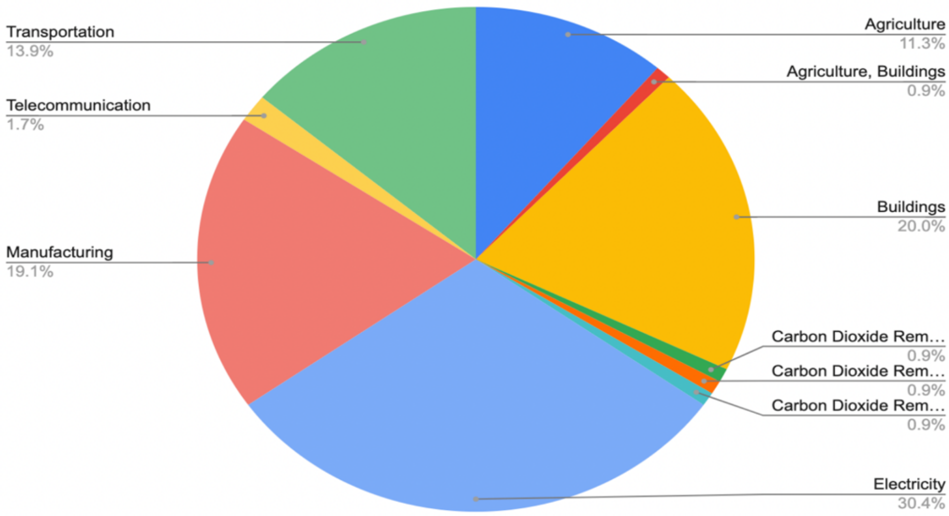

Figure 8: Breakdown of CRANE Technologies by Sector.

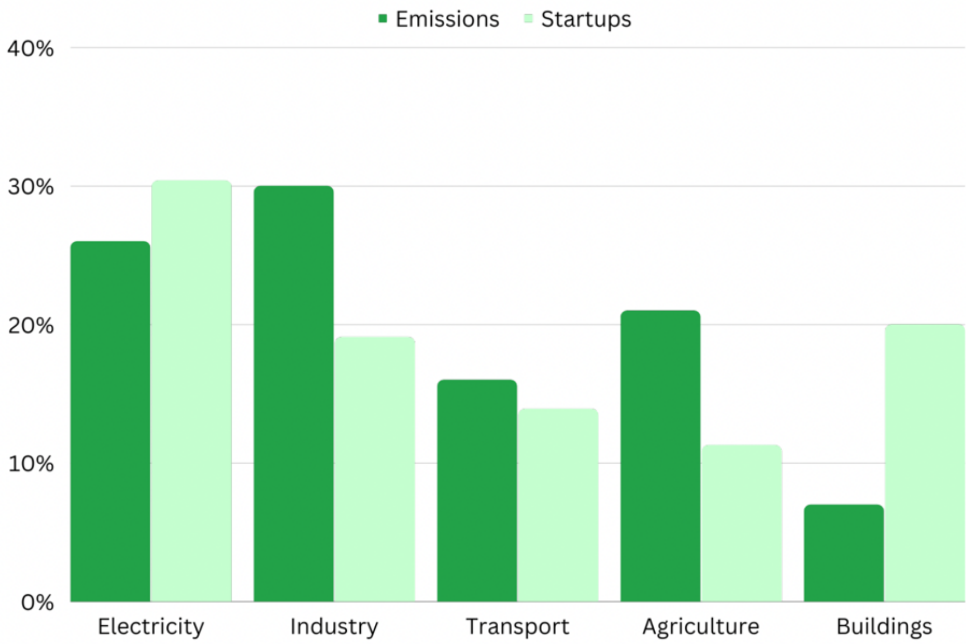

Figure 9: Comparison of Emissions and Start-ups by sector.

Table 2: Crane Technologies by ERP mean.

Rank	name	year	erp_mean
1	CO2-based enhanced geothermal system (EGS)	2050	104588
2	Direct air capture of carbon dioxide	2050	39954
3	Ocean thermal energy	2050	25614
4	Ocean tidal energy	2050	24739
5	Energy storage facility	2050	16510
6	Deep geothermal well	2050	9311
7	Distributed energy aggregation	2050	7894
8	Post-combustion	2050	7532
9	Small modular reactor (SMR)	2050	7034
10	Molten salt reactor	2050	6528
11	Biomass carbon sequestration	2050	5630
12	Ocean current energy	2050	5249
13	Ocean wave energy	2050	5019
14	Small wind turbines retrofit	2050	4847
15	Offshore wind power	2050	4735
16	Hydrogen storage	2050	4599
17	Fast-ramping concentrating solar thermal power	2050	4413
18	Behind the meter generation	2050	4299
19	Emergency, stand-by, or back-up generation	2050	3713
20	Supercapacitor grid energy storage	2050	3084
21	Distributed generation	2050	2998
22	Solar photovoltaic (PV) systems, utility scale	2050	2687
23	Onshore wind power	2050	2430
24	Pumped hydroelectric energy storage	2050	1941
25	Pneumatic storage	2050	1713
26	Inertial confinement fusion	2050	1441
27	Co-generation (waste heat recapture)	2050	1334
28	Advanced distribution management systems (ADMS)	2050	506
29	High voltage direct current transmission	2050	204
30	Microgrid	2050	200
31	Demand-side management through demand response	2050	41
32	Conservation voltage reduction (CVR)	2050	38

3.2 Tech to Start-up Matching Model

Net Zero Insights operates the Net0 Platform, which is a software that gathers and classifies climate tech companies by climate change challenge area, technology, activity sector, business model, and much more. The team at Net Zero Insights has developed a proprietary keywords-to-company webtext matching algorithm that is used for this thesis. For each company, the Net0 Platform contains all the text from the company's websites. The matching works by developing a list of keywords or keyword pairs based on the description of the technologies and then run the algorithm to find start-ups in the database that meet the matching criteria. The algorithm is run through the software Google Colab. Once the matches are made, a manual review is done to understand the accuracy of each keyword used. If for any keyword the accuracy is low, then they are removed, and new ones are tested. It is an iterative process until all the keywords used are performing well.

