Barriers to the Timely Deployment of Climate Infrastructure

Full Report

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[1] FOAK projects are first-of-a-kind projects. FOAK (1-to-n) projects are the first 1-to-n-of-a-kind projects, where n is the number of times the same type of project gets implemented. Further details around the definition of a FOAK project can be found in Chapter 3.

Prime

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Background

In February 2021, Prime Coalition, Schmidt Futures, and Blue Haven Initiative came together to launch an exploration project implemented at Prime to characterize the gaps holding back the deployment of climate infrastructure in the U.S. and to explore whether catalytic[2] capital could help bridge those gaps.

The project focused on the dual objectives of:

- Enabling deployment of nascent climate solutions.
- Accelerating deployment of existing climate solutions.

The output of that exploration is captured here and draws on:

- Primary research: interviews with over 140 senior members[3] of the climate ecosystem.[4]
- Secondary research: written publications[5] on the topic.

Acknowledgements

The author is grateful to Richard Kauffman, Mark Barnett, Sarah Kearney, Matthew Nordan, Johanna Wolfson, and Lou Schick for their invaluable support and advice throughout the exploration phase and the production of this report; the interviewees for their time and contributions to the analysis; and Steven Fox for his contribution to sector deep dives. The author thanks Anjali Deshmukh and Sophia Sun for proofreading, and Sylvia Weir for designing the report.

[2] In this paper, we will use catalytic capital, catalytic investors, or catalytic capital providers to mean those whose paramount priority is charitable impact, for whom financial returns are not the top priority, and who are able to absorb risk, timelines, or financial returns that finance-first capital cannot. Catalytic Capital is further defined in Chapter 9.

[3] See Appendix F.

[4] Including Project Finance capital providers, VCs, federal and state governmental institutions, technology companies, developers, catalytic capital providers, academics and philanthropic organizations.

[5] See Appendix G.

1. "Code Red for Humanity"

In August 2021, U.N. Secretary General António Guterres described the latest Intergovernmental Panel on Climate Change ("IPCC") report on climate as a "code red for humanity." The report stated that "Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in carbon dioxide (CO_2) and other greenhouse gas emissions occur in the coming decades."[6] He added: "If we combine forces now, we can avert climate catastrophe. But, as today's report makes clear, there is no time for delay and no room for excuses."

Figure 1: Climate Facts

1.1°C	**The increase in temperature since pre-industrial times**
2,400bn tonnes	**CO_2 humans have emitted to date**
500bn tonnes more	**Would leave only a 50-50 chance of staying under 1.5°C**
40bn tonnes	**Rough amount of CO_2 humanity emits every year**

Source: IPCC

Solving the emissions reduction puzzle will require an all-hands-on-deck approach, with a combination of (a) accelerating the deployment of renewable energy, electric vehicles, and energy efficiency measures, (b) reshaping industries and value chains, including for agriculture, transportation, manufacturing processes and hard-to-abate industries such as cement, steel, glass and others, and (c) removing atmospheric carbon.

De-risked solutions are currently being deployed at scale (e.g., wind and solar generation projects and, to a lesser extent, electric vehicle charging infrastructure), but their breadth and speed of deployment need to be accelerated. In addition, deploying wind and solar alone will not be sufficient.[7] Climate solutions need to include green hydrogen, supply chain efficiency improvements, carbon reducing and/or removal technologies, and a range of natural solutions. For most of these additional solutions, technologies are still nascent and need to be demonstrated to work; markets need to be developed; and solutions commercialized and then taken to scale. Achieving these objectives will require pushing nascent climate solutions through the scale-up and deployment process faster than would otherwise happen if left to typical market dynamics. Given the lengthy development and implementation cycles, solutions will in large part need to be commercially proven (i.e., bankable[8]) by 2030 in order for them to be scaled up between 2030 and 2050.

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[6] IPCC, 2021. "Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change" [MassonDelmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press. https://www.ipcc.ch/report/ar6/ wg1/downloads/report/IPCC_AR6_WGI_Headline_Statements.pdf

[7] According to the International Energy Agency ("IEA"), around 35% of GHG emissions reduction must come from technologies currently at the prototype or demo phase.

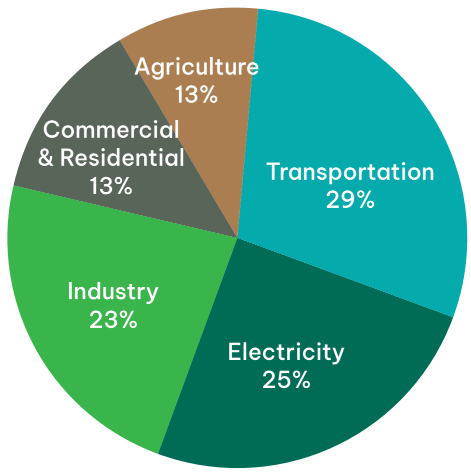
[8] To be considered commercially proven or bankable, technologies need to have been implemented and operated continuously for a significant length of time in the same conditions (same feedstock, temperature, seasonality, equipment, etc.) as the project contemplated to be funded.

2. Macro Perspective

Solving the global climate challenge demands large-scale technological and market innovation and transitions in virtually all sectors of the economy.

Innovation in most of these sectors is not a new phenomenon. Historically though, most of the innovation in power generation or transportation, for example, consisted of incremental technology improvements (e.g., next generation gas turbines, steam turbines, etc.) in the hands of incumbent, large companies with deep pockets (e.g., GE, ABB, Siemens for power). These companies would fund, test, correct, and improve the given technologies until ready for prime time. Performance guarantees from such companies and/or direct funding for these early projects would then accompany the first few deployments, until enough track record was established and at such time, the project became bankable, allowing for third parties to take over.

Figure 2. Total U.S. Greenhouse Gas Emissions by Economic Sector in 2019



Source: EPA[9]

Today, the scale of innovation needed to solve the climate crisis needs to be transformational as well as incremental. Efficiency improvements alone are not sufficient. Yet, for companies in the S&P 500, average R&D spending in 2020 was close to 0% of revenues for Utilities (0.0%), Industrials (0.7%), and the Energy sector (0.1%) (compared to 10.2% in Healthcare and 11.4% in Information Technology, and 5% for Tesla, for example). Furthermore, some of these transformations — while essential — also threaten the fundamental business for incumbents. Most of the transformational innovation thus seems to be happening in the hands of young, undercapitalized startups,[10] who rely on venture capital to grow.

