Getting Started with CRANE

What is CRANE?

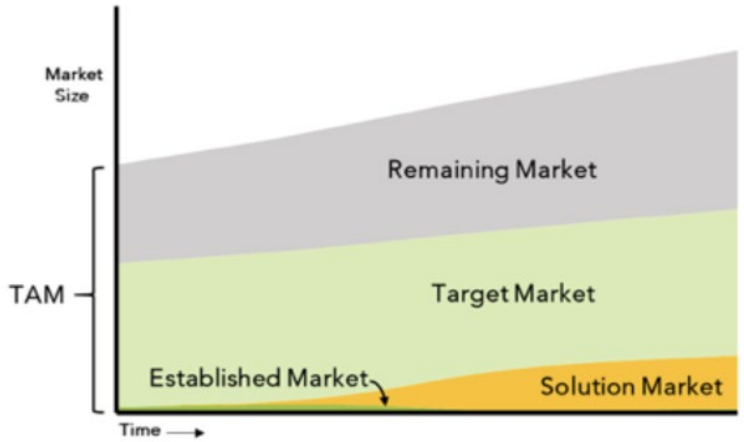
CRANE (Carbon Reduction Assessment for New Enterprises) is an open access, web-based application that allows users to evaluate the greenhouse gas (GHG) reduction potential of emerging technologies The goal of the software is to greatly reduce the time and resources required for investors, entrepreneurs, government agencies, incubators, and philanthropies to perform forward-facing, rigorous and transparent climate impact assessments. The key result is an **emissions reduction potential (ERP)** for the technology or company, which is the magnitude of the greenhouse gas emissions in million metric tons of carbon dioxide equivalent (MMtCO2e) that have the potential to be avoided or abated as a result of deploying the new technology. Every analysis includes a summary report that provides additional metrics, detailed assumptions, references, and calculations. Each analysis can be downloaded in multiple formats and shared among stakeholders for further review and improvement.

CRANE's mission is to make GHG modeling capabilities publicly and globally available, while contributing to a digital ecosystem of organizations and people working on real climate solutions. CRANE does not precisely forecast the future, but rather provides an estimate for future emissions reduction potential and a logical basis for that estimate. We hope our users will view CRANE output reports as a helpful starting place for considering climate impact in their own diligence, integrated reporting and conversations.

[Click here to download a shareable 1-page overview of CRANE]

CRANE's Methodology

The CRANE methodology originated from Prime's in-house process, which was formalized and published in a 2018 report entitled Climate Impact Assessment for Early Stage Ventures. Since then, the methodology has been subtly refined in order for it to be applicable to a broad range of sectors and manifested in software. However, the core framework and approach has not been altered.



The high-level approach of the methodology is to calculate the difference in emissions between two divergent futures (scenarios):

- The Reference Scenario, which may be any of a range of possible futures in which the new technology has not been deployed, and the market demands continue to grow at expected rates
- The Solution Scenario, a future in which the new technology has been deployed.

Each scenario includes projections of the Total Available Market (the largest or broadest market that a technology could theoretically displace), Target Market (the specific market that a technology will displace over time), and Established Market if applicable (an existing, clean technology market that falls within the same total available market as the new technology). The Solution Scenario also includes the Solution Market (the market share captured by the New Technology). The remaining market is the Total Available Market less all the other markets incorporated in the analysis.

For more detailed information on the calculations, we recommend reviewing the Calculation References tab of a CRANE analysis.

This framework does not assess the probability of a given venture to achieve commercial success. Rather, it focuses on describing ERPs that allow investors in a variety of industries and subsectors to compare the potential impact of one venture relative to another and to investigate the underlying assumptions.

Getting Started

CRANE Inputs & Key Outputs

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Custom Technology Modules

Tutorial Videos & Live Demos

Frequently Asked Questions & Glossary of Terms

Climate Impact Assessment for Early-Stage Ventures

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December 2017

Prime

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

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EXECUTIVE SUMMARY

PRIME Coalition and NYSERDA – along with many other government agencies, investors, and philanthropists – share a common interest in supporting early-stage (Pre-Seed through Series A) companies that promise dramatic reductions in global greenhouse gas emissions. In some cases, investors aspire to use the potential climate impact of a new venture as part of their decision-making process about whether or not to invest. For many organizations, climate impact assessment is also important after making an investment for reporting purposes.

However, despite the importance of, and interest in, guiding investments to early-stage ventures with large potential climate impact, early-stage investors today lack a common lexicon with which to discuss the potential climate impacts of early-stage companies. Furthermore, early-stage investors do not employ standard methodologies for assessing the potential climate impact of a new venture and the technologies, solutions, or business models they are looking to bring to market. Today's climate impact assessment tools and services are designed exclusively to retrospectively assess the climate impact of a business as it exists today. For early-stage businesses with small operations and limited or no product deployment, these tools and services do not provide actionable insights. **There is a gap in the marketplace for tools that can inform investors about the potential for their investments to mitigate future emissions.**

In an attempt to help fill this gap, PRIME partnered with NYSERDA, New York State's energy innovation agency, to develop a methodology for assessing the potential climate impact of early-stage ventures. The ultimate goal of this project is to help early-stage (Seed and Series A) investors allocate capital to new ventures that promise climate change mitigation at large scale. This report makes three primary contributions toward this goal. Specifically, this report:

1) Highlights the need for actionable climate impact tools for early-stage investors, and introduces Emissions Reduction Potential as the metric required for early-stage investors to make better informed investment decisions based on the *potential* climate impact of a new venture;

2) Defines a methodology for down selection – a process for narrowing from many companies to a smaller subset of potential investment targets – based on potential climate impact; and

3) Develops a methodology for estimating the Emissions Reduction Potential of a new venture.

Peter Drucker – the famous management scholar – stated that "you can't manage what you can't measure." We review the landscape of existing climate impact assessment and find that existing tools – while powerful and highly impactful for well-established late-stage and public companies – do not provide early-stage investors with the information needed to manage their climate impact investments. We thus introduce a new metric – Emissions Reduction Potential – that describes a venture's ability to mitigate future emissions.

In the absence of tools or analytic platforms for estimating Emissions Reduction Potential, the process can be time consuming and challenging. We therefore introduce simple heuristics that investors can use as proxies for potential climate impact in a down selection process. These proxies are based on affiliations with organizations that measure potential energy or climate impact, solutions that have been identified as highly impactful by third-parties, and rule-based submissions from entrepreneurs. The down selection methods introduced are designed to save climate-motivated investors time and resources.

Finally, we introduce a method for estimating the Emissions Reduction Potential of a new venture. This method requires estimating the potential impact of a venture far into the future – a process wrought with uncertainty. We describe a process for estimating the emissions displaced by deploying the new venture's product, estimating how much of the new product's deployment is additional to what would have occurred in its absence, and estimating future product deployment. Rather than trying to predict the future impact of a venture, we attempt to navigate future uncertainties in a consistent manner, with the goal of creating metrics that can be used to compare the relative climate impact of one venture versus another. This method introduces many unresolved challenges, laying the groundwork for further future methodological development.

Given the lack of available tools and analytic platforms, assessing the potential climate impact of a new venture is today a time and resource intensive process for most investors. Given the scale and urgency of addressing the climate challenge, effective capital allocation is critical, and effective capital allocation requires actionable metrics and assessment tools. We thus encourage early-stage investors interested in tackling the climate challenge to consider the concepts introduced in this report, regardless of whether or not they plan to utilize the methods we describe.

This report takes the first step toward streamlining the climate impact assessment process by outlining the key considerations in assessing potential climate impact and developing a methodology climate impact assessment that accounts for these considerations. In the coming months and years, PRIME and NYSERDA plan to build upon the foundation laid in this report to develop more streamlined and accessible climate impact tools for early-stage investors. We welcome all partners and input into this effort, and are currently engaging both universities and private companies to further build tools based on the concepts outlined in this initial report.

Reducing global greenhouse gas emissions to stave off the worst effects of climate change is an imperative for humanity. Early-stage investors hold one of the most important arrows in the quiver of climate solutions: risk capital. Assessing the potential climate impact of a new venture is challenging but achievable and can, over time, help bring new and innovative emissions-mitigating solutions into the market.

Contents

1. PROJECT OVERVIEW

Humanity is running out of time to make the investments necessary to avoid the worst effects of climate change. At current emissions rates, humanity will have emitted enough greenhouse gases to exceed 2 degrees Celsius of warming by 2040. All levels of warming carry negative consequences. However, exceeding 2 degrees Celsius of warming will lead to irreversible, dangerous, and costly climatic change.[1]

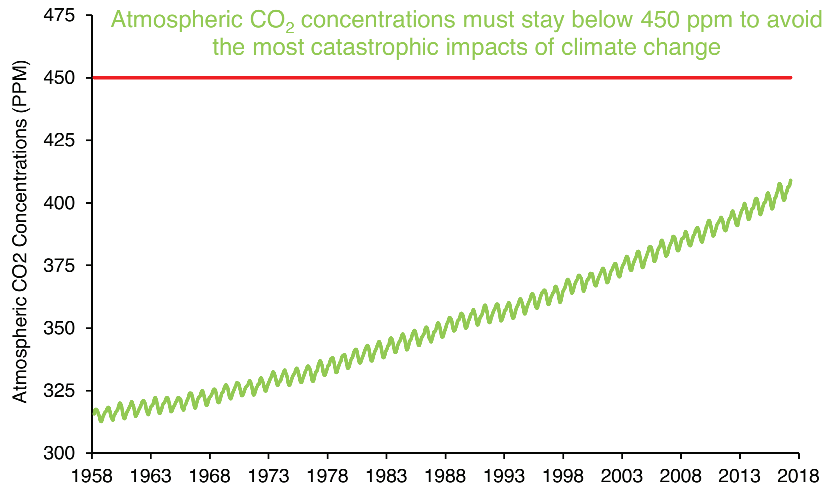

Figure 1: Atmospheric greenhouse gas concentrations must be kept below 450 parts per million to avoid the worst effects of climate change

Mobilizing private capital to the market-based solutions most capable of mitigating greenhouse gas emissions at scale – whether those solutions are new financing mechanisms, business models, or technologies – is one of the most powerful tools society has for combatting climate change. While investors can effect change by supporting solutions at varying points along the development and deployment pipeline, investing in early-stage climate solutions is imperative. In the context of this report, early-stage solutions are Pre-Seed, Seed- and Series-A stage innovations that must be further developed to reach commercial scale and competitiveness. In the words of former Secretary of Energy Ernest Moniz, "clean energy innovation is the solution to climate change…put simply, we can't beat climate change with only the technology we have today."[2] Combatting climate change will require funding nascent solutions that can fill market gaps and complement today's clean technologies.[3]

However, despite the importance of, and interest in, guiding investments to the most impactful early-stage energy and climate solutions, climate investment practitioners lack a common lexicon with which to discuss the potential climate impacts of early-stage solutions and do not employ standard methodologies for assessing climate impact.

Early-stage investors lack the tools necessary to identify the ventures with the highest potential impact

No tools exist to help early-stage investors allocate capital to ventures with the greatest potential climate impact. Given the nascency of early-stage companies, early-stage investors require information about potential future climate impacts, not the climate impacts of the company's products or services as they're deployed today. Some early-stage investors today use proprietary methods to identify investments with high potential impact. However, because the methods, tools, and data these investors employ are not standardized, investment professionals struggle to compare one company to another, and asset owners struggle to compare one investment professional to another.