3.2.1 Matching criteria

The matching algorithm is designed around a few parameters that can be changed to find the most accurate matching results. The criteria are the following:

THRESH: #number of keywords matched that have to match the text_type, usually 1 or 2

TEXT_TYPE: # this determines which text is used for matching.

'ALL' : web text + pitch lines + descriptions
'PITCH': pitch line is what the company does in one sentence.
'DESC': Descriptions are multiple paragraphs describing what the company does.
'PITCH_DESC': pitch lines and descriptions
'WEBTEXT' : webtext is all the text taken from the company's website.

REGEX_Nwords: # how many WORDS to have in between the keyword pair.

REGEX_Nletters: # how many LETTERS to have after the end of the first keyword (e.g. so that PRODUC matches production, produce, product, etc.)

After experimenting and testing the accuracy of different combinations of parameters it was decided that for consistency and the highest accuracy the following parameters would be used and kept constant for all the technologies:

THRESH: 1

TEXT_TYPE: 'PITCH'

REGEX_Nwords: 4

REGEX_Nletters: 5

3.2.2 Matching Example

To demonstrate what the keywords and matching results look like, below is an example of the technology solution: Hydrogen Storage. The description provided for Hydrogen storage is:

Hydrogen energy storage works by using electricity to create hydrogen gas via electrolysis. Hydrogen can then be stored as either a gas or liquid. Its energy can be recovered via fuel cells or combustion turbines. The ease of storage and re-electrification makes hydrogen energy storage a viable grid storage solution for variable renewable energy sources such as wind and solar (CRANE, 2022).

Table 3 shows the keywords/ keyword combos that were used and the resulting matching stats shown by the count of matches. This matching resulted in the identification of 32 start-ups developing or utilizing hydrogen storage technology.

Table 3: Keyword Matching example - Hydrogen Storage.

Keyword 1	Keyword 2	Match count
Hydrogen energy storage		2
Hydrogen storage		30
energy storage	hydrogen	6

To further show how the matching works based on the parameters selected, Table 4 contains one matching example for the keyword. In the Pitch line column, the keywords are bolded to highlight the accuracy of the matching and how the keyword combos work.

Table 4: Example of Matching Results.

Keyword	Company Name	Pitch line
energy storage: hydrogen	Solenco Power	Solenco Power produces the Solenco Power Box (SPB), an **energy storage** system based on **hydrogen** tech.
Hydrogen storage:	Hydro Genious	Developing a new technology for **hydrogen storage** in Liquid Organic Hydrogen Carriers LOHC.
Hydrogen energy storage:	H2Go Power	Developer of **hydrogen energy storage** technology designed to offer zero-emission, safe, and reliable power supply.

Chapter 4
Analysis

This chapter provides an overview and analysis of the result of the methodology presented.

4.1 Matching Results

The methodology presented in Chapter 3 was applied to all the electricity technologies. A full list of all the keywords used per technology can be seen in Annex 3. At the time of running the matches, the Net0 Platform contained a population of roughly 30,000 start-ups. Of that population, the matching process resulted in 591 matches. The breakdown of the number of matches per technology can be seen in Table 5.

Table 5: Crane Technologies and Count of Matches.

Crane Technologies	**COUNT of Matches**
Advanced distribution management systems (ADMS)	2
Behind the meter generation	4
Biomass carbon sequestration	60
Co-generation (waste heat recapture)	74
CO2-based enhanced geothermal system (EGS)	3
Conservation voltage reduction (CVR)	1
Deep geothermal well	31
Demand-side management through demand response	31
Direct air capture of carbon dioxide	31
Distributed energy aggregation	1
Distributed generation	44
Emergency, stand-by, or back-up generation	8
Energy storage facility	12
Fast-ramping concentrating solar thermal power	9
Flywheel storage	9
High voltage direct current transmission	1
Hydrogen storage	31
Inertial confinement fusion	13
Microgrid	43
Molten salt reactor	5
Ocean current energy	2
Ocean thermal energy	5
Ocean tidal energy	19
Ocean wave energy	16
Offshore wind power	38
Onshore wind power	41
Pneumatic storage	5
Post-combustion	1
Pumped hydroelectric energy storage	6
Small modular reactor (SMR)	4
Small wind turbines retrofit	22
Solar photovoltaic (PV) systems, utility scale	11
Supercapacitor grid energy storage	8
Grand Total	**591**

4.2 ERP Combined with Net0 Score Results

The final step to identify high impact potential start-ups is comparing the start-ups, utilizing the same technologies, by their Net0 Score. This was done for the top 15 technologies (based on ERP).

Table 6 is an example of how the Net0 score varies for companies matching the same technology. Here the technology is Biomass carbon sequestration. There were 60 start-ups identified for this technology and this table shows the top 7

Table 7 shows the top 1, 2, and/or 3 start-ups identified per each technology with the highest Net0 scores. If a technology only has top 1 or 2 start-ups that means those are the only start-ups matched for that specific technology. For technologies with many matches the top 3 based on the Net0 score are presented. The total funding of the companies it also shown to reveal the range of funding that exists.