VCs have adapted and are increasingly investing in early-stage asset-heavy tech companies. Frontier project investors are expanding investments to more innovative business models around proven technologies. But innovative hard tech companies, which are often small undercapitalized start-ups, end up facing funding gaps when they reach the stage where they either need to develop and implement larger demonstration projects, or when these projects[11] are not yet deployed at a scale sufficient to warrant project financiers' attention.

[9] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

[10] While certain large industrial companies have in house innovation activities, many of these companies subscribe to a "purchase" model, where they wait for new technologies — and access to markets — to be developed and de-risked prior to acquiring them.

[11] This report focuses on deployment of projects, i.e., either installation and/or construction of projects by a special purpose entity that delivers a product to one or more customers, either physically or as a service. Commonly structured as Project Finance transactions, these deployments are typically funded —once mainstream — by a combination of sponsor equity and limited recourse debt.

2.1. Significant Contextual Tailwinds

The news is not all bad. In fact, one may think there are sufficient tailwinds for the U.S. to achieve its stated objectives:

- Climate is no longer a fringe concern, with consumers oftentimes being the impetus behind the decarbonization and waste reduction efforts of supply chains and production processes.
- Corporations are stating ambitious plans to decarbonize, signing net zero pledges (e.g., Microsoft, Amazon)[12] and/or purchasing carbon offsets (e.g., Google[13], Shopify[14]).
- Climate transition funds are being raised at unprecedented speed and in staggering amounts.
- Governments are stepping in and proposing ambitious plans to address some of the gaps.

These observable tailwinds to the deployment of climate solutions in 2021 should serve as critical evidence to catalytic investors that once projects become ready for "widespread adoption," large pools of finance-first[15] capital are ready to take up projects for the next stage of deployment.

2.2. But the Deployment of New Capital Intensive Innovation Faces Major Headwinds

Unfortunately, the following dimensions often keeps climate innovations stuck[16] in early deployment purgatory:

- **Lengthy timelines to widespread adoption, due to:**
  - The need to prove the technology works reliably;
  - The need to establish customer adoption;
  - The need to prove the product can be built at scale;
  - Ensuring adjacencies – if any – are also ready for deployment;
  - Long project development timelines and/or high costs;
  - Policy or regulatory bottlenecks or dependencies; and
  - The need for economies of scale and technology maturity to bring costs down.

  Most of these steps take place sequentially, often resulting in decades before reaching a point of "widespread adoption," as evidenced by the solar example.[17] By the early 2000s, solar panels were largely "ready for deployment," at least from the perspective of module manufacturers and venture investors. Most of the delay in scaling deployment (in the mid-2010s) was due to delays in customer adoption, a tenuous value proposition for utility scale solar given the relatively high costs of solar generation compared to traditional fossil fueled power at the time, as well as the lack of experience and comfort of capital providers[18] around the underwriting criteria (including precision around insolation calculations, panel degradation risks, tax equity markets, etc.)

[16] "Despite these facts, many companies have recently been raising large amounts of capital from VCs, as illustrated by Commonwealth Fusion Systems, as an example, who recently raised $1.8Bn in Series B funding to "commercialize fusion energy."

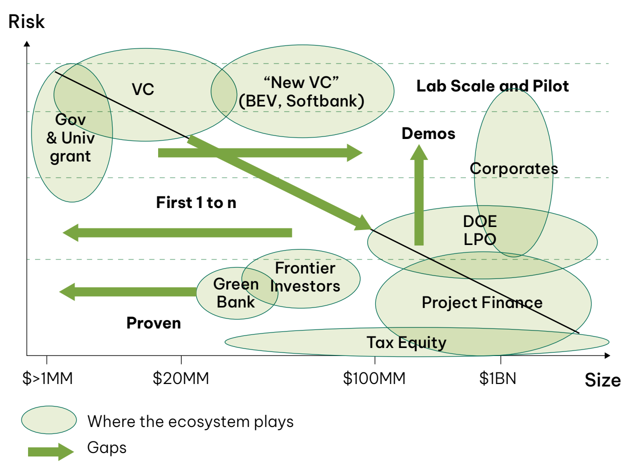
[17] See Appendix A.

[18] Equity and debt providers.

- **Risk/size/return profile fits with neither mainstream VC nor Project Finance**
  A helicopter view of the ecosystem where VCs[19] and Project Finance capital providers currently play supports the empirical conclusions:
  - Project Finance capital providers typically focus on low risk, low return, and large investments (with long term horizons for equity investors).
  - VC investors typically focus on high risk, high return, and historically small investment sizes[20] (and a short term horizon), using a portfolio diversification approach to meet overall return targets.

  Layering in the current investment ecosystem, and stages of technology innovation, gaps appear at virtually every level of deployment, particularly when:
  - Climate solutions require a combination of higher risk and larger investment amounts (e.g. demonstration projects larger than $20mm, FOAK (1-to-n)).
  - Climate solutions require smaller investment amounts (e.g., small distributed projects, regardless of whether the technology is proven.

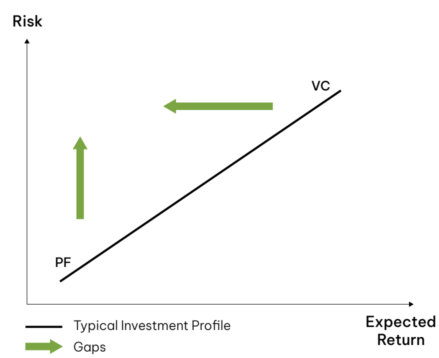
Figure 3. Investment Ecosystem for Climate Solutions