A litany of data, tools, and service providers exist to help late-stage private and public equity investors assess and improve the climate impact of their portfolios (see Figure 2). However, these tools have three critical shortcomings that prevent them from helping early-stage investors with climate impact-motivated capital allocation decisions:

1. Existing tools retrospectively calculate the emissions reduced by the company as it exists today, while many potentially impactful early-stage ventures will not meaningfully reduce emissions for years to come. These tools do not assess the potential for a new venture to reduce future greenhouse gas emissions, and thus don't provide early-stage investors with actionable information.

2. Existing tools often require significant amounts of company-reported data, which is often unavailable or highly uncertain for early-stage ventures.

3. The majority of these tools are proprietary, making it challenging to compare impact assessments performed by different firms or using different tools.

Figure 2 maps the landscape of existing climate impact assessment tools and service providers in (note: this map does not include investors). Our map reveals many powerful tools, but none that provide the full suite of necessary information for early-stage investors. That is, no tools today quantify or provide information about the potential for a new venture to reduce future greenhouse gas emissions.

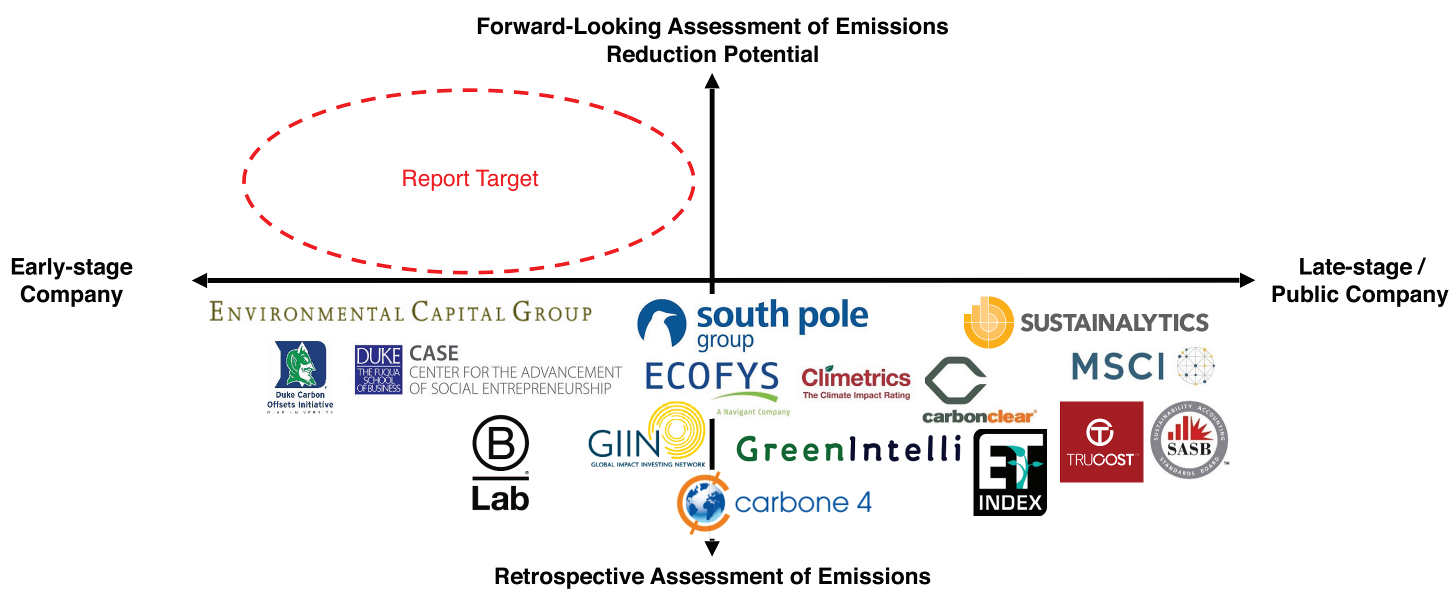

Figure 2: The landscape of climate impact assessment tools

The purpose of this report

This report takes the first step toward filling the gap in the climate impact assessment landscape. The purpose of this report is to guide investors in the process of assessing the potential climate impact of an early-stage venture. Our goals are two-fold: 1) to improve the climate impact assessment capabilities at PRIME and

NYSERDA specifically, and 2) to help build the field writ large with our findings. Our vision is to create actionable information that can be used to measure and compare one venture's potential climate impact against another's, and, in the long term, may be used to measure and compare the potential impact of one investor's portfolio against another's. As we will detail in the sections that follow, we accomplish this vision by outlining a methodology to calculate forward-looking estimates of the greenhouse gas Emissions Reduction Potential ("ERP") of a new venture.

This report was written by climate-motivated investors, for climate-motivated investors

This report is intended for early-stage investors that use or aspire to use the potential climate impact of a new venture as part of their investment decision-making process. We hope to shed light on questions such as: if an early-stage investor is interested in maximizing the climate impact of his or her portfolio, how should he or she go about doing so? How can an investor compare the potential climate impact of one venture against another, given the systemic uncertainties about the future of every company and industry?

We recognize that investors have a myriad of motivations. Some investors are motivated by purely financial returns, others by purely social or environmental returns, and still others by a blend of social, environmental, and financial returns. Our data shows that the subset of investors that are interested in the social and environmental impact of their investments continues to grow. We also recognize that the range of social and environmental impacts that motivate investors extend well beyond climate change mitigation. This report does not intend to elevate climate impact investing over other forms of impact investing, but rather to further support those investors that are motivated to invest to mitigate climate change as one of their stated investment criteria.

The majority of investors consider a variety of factors beyond potential climate impact in deciding whether to make an investment. This report aims to arm investors of all types with actionable climate impact information, recognizing that this information will not be the sole driver of investment decisions in the vast majority of cases.

This report does not attempt to predict the future

While the purpose of this report is to create forward-looking climate impact metrics, the report is not designed to help investors predict the future. This fact manifests itself in two primary areas, as we will describe in detail in Section 4, our proposed methodology for estimating the emissions reduction potential of a single company.

First, the process we describe for **estimating** the Emissions Reduction Potential of a company is *not* a process for **predicting** the Emissions Reduction Potential of a company. Rather, we describe a process for navigating the systematic uncertainties facing any forward-looking analysis to create *consistent* climate impact metrics that can be compared across similar and dissimilar ventures and investors. In other words, the methodology described in this report is not intended to predict the emissions that a company will ultimately reduce in the way that a meteorologist might try to predict what the temperature will be at noon tomorrow. Rather, given the uncertainties involved, we attempt to create metrics that enable relative comparisons of one company's potential impact against another's. In the weather analogy, our goal is not to predict the temperature, but rather to estimate whether one summer day is likely to be hotter than another. This may seem counterintuitive, as, in order to do this, we use a variety of forecasts. We use forecasts from recognized third-party forecasting agencies in order to establish a common baseline for market and emissions growth or decline. Using common baselines establishes standardization, which allows for company to company relative comparison.

Second, while we do create estimates of a venture's growth, we do not comment on the likelihood of a venture achieving that growth. The ultimate impact of any new venture will depend on its ability to succeed commercially and deploy its product in its target market(s) (i.e. profitably outcompete incumbents and competitors). We describe a standardized methodology for estimating a company's potential penetration in a particular market. However, we do not intend for investors to use this methodology to predict the company's success in their market. Our intention is to define a method for estimating market growth that is standard across all companies to enable investors to compare the relative potential climate impact of one company versus another. We recognize that investors have their own unique methods for assessing the potential attractiveness of a market and the growth of a company within that market. Our goal is not to instruct investors how to best do their market or company assessments.

2. CLIMATE IMPACT METRICS

Greenhouse gas Emissions Reduction Potential (ERP) is the primary metric assessed in this report

Climate change will impact the planet in a variety of ways. Given the many social/impact/charitable outcomes of a changing climate, any impact investor could quantify outputs related to water scarcity, geopolitical conflict, community deterioration, food scarcity, natural disasters, habitat destruction, et cetera.

Despite the complexity of climate systems, the accumulation of greenhouse gases (GHGs) in the atmosphere is the primary driver of all climate-related social outcomes. Mitigating these emissions is the primary lever investors have to help humanity avoid these negative outcomes. We therefore measure a company's climate impact by assessing its ability to mitigate greenhouse gas emissions. An estimate of the climate impacts of an early-stage company as it exists at the time of investment does not provide an adequate picture of the true impact of that company. Early-stage companies must be assessed based on their potential to mitigate greenhouse gas emissions in the future: their Emissions Reduction Potential ("ERP").

Given the long business development and commercialization timelines of many climate-relevant companies and the time required for new companies to achieve significant market penetration, we must define ERPs over a timeframe that is meaningful to the companies in question. For the purpose of this report, we define a 30-year time period for the measurement of potential impact. Investors with different priorities may define alternative timescales, but it is critical that the chosen timescale adequately accounts for the long-term potential benefits of a new venture. Furthermore, in order to create assessments of ERP that are comparable across companies, it is critical for a common timeframe to be used across assessments.

Standard metrics can be useful in estimating ERPs

The Global Impact Investing Network (GIIN) defines a number of generally accepted impact metrics in its IRIS database, some of which are useful in assessing Emissions Reduction Potential. Specifically, the IRIS metric **Greenhouse Gas Reductions due to Products Sold (IRIS ID PI5376)** is the most relevant IRIS metric to this report and the methodology we propose. This metric is combined with estimates of future product sales to create ERPs (a process described in depth in Section 4 of this report). Greenhouse Gas Emissions due to Products Sold is comprised of two additional IRIS metrics:

1) The lifecycle emissions embodied in the product produced by the venture (Greenhouse Gas Emissions of Product – IRIS metric PD9427)
2) The lifecycle emissions of the incumbent product being displaced (Greenhouse Gas Emissions of Product Replaced – IRIS metric PD2243)

Assessing ERP requires estimates of product impacts and potential product deployment over the timeframe defined in the Emissions Reduction Potential estimate; again, in this report, 30 years. Section 4 of this report discusses how to consistently create these estimates. The following simplified formula for ERP relies only on product impacts and potential product deployment.

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

Potential Climate Return on Investment (pCROI) is a useful extension of the ERP concept when considering an explicit investment (as opposed to assessing the potential impact of a venture outside of the investment context). Potential Climate Return on Investment is calculated as the greenhouse Emissions Reduction Potential of a company, organization, or project, divided by the estimated net present cost (NPC) of the investments required to achieve that emissions reduction.

$$pCROI = \frac{Emissions\ Reduction\ Potential}{Net\ Present\ Cost\ of\ Investment}$$

While pCROI may be an informative metric for some investors, we do not advocate using it as the sole climate metric. pCROI can systematically favor capital-light solutions such as software or finance innovations; as such, we encourage investors to consider both the magnitude of the ERP, as well as pCROI.

When considering two ERPs or pCROIs, it is useful also to consider the timing of the emissions reduction. Greenhouse gases have long residence times in the atmosphere. Therefore, if all else is equal, it is more impactful to mitigate a ton of greenhouse gases today than ten years from today. This general rule of thumb can help investors when considering two or more similar pCROIs or ERPs.

3. CLIMATE IMPACT ASSESSMENT IN DOWN SELECTION

What is down selection, why is it necessary, and how is down selection performed today?

Before diving into the process of assessing ERPs, we take a detour to introduce a climate-motivated down selection process. As we will describe in Section 4, any ERP assessment process can be time- and resource-intensive. Any one investor or investment firm may not have the time or budget to perform high-quality ERP calculations of every new venture that comes across their desk. Down selection is a process for selecting a company or set of companies for deeper due diligence and ERP assessment from the entire universe of potential investments. Down selection is therefore not a part of our proposed ERP assessment methodology per se; but instead it's designed to save investors time and money without sacrificing climate impact overall. Nearly all investors employ some sort of down selection process today – the key question is how to incorporate potential climate impact into this down selection process?