Table 6: Example Net0 Score Comparison.

Biomass carbon sequestration Start-ups	Pitch line	Net0 Score
Ecotree	Developer of a plantation platform intended to initiate the planting of trees and develop a benevolent ecosystem.	0.7011219263
Pachama	Developer of remote sensing platform intended to verify and monitor carbon capture by forests to help finance conservation and reforestation.	0.6962416172
The Future Forest Company	Operator of a company intended to fight climate change by planting super-charged forests that remove CO2 from the atmosphere at scale.	0.6451198459
Zeroco2	zeroCO2 is a benefit corporation that deals with environmental sustainability through reforestation projects with high social impact	0.6263267398
Terraformation	Provider of reforestation services intended to accelerate carbon drawdown.	0.6175467968
DroneSeed	DroneSeed plants tree-seeds using drones with pneumatics.	0.6077279449
Treedom	Treedom is a platform that allows people to finance the planting of trees globally, in order to help reforestation and feed local populations.	0.4540241957

Table 7: Top Potential Impact Start-ups Identified.

Technology Name	erp_mean	Company Name	Net0 Score	Total Funding
CO2-based enhanced geothermal system (EGS)	104588	Fervor Energy	84%	€ 168M
		Terracoh Inc	81%	€ 1.35M
		Greenfire Energy	73%	€ 7.2M
Direct air capture of carbon dioxide	39954	Climeworks	93%	€ 710M
		Carbon Engineering	91%	€ 87.5M
		Mission Zero Technologies	78%	€ 400k
Ocean thermal energy	25614	Global Otec Resources	69%	€ 50K
		Seatrec	67%	€ 6.8M
Ocean tidal energy	24739	Nova Innovation	93%	€ 34M
		Sabella	93%	€ 13M
		Orbital Marine Power	93%	€ 23M
Energy storage facility	16510	Teraloop	83%	€ 4M
		Statera Energy	82%	-
		Jenabatteries	81%	-
Deep geothermal well	9311	Quaise	87%	€ 67M
		Qheat	86%	€ 2.5M
		Geokoax Gmbh	81%	-
Distributed energy aggregation	7894	Dynargy	59%	-
Post-combustion	7532	Svante	93%	€ 11M
Small modular reactor (SMR)	7034	X-Energy	93%	€ 5.5M
		Ultra Safe Nuclear	92%	€ 44M
		Nuscale Power	85%	€ 982M
Molten salt reactor	6528	Seaborg Technologies	87%	€ 22M
		Terrestrial Energy	80%	€ 60M
		Core Power Uk Ltd	74%	€ 16M
Biomass carbon sequestration	5630	Ecotree	70%	€ 17M
		Pachama	70%	€ 73M
		The Future Forest Company	65%	€ 160k
Ocean current energy	5249	Minesto	93%	€ 42M
		Aquantis	66%	-
Ocean wave energy	5019	Corpower Ocean	93%	€ 40M
		Wello Oy	93%	€ 17M
		Mocean Energy	93%	€ 5.7M
Small wind turbines retrofit	4847	Innoventum	86%	€ 300K
		Luvside Gmbh	83%	-
		Torque Wind Turbine	81%	-
Offshore wind power	4735	Bw Ideol	93%	€ 168M
		Hexicon	93%	€ 133M
		Hydro Wind Energy	93%	€ 51M

In Table 7, there are 39 start-ups identified from the top 15 electricity technologies. This table represents the main outcome of this thesis. To understand more about what can be done with such results, these 39 start-ups are treated as a sample population for further analysis.

4.3 High-Impact Potential Start-up Insights

From this population of start-ups, most of them (56.4%) are in the scaling stage, as seen in Figure 10. This is not surprising since the Net0 Score places a higher weight on the stage of companies. However, the fact that 10% of the population is in the early stage is quite interesting. This shows that these companies are demonstrating very high impact potential while still in the early stages of development. Which in the future may be a very useful understanding for impact-focused decision-makers. On top of this, even though most of the start-ups are scaling, there are very few start-ups that are large companies. The most common company size is 11-50 employees, as seen in Figure 11. This could mean that these technologies are scalable without the need for large spending on human capital.