Note: Size axis is indicative (not at scale) and different across tech stages

Source: Prime Coalition

Figure 4. Risk Return Profile for Project Finance and VC



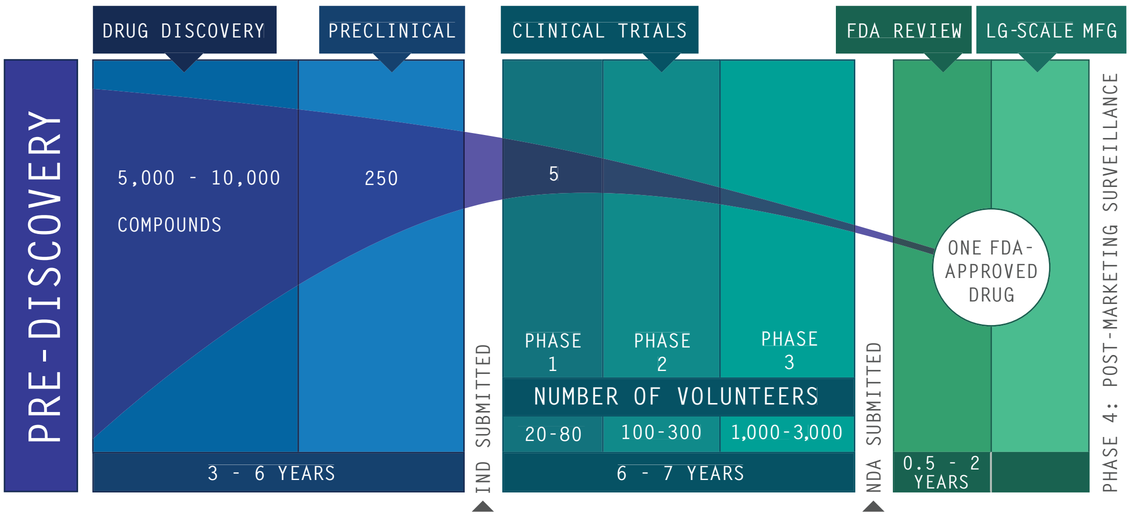
Source: Prime Coalition

  Gaps are particularly glaring when returns fall below their expected risk-adjusted levels, which often happens for early deployments (as expected economies of scale or learnings have not yet been reached).

- **Lack of standards from pilot to proven**
  The lack of standardization — and endorsement by a trustworthy body — of the steps from pilot to bankable makes it hard to create immediately obvious tangible value from these investments. For example, compared to climate innovations, in drug development cycles for drug discovery, the investments and timelines are potentially as high, lengthy and risky, but, in contrast, the various accretive steps are clear and standardized, as shown in Figure 5, making it easier for investors to determine the appropriate risk adjusted returns, prerequisites for investing and performance metrics at each stage of the process.

[19] For purposes of this analysis, we are including Seed, early stage VCs, Late stage VCs and Growth investing under the "VC" label.
[20] There are exceptions such as BEC, Softbank, etc. that have recently started investing larger amounts in climate innovation, but they will still look for high return investments.

Figure 5. Drug Discovery and Development



Source: Pharmaceutical Research and Manufactuers of America

The lack of standardization stems to some extent from the variations in the process across technologies.[21] But the absence of standards and process certification generates a great level of confusion among capital providers (who rarely represent a combination of technical/operational/market experts specialized in a specific technology) on how to assess the risks or value of a particular deployment. It is much easier to wait for a track record of operating hours across several similar projects. In addition, even for technology providers, the lack of standards and push for results from their investors sometimes leads executives to knowingly or unknowingly[22] skip steps, while in search for earlier revenue/value generating opportunities, or get stuck in a permanent "demonstration" phase, when the right parameters are not taken into account.

[21] In his 2017 report, titled "Across the "Second Valley of Death": Designing Successful Energy Demonstration Projects," David Hart states the "Muddle in the middle stems from an effort to overgeneralize the innovation process, which varies greatly across technologies."

[22] One of the interviewees, a technology company executive, referred to his VC investor's imposed target to "be at the demonstration stage" by a given date, without definition of what that meant. There are no standards for what a demonstration stage entails. The executive in question welcomed an effort to standardize definitions and processes.

- **At times, lack of compelling economics in the early days until costs come down or incentives are legislated**
  In the early days of the deployment of a solution, it is not uncommon for the economics of a new technology deployment to be suboptimal, due to a number of possible factors:
  - **Economies of scale needed to bring costs down:** when fixed costs of equipment production are amortized over a small number of early projects, costs are much higher than when they are amortized over a large volume of products. In the example of a long term storage technology provider currently in the demonstration phase, the estimate was that the initial five deployments would be more costly than the subsequent ones, due to the initial tooling costs. For other technologies or manufacturing processes, it may take 100 deployments or more to achieve economies of scale.
  - **Technology learning curve:** certain technologies lend themselves to learning curves. As deployments or manufacturing facilities increase, incremental improvements to operations, efficiencies, installation methods, logistics, etc. contribute to future generations of installations to be cheaper.
  - **Optimization of soft costs:** the levelized cost of a deployment is a function of its installation costs, transaction costs, operating costs, and financing costs. For small transactions (e.g., distributed generation, anaerobic digesters, energy efficiency), transaction and structuring costs can represent a high percentage of the total costs and be prohibitive. While structures and legal documents for VC investments tend to be standardized, Project Finance tends to be highly customized. Thus, for these smaller transactions, standardizing structures, diligence and documentation can lead to significant cost savings.
  - **Financing costs:** the cost of capital for earlier, riskier projects is, by construct, higher than once risks are retired, contributing to a higher levelized cost for early stage commercialization projects.
  - **"Waiting for Godot":** certain solutions are dependent on incentives that may or not be fully available (yet). As an example, carbon capture and sequestration projects rely on Section 45Q credits, certain state incentives and/or carbon offset markets. President Biden's American Jobs Plan includes proposals to extend (and increase credit amounts under) the Section 45Q tax credit for hard-to-decarbonize industrial applications, and direct air capture. Projects may be waiting for these proposals to be approved by Congress to ensure a higher source of revenue for these projects. Similarly, the establishment of mandatory carbon offset markets at higher clearing prices would provide a revenue source that is currently much less reliable in the U.S. Therefore, projects may be waiting for either the new and improved Section 45Q tax credits and/or a mandatory carbon offset market, in order to be economical.

    Whether for higher costs or lower revenue reasons, the early deployment of these technologies is subject to finding niche offtakers willing to bridge the revenue gap to make these projects economically viable. In the early days of solar generation deployment, utilities subject to Renewable Portfolio Standards entered into higher priced offtake agreements that allowed these projects to proceed. In the fashion or luxury markers, less cost sensitive customers may be willing to pay a "green premium" for greener products. For most of the industries in question though, the products in question (e.g., electricity, cement, steel, chemicals) are mass market commodities where the end customers will likely not be willing to pay a green premium. These projects — unless subsidized by niche participants, governments, or philanthropy — will have trouble getting through the early deployment stage.

- **Long history of "failures" of first-of-a-kind ("FOAK") projects taint new efforts**
  Any long term Project Finance investor can tell you anecdotal stories of failed FOAK projects (or projects in specific sectors) that they will use as the reason they would never invest in a similar effort. Perhaps equally anecdotally, large highly publicized stories of failures of early stage commercialization projects abound in the news and industry level reports. The controversial FOAK Kemper IGCC (Integrated Gasification Combined Cycle) with carbon capture project was supposed to be built for $2.4 billion and the first clean coal project in the U.S. However, costs increased to $7.5 billion before the project was abandoned and the facility converted to natural gas. Appendix D highlights lessons learned from these (and other) early stage attempted deployments, but the failure of such highly visible projects can cast a doubt on the viability of similar projects in the future.

