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

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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.**

Introduction

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 [1]. 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 [2].

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 [3]. 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.

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 [4].

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.

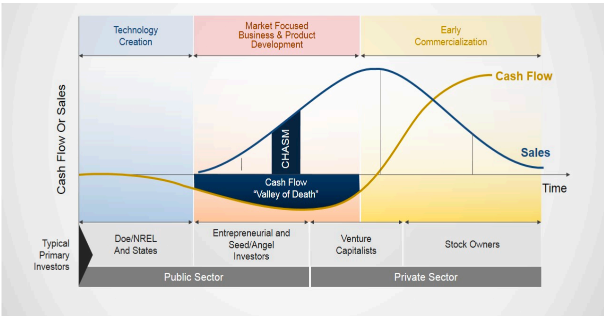

Figure 1: High technology adoption lifecycle [5]).

Historically, low-carbon technologies have faced a critical funding gap during the validation and early deployment stages, causing technology development to stall [6]. 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.

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 [7].

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 [8], up from <$2bn in 2010 [9]. 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.

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

State of the Art

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

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.

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 [1]. 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 (CO_2), methane, and nitrous oxide. CO_2 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 [10]. Since 1751, the world has emitted over 1.5 trillion tonnes of CO2 [11].

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.

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.

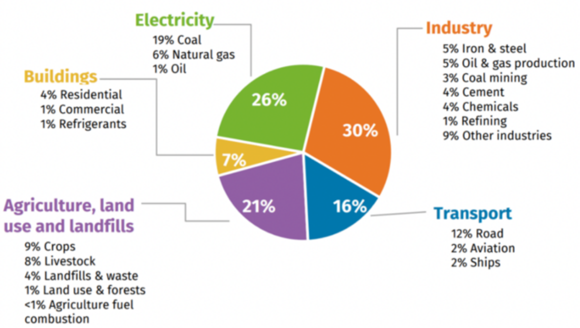

Figure 2: Global Greenhouse gas emissions by sector, 2019 [13]).

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 [12].

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 [12].

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 [12].

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.

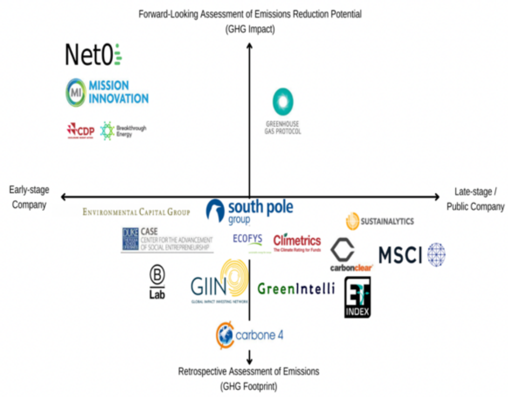

Figure 3: The landscape of climate impact assessment tools. Adapted from [14].

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.

The five frameworks are Greenhouse Gas Protocol, Projects Accounting, Breakthrough Energy/CDP, Emerging Climate Technology (ECT)Framework, Prime Coalition/NYSERDA/ Rho Impact, Emissions Reduction Potential (ERP) Framework, and Net Zero Insights, Net0 Score. In the full version of this thesis, all five methodologies are summarized, and the key differentiating points are commented.

Assessments Comparison

A result of studying the landscape of existing impact methodologies is the comparison based on 5 metrics. 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. In the full version of this thesis, exists a table containing the full comparison of the assessments.

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 giving 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 the later parts of this thesis builds off the ERP assessment from Prime/NYSERDA and the Net0 Score from Net Zero Insights. Therefore, in the full version of this thesis, these two assessment methodologies are detailed further.

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 [13].

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

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 of the full thesis. 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. For this analysis the electricity start-ups were sorted by their ERP mean value in 2050. The complete list can be seen in the full version of the thesis. 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.

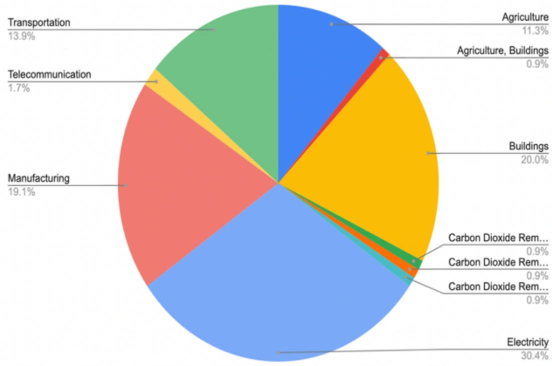

Figure 4: Breakdown of CRANE Technologies by Sector.

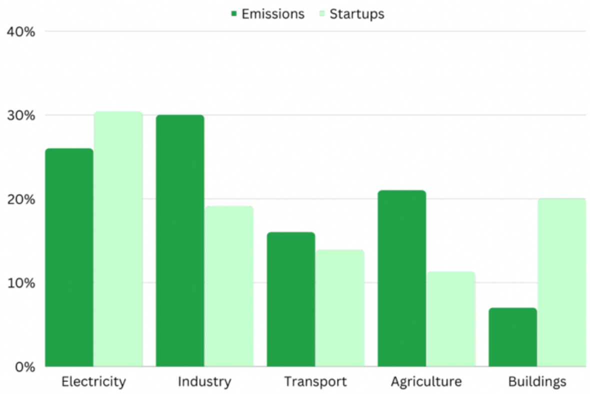

Figure 5: Comparison of Emissions and Start-ups by sector.

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.

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

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 in the full thesis. 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. A subset of the breakdown of the number of matches per technology can be seen in Table 1. The complete table can be seen in the full thesis.

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
Grand Total	**591**

Table 1: Crane Technologies and Count of Matches.

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 2 is an example of how the Net0 score varies for companies matching the same technology. A complete table with more companies matched under Biomass carbon Sequestration can be found in the full thesis. There were 60 start-ups identified for this technology and this table shows the top 2.

In the full thesis there is a table showing 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.

Table 2: 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

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.

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. This could mean that these technologies are scalable without the need for large spending on human capital.

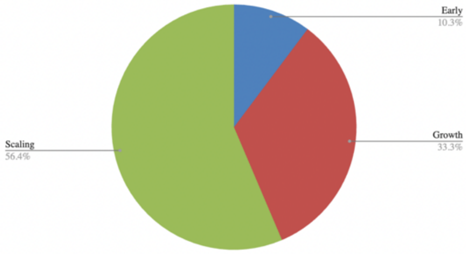

Figure 6: Sample population breakdown by stage.

In the full version further analysis of the start-ups identified is provided. Some of the key findings include:

- Out of the 39 start-ups ~10% have headquarters in the United States.
- 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.

Conclusions

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.

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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