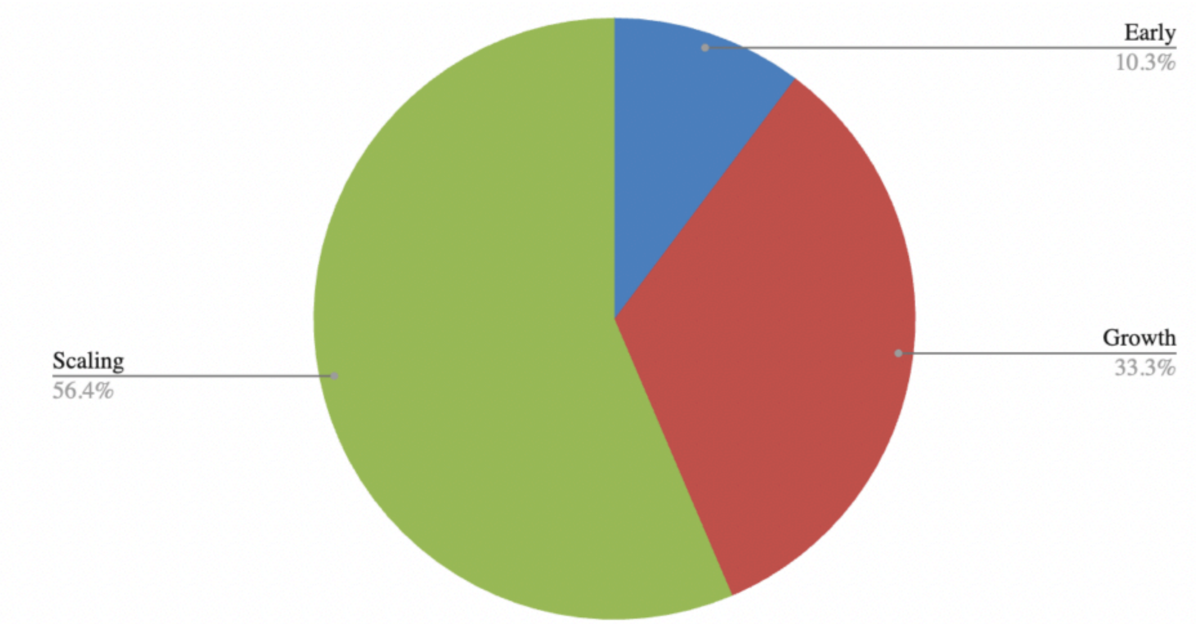

Figure 10: Sample population breakdown by stage.

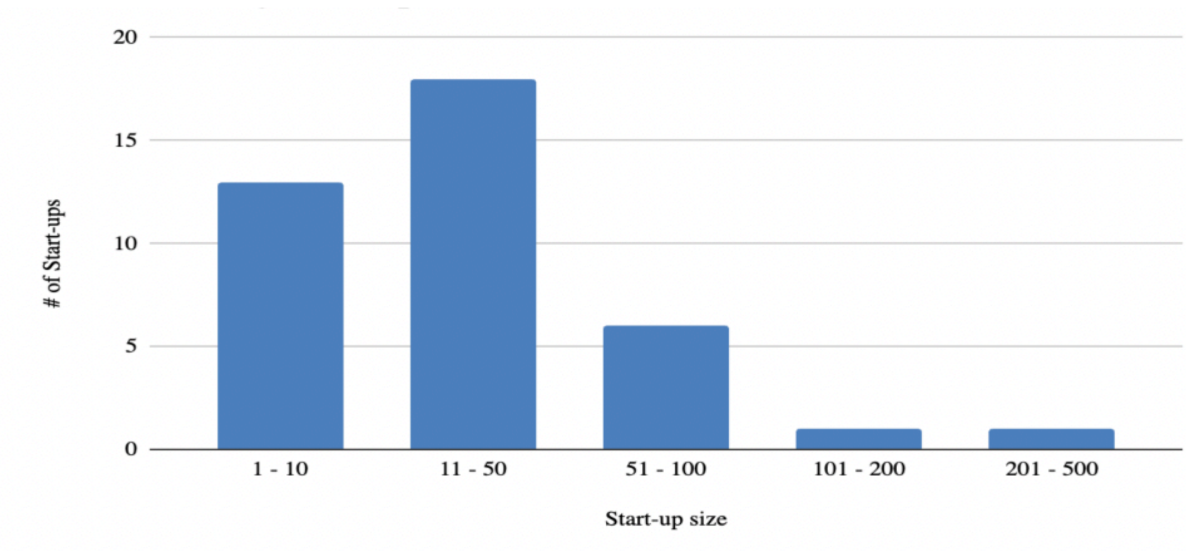

Figure 11: Sample population breakdown by size.

Another interesting finding is that out of the 39 start-ups ~10% have headquarters in the United States. Figure 12 shows the breakdown of the headquarters of all of the 39 start-ups. It's clear, country wise the United States and the United Kingdom are leading, revealing the strength of their innovation/entrepreneurship ecosystems. However, comparing Europe and North America, Europe has the larger portion with 64% of the start-ups.