3. On the Road from Innovation to Adoption: A Subset of Early Deployments Are Stuck in Between Asset Classes

3.1. Defining "Early Deployments": Our Focus in This Analysis

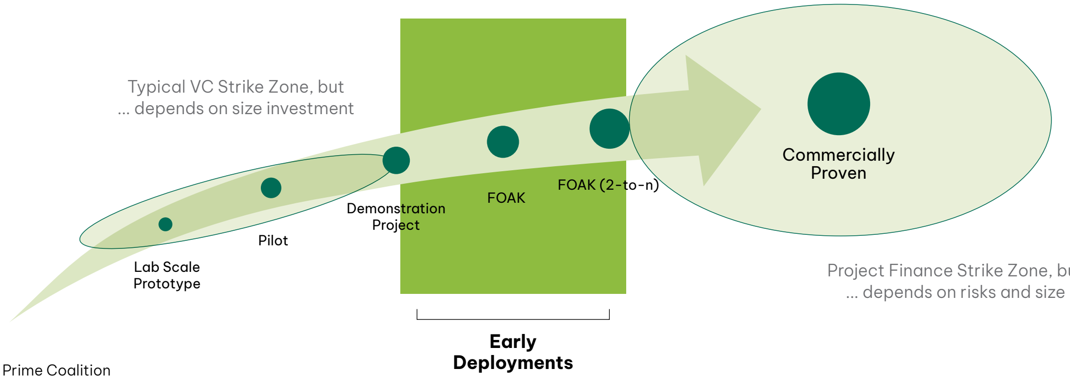
We define "early deployments" to include all of the following situations:

- In the context of a new climate innovation: early commercial deployments of projects in the sequence from innovation to adoption (including demos, FOAK, and FOAK (2-to-n) projects, as detailed in section 3.1.1. below);
- In the context of a new business venture: the first few project deployments for a business on its way to scaling up (regardless of whether the underlying technology/solution is innovative), as detailed in section 3.1.2. below; and
- In the context of a new "greenfield" project: the early stages of a project deployment's lifecycle, i.e., the ''development" of a project ahead of the project getting constructed (regardless of whether the underlying technology/solution is innovative), as detailed in section 3.1.3. below.

3.1.1. New Climate Innovation: Sequence from Innovation to Adoption

The road from innovation to adoption passes through several stages, starting with proving a concept at the lab (or prototype) scale in controlled settings, then moving to a pilot project (often a larger installation that is still subscale and not necessarily in the relevant environment), before moving to one or more incrementally larger demonstration projects to prove the technology's viability at scale. It is only then that a commercial scale demonstration project gets built, and followed by the first commercial deployment (described as FOAK). Project Finance capital providers typically look for several implementations of a FOAK project (such implementations called "FOAK (2-to-n)," and, collectively with FOAK, "FOAK (1-to-n)" in this report) before a solution is deemed "commercially proven." Early deployments, in this context, include demonstration, FOAK, and FOAK (2-to-n) projects, where n will vary by the type of solution, but is determined by whenever a climate solution graduates to widespread adoption.

Figure 6. Sequence from Innovation to Adoption



Source: Prime Coalition

The following are our proposed definitions, not industry-wide accepted and used ones. We believe the confusion around what step a project is really in, and/or potentially skipping some of these phases, often gives rise to (a) confusion among participants on who is best positioned to fund the effort, (b) the wrong targets, and (c) the wrong measures for a successful outcome.

- **Pilot project:** proof of concept. These projects are often subscale and not always in the relevant environment. They are intended to show the technology works.
- **Demonstration project:** should be done in the relevant environment, at the smallest scale needed to prove the technology works at scale.[23] These projects should endeavor to demonstrate what the industry is most afraid of, including scale, yield, availability, understanding of costs and serviceability, meeting customer specifications, and customer validation. A demonstration project is unlikely to be profitable, as it (a) often requires trials and errors to get the system to work, which can result in higher costs and longer timelines (b) is focused on making the system work reliably as opposed to optimizing scale, costs and logistics, and (c) cannot commit to long term customer deliveries until reaching stability. Certain technologies, depending on their complexity and scale up risk, may require several incremental demonstration projects.
- **FOAK project:** the first commercial project. FOAK projects are intended to be profitable, demonstrate the project can be commercially feasible, and are the reference for the upcoming projects. FOAK projects learn from the demonstration projects and are optimized around costs and output. These projects should be structured as a traditional Project Finance transaction to the extent possible. However, they still have much greater risk than "proven" projects, given the absence of precedents beyond the lessons learned from the demonstration project. FOAK projects serve to establish a track record for the next generation of projects.
- **FOAK (2-to-n) projects:** depending on the complexity of the first project, its level of success, profitability, and most importantly, the stability of incentives (if any), a technology may need several iterations before it is commercially proven and bankable.
- **Commercially proven projects:** projects become mainstream and can be funded by the Project Finance community (banks, equity investors). Bankability is fundamentally related to the risks (or perception of risks) and profitability of a project.

At what point in the process can the proposed solution be stamped with a "proven" label? From a VC investor's (or technology provider's) perspective, once (a) a technology has been tested (and tests show it works), (b) a business model (sales, asset based, etc.) is chosen, (c) the addressable market is large, and (d) a diverse set of customers indicate interest, a technology is largely considered proven and the remainder is a matter of execution, including getting the right salesforce, manufacturing facilities or partners, projects deployed, etc. If the business model consists of project deployment, it is largely anticipated (or hoped) that the Project Finance community will take over and fund construction of such projects.

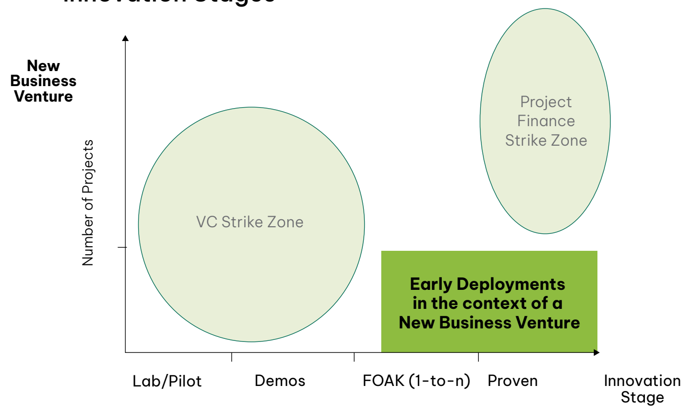
From a project capital provider's perspective, however, at that point the technology is still largely unproven. Where typical VCs have an investment horizon of 5 to 8 years, project investors typically consider a 20+ year economic life for a single project. As a result, project investors look for stable technologies with a track record of numerous deployments in similar conditions (FOAK (2-to-n)), a high level of confidence in construction costs and schedule, and a certain number of operating hours to establish operating performance and maintenance requirements.