Today, nearly all investors use heuristics to down select. These down selection processes rely on proxies for potential business success, as opposed to proxies for potential climate impact. Common down selection filters are based on:

- References to companies from trusted colleagues;
- Company affiliations with notable institutions (e.g. universities, incubators, or accelerators);
- Sectors/subsectors/industries of interest to the investor;
- Ability of a company to demonstrate certain performance metrics or provide other relevant data;
- Competitive position and defensibility of a company's technology or solution (e.g. intellectual property, trade secrets, or time of entry to market);
- Pedigree and/ or relevant experience of the company's founding team;
- Et cetera.

Incorporating potential climate impact into down selection

Early-stage companies still developing a product and/or working on product-market fit typically do not have enough operating data for investors' data-driven heuristics to prove effective. Other traditional heuristics – for example, the background of the founders or references from notable institutions – often provide little information about potential climate impact (ERP). Thus, we need to define specific down selection heuristics for climate change mitigation-motivated investors. Here we identify three pathways for climate impact-based down selection:

1. Company affiliation with specific climate-focused institutions;
2. Company focus on a product(s) that has been identified as high-impact by credible analysis;
3. Company-submitted impact estimates benchmarked against a pre-established impact hurdle.

These down selection methods are imperfect proxies for ERP, but they enable investors to more quickly filter the universe of potential investments and more effectively screen and prioritize certain companies for further diligence.

Method 1: Affiliation-based down selection

Some organizations explicitly define climate impact hurdles as part of their investment or affiliation criteria. Using an investment from or affiliation with these organizations as a down selection filter essentially outsources the process of impact assessment to those other organizations. Investors should practice caution when using affiliation-based down selection methods, as not every company with a strong affiliation will meet an individual investor's needs.

Based on research for this project and in addition to our own down selection criteria at PRIME Coalition, two organizations in the US – ARPA-E and Breakthrough Energy Ventures (BEV) – state publicly that their staff incorporates climate or energy impact hurdles in their down selection processes. We reiterate that affiliations with these organizations are imperfect proxies for high Emissions Reduction Potential. For example, ARPA-E has a number of non-climate-related motivations for choosing to support specific companies or projects, such as national security or geopolitical impacts; these types of non-climate factors highlight why affiliation-based down selection is only a proxy for potential climate impact, not a replacement for assessing that impact. However, for time and resource-constrained investors, affiliations can be useful.

> Breakthrough Energy Ventures' stated goal is to only support ventures capable of mitigating 500 million tons of emissions.
>
> ARPA-E's stated goal is to only support ventures or projects capable of reducing or displacing 1% of total U.S. energy consumption.
>
> NYSERDA and MassCEC incorporate potential climate impact in their decision-making processes without defining specific climate impact thresholds.

Other organizations, such as NYSERDA and the Massachusetts Clean Energy Center (and potentially others) use potential climate impact in their investment decision-making processes. These investors require companies to demonstrate tangible and sizeable climate impact before placing an investment. While these investors do not define an explicit climate impact threshold, they do incorporate potential climate impact as a key factor in their investment decision-making process. Thus, these investors are also suitable for reference in a climate-motivated down selection.

Many climate-related innovation ecosystem organizations, such as incubators, accelerators, other venture development organizations, and business plan competitions – while doing incredibly important work – do not explicitly incorporate a calculation of potential climate impact in their decision-making processes for supporting a company. Organizations like Greentown Labs, Cyclotron Road, ACRE, the Wells Fargo Innovation Incubator, and many others are making great strides in supporting low greenhouse gas solutions as they develop and come to market. However, we do not list these organizations as potential references in a down selection process today because they do not formally incorporate climate impact in their decision-making processes.

Method 2: Technology-based down selection

A myriad of scholars have rigorously studied and published information on the emissions reduction potentials (or some variant of emissions reduction potential) of different technologies, technology classes, and other climate solutions. If a company is developing a product that has previously been identified as highly impactful, this venture may merit further analysis. Investors must be cautious of two key factors when using technology-based filters:

1. It is important to define a set of technology buckets that are granular enough to be meaningful; for example, simply defining solar photovoltaics (PV) as a high impact technology may not provide meaningful filtering, given the number of companies working on solar PV solutions.

2. Relying too heavily on a single technology bucket or a limited set of technology buckets could concentrate risks. Solving the climate challenge will require a broad portfolio of solutions across a wide variety of sub-sectors related to energy, agriculture, waste, and water. Investors should be wary of overly concentrating bets.

PRIME has identified two lists of promising technologies that can aid in down selection processes. The first, developed by PRIME, is aggregated from academic research, U.S. Department of Energy (DOE) reports, and other public resources. Breakthrough Energy Ventures has also highlighted a number of “Technical Quests” that could be used in a down selection process. The PRIME and Breakthrough Energy Venture’s lists share many common technology priority areas. The climate impact investing community could benefit greatly from ongoing, scholarly research to identify high priority technologies or solutions for investors to explore.

Electricity and Heat Production	Agriculture and Other Land Use	Buildings	Transportation	Industry
Greater than 30% efficient, less than $0.10 per Watt solar PV	Zero-GHG fertilizer production	Improved dehumidification, latent, & sensible cooling HVAC technologies	Lightweight structural components with high throughput manufacturing capabilities	Industrial process integrated CCS
High capacity factor, low-cost wind	Non-meat-based meat-protein substitutes	Low cost cold weather heat pumps	Non-food-based biofuels	Low-GHG steel and aluminum production
Low- or zero-GHG flexible "baseload" power plants	Advanced grassland, cropland, and forest management solutions	Autonomous, efficient building management	High efficiency, low cost electricity-to-fuel pathways	Low-GHG cement production
Flexible, fail-safe nuclear energy technologies	High efficiency vertical farming solutions	Ultra-low cost, efficient building envelope materials	Electric- or hydrogen-fueled aircraft	Non-fossil-based pathways to today's petrochemicals
Low cost seasonal energy storage	Fail-safe geoengineering solutions	Non-vapor compression (VC) cycle refrigeration	Next-generation battery solutions	Low grade waste heat capture solutions
Cost effective, low-parasitic load carbon capture and storage (CCS)		Low cost, long duration thermal energy storage	Multi-purpose, high-performance biomass feedstocks	High efficiency industrial separations
Non-wires-based electricity transmission			High efficiency hydrogen production pathways	High fidelity, broad input recycling solutions

Scalable bioenergy-based CCS	High efficiency, low cost gas storage and transport
Low cost hydrogen storage and delivery	Next generation non-vehicle-based transportation solutions
Nuclear fusion	
Next-generation transformers & network infrastructure	

Figure 3: Down selection method 2 – Technology-based down selection; Example 1 - PRIME Coalition's Breakthrough Technology Areas

ELECTRICITY

- Next-Generation Nuclear Fission
- Enhanced Geothermal Systems (EGS)
- Ultra-Low-Cost Wind Power
- Ultra-Low-Cost Solar Power
- Nuclear Fusion
- Ultra-Low-Cost Electricity Storage
- Ultra-Low-Cost Thermal Storage
- Ultra-Low-Cost Transmission
- Low-Cost Ocean Energy
- Next-Generation Ultra-Flexible Grid Management
- Fast-Ramping, Low-GHG Power Plants
- Low-GHG, Reliable, Distributed Power Solutions
- CO_2 Capture
- CO_2 Sequestration and Use

TRANSPORTATION

- Batteries for Gasoline Equivalent EVs
- Lightweight Materials and Structures
- Low-GHG Liquid-Fuels Production—Non-Biomass
- Low-GHG Gaseous Fuels Production—H_2, CH_4
- High-Energy-Density Gaseous Fuel Storage
- High-Efficiency Thermal Engines
- High-Efficiency, Low-Cost Electrochemical Engines
- Low-GHG Liquid Fuels Production—Biomass
- Transportation-System Efficiency Solutions
- Technology Solutions that Eliminate the Need for Travel
- Technology-Enabled Urban Planning and Design
- Low-GHG Air Transport
- Low-GHG Water-Borne-Goods Transportation

AGRICULTURE

- Reducing CH_4 and N_2O Emissions from Agriculture
- Zero-GHG Ammonia Production
- Reducing Methane Emissions from Ruminant Animals
- Developing Low-Cost, Low-GHG New Sources of Protein
- Eliminating Spoilage/Loss in the Food-Delivery Chain
- Soil-Management Solutions for GHG Reduction and CO_2 Storage
- Manure
- Agriculture-Related Deforestation

MANUFACTURING

- Low-GHG Chemicals
- Low-GHG Steel
- Low/Negative-GHG Cement
- Waste Heat Capture/Conversion
- Low-GHG Industrial Thermal Processing
- Low-GHG Paper Production
- Extreme Efficiency in IT/Data Centers
- Fugitive Methane Emissions from Industry
- Extreme Durability for Energy-Intensive Products and Materials
- Transformative Recycling Solutions for Energy-Intensive Products and Materials
- Increasing Biomass Uptake Rate of CO_2
- CO_2 Extraction from the Environment

BUILDINGS

- High-Efficiency, Non-HFC Cooling & Refrigeration
- High-Efficiency Space/Water Heating
- Building-Level Electricity and Thermal Storage
- High-Efficiency Envelope: Windows and Insulation
- High Efficiency Lighting
- High-Efficiency Appliances and Plug-Loads
- Next-Generation Building Management
- Technology-Enabled Design of Efficient Buildings and Communities

Figure 4: Down selection method 2 – Technology-based down selection; Example 2 – "Technical Quests" Identified by Breakthrough Energy Ventures

It is important to note that some of the leading organizations studying technology pathways to decarbonization – and the investment opportunities these pathways create – do not provide investment-level granularity. For example, the IEA's Energy Technology Perspectives studies provide high-level overviews of technology investments required to limit warming to 2 degrees Celsius, but do not describe priority technologies with enough granularity to be actionable in investment decision-making. Similarly, Project Drawdown provides a portfolio of 100 potentially impactful climate solutions, but does not provide investment-level granularity.

Method 3: Company submission-based down selection

Many investors enable companies to express inbound interest in receiving investment. In these scenarios, investors may wish to enable companies to submit their own climate impact assessment. Companies that clear a pre-specified threshold of potential climate impact can be considered for further diligence. Each investor should set a threshold that fits their needs; investors looking for "breakthrough"-type solutions may set high thresholds (e.g. an ERP of at least 1,000 million metric tons), while other investors may set lower thresholds. This process can be an effective down selection method that requires relatively little investor input.

Investors must take caution when reviewing company-submitted information; companies have a natural incentive to inflate their own estimates of their company's potential climate impact. In addition, different companies will use different methodologies for assessing their potential impact, making it impossible to compare one company's assessment to another's. Investors should set clear boundaries around what should and should not be included in a company's analysis. While company-submitted analysis can complement an investor's own assessment of ERP, it should not be viewed as a replacement.

Company-submitted estimates should follow some simple best practices in order to be useful to investors. We suggest setting the following simple requirements for any company-submitted climate impact assessment:

1. Companies should submit their estimate of their ERP over a 30-year period, expressed in millions of metric tons of carbon dioxide-equivalent.
2. Company estimates should be based on a full life-cycle assessment (i.e. an assessment of production-, use-, and disposal-related emissions) or include documentation of why a given stage of emissions was excluded.
3. Companies should submit full documentation of their calculations in a single file so that investors can "pressure test" the results.
4. Companies should submit all resources (e.g. reports, papers, etc.) used in the assessment.