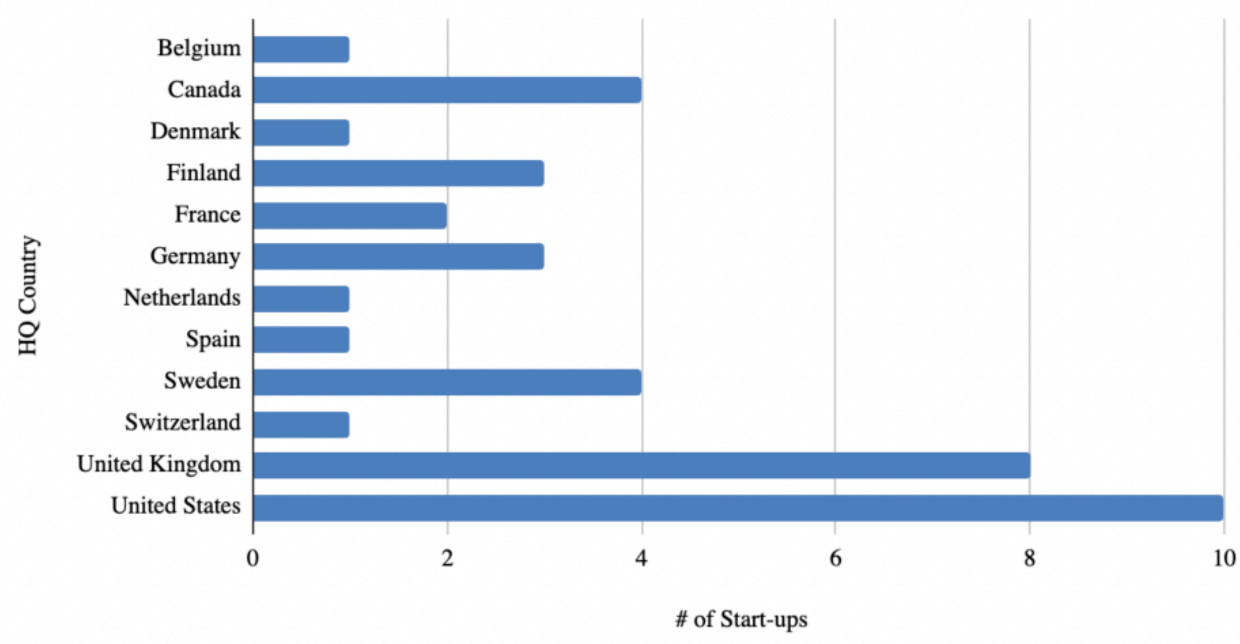

Figure 12: Sample population breakdown by HQ Country.

Analyzing the funding of the population, from the 39 start-ups there has been a total of 163 funding rounds. The sum of all the investments for these start-ups from 2014-2022 is € 2.5 Billion. Figure 13 shows the funding year by year from 2014-2022 combined with the number of deals per year. Looking at the graph, these companies and thus the technologies behind them have been gaining significant attention in recent years. The number of deals and the size of the deals have strong increasing trends. This is an indication that these start-ups will be able to continually reduce emissions at higher rates.

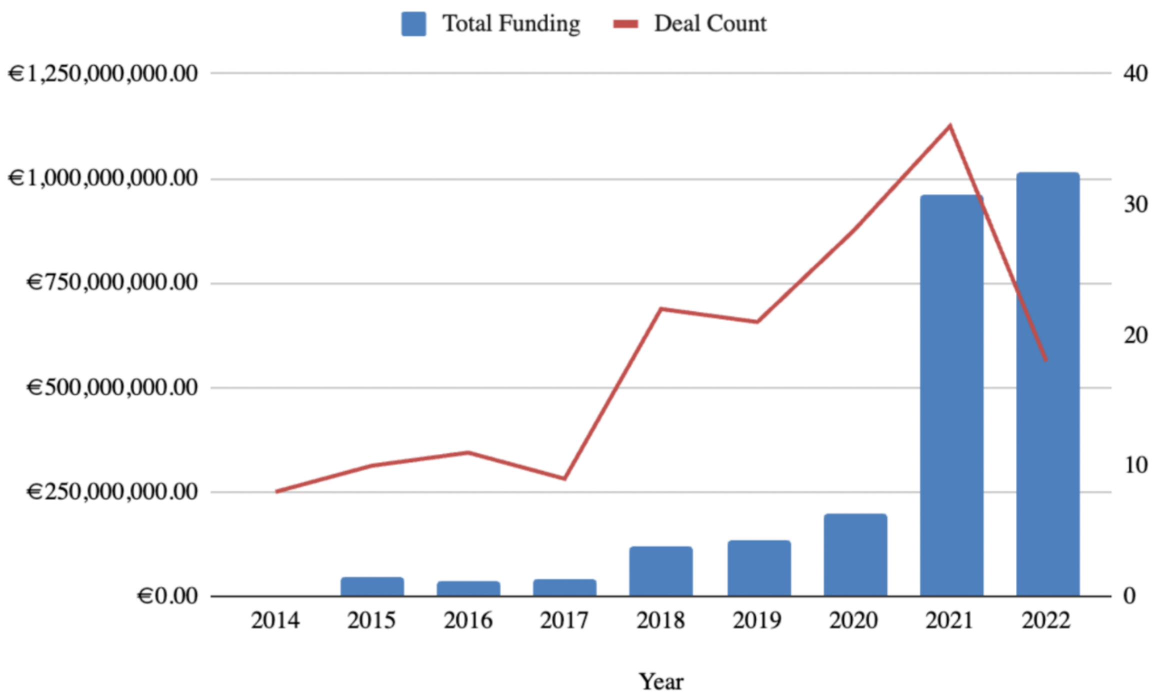

Figure 13: Year-by-year Funding of Sample Population.

When comparing the funding of this small sample population with the full climate tech start-up database of Net Zero Insights, we see that the average deal size per quarter is higher for the sample population. Figure 14 shows that out of the last seven quarters, the sample population has a higher average funding amount per deal for 5 of the quarters. Although this might be a biased comparison because the sample population is heavily weighted for scaling companies due to the Net0 Score, it does provide an indication that the start-ups identified are promising opportunities. This means that start-ups developing high-impact potential technologies are able to be successful impact-wise and financially speaking.