[23] "At scale" is the size the technology is intended to be ultimately commercialized at.

3.1.2. New Business Venture on Its Way to Scaling Up

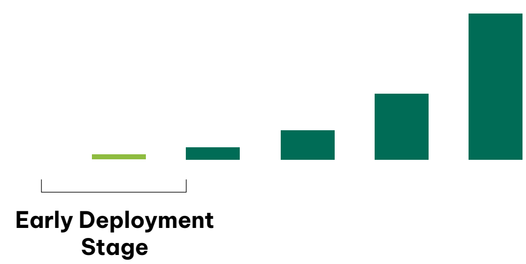
Before it scales up its commercial, engineering, development, and capital resources, a new small business will typically start by deploying projects sequentially, progressively scaling up its operations and financial resources to be able to deploy several projects in parallel. Early deployments, in this context, refer to the deployment of the first few sequential projects (whether proven or innovative).

Figure 7. New Business Venture Across Innovation Stages



Source: Prime Coalition

Figure 8. Number of Projects Over Time for a New Business Venture

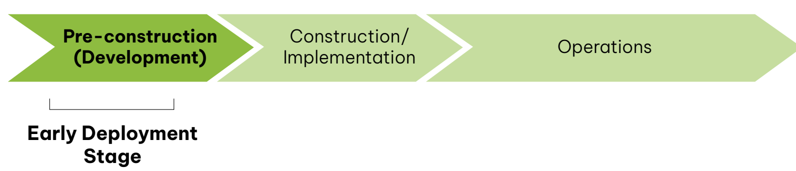


Source: Prime Coalition

3.1.3. New Greenfield Project: Early Stages of a Project's Life Cycle

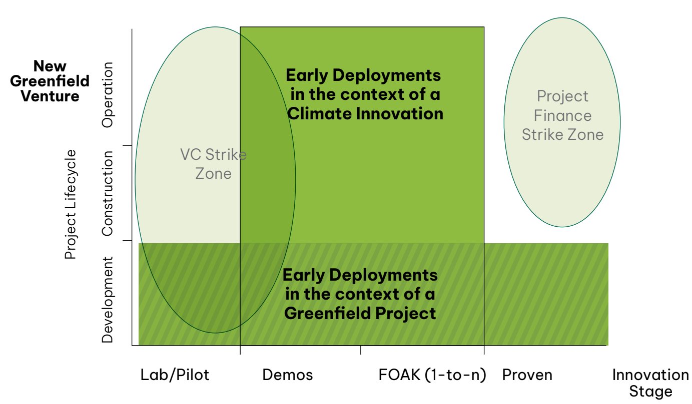
The life cycle of a project consists of three stages: (a) development (consisting of pre-construction activities), (b) construction/implementation, and (c) operations:

Figure 9. Project Life Cycle



We define early deployments, in this context, as the pre-construction activities involved with implementing any new project, whether proven or innovative.

Figure 10. New Greenfield Project Across Innovation Stages



Source: Prime Coalition

3.2. Empirical Conclusions: Four Major Gaps

Early project deployments, whether in the context of a new climate innovation, a new business venture, or a greenfield project, were nearly unanimously flagged by interviewees as unable to efficiently and effectively attract capital, primarily because returns for these projects were often not commensurate with their risks. More specifically, the gaps centered around the following four areas (ranked from most acute to least):

Gap 1: FOAK (1-to-n) projects.
Gap 2: Demonstration projects with a deployment[24] cost in excess of $20 million.
Gap 3: Early deployments of small (distributed) projects with a deployment cost below $20 million.
Gap 4: Projects in the development stage (particularly early development).

Table 1: Early Deployment Gaps, Rationale, and Examples

Included in our definition of "early deployments"	Why projects are stuck between mainstream asset classes	Examples
FOAK (1-to-n) projects **Demonstration projects >$20MM**	Too capital intensive and low return for VCs; too risky and sometimes uneconomical for Project Finance	The first commercial scale (200 tpd) facility for a CO_2-to-supplementary-cementitious-material technology that reduces CO_2 emissions associated with concrete
Early deployment of small distributed projects <$20MM	Do not meet return hurdles for VCs; too small to warrant the structuring and diligence costs of Project Finance capital providers	Modular direct-air-capture-to-food-grade-CO_2 company looking to raise $5-$10MM to fund the first few installations
Projects in the development stage	Requires deep knowledge of Project Finance; but with a binary risk/return profile, is ill-adapted to Project Finance capital providers' appetites	$10-$15MM funding to project developer to develop a large scale green hydrogen facility (i.e., find a site, do the front end design and feasibility analysis, structure the project, etc.)

Source: Prime Coalition

When interviewees were further probed on how one might accelerate the pace of deployment for projects (whether using proven or unproven technology), the following bottlenecks were repeatedly cited:

- Scarcity of qualified project developers (and industry experts more generally).
- Capital providers' credit underwriting criteria exclude some of the most impacted (and disadvantaged) communities.
- Insufficient tax equity for riskier/more complicated projects and/or lesser known developers.

[24] Deployment costs comprise project development and construction costs.

4. A Deeper Dive on FOAK (1-to-n) Projects: The Perfect Storm

For a given climate solution, the FOAK project, designed to be the first (at scale) commercial deployment, often presents the perfect storm from a financing perspective. It typically encompasses most, if not all, of the typical "Project Finance deal breakers:"[25] technology[26] risk, market risk, policy/regulatory risk, and sometimes insufficient returns relative to these risks. It is also where our research found the most acute capital gap.

While a properly constructed demonstration project should shed light on the expected construction, commissioning and operating costs of the FOAK deployment, as well as its expected performance, the variability around these expectations is still generally larger[27] than they are after a few have been built. At this stage of the innovation roadmap, one is unlikely to find an engineering, procurement and construction ("EPC") contractor willing to absorb such risk.