Some additional factors may help investors in considering the value of a given company-submitted ERP. For example, if the company is developing a technology that requires manufacturing, it may be helpful to consider whether the company in question is forward thinking regarding sustainable or efficient manufacturing processes. Market pivots are common for early-stage ventures; it may therefore also be helpful to consider whether the company has identified several potential low GHG markets to target.

4. A METHODOLOGY FOR ASSESSING ERP PRE-INVESTMENT

Assessing ERP requires looking far into the future. Investors assessing ERP must therefore grapple with systemic uncertainties. The key challenge addressed in this section is how to handle these uncertainties in a consistent and transparent manner, creating ERPs that can be used to assess the relative potential impact of similar and dissimilar companies. As ERP assessment processes become standardized, our proposed methods could also be used to compare investor portfolios, in the same manner that GIIRS ratings are used today.

There are several uncertainties that investors must navigate. These include:

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 deployment of the venture's product.

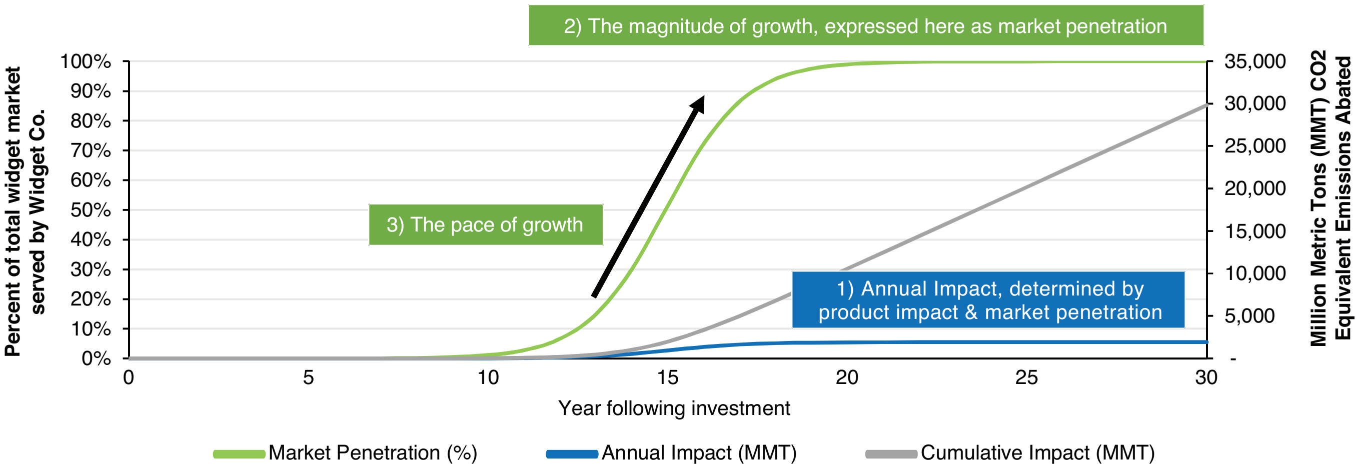

Figure 5: Estimating ERPs requires navigating systemic uncertainties

This report does not assess the probability of a given venture to achieve commercial success

Any new venture will face many risks – commercial, technical, policy, etc. – in its development. The ultimate impact of a venture will depend critically on how the venture mitigates these risks and realizes success in deploying its product. An investor may therefore be tempted to consider both the venture's ERP and its probability of achieving that potential, creating something akin to an *expected* ERP. However, different investors will have different opinions about the probability of success of any given investment. As proof of this point, the early-stage investment community is littered with stories of historically successful investors deciding not to invest in ventures that ultimately prove successful, and vice versa. Thus, we do not comment on the probability of success of a given venture, but rather focus on creating a methodology for assessing ERPs that allows investors to compare the potential impact of one venture relative to another, across industries and sub sectors. In order to accomplish this goal we use standardized third-party forecasts of market growth and standardized market penetration models. We do not use these models for prediction, but rather for standardization.

Guiding principles for assessing ERP:

- **Consistency**: use the same assumptions in all assessments of common companies. For example, if assessing five solar PV manufacturers, use the same assumptions about future market size in all assessments.

- **Transparency**: detail and communicate key assumptions. This is critical for two primary reasons. First, if assumptions are stated clearly, they can be updated as more information becomes available. This is important as market forecasts and emissions information are updated. Second, outlining assumptions enables asset owners and other interested parties to compare the methods used and ERPs produced by different investors. As the investment industry moves to standardize climate impact reporting, it will become increasingly important to use a standard set of baseline assumptions. Just as the Sustainable Accounting Standards Board and the Greenhouse Gas Protocol ensure all public companies and investors use common reporting methods, it is our hope that early-stage investors can standardize ERP measurement.

- **Conservatism**: when forced to make simplifying assumptions, attempt to make conservative assumptions. If a company has a high impact potential under conservative assumptions, this company is more likely to be a high impact company in actuality.

Common assumptions used in assessing ERP:

- **Averages**: many details about an early-stage company are unknown or uncertain. When establishing base-case ERP assessments, use average values for certain key variables in these cases. For example, if it is not yet known where a company may deploy its products, use the global average value for the emissions of any displaced products. Similarly, if it is not yet known where a company may manufacture its products, use average values for the emissions required to produce the product. This assumption strategy can be in conflict with the conservatism principle; however, we also recommend using extreme cases to gain an understanding of the bounds on a company's ERP.

- **Extremes**: in addition to estimating a base-case ERPs using averages, strive to calculate ERPs under best and worst cases. Using best and worst cases creates an understanding on the bounds of ERP estimates. Aggressive and conservative cases can be established by using high and low values for product impacts combined with aggressive and conservative estimates for product deployment. While establishing aggressive and conservative cases provides useful insights, doing so can be cumbersome.

- **Magnitude**: attempt to identify the minimum viable information required to adequately assess a company's impact. An ideal assessment would include all relevant upstream and downstream emissions for every year into the future for every company. However, this information is incredibly challenging to gather and is riddled with uncertainty. Thus, use judgement to determine which variables will estimate the primary impacts of a venture. For some companies – companies developing data-based products, for example – the emissions that result from making and delivering the company's product (the embedded emissions) may be relatively small; for other companies, such as those with heavy manufacturing, the embedded emissions may be significant. Complying with the principles of consistency and transparency will limit the bias created in exercising judgement in this manner.

Methodology for assessing ERP pre-investment

Our proposed methodology for estimating Emissions Reduction Potential is summarized in the figure below and detailed in the remainder of this section.

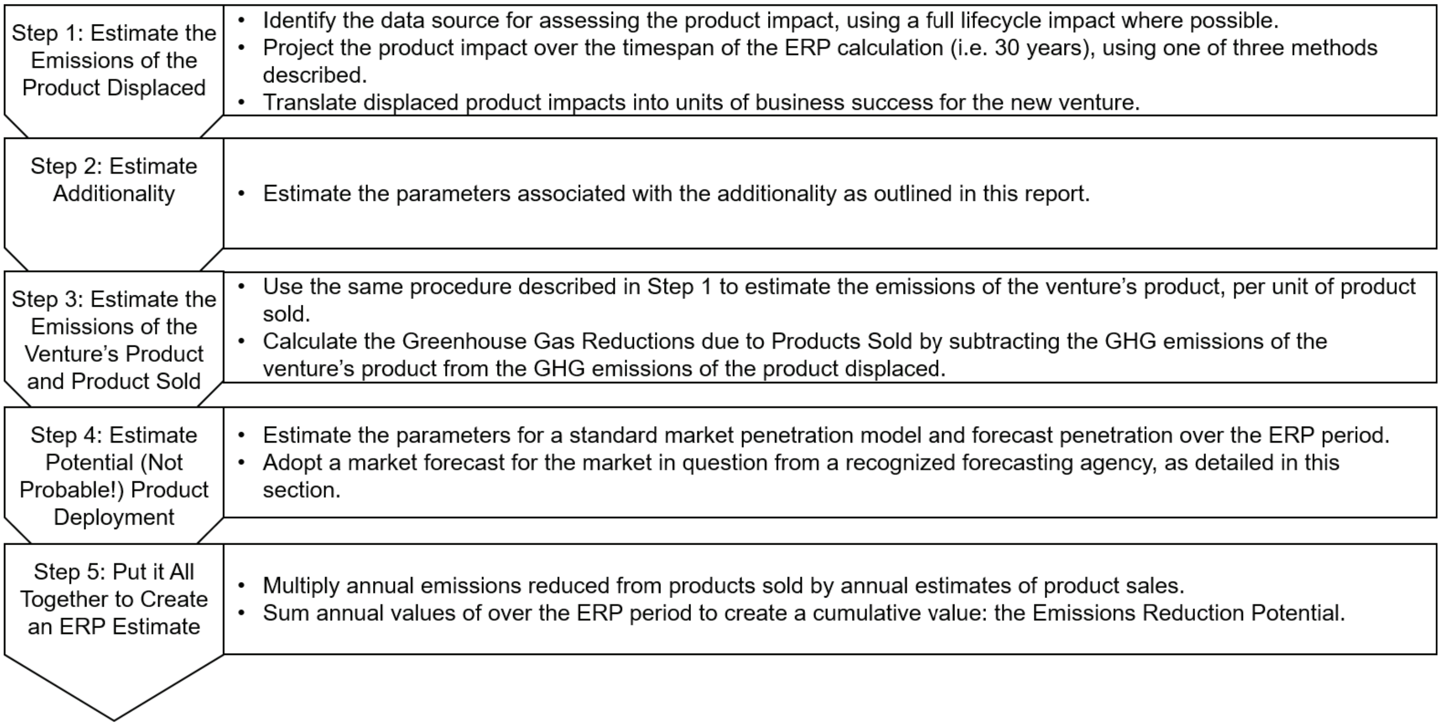

Figure 6: ERP estimation process

Step 1: Estimate the emissions of the product displaced

Using LCA and emissions factor databases

There are three broad types of product emissions that must be accounted for: emissions related to the production of the product (this would include all emissions associated with the businesses' operations), emissions related to operating the product, and emissions related to the end of life of the product. For many products, the bulk of product emissions may be related to operations; this may be broadly true for products with energy-intensive operations. However, for short-lived goods or goods without energy-intensive operations (for example, consumer goods, agricultural goods, or renewable energy resources), the bulk of product emissions may be related to the production or disposal of the product. Following assumptions of magnitude, use published information and intuition to determine which product impacts are more critical. Investors may use average values for base case projections, and high- and low-end values of displaced product emissions for aggressive and conservative cases.

Lifecycle assessments (LCAs) are often quite useful for estimating production-, operation-, and end-of-life-related emissions. Many reputable organizations maintain databases of the results of LCAs. For example, several U.S. federal government agencies maintain LCA databases (link). The Greenhouse Gas Protocol provides links to many other LCA tools (link). Consider using these databases to find the lifecycle emissions of the product displaced by the venture's product.

In many cases, data regarding the production- or disposal-related emissions for a given product are not available, and investors can create an estimate or ignore this potential source of emissions. This is a key assumption and should, according to the transparency principle, be outlined as such when made.

There is no universal data source or process for estimating the operations-related emissions of an incumbent product. However, the U.S. Environmental Protection Agency (link), the Intergovernmental Panel on Climate Change (link), and the Greenhouse Gas Protocol (link) maintain databases of greenhouse gas emissions factors; emissions factors detail the amount of greenhouse gases emitted in the production or use of certain products. These databases are often the most reliable sources of information for assessing the operational emissions of incumbent products.