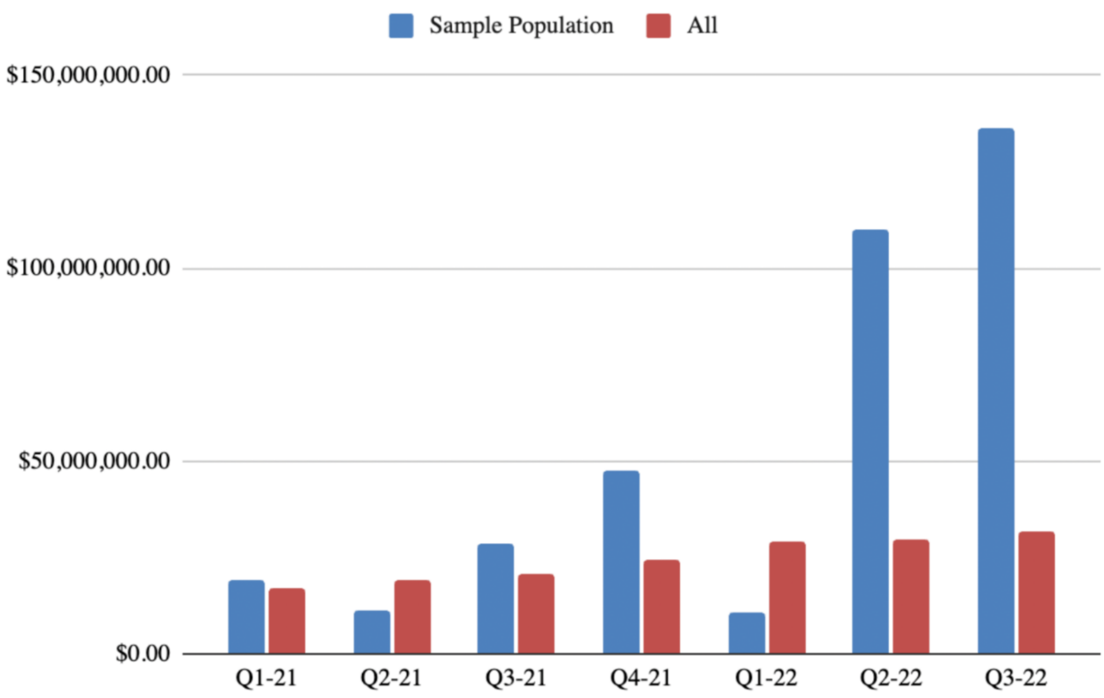

Figure 14: Comparison of Sample Population and Full Population (Net Zet Zero Insights, 2022).

Chapter 5

Conclusions

This chapter finalizes this work, summarizing conclusions and pointing out aspects to be developed in future work.

This work addressed the need for decision-makers to have impact assessment tools when looking at early-stage start-ups. In recent years, there has been a lot of work around assessing the present and past impact of organizations. However, these assessments do not serve the same purpose for start-ups. When talking about the impact of start-ups, a forward-looking approach is more valuable.

The previous work done around forward-looking climate impact assessments was discovered and compared. Five different frameworks were researched and compared. The findings showed that the different frameworks have separate characteristics and serve different purposes.

In an attempt, to begin work on a unified approach that can be easily scaled, a new framework was developed to combine ERP assessments with the Net0 Score. Combining the two led to a technology-based down-selection methodology. The methodology was then implemented to identify a list of the highest-impact potential start-ups within the Net Zero Insights climate tech start-up database. With roughly 30,000 start-ups, the first step was to match the CRANE technologies to the start-ups. This resulted in the matching of 591 start-ups that use emerging climate technologies in the electricity sector. From the 591, the top 39 start-ups based on the Net0 score were identified for further analysis. After looking into the companies' stage, HQ location, size, and funding it was shown that these start-ups are performing well compared to the rest in the database.

The main limitation of this work was how new this topic is. This made finding relevant resources difficult. On top of this results shown are only as good as the data provided for the work. Both the CRANE tool and Net0 Score are in their early stages of development, so as they are improved so with the comprehensiveness of combining them.

5.2 Future Work

In the future, there is much more work that can be done on this topic. To start only a small portion of the CRANE technologies were utilized, so the matching methodology can be expanded to the full list. Second, at the time of running the matches, the Net0 Platform contained ~30000 start-ups and at present, it has increased to ~45000. This means that all the matching can be repeated to identify more companies.

Additionally, the methodology presented is an example of technology-based down selection, but other approaches such as affiliation-based down selection and company submission-based down selection can be demonstrated in a similar way.

Lastly, the impact metric of focus was GHG emissions but there are many other metrics that can and should be also assessed in the future. These metrics include biodiversity, water consumption, team diversity, etc.

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Annex 1

Glossary of important terms.

Attribution

The process of allocating credit for GHG impact based on the relative contributions of various participants in the value chain.

Baseline Scenario

A projection of GHG emissions over time, representing what would have happened in the absence of an investment or a climate solution.

Down Selection

A process for narrowing from many companies to a smaller subset of potential targets- based on potential climate impact.

Green premium

The difference between the final consumer price of a low-carbon solution and the final consumer price of the incumbent solution.

Incumbent solution

The comparable technology, product, service, device, or process (i.e. status quo) that a proposed climate solution aims to displace in the market.

Planned Impact

The impact expected from a company, or a proposed climate solution based on a realistic analysis of its business model.

Potential impact

The impact a proposed climate solution could have based on a standardized growth trajectory that assumes the proposed solution takes over the Total Addressable Market.

Scope 1 Emissions

Direct emissions from owned or controlled sources.

Scope 2 Emissions

Indirect emissions from the generation of purchased energy.

Scope 3 Emissions

All indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.