In addition to the technology risk, FOAK projects are often subject to high early costs (pre learning curve and economies of scale), and less established niche offtake markets, if any. Project sponsors are often confronted with an impossible dilemma: (a) have fixed volume and price offtake agreements with niche customers that provide some theoretical level of revenue certainty, but potentially face penalties and liquidated damages for failure to produce the promised amounts, or (b) keep volume and price variable depending on amounts produced and market prices at the time of production, but leave the project to potentially compete with lower priced incumbents. In either case, it is unlikely that capital providers would be willing to absorb the combination of technology and market risk.

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[25] See Appendix C.

[26] Technology risk encompasses construction and completion (cost and delay) risk, performance risk, and potential integration issues.

[27] Where a 5%-10% total cost contingency is reasonable for steady-state projects, the uncertainty band is likely close to 15%-20% for certain FOAK projects, and much higher when the large scale demo stage has been skipped.

4.1. Research and Interviews

Capital providers highlighted the following challenges associated with funding FOAK projects:

- Difficulty in underwriting FOAK projects without a clear track record of on-time and on-budget construction, as well as performance data. Simply put, it is hard for capital providers to accurately quantify this level of technology risk (including uncertainty around installation cost, operating costs, and performance).
- An expectation that "others" would fund early projects until a sufficient track record is built.
- Inadequacy of returns given the higher risks of the transaction.
- Lack of Project Finance sophistication for many in-house developed projects for smaller nascent solutions (e.g., poorly structured contracts; unrealistic or incomplete financial models).

Technology companies and FOAK developers highlighted the following challenges associated with raising capital:

- Difficulties and haphazard approaches in finding capital for FOAK projects.
- Even when capital is found, it is not always the optimal structure for a given project. Sponsors have to "force fit" the structure around the capital available, which leads to suboptimal outcomes.
- Even when capital is found, it is often at the end of a long and laborious process (up to 20 years for one company, and 3-4 years of capital raising efforts on average).

4.2. The Track Record for FOAK Deployment Is Mixed, Biased and Poorly Publicized

It is particularly difficult to complete a comprehensive analysis of the track record of FOAK projects for a variety of reasons, including:

- Nomenclatures and the absence of processes make it difficult to differentiate between FOAK commercial projects on one hand and demonstration projects on the other. In most studies, they are blended together.
- Unless truly revolutionary, FOAK projects are rarely advertised as such, and most often presented[28] as "mostly proven, using off the shelf equipment."
- Spectacular failures and/or successes tend to be advertised, while everything in between is rarely spoken about publicly, as capital providers aren't required to publicize financial information. As a result, most of the transactions where performance has been analyzed come from either large publicly funded (DOE, Municipal bonds, etc) projects, or highly visible ones, without much distinction between actual FOAK projects and those advertised as such. Various case studies, spanning carbon capture and storage demonstration projects, DOE LPO financed utility scale photovoltaic projects, and FOAK biofuels projects, outline both major failures and success stories, as highlighted in Appendix D.

Negative outcomes for FOAK projects include:

- Non-completion.
- Cost overruns and project delays beyond available contingency.
- Sub-market returns to finance-first capital providers.
- Defaults on contracts (e.g., loan or offtake agreements).

[28] This relates to the notion of different languages spoken by different constituents in the ecosystem. From the sponsor's perspective, they sometimes genuinely believe the technology is proven (i.e., "works"). Risks may lie in construction costs, yield variability, etc. but the underlying technology is indeed expected to "work."

In looking at various case studies[29] and feedback from interviewees the following factors predispose FOAK transactions toward negative outcomes:

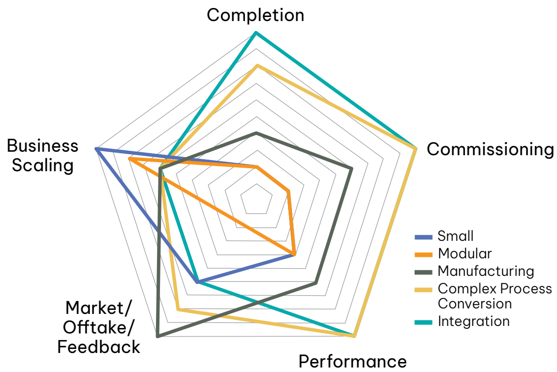
- **Skipping the demonstration phase:** Several (if not most) of the "failed" projects identified in the studies (perhaps with the exception of the manufacturing projects financed or guaranteed by the DOE LPO) had either skipped the demonstration phase, or effectively consisted of "commercial" demonstration projects, not FOAK projects. Conversely, the success story of the utility scale solar projects stemmed, in large part, from the fact that the underlying technology was largely proven at a smaller scale (and the technology was modular, therefore easier to scale up). Similarly, integration of several technologies presented a high degree of uncertain outcomes, as demonstration projects tend to be undertaken by the technology provider. In the case of a solution requiring the integration of several technologies, no single entity is responsible for demonstrating the technical and economic viability of the proposed solution. As Jennifer Holmgren, CEO of Lanzatech, reflected: "there are no shortcuts in science. Each step is critical in avoiding big mistakes at a larger scale. Skipping steps leads you to run out of capital, as fixing problems at large scale is more expensive than fixing a pilot or demonstration project. In addition, by skipping steps, one reduces the opportunity to improve the technology to reduce costs and optimize the techno economics."
- **Shortcuts in the development process:** Given the risks and costs involved with project development,[30] project developers sometimes delay detailed design and/or engineering to financial closing (i.e. at start of construction), when third party capital is usually more readily available. However, at that point in time, total project costs and associated funding are fixed, and unexpected costs resulting from such detailed engineering may result in unfunded cost overruns and impact project feasibility.
- **Uneconomical solutions:** A variety of situations may impact the economic viability of a FOAK project, such as marginally profitable projects often ending up being uneconomical because of cost overruns, or solutions that are very dependent on specific market conditions (e.g., high oil or gas prices) suddenly finding themselves out of favor when market conditions change.
- **A weak or inexperienced management team:** As a general matter, experienced and detail oriented structuring of projects ahead of construction reduce the risks of uncertainties and challenges once construction commences. Issues must be anticipated before contracts are finalized and contingencies ensured. The need for an experienced management team becomes even more crucial in the case of challenging technologies or the combination of technologies and/or when issues expectedly arise. The ability to discern between a bump in the road and a fatal flaw, to bring together different expertise and cultures, and to manage investor and lender expectations is not necessarily a skill present in many small (or large) start ups. For example, compare the description of the management team for KiOR,[31] who went from an IPO and "reports of high yields, construction at full-scale, multiple projects on the way" to bankruptcy within three years with that of Petra Nova, referenced in Appendix D, Study 2. In Study 2, the author attributes much of Petra Nova's "success"[32] to an "A list management team."