Estimating the impact of long-lived products

For displaced products that have multi-year lifetimes, it is important to credit the venture for the emissions avoided over the lifetime of that product. For example, if an electric vehicle (EV) provider displaced a gasoline-powered vehicle, the EV would displace all of the emissions of the gas vehicle over the lifetime of that vehicle. These displaced emissions should be accounted for in the year that the vehicle is displaced (this is outlined as a best practice by the Greenhouse Gas Protocol). For example, in the vehicle case, if the vehicle is an average U.S. light duty vehicle and emits roughly 4.73 tons of greenhouse gases per year and is expected to last roughly 10 years, the sale of an EV in year *y* could be counted as displacing 47.3 tons of greenhouse gases in year *y* (note that we will then have to calculate the emissions created by the EV in manufacturing, charging, etc.).

Estimating the future progression of the displaced product's emissions

Industries are constantly changing over time, and many industries are taking strides to decrease the emissions of their products. As a result, the nature of the incumbent product that a new venture is displacing is likely to change over time. Thus, a product sold today that displaces today's incumbent products will have a very different impact than the identical product sold in the future. We must therefore estimate the future progression of the displaced product's emissions.

There is no universal method for assessing the future progression of an incumbent product's emissions. Three assumptions are useful for estimating the future progression of an incumbent technology: 1) assume future trends will look like historical trends, 2) assume any industry-specific targets will be met, and 3) assume the future will look like the present.

One conservative method is to use historical data to estimate the historical rate of improvement in incumbent product emissions; this rate of improvement can then be used to estimate future emissions (e.g. if a technology's marginal emissions have been falling by X% per year for the previous 10 years, consider assuming that this trend will continue into the future for some period of time). An alternative conservative assumption is to assume that industry targets will be met. Many industries or governments set performance targets for key products. For example, the U.S. federal government and states like California have set targets for the fuel economy of vehicles. Consider adopting these targets (using linear or compounded growth to bridge the gap from the present to the target year). These two methods are conservative because they have the effect of lowering the future displaced emissions of the new venture's technology.

Finally, when information about trends in incumbent product emissions or emissions targets is unavailable, assume that future emissions will be roughly equivalent to today's. This assumption is likely to overestimate future displaced emissions. Detail whichever assumption is used for reporting and standardization purposes.

Key assumptions in estimating future displaced product emissions

Two assumptions are embedded in any approach to estimating the future progression of an incumbent product. First, there is the assumption detailed above about how the displaced product will progress. The second, less obvious assumption, is an assumption that the incumbent product with which the new venture's product is competing will be the same in the future; this may not be the case in the presence of competing technologies or changing policies. Consider, for example, an electric aviation company. One may assume that in the near future, this company would displace fossil fuel-powered jets. However, if a breakthrough in biofuels were to occur, this electric aircraft may in fact compete with biofuel-powered jets. Thus, it's helpful to detail assumptions about the assumed incumbent product. The same logic applies to uncertainty of the policy environment (i.e. whether or not a carbon price will be established).

Translating displaced product emissions into displaced emissions per unit of product deployment

The final step in estimating the emissions of the product displaced by a new venture is expressing the incumbent product's emissions in terms that are relevant to the venture being assessed. The best way to do this is to express incumbent product emissions as emissions per unit of new product sold. For example, if a new venture is selling solar panels, incumbent emissions should be detailed as emissions per unit of energy produced by the solar panels sold (note that this requires translating solar products sold into energy produced); alternatively, if a venture is selling a product to increase crop yields, incumbent emissions could be expressed in terms of emissions per acre of crop, etc. The goal is to translate displaced product emissions into units relevant to the venture's success. In many cases this process is quite simple. For example, sales of a solar PV product will displace a certain amount of fossil fuel-fired energy, and incumbent emissions can be expressed per unit of energy. However, in other cases this can require a careful assessment of the amount of emissions that are attributed to a single sale by the new venture.

Step 2: Estimate additionality

In recent years, technological, business, and finance innovation has yielded solutions capable of mitigating large amounts of greenhouse gas (GHG) emissions. The goal of bringing any new climate product to market is to spur emissions reduction that would not occur but for the existence of the product. This is known as *additionality*.

While estimating additionality can be challenging, it is very critical, as it can avoid counting emissions reductions dramatically overestimating the impact of a given product. Consider, for example, the impact of a rooftop solar PV company. Imagine that the company installs a PV system in a coal-heavy electricity grid. Imagine that the customer – a homeowner – found the solar PV company through an online portal and financed the system through a third-party financier. If the rooftop solar PV company, the online portal, and the financier all count the full emissions reduced from the deployment, the reduction would be triple-counted. This becomes extremely problematic when considering large-scale product deployments and can lead to misguided capital allocation.

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; or
4) Introduce a new low GHG product into a market without existing low GHG products.

Performance improvements for GHG emitting products

A new venture may achieve additionality by improving the GHG performance of an existing GHG emitting product beyond what would be achieved by existing and line-of-sight technologies (consider, e.g., a technology that substantially improves the GHG efficiency of a natural gas power plant). In this case**, the impact of the new venture's deployments is equal to the decrease in emissions associated with the increased performance of the incumbent product**. "Rebound" effects – that is, increases in emissions from the introduction of a higher performing technology because of unexpected behavioral or system responses – can be important for some performance improving technologies. In some cases, rebound effects can result in net *increases* in GHG emissions. However, these rebound effects can be extremely challenging to estimate in practice and may take years to become observable. Absent concrete information regarding rebound, make one of two assumptions: first, that there are no increases in sales or use of the emitting product due to its increased performance, or second, assume that only a fraction of the estimated efficiency gains will be achieved (following the conservatism principle). For example, if a new venture's product is expected to improve a GHG emitting product's efficiency by 50%, assume that it will only increase efficiency by 25% due to rebound effects.

Performance improvements for existing low GHG products

A new venture may achieve additionality by improving the performance of an existing low GHG emitting product beyond what would be achieved by existing and line-of-sight technologies (e.g. by improving the efficiency of a solar PV product). In this case, **the impact of the new venture's deployment is equal to the increase in displaced emissions associated with the increased performance of the incumbent low GHG product**. For example, if a new product makes a solar PV system 50% more efficient, each deployment will result in 50% more displaced emissions (the GHG of displacing emissions will in turn depend on the GHG intensity of the fuel mix).

Deployment increases for existing low GHG products

A new venture may achieve additionality by increasing the deployment of a low GHG above and beyond what would otherwise occur. This can happen by either improving the cost of an existing low GHG product at a given level of performance, or improving the performance of an existing low GHG product, or both. In this case**, the impact of the new venture's deployment is equal to the increase in sales that occur due to the increased competitiveness of the product** (e.g. every unit of the company's product deployed results in an X % increase in the total sales of the relevant low GHG product). Measuring the impact of a performance or cost improvement on deployment is, in practice, extremely difficult. This requires an understanding of the "elasticity" of demand for the product with respect to a change in performance or cost. Describing the process for rigorously assessing the elasticity of a given product is outside the scope of this report. A conservative assumption is to assume that an increase in performance does not result in any increase in sales. For new products that improve the costs of an existing product, use conservative assumptions about the price elasticity of demand for the existing product (e.g. for every 1% market share of the new product, the size of the market for the existing product grows by 0.1%). We do not recommend a specific value given the diversity of industries and potential investments that exist. Whichever value of elasticity is chosen, use the consistency, transparency, and conservatism principles.

Introduction of a new low GHG product

Finally, a venture may achieve additionality by introducing a low GHG product into a market where no low GHG products exist (e.g. introducing a low GHG cement technology). In this case, **the impact of the new venture's deployments is equal to the displaced emissions of the incumbent product** (e.g. every 1% market share results in 1% fewer emissions of the incumbent GHG emitting product).

The challenge of estimating the impact of system-enabling products

Some technologies can be considered "system-enabling" in that they alter the characteristics of the energy or product system in a way that lowers emissions. The Breakthrough Energy Ventures list of technical quests identifies many such system-enabling technologies: electricity storage, fast-ramp power plants, grid management, thermal storage, gas storage, transmission, transportation system efficiency solutions, and technology-enabled urban planning and design.

Consider energy storage, for example. Novel energy storage technologies may reduce emissions by enabling the deployment of more low-GHG solutions such as renewable energy and electric vehicles.

The key challenge is to estimate the additional deployment of low GHG products that result per-unit of new system-enabling product deployed. This can, in practice, be very challenging to estimate. Counterfactual modeling techniques may be better suited for this type of analysis. Counterfactual analyses model the system-level emissions with and without the enabling technology and compare the results. However, the modeling tools required to perform such an analysis may not be available to all investors. In the absence of such sophisticated techniques, make a simplifying assumption about the per-unit increase in low-GHG product deployment associated with the system-enabling solution.

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

Not all climate-friendly products are zero-greenhouse gas products. Most products that require manufacturing, for example, will create emissions in the production and shipping of the product. For many products, these emissions may be negligible in comparison to the emissions of the product displaced. Use the principle of magnitude to identify when it is necessary to account for the emissions of the venture's product. Where it is necessary to calculate the emissions of the venture's product, use the same procedure used to estimate the emissions of the displaced product.

Estimating the emissions reduced per product sold is straightforward once estimates of the emissions of both the displaced product and the new venture's product are created. Figure 7 demonstrates the hypothetical output of steps 1-3 of this process.

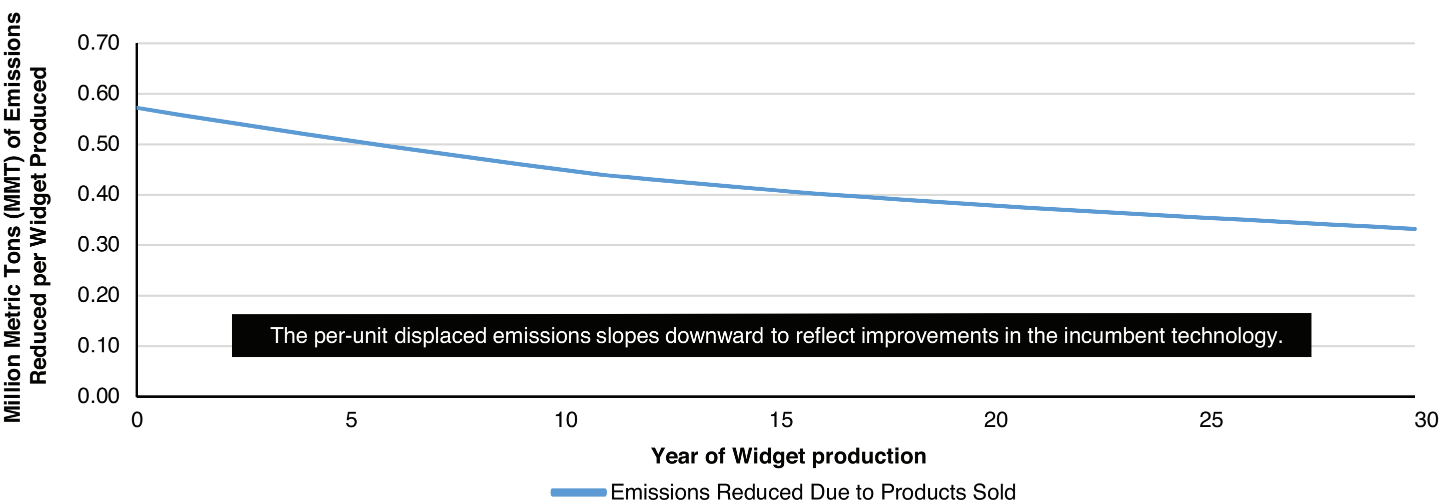

Figure 7: The per-unit displaced emissions of a hypothetical "widget" manufacturer

Step 4: Estimate potential product deployment

Using standardized and empirically demonstrated models of technology diffusion can create estimates of potential product deployment that allow for comparisons across companies.