Annex 2

Full List of Crane Technologies

Agriculture

1. Aquaculture (algae)
2. Aquaculture (fish, shellfish)
3. Biomass burial as biochar
4. Composting of food and agricultural waste
5. Crop polyculture
6. Cropland soil sequestration
7. Dairy cows: Feed and nutrition
8. Dairy cows: Genetics and breeding
9. Dairy cows: Rumen manipulation
10. Ecosystem restoration: Peatlands
11. First expired first out or intelligent stock rotation
12. Forest protection
13. High density polyethylene returnable plastic boxes
14. In vitro and lab cultured meat: Beef
15. In vitro and lab cultured meat: Pork
16. In vitro and lab cultured meat: Poultry
17. In vitro and lab cultured meat: Sheep
18. In vitro or lab cultured fish/shellfish production
19. Insect protein
20. Manure management: Collection
21. Manure management: Sand separation
22. Nitrification inhibitors for pasture manure
23. Plant-based protein: Pulses
24. Polyculture of trees, forage and livestock (silvopasture)
25. Regenerative grazing
26. Restoration of cultivated lands (farmland)
27. Rice cultivation
28. Synthetic fertilizer
29. Zero-GHG electrochemical ammonia production
30. Zero-GHG hydrogen addition ammonia production
31. Zero-GHG solar conversion ammonia production

Agriculture, Buildings

1. High efficiency, low-GHG cookstoves

Agriculture, Buildings, Manufacturing

1. Water use efficiency technologies

Buildings

1. Air-source heating
2. Appliance management
3. Battery energy storage for buildings
4. Better refrigerant management in use, servicing, and disposal
5. Building automation systems
6. Building insulation
7. Chemical energy storage for buildings
8. Compressed air energy storage (CAES) for buildings
9. Efficient propane and fuel oil heating
10. Electric excavators
11. Electric heating
12. Electrochromic window glass
13. Energy scheduling
14. Energy storage for buildings
15. Geothermal heat pumps
16. Green roof technology
17. Heat exchangers
18. High efficiency natural gas heating
19. High efficiency roofs
20. High efficiency windows and doors
21. Improved appliance efficiency
22. Infiltration / airtightness
23. Lighting management
24. Networked standby power consumption
25. Reduced lighting usage through control technologies
26. Renewable district heating
27. Roof cooling technology
28. Solar thermal heating
29. Thermal insulation, thermal mass, and phase change materials
30. Upgrading bulbs for high-efficiency LED lighting
31. Variable speed compressors

Carbon Dioxide Removal

1. Photocatalytic reduction of CO2 using semiconductors: Methane
2. Photocatalytic reduction of CO2 using semiconductors: Methanol
3. Waste mineral carbonation (WMC)

Carbon Dioxide Removal, Manufacturing

1. Direct mineral carbonation with olivine: Magnesite
2. Direct mineral carbonation with wollastonite: Calcite
3. Dry methane reforming with CO purging: Methanol
4. Dry methane reforming with H2: Methanol

Electricity

1. Advanced distribution management systems (ADMS)
2. Behind the meter generation
3. Biomass carbon sequestration
4. Biomass carbon sequestration
5. Co-generation (waste heat recapture)
6. CO2-based enhanced geothermal system (EGS)
7. Conservation voltage reduction (CVR)
8. Deep geothermal well
9. Demand-side management through demand response
10. Direct air capture of carbon dioxide
11. Dispersed Generation
12. Distributed energy aggregation
13. Distributed generation
14. Dynamic volt ampere reactive (VAR) planning
15. Emergency, stand-by, or back-up generation
16. Energy storage facility
17. Fast-ramping concentrating solar thermal power
18. Fast-ramping gas cycle turbines
19. Fast-ramping reservoir hydro
20. Flywheel storage
21. Heavy water reactors
22. High temperature gas reactor (HTGR)
23. High voltage direct current transmission
24. Hybrid fusion
25. Hydrogen storage
26. Inertial confinement fusion
27. Large light-water reactors (Gen III)
28. Liquid metal reactor
29. Low temperature differential geothermal
30. Magnetic confinement fusion
31. Magnetized target fusion
32. Microgrid
33. Molten salt reactor
34. Nuclear battery
35. Ocean carbon sequestration
36. Ocean current energy
37. Ocean thermal energy
38. Ocean tidal energy
39. Ocean wave energy
40. Offshore wind power
41. Onshore wind power
42. Oxy-combustion
43. Pneumatic storage
44. Post-combustion
45. Pre-combustion CO2 capture
46. Pumped hydroelectric energy storage
47. Small modular reactor (SMR)
48. Small wind turbines retrofit
49. Solar photovoltaic (PV) systems, utility scale
50. Supercapacitor grid energy storage
51. Water-based enhanced geothermal system (EGS)

Manufacturing

1. Advanced paper recycling
2. Bamboo composites for construction
3. Carbon dioxide (CO_2) for carbon fiber to replace metals
4. Carbon-injected cement
5. Cement finish grinding
6. Cement kiln feed preparation
7. Clinker production
8. Coke dry quenching (CDQ) in steelmaking
9. Combined heat and power (CHP) in BF/BOF steelmaking
10. Compressed air systems for pneumatic controllers
11. Concentrating solar system
12. Cross laminated timber for construction
13. Direct reduced iron electric arc furnace (DRI EAF)
14. Direct use geothermal
15. Dry seal-type centrifugal compressors
16. Dry type top pressure recovery turbines (TRT)
17. Durable clothing
18. Durable concrete using polymer fiber
19. Durable plastics
20. Durable steel
21. Electric Furnace (EAF) steelmaking
22. Electrolytic hydrogen production
23. Evacuated tube solar collector
24. Gas and heat recovery from basic oxygen furnaces (BOF)
25. Kimray pump alternatives
26. Leak detection and repair (LDAR)
27. Load preheating
28. Low GHG aromatics
29. Low GHG soda ash production
30. Low temperature energy recovery for power generation
31. Metal organic framework for ethylene
32. Microchannel heat exchangers
33. Nitric acid production
34. Petrochemical production from biomass
35. Polyvinyl chloride (PVC) from renewable materials
36. Recycled metal: Aluminum
37. Smelting by FINEX process
38. Thin slab steel casting and rolling (TSCR)
39. Titanium dioxide production
40. Top gas recycling in oxygen blast furnaces (TGR-OBF)
41. Waste heat recovery for power generation