It is interesting to note that the common drivers of failure for FOAK projects are strikingly consistent with several of the other funding gaps identified in the exploration. In addition to addressing specific risks (e.g., technical, market, policy, etc.), could part of the solution include providing catalytic funding and support for demonstrations, early development and uneconomical projects?

[29] See Appendix D.
[30] See Section 7.
[31] Lane, Jim. 2016. "KiOR: The inside true story of a company gone wrong." Biofuels Digest. https://www.biofuelsdigest.com/bdigest/2016/05/17/kior-the-inside-true-story-of-a-company-gone-wrong/
[32] Despite its qualification of "success" by the DOE and author of the study, Petra Nova missed its carbon capture targets by 17%, before shutting down in 2020 as a result of low oil prices.

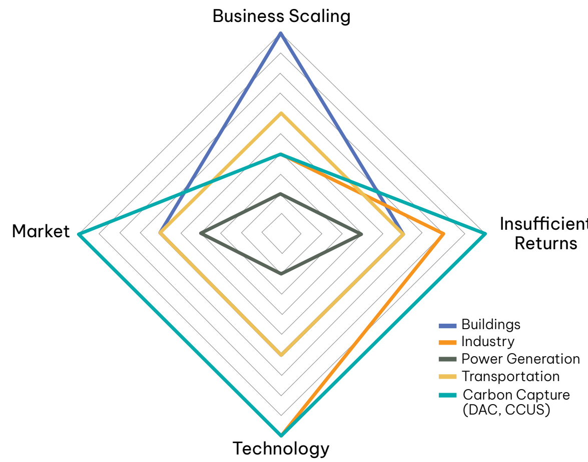
4.3. The Remaining Risks are Real and Vary with Type of Technology, Size and Sector

Figure 11.a. Risks by Type of Technology



Source: Prime Coalition

Figure 11.b. Risks by Sector



While there are exceptions to the rules, technology risk, including completion, commissioning and performance, tends to be the highest for complex process technologies and projects requiring the integration of several different technologies. These projects generally, but not always, tend to be larger. Conversely, market risk and associated cost competitiveness tend to be the primary drivers of underperformance for manufacturing projects. And business scaling risk is one the main reasons small projects have a hard time getting funded. When looking at the prevalence of these risks across sectors, technology and market[33] risks rank first for industrial applications and carbon capture projects, closely followed by inadequacy of returns, whereas business scaling risk is usually the main roadblock for projects in the buildings sector.

4.4. What is the End Game? What Should "n" Be?

When contemplating investment track record, the assumption in most studies is that if construction of a project is completed, the project is successful.[34] While this is indeed necessary, it is not sufficient. From a finance-first capital provider's perspective, a project is considered successful not only if it is completed, but it must also stay operational, meet debt covenants (if levered), and achieve investor returns within a reasonable range.

From the perspective of whether a FOAK project provides a solution to the climate issue, the definition of "success" would include whether the completion of the FOAK project leads to other similar projects being developed and financed (FOAK should ideally be one of many). However, while some of the risks associated with a FOAK project are typically lower by the second project, a few of the bottlenecks may linger for another few (n[35]) projects, and thus make it hard for finance-first capital providers to deploy capital until these issues (or risks) are retired as well. For instance, it may take several iterations of projects for (a) costs to come down[36] sufficiently for certain projects to become more competitive (a green premium on the sales price, or other forms of incentives would be needed in the meantime), (b) certain markets to be developed enough (e.g., carbon offsets for DAC or CCS projects, revenue stacking for storage), or (c) for a solution to be considered "effective" and worth spending time and capital on (e.g., many of the projects addressing the built environment are individually too small for most capital providers to bother with; the hydrogen sector didn't become "trendy" until the magnitude of the opportunity became obvious).

[33] Market risk includes policy risk in this case for carbon capture projects, as the market/revenues are largely dependent on incentives.
[34] Petra Nova is an example of a project described as successful despite the project not meeting its performance objectives and being mothballed a few years into operations before shutting down in 2020 as a result of low oil prices.
[35] The value for "n" will depend on the type of project, technology, and size.
[36] Due to the learning curve and/or economies of scale.

5. A Deeper Dive on Demonstration Projects: The Neglected Sibling in Search of an Identity

Several of the case studies referenced in the FOAK section of the report were in fact demonstration projects, sometimes properly identified as such, and other times marketed as FOAK projects. How — and why — can we tell them apart?

5.1. Theoretical Framework

We define a demonstration project as the "deployment of a solution (a) in the relevant environment, (b) at the smallest scale needed to prove the technology works at scale, and (c) for the purpose of demonstrating whatever the industry[37] is most afraid of (including scale, performance, yield, availability, longevity, understanding of costs and serviceability, meeting customer specifications, customer validation)."[38]

From a practical perspective, the line between large scale demonstration and a FOAK project is often blurred, and relates to the objectives of the project. Mischaracterizing demonstration projects as FOAK or targeting the wrong objectives helps explain why the "track record" of projects outlined in the various case studies[39] is far from being positive, particularly for larger projects.

Table 2. Demonstration vs. FOAK projects

	Demonstration projects	FOAK projects
Objective	(a) Validate (or assess whether) the technology or solution works at scale, (b) Establish the product meets customer specifications (c) Provide the basis for a narrower band of uncertainty around cost, performance and profitability variability	(a) Be built and operated within an expected time, cost and performance band (b) Serve as first of many (c) Establish a "proven" track record
Profitable?	Unlikely to be profitable, as it (a) will often require trial and error to get the system to work, hence higher costs and longer timelines, and (b) will focus on making the system work reliably as opposed to optimizing scale, costs, and logistics	Intended to be profitable
Characteristic	Subject to enough uncertainty and variability that a traditional project financing and/or offtake package may not be the appropriate design, at least until the project reaches some level of stability	Can be structured[40] as traditional Project Finance transactions, with the ability to commit to certain output quantities and prices, and – in theory – financed with a combination of project equity and debt

Source: Prime Coalition

[37] Including capital providers, EPC firms, customers, etc.
[38] See Section 3.1.1. for definitions.
[39] See Appendix D.
[40] Subject to additional contingent equity, guarantees or subsidies where needed.