Once the emissions of the displaced product over time, the emissions of the venture's product over time, and the additionality of the product have been estimated, the next step is to estimate the penetration of the venture in question's technology over the 30 years following investment. This process is as fraught with uncertainties as any projection of the future. As Yogi Berra famously stated, "it's tough to make predictions, especially about the future."

Investors live and die by their ability to understand markets and predict the future success of a business. Our intention with this section of the report is not to instruct investors on how to predict a company's success. Rather, our goal is to use a method that can be standardized from company to company and from investor to investor. As we highlight throughout this report, different investors are likely to have different views about how the future might unfold. The goal in this step is to describe a process for estimating the potential future success of a business in a consistent manner so that we can make comparisons between similar and dissimilar.

There are a variety of ways to approach this problem. We introduce three possible pathways for estimating the potential growth of a new venture, and argue that one method – using proven technology diffusion models – provides the best mix of accuracy, consistency, and simplicity.

The first pathway involves using a venture's own estimates of potential product sales; if a venture estimates that they will produce 100 units of their product in a future year, we could estimate the emissions reduced by these 100 units. There are two key challenges with this pathway. The first is that it gives ventures a natural incentive to inflate their estimates of their potential sales; the second is that, because different ventures will use different methods for estimating potential sales, it does not provide a consistent framework to compare companies. The second pathway involves using complex modeling techniques such as those employed by ARPA-E or academic groups to develop a precise estimate of potential future product adoption. While these modeling methodologies can be quite powerful, the complexity of these models generally make them inaccessible to non-experts (this could change if the models were packaged in an investor-facing software product). The final method – the method described in this report – sacrifices detail for consistency and simplicity and relies on empirically-proven technology adoption models.

Using standardized technology adoption models

Predicting the pace and timing of product adoption is incredibly complex. However, over time, most successful products follow a relatively predictable adoption pattern. This pattern – known as an S-curve – has been empirically demonstrated across a variety of products and product classes, as demonstrated by the figure below. This adoption pattern is general across all product types and is not unique to clean technologies. Furthermore, S-curve models are simple – they require only three parameters – and can be created repeatedly in a consistent fashion. S-curves are therefore a good resource for estimating ERPs that are comparable across varying product types.

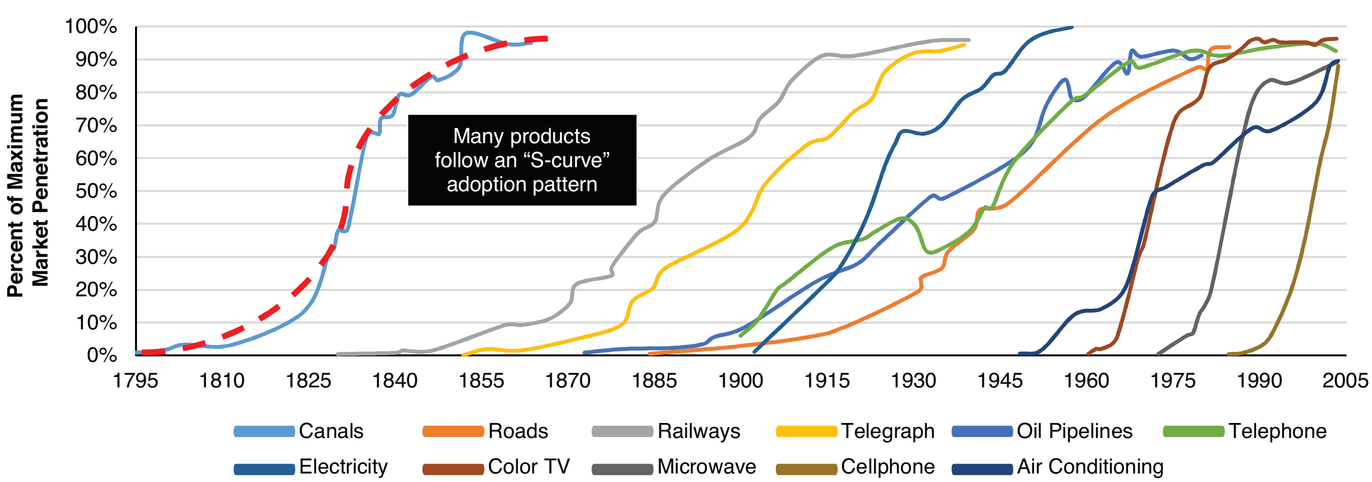

Figure 8: The diffusion of a technology in a market often follows an S-curve[4]

In an S-curve model, the penetration of a given product (and therefore its impact) in a given year is determined by the following function:

$$Penetration\ in\ year\ y = \frac{M}{1 + e^{-k(y-x)}}$$

"*M*" is the maximum penetration that a product will be able to achieve (this number will be between 0% and 100%). "*k*" is a factor that controls the speed of penetration. Higher values of *k* mean that a product will penetrate the market faster. Finally, "*x*" is the year in which the product achieves 50% of its maximum penetration (*M*). The key question is how to decide on values for *M*, *k*, and *x*? Different values for these three parameters can create enormous differences in the derived Emissions Reduction Potential.

Note that if a new venture is developing a product or service that can service multiple markets or is developing multiple markets, this analysis must be performed for each market.

Estimating the parameters of the adoption model and identifying the proper market

Market *penetration* follows a predictable pattern while market *growth* does not necessarily follow the similar predictable patterns. We thus find it more reliable to use market penetration to estimate a company's impact potential. Within a given market, we argue that the parameter *M* should be 100%. We make this assumption for the purpose of standardization and for the purpose of measuring the technical mitigation potential. As different investors may have different opinions about what a reasonable market share might be, we choose to define the potential based on the entire market. Identifying the proper market is therefore critical.

We define the market as the entire market for the product that the company is developing. That is, we don't define the market as the portion of the market that we believe the company is likely to achieve. We do not describe the company's potential market share. For example, in electric power, steam turbines power nearly all coal-fired power plants, despite the fact that there are many providers of steam turbines (GE, Siemens, etc.). A venture developing a product to improve the efficiency of a steam turbine should consider the entire steam turbine market as its potential market, rather than considering the market size of a specific provider (unless, of course, the venture's product was only applicable to a single company's turbine).

For products competing in markets that do not already have a low GHG alternative product, the proper market is the market of the incumbent GHG emitting product. For example, if a new venture were developing a novel low carbon cement production process or an electric aircraft – markets in which few, if any, existing low carbon products compete – penetration would be defined as the total amount of the traditional cement or aircraft market that the venture had captured.

For new ventures competing in markets with existing low GHG alternatives, the proper market is the market of the product that the new venture is enabling or displacing. For example, if a venture were developing a solar

PV technology that was expected to displace today's dominant solar technology – crystalline silicon – the proper market would be the crystalline silicon PV market.

The next key step is to estimate this market's growth over time.

Using widely accepted forecasting agencies to estimate a market's growth over time

By now, the reader understands that there is no universally accepted method for estimating the future growth of a market. We introduce two possible pathways for estimating the potential growth of a market, and argue that one method – adopting the forecasts provided by recognized forecasting agencies – provides the consistency and simplicity required by early-stage investors.

The first pathway involves using an investor or entrepreneur's own estimates of the potential growth of a market. While these estimates may be informed by significant expertise, there are two key challenges with this method. First, entrepreneurs (and, in some cases, investors) have a natural incentive to inflate estimates of market growth and time to market. Second, one investor's view of the future may be dramatically different from another's, so this method does not create the consistency necessary to compare across ventures and investors.

The most promising approach is to use widely-accepted forecasts as benchmarks for market growth (the challenges of using these forecasts are discussed below). The forecast used will depend on the market in question. For example, for electric power forecasts, the most reliable source may be the International Energy Agency (IEA). For forecasts of air traffic demand, the most reliable source may be the International Air Transport Association. For forecasts of demand for agricultural products, the U.S. Department of Agriculture is useful, etc. Regardless of which forecast is used, be consistent and use the same forecasts when considering all electric power products, the same forecast when considering all agricultural technologies, etc.

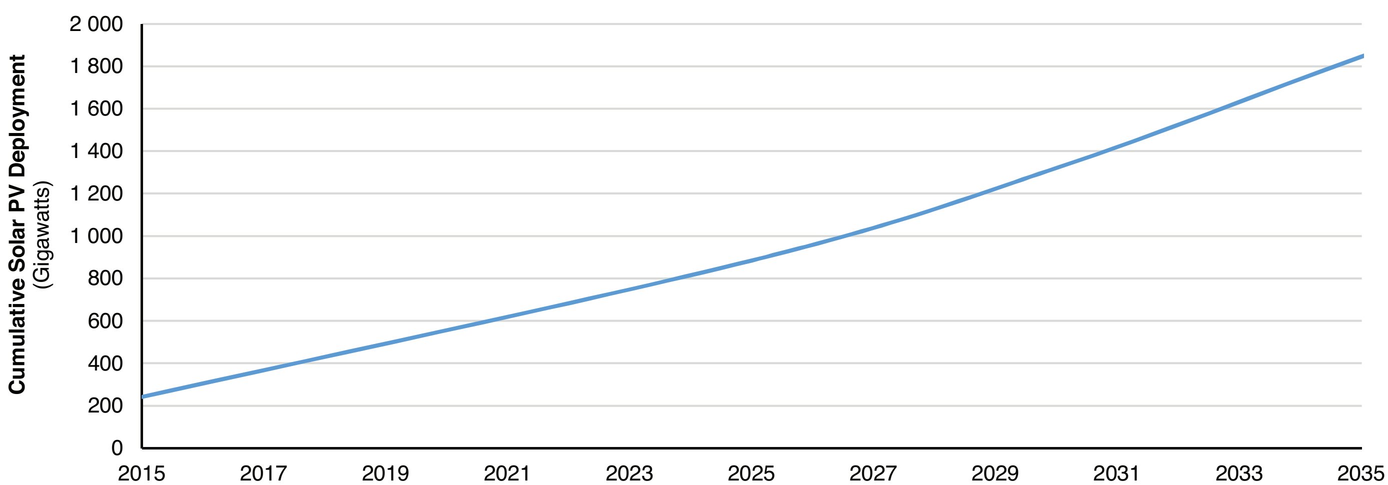

Figure 9: Forecasted solar PV market growth in the IEA's 2-Degrees Scenario. The IEA is one source of standardized market forecasts.

Some forecasting agencies – such as the IEA – provide forecasts of the growth of many major industries (for example, solar, wind, electric vehicles, etc.). Using forecasts from a single agency creates internally consistent estimates across products. However, it is not always possible to use internally consistent forecasts. This creates potential unavoidable discrepancies between estimates for companies in different markets. Regardless, the key is to use a third-party forecast that can be referenced by any investor, rather than a proprietary forecast.

Be wary of potential constraints on scaling. For example, if a product relies on a certain rare element, the market for this product cannot be so large as to exceed the global supply of this element. While these constraints can be challenging to identify, they may be important to consider. Therefore it is important to assess whether a given product relies on scarce natural resources or is targeting only a niche portion of a larger market.

Conservative, base, and aggressive forecasts and the challenges of using widely accepted forecasting agencies

It is critical to note that the goal of using forecasts established be recognized forecasting agencies is not to achieve greater degrees of accuracy – indeed, as we will describe, credible forecasting agencies have demonstrated consistently poor results over time. Rather, the goal is to use forecasts that can be leveraged and referenced by any investor and any startup and that do not rely on any individual company's or investor's biases.

Forecasts – even those performed by the most experienced organizations such as the IEA – will most often not predict the future with great accuracy. For example, the International Energy Agency has consistently underestimated the growth of solar PV due to a variety of factors. Figure 10 below demonstrates this failure. This fact underscores the idea that these forecasts should be used to create estimates of Emissions Reduction Potential that are consistent across new ventures, rather than to make predictions about the potential future success of a new venture.