Telecommunication

1. Smartphones
2. Tablets

Transportation

1. Advanced high-power lead acid batteries: Stop-start
2. Battery electric vehicles
3. Carpool enabling technology
4. Compressed natural gas for light-duty vehicles
5. Electric bicycle technologies
6. Electric hybrid planes
7. Electric/hybrid retrofits for gas and diesel engines
8. Electrochemically produced liquid fuels
9. Fleet vehicle electric hybrid retrofit
10. Fully electric planes
11. High efficiency diesel engines
12. Homogeneous charge compression ignition (HCCI) engines
13. HVAC system for buses using phase change materials
14. Hybrid pathways for liquid fuel production
15. Hydrogen fuel cell for light-duty vehicles
16. Lean/dilute combustion
17. Light-duty hydraulic hybrid vehicle
18. Lithium ion battery for light-duty vehicles
19. Low temperature combustion (LTC)
20. Natural gas engines
21. Ocean freighters / cargo ships
22. Solid oxide electrolyzer cell co-electrolysis: Diesel
23. Solid oxide electrolyzer cell co-electrolysis: Ethanol
24. Solid oxide electrolyzer cell co-electrolysis: Methane
25. Solid oxide electrolyzer cell co-electrolysis: Methanol
26. Solid oxide electrolyzer cell electrolysis: Diesel
27. Solid oxide electrolyzer cell electrolysis: Methane
28. Solid oxide electrolyzer cell electrolysis: Methanol
29. Sustainable aviation fuels (SAFs)
30. Thermochemically produced liquid fuels
31. Ultracapacitors for light-duty vehicles
32. Wireless charging for light-duty vehicles

Annex 3

Full List of Technologies and Keywords for Matching

Onshore wind power	MW	wind
	Next generation	wind power
	Onshore wind	farm
	large scale	wind
	utility	wind turbine
	utility scale	wind
	utility-scale wind	
Microgrid	micro grid	
	microgrid	
	mini grid	
	minigrid	
Biomass carbon sequestration	afforest	
	forest management	
	mangrove	
	reforest	
	soil carbon storage	
	wetland	
Hydrogen storage	Hydrogen energy storage	
	Hydrogen storage	
	energy storage	hydrogen
Small wind turbines retrofit	micro wind turbine	
	off grid	wind turbine
	off-grid	wind turbine
	small wind turbine	
Offshore wind power	Develop	offshore wind
	Offshore Wind Power	
	deep-water offshor	
	floating wind	turbine
	offshore wind	project
	offshore wind energy	
	offshore wind farm	
Co-generation (waste heat recapture)	CHP	
	Co-generation	
	Cogeneration	
	combined heat and power	
	waste heat recovery	
	company	CSP
	plant	CSP

Fast-ramping concentrating solar thermal power	CSP	tech
	concentrated solar power	
Direct air capture of carbon dioxide	DAC	
	Direct air capture	
Supercapacitor grid energy storage	Supercapacitor	stor
	stor	Supercapacitor; ultracapacitor
	ultra capacitor	stor
	ultracapacitor	stor
Distributed generation	Distributed generation	
	distributed energy resource	
Ocean wave energy	Ocean wave energy	
	wave energy converter	
Demand-side management through demand response	demand response	
Emergency, stand-by, or back-up generation	back up	generat
	backup	generat
	back-up	generat
	emergency generat	
P`umped hydroelectric energy storage	pumped	energy storage
	pumped hydro	
Behind the meter generation	BTM	
	Behind the meter	
Pneumatic storage	CAES	
	compressed air energy storage	
Distributed energy aggregation	Distributed energy aggrega	
	energy aggrega	
	aggreg	Distributed energy
Deep geothermal well	Deep geothermal well	
	Deep	geothermal
	geothermal	energy
	deep geothermal	
	Geothermal well	
	Geothermal	deep
Ocean current energy	Ocean current energy	
	Ocean current	energy; power
Ocean tidal energy	tidal power	
	tidal energy	

	Ocean tidal energy	
Small modular reactor (SMR)	Small modular reactor (SMR)	
	Small modular reactor	
	SMR	
	small	nuclear fission
CO2-based enhanced geothermal system (EGS)	CO2	geothermal
	enhanced geothermal	
Conservation voltage reduction (CVR)	Conservation voltage reduct	
	CVR	
	reduce peak demand	
	volatge reduc	
High voltage direct current transmission	High voltage direct current transmission	
	HVDC	
	transmit electricity	
	HV cable	
Ocean thermal energy	Develop	Ocean Thermal Energy
	Electricity	Ocean Thermal
	OTEC	
	Ocean Thermal Energy	
	offer	Ocean Thermal Energy
Energy storage facility	Energy storage facilit	
	Energy storage	arbitrage
	arbitrage	Energy storage
	energy arbitrage	
	utility scale; large scale	storage
Molten salt reactor	Molten salt reactor	
Solar photovoltaic (PV) systems, utility scale	Solar photovoltaic (PV) systems, utility scale	
	utility scale	PV
	Solar photovoltaic	utility scale
	utility scale	Solar
Advanced distribution management systems (ADMS)	Advanced distribution management system	
	ADMS	
	demand management	system
	distribution management	system

	platform	distribution management
Flywheel storage	Flywheel storage	
	Flywheel	storage
Inertial confinement fusion	Inertial confinement fusion	
	fusion technolog	
	fusion reactor	
Post-combustion	Post-combustion	CO2