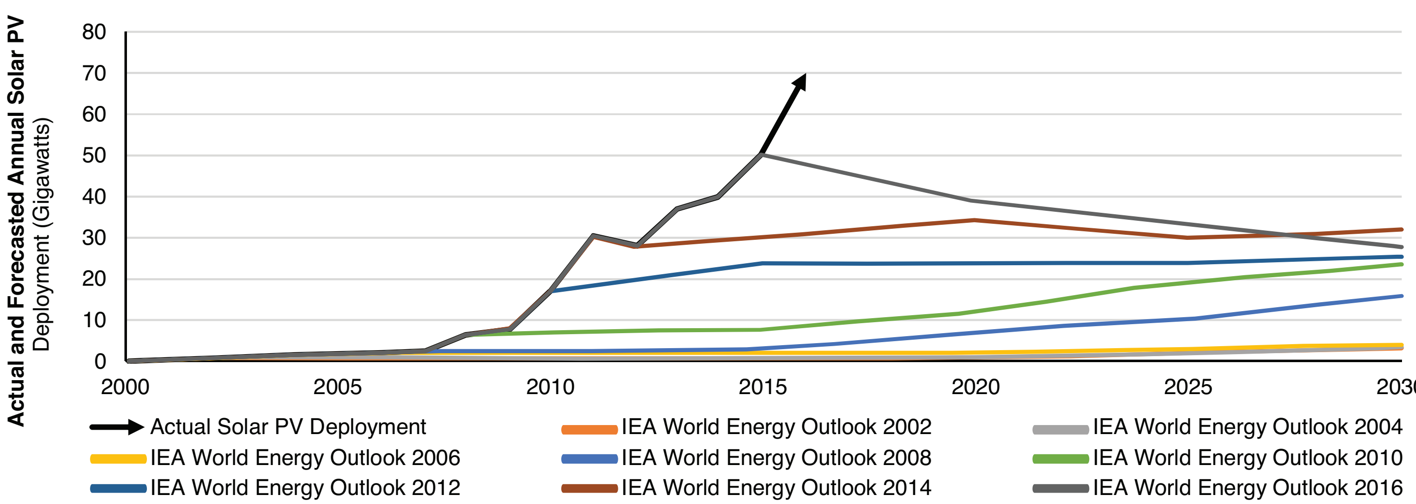

Figure 10: The International Energy Agency has consistently underestimated the growth of solar PV, demonstrating the challenges of relying on forecasts as predictions of the future[5]

The solar PV example reveals a key challenge of using the forecasts of organizations such as the IEA. If, for example, an investor had been considering an investment in a solar PV company in the year 2000, he or she may have estimated low potential impact given the IEA's small forecasted market size. This would, of course, be a poor estimate. It is important, therefore, to use such forecasts with caution and consider creating aggressive, conservative, and base cases. Additionally, as we will discuss in Section 5, ERPs should ideally be updated annually as new forecasts becomes available.

We recommend using the following forecasting agencies for conservative, base, and aggressive forecasts:

- **Conservative forecast:** IEA World Energy Outlook "Current Policies" Scenario;
- **Base forecast:** IEA Energy Technology Perspectives "Reference Technology Scenario";
- **Aggressive forecast:** IEA Energy Technology Perspective "2°C Scenario."[6]

Estimating the pace of growth

Once the appropriate market has been identified, the next step is to estimate the rate of adoption of the new venture's technology – in other words, estimate *x* (the year in which a technology achieves 50% market share) and *k* (a parameter that roughly describes how fast a company scales). Estimating *x* and *k* is the most challenging, and, in some cases most subjective, part of estimating the potential growth of a given product. There are two primary paths for estimating *x* and *k*. The first involves using an appropriate benchmark such as the rate of penetration of a similar product or venture. The second simply involves making an assumption.

For many mature markets, it is possible to use historical information to identify when certain products were introduced into the market and when these products reached roughly 50% market share. In these cases, these values can be adopted. However, for many immature markets, it may be very challenging to properly estimate *x* and *k*, as different values of *x* and *k* can create adoption curves that look similar in early stages of adoption (see Figure 11). Thus, we recommend benchmarking with caution.

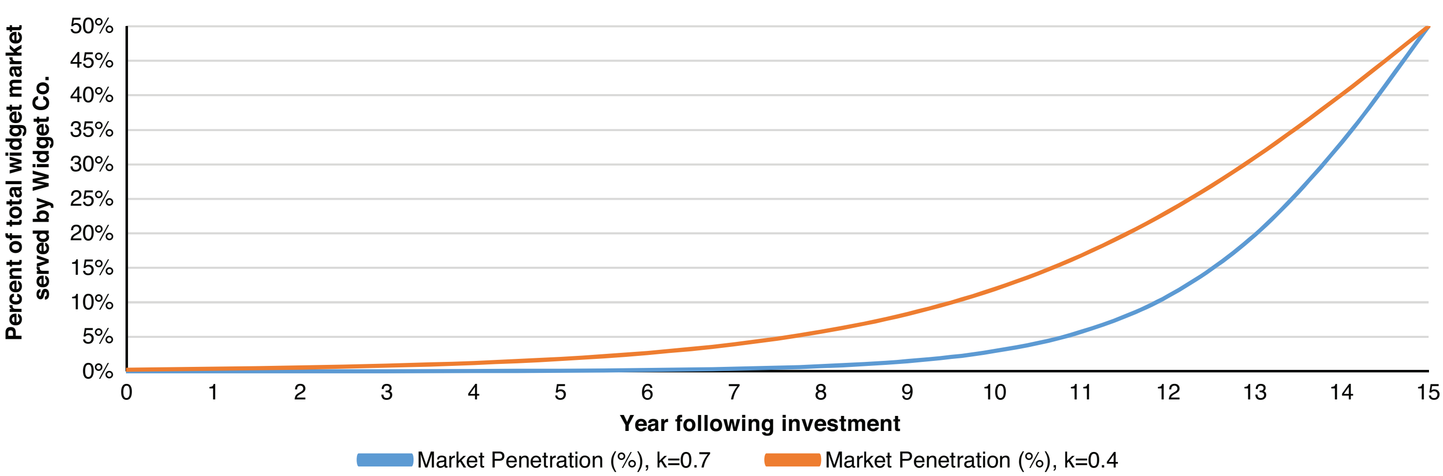

Figure 11: In the early stages of adoption, it can be challenging to differentiate between different growth pattern

Where data is unavailable or unsatisfactory to perform a proper benchmark, simply assume specific values for *x* and *k* and use these values for all other estimates where data is sparse. While this assumption-driven process may be unsatisfying for those of us that prefer precision and data-driven approaches, it creates estimates that are comparable across companies – a critical feature of useful climate impact metrics.

Step 5: Putting it all together to estimate Emissions Reduction Potential.

Once we have estimated all factors – the mechanism of impact, the emissions of the displaced and produced products, and potential product deployment – it is straightforward to combine these factors to create an estimate of Emissions Reduction Potential. We do so according to the function detailed below (this function is a more elaborate version of the function introduced at the earlier in this document). The basic process is to calculate the marginal emissions per unit of the new ventures deployment, and multiply it by the amount of product deployed. We must account for additionality in the calculation of the emissions of the displaced product. Example Emissions Reduction Potential calculations are provided in the Supplemental Materials.

$$\begin{aligned} &Emissions\ Reduction\ Potential \\ &= (Total\ system\ emissions\ in\ scenario\ without\ the\ new\ venture's\ product \\ &- total\ system\ emissions\ in\ scenario\ with\ the\ new\ venture's\ product) \\ &= \sum_{y=1}^{30}\left[\left(\frac{Emissions\ of\ Displaced\ Product\ in\ year\ y}{Unit\ of\ Product\ Sold} - \frac{Emissions\ of\ Product\ in\ year\ y}{Unit\ of\ Product\ Sold}\right) \right. \\ &\left. * (Penetration\ of\ Product\ in\ year\ y) * (Market\ Size\ of\ Product\ in\ year\ y)\right] \end{aligned}$$

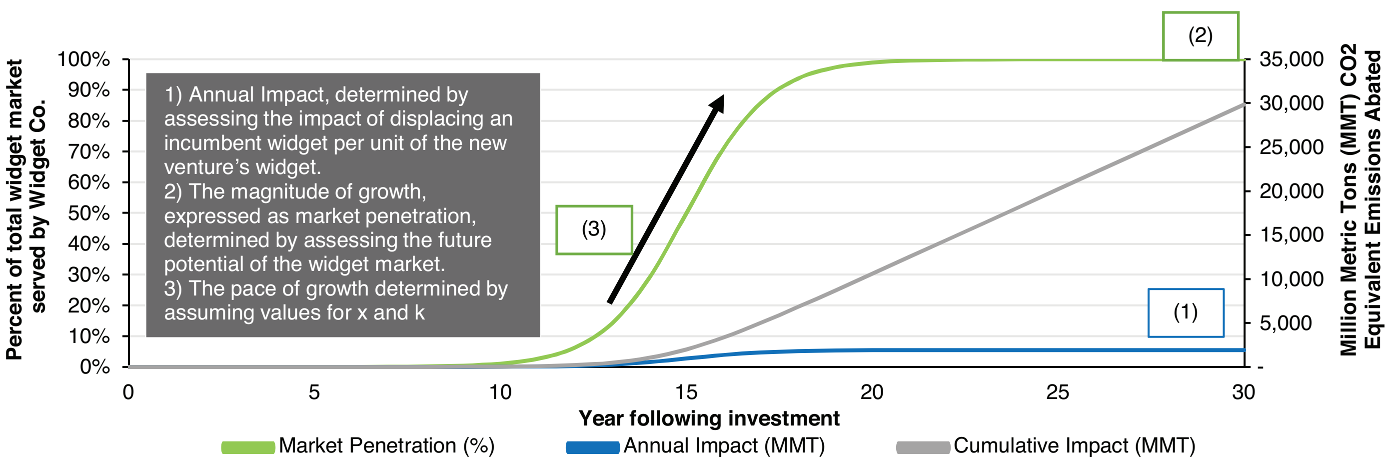

Figure 12: The Emissions Reduction Potential of a hypothetical "widget" manufacturer

5. TRACKING EMISSIONS POST-INVESTMENT

Once an investment is made and a company eventually begins deploying its product, investors have many tools at their disposal with which to measure and track impact. However, pre-product and pre-revenue companies or companies whose product is still very nascent will have insignificant immediate impact. From a climate-impact perspective, there is little tracking that can be done post-investment while the company remains pre-product. Investors can engage in two primary tasks. First, we can continuously update the assumptions used in their initial estimate of ERP to better reflect reality. Second, we can support entrepreneurs in building a more impactful company.

As new information becomes available, investors may wish to update their assessments to better reflect the ERP of their investment or portfolio. This process may involve changing the timeline to market or updating market forecasts. As we noted previously, forecasting agencies consistently change their market forecasts, so updating this information can in some cases dramatically change an impact estimate.

In some cases, investors may wish to compel their portfolio companies to develop more impactful development pathways. The purpose of this report is to estimate ERP, so we highlight these options without advocating for them. Certain reporting frameworks – such as those provided by B Labs, a non-profit that provides impact assessments and certifications, and the market leader in impact reporting frameworks for early-stage companies – push companies to develop more environmentally friendly supply chains and/or energy procurement strategies. B Impact Assessment also assesses many factors beyond climate impact. B Lab is a leader in impact reporting frameworks for early-stage companies, but it is not the only organization providing such frameworks.

Once a company has begun manufacturing and deploying its product, it is possible to track the emissions created in the production, delivery, and operation of the product, as well as the emissions displaced by product usage. A number of organizations support impact tracking for operating companies. For example, B Labs aggregates B Impact Assessments into GIIRS ratings which can be used to compare and track the progress of funds. The ImPact – a non-profit dedicated to helping investors better track and manage their impact investments – helps investors track a variety of metrics using a customized platform built on Addepar.

Impact reporting frameworks must balance detail and burden – more detail allows investors to make more informed decisions, but strict reporting requirements can distract a new venture from growing and achieving impact. Ideally, a reporting framework would track the key details that allow an investor to understand the climate impact of the venture: the emissions associated with the production and operation of the venture's product, the location and volume of deployments, and the key characteristics of the incumbent products in the locations of deployment.

Pivots are extremely common in early-stage ventures. In some cases, a company may pivot from one market that promises dramatic GHG reductions to a market that promises few GHG reductions or even potentially GHG increases. In some cases a pivot can serve as a bridge to longer term success in a GHG mitigating market, while in other cases, the pivot may mean the company never achieves any appreciable emissions reduction. Investors must make their own decisions as to whether or not to continue to support the new venture in the face of these pivots.

6. CONCLUSIONS

Creating actionable climate impact metrics for early-stage ventures is challenging. This report seeks to clarify the key challenges that we as investors face in estimating potential climate impact and to propose workable solutions to these challenges for the benefit of the field. Mobilizing capital to the most promising climate solutions requires sound metrics and methodologies for assessing potential climate impact. This report takes the first step toward establishing such metrics and methodologies with three primary contributions:

1. An introduction to the metrics needed by climate-motivated early-stage investors: Emissions Reduction Potential.

2. A process for down-selecting the universe of potential investments based on potential climate impact.

3. A methodology for creating actionable and consistent forward-looking climate impact metrics for early-stage ventures.

Notably, investors need information about the Emissions Reduction Potential of their early-stage investments. Financing early-stage ventures that are attacking the climate challenge is a powerful arrow in the quiver of climate solutions. Because the majority of today's impact metrics and assessments are retrospective in nature and focus on the emissions reduced by the company as it exists today, they do not provide early-stage investors with the information needed to make informed decisions.

Estimating the Emissions Reduction Potential can be a time-intensive process. Thus, in order to save investors (and companies) time and resources, this report proposes a process to allow investors to down select from the universe of potential investments to a small number of investments based on proxies for climate impact such as affiliation, technology focus, and entrepreneur input. Down selection does not replace impact assessment processes, but rather allows investors to focus their efforts on a select set of ventures.

This report introduces, for the first time, a methodology for estimating the Emissions Reduction Potential of a new venture. The methodology we propose requires looking forward into an uncertain future. Given the systemic uncertainties that plague any vision of the future, the goal of the proposed methodology is to provide a consistent framework within which to compare similar and dissimilar startups. The defined methodology allows investors to understand the relative potential impact of one venture versus another. As methods and assumptions become transparent and standardized, these metrics can be used by asset owners and advisors to compare the performance of investors as well. Many elements of the framework proposed require further development. By laying out the elements of a successful climate impact assessment methodology, this report creates the groundwork upon which this development can take place.

Based on the work we conducted for this report, we are certain the field would benefit from a streamlined analytics software platform purpose-built for varying types of early-stage investors that might want to assess climate impact – angels, venture capital firms, corporate/strategic investors, or philanthropists. The complexities of building such a tool demand further research and development which is outside the scope of this report, but which we hope to help advance for the field in the years ahead.

It is our hope that the methods and concepts identified in this paper will one day translate into standards used by early-stage investors of all types. We believe the early-stage investment community could benefit from the same standardization of sustainability metrics and reporting processes that has occurred for late-stage and public companies. Moving forward PRIME and NYSERDA hope to support this standardization and metric development, which could build off of a more streamlined analytics platform.

Investors will be critical to combatting climate change by investing in the development and deployment of low greenhouse gas solutions. Due to the combined investments from the public and private sectors, the cost and competitiveness of many clean energy solutions such as solar PV, wind, LEDs, and electric vehicles have made incredible progress in recent years. These successes mean that today, late-stage, public equity, and debt investors have a variety of ways to optimize their portfolios for climate impact, and have the tools, services, and data necessary to balance their climate impact against other goals. Early-stage investors cannot sit on the sidelines: the climate challenge is too urgent and the opportunity is too large. By estimating and tracking potential climate impact, early-stage investors can begin to mobilize capital to the most impactful solutions – solutions that will save lives and ecosystems in the future. Many early-stage investors are already investing to help avoid the worst effects of climate change. But these investors – and many more – must redouble their efforts. Humanity's ability combat climate change depends on our ability to harness the power of innovation.

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Climate Impact Advisors

The first set of advisors, Climate Impact Advisors, are experts in the fields of climate science, energy systems, and impact analysis. These advisors guided PRIME and NYSERDA in the development of a scientifically grounded and rigorous impact assessment process.

Advisor	Title	Affiliation
Bob Armstrong	Director, MIT Energy Initiative, and Professor of Chemical Engineering	Massachusetts Institute of Technology
Ken Caldeira	Climate Scientist and Professor (by courtesy)	Carnegie Institution for Science, Department of Global Ecology and Stanford University, Department of Earth System Science, Stanford University
David Danielson	Managing Director	Breakthrough Energy Ventures
David Henshall	Former Deputy Director for Commercialization	Advanced Research Projects Agency – Energy (ARPA-E)
Ory Zik	Chief Research Officer	ImpactIQ

We are also deeply grateful to the colleagues of the above advisors that made thoughtful comments and edits to this report. Specifically Lucas Spangher of ARPA-E, and Anna Goldstein and Fan Tong, who are both researchers working with Professor Ken Caldeira.

Climate Investment Advisors

In addition to the Climate Impact Advisors listed above, PRIME engaged a number of Climate Investment Advisors. These advisors are experts in the investment ecosystem that supports climate innovation, and

guided PRIME and NYSERDA in ensuring that the report reached its target audience, which include their members, clients, benefactors, investors, or constituents.

Advisor	Title	Affiliation
Doug Buerkle	Founding Executive Director	NEXUS-NY
Regine Clement	CEO	CREO Syndicate
Alison Ernst	Senior Manager of Investments	Massachusetts Clean Energy Center (MassCEC)
Dana Lanza	CEO and Co-Founder	Confluence Philanthropy
Ken Locklin	Director	Impax Asset Management
Peter Rothstein	President	Northeast Clean Energy Council (NECEC)
Nicholas Querques	Program Manager	NYSERDA
Pearline Yum	Senior Associate	The ImPact

We are also deeply grateful to the colleagues of the above advisors that made thoughtful comments and edits to this report. Specifically Mark Torpey of NYSERDA, Logan Yonavjak of the CREO Syndicate, and Mark Allegrini of Confluence Philanthropy.

Individuals interviewed in the production of this report

In the development of this report, PRIME conducted over 40 interviews with the individuals highlighted in the table below.

Interviewee	Title	Affiliation
Alicia Seiger	Deputy Director	Stanford Steyer-Taylor Center for Energy Policy and Finance, and Member of the Board of Directors of PRIME Coalition
Alison Ernst	Senior Manager of Investments	Massachusetts Clean Energy Center (MassCEC)
Amanda Feldman	Director	Bridges Impact+
Anna Goldstein	Postdoctoral Research Fellow	Harvard Kennedy School
Bob Armstrong	Director, MIT Energy Initiative, and Professor of Chemical Engineering	Massachusetts Institute of Technology
Christina Zimmermann	ESG Integration and Impact Investment Consultant	Independent
Christopher Farrow	Program Associate	B Lab
Clara Vondrich	Global Director	Divest-Invest Philanthropy

Curtis Probst	Managing Director	Rocky Mountain Institute
Dan Steingart	Associate Professor of Mechanical and Aerospace Engineering	Princeton University
Dana Lanza	CEO and Co-founder	Confluence Philanthropy
David Danielson	Managing Director	Breakthrough Energy Ventures
David Henshall	Former Deputy Director for Commercialization	Advanced Research Projects Agency – Energy (ARPA-E)
Doug Buerkle	Founding Executive Director	NEXUS-NY
Fan Tong	Postdoctoral Research Scientist	Carnegie Institution for Science
Ingo Michelfelder	Postdoctoral Fellow	Massachusetts Institute of Technology
Jacob Donnelly	Senior Vice President	Bain Capital Double Impact
Jean Shia	Head of Portfolio and Investment	The AutoDesk Foundation
Jeff Waller	Principal, Sustainable Finance	Rocky Mountain Institute
Jennifer Signori	Director	Bridges Impact+
Joe Silver	Program Manager	ACRE
Jonathan Bailey	Head of Environmental, Social & Governance Investing	Neuberger Berman
Julia Byrd	Operations Manager	PowerBridgeNY
Ken Caldeira	Climate Scientist and Professor (by courtesy)	Carnegie Institution for Science, Department of Global Ecology and Stanford University, Department of Earth System Science, Stanford University
Ken Locklin	Director	Impax Asset Management
Laura Kutnick		Kutnick Family Foundation
Logan Yonavjak	Manager, Research and Analysis	CREO Syndicate
Lucas Spangher	Data Science Fellow	Advanced Research Projects Agency – Energy (ARPA-E)
Mark Allegrini	Climate Solutions Collaborative Manager	Confluence Philanthropy
Mark Torpey	Director, Research & Development	NYSERDA
Monique Aiken	Director	Tideline
Nick Rancis	Regional Director	Rocky Mountain Institute
Ory Zik	Chief Research Officer	ImpactIQ
Paul Bodnar	Managing Director	Rocky Mountain Institute
Pearline Yum	Senior Associate	The ImPact
Pete Murphy	Senior Associate	The Global Impact Investing Network (GIIN)

Regine Clement	CEO	CREO Syndicate
Santiago Perez	Analytics Associate	B Lab
Toren Kutnick		Kutnick Family Foundation

HELPFUL RESOURCES

Resources for climate impact metrics

1. The IRIS database, maintained by Global Impact Investing Network, provides a number of useful metrics as well as reports on impact measurement: https://iris.thegiin.org/

Resources for assessing ERP

1. Lifecycle assessment databases provide useful information regarding the greenhouse gas impacts of certain products.
   - Life Cycle Assessment Commons: https://www.lcacommons.gov/catalog
   - Greenhouse Gas Protocol Lifecycle Databases: http://www.ghgprotocol.org/life-cycle-databases
2. Emissions factor databases can be useful in estimating the impacts of operating certain products.
   - EPA Center for Corporate Climate Leadership GHG Emission Factors Hub: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub
   - IPCC Emissions Factor Database: http://www.ipcc-nggip.iges.or.jp/EFDB/main.php
   - Greenhous Gas Protocol Calculation Tools: http://www.ghgprotocol.org/calculation-tools
3. Energy analysis agencies can be useful for creating standardized market growth estimates.
   - The IEA World Energy Outlook reports and associated data tables can be found online here: https://www.iea.org/weo/
   - The IEA Energy Technology Perspectives reports and associated data tables can be found online here: http://www.iea.org/etp/

Resources for tracking emissions post-investment

1. B Analytics' impact assessment and reporting tools can be useful for later stage companies that want to track and report their impact: http://www.b-analytics.net/

End Notes

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[5] Data source: IEA World Energy Outlook reports, 2002-2016.

[6] The IEA World Energy Outlook reports and associated data tables can be found online here: https://www.iea.org/weo/
The IEA Energy Technology Perspectives reports and associated data tables can be found online here: http://www.iea.org/etp/


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