5.2. Practical Considerations

Feedback gathered during the interview process indicate:

- The funding gap for demonstration projects is particularly acute for projects exceeding $20MM in construction costs (smaller projects are usually funded by a mix of VCs and government grants).
- While the government does play a role in funding certain demonstration projects, it typically does so in collaboration with private capital, and the scale of the need is outsized compared to availability of willing capital.[41]

Beyond capital constraints, some of the issues preventing demonstration projects from either being implemented or being successfully implemented include:

- Uncertainty around whether what is being demonstrated will address what project financiers will want to see a track record of for the next deployment.
- Lack of clear interpretation/documentation on the lessons learned from demonstration projects.
- Pressure from existing investors and/or management teams to skip steps and build the biggest "commercial" project as quickly as possible, in the hope of reaching higher profitability faster.

5.3. Lessons Learned from Government Funded Projects and Interviews

Based on the interviews conducted in the exploration phase as well as the various case studies outlined in Appendix D, the following lessons emerge:

- Demonstration projects are expensive, difficult and prone to "failure." Different kinds of problems must be solved at each stage of the scale up, and skipping stages does not work.
- Beyond the single niche application of a demonstration project, there should be a business case and a reasonable expectation of a supportive environment for follow-on investments, ideally taking into account the impact of the potential evolution of markets and policies. Developers should purposefully create alliances among actors along future value chains. Getting funding and support for a bespoke project that provides no lessons learned for the next 2-3 projects is useless.
- Success — or failure — is a meaningless concept without a clear goal to measure against; objectives for each demonstration project should be defined, with a clear perspective of what will be needed for the next iteration of project deployment (larger demonstration, first commercial facility, etc.). The danger is to lose sight of that objective and potentially cut corners to reduce cost or accelerate results for the demonstration project.
- The "wrong" capital structure can be worse than "no capital." Funding and portfolio management of demonstration projects need strong, credible and unbiased/independent technical, operational, and financial oversight, as well as a knowledge of what the next generation of capital providers will require to be proven.
- While funding from the government[42] and large corporations are definitely needed for large projects in particular, care should be taken that selection, funding and shutting down demonstration projects should be isolated from political (or competing strategic) influence.

[41] This could be changed in the U.S. depending on the implementation of President Biden's infrastructure bill, which significantly increased amounts allocated to demonstration projects.
[42] In December 2021, the Department of Energy announced the creation of the Office of Clean Energy Demonstrations, whose mandate will be to help bridge the demonstration gap.

6. A Deeper Dive on Early Deployment of Distributed Solutions

As indicated earlier, a new business – on its way to scaling up – will tend to deploy solutions sequentially in the early days. For solutions at the small distributed[43] level (i.e., where project implementation costs are less than $20MM), it is typically very difficult to find Project Finance capital until several of these projects can be aggregated, regardless of how proven the technology itself may be. In some instances, the step by step approach to developing and building/installing projects sequentially comes from a prudent deployment strategy, particularly when the technology itself is not fully mature. In other cases, small companies (developers, technology providers) don't necessarily have the capital, resources or infrastructure to deploy several projects in a parallel, highly concentrated fashion.

Paradoxically, it is often easier to find capital (typically VC) to fund the earlier stages of demonstration for these small-scale distributed deployments. The issue primarily rises when companies look for cheaper Project Finance capital, e.g. for FOAK projects or even for proven solutions.

The primary drivers that make these projects fall into a capital gap include:

- Becoming uneconomical once the investment team overhead and diligence/structuring costs are included.
- Business model scaling risk.
- Credit risk (for offtakers as well as technology providers).

Diligence and structuring for projects requires extensive efforts and costs, which disproportionately affect smaller projects and renders them uneconomical on a standalone basis. With hundreds of millions (or more) to deploy, it is hard for capital providers to justify spending the time and effort analyzing and structuring these projects, unless they (a) foresee a large market opportunity for the solution in question, (b) such opportunity is reflected in a pipeline actionable in the next 12 months that aggregates to more than $50mm in investments, (c) such pipeline consists of cookie cutter opportunities, and (d) returns are high enough that they can absorb structuring and diligence costs over that same period.

In addition, beyond business scaling risk, more often than not, these projects are developed by thinly capitalized, VC funded companies whose balance sheet and credit are insufficient to provide construction or performance guarantees the Project Finance community would be satisfied with.

[43] While it is natural to focus on very large scale projects as a faster and more meaningful solution to the problem, the reality is that both distributed (i.e., small and numerous) and centralized solutions will be needed. In addition, many of the large scale solutions themselves, when modular, have their first deployments at a small scale.

7. A Deeper Dive on Projects in the Development Stage: A Bottleneck to the Proliferation of Climate Solutions

Beyond the capital gaps outlined above, other areas of underfunding persist, resulting in bottlenecks[44] to the broader and faster proliferation of climate solutions. One of the main underfunded areas includes project development (also known as pre-construction activities), for both proven and nascent solutions. Taking one extreme example, proven low risk solutions such as renewable projects (solar or onshore wind generation projects) have no shortage of capital to fund construction of these projects. If anything, there aren't sufficient projects for the amount of capital available (or for the targets one needs to achieve by 2050), which is partially attributable to the difficulties in funding early project development activities.

Figure 12. GHG Numbers in the U.S.

Deployment of proven solutions needs to be significantly accelerated	GHG Numbers in the U.S.	
	10.5 Gigatons/yr	GHG reduction need by 2050
	0.6 Gigatons/yr	Current GHG reductions due to renewables

7.1. The Earliest Step in the Lifecycle of a Project

Project development includes the following pre-construction activities:

- Development of a concept.
- Site selection and control (lease/purchase).
- Preliminary feasibility analysis and design.
- Permitting, interconnection (where applicable), licenses, environmental assessments.
- Detailed engineering/FEED study.
- Equipment provider and contractor selection.
- Sometimes down payments for equipment orders with long lead times.
- Locking in offtake arrangements (and feedstock, where applicable).
- Development and negotiation of commercial agreements (including offtake, engineering, procurement, and construction contracts).
- Financial structuring and negotiations.

A successful development process culminates with Financial Closing (milestone where the investors take ownership — with or without the developers — of the special purpose company that will build the facility, and debt providers, if any, commit to disbursing loans), and issuance of a Notice to Proceed with construction. At this stage, "Project Finance" is in place and the facility starts getting built.

The development process is one of the most important (and riskiest) steps of the process of deploying a solution. The viability of the project relies on the fact that project development activities accurately pre-empt potential issues in the construction and operating phases, and properly allocate these risks to the parties involved. The order in which these activities will/should be performed and the risks associated with each step of the process will depend on the technology, location, regulatory regime and market conditions. It is typically a balancing act between capital at risk and retiring important risks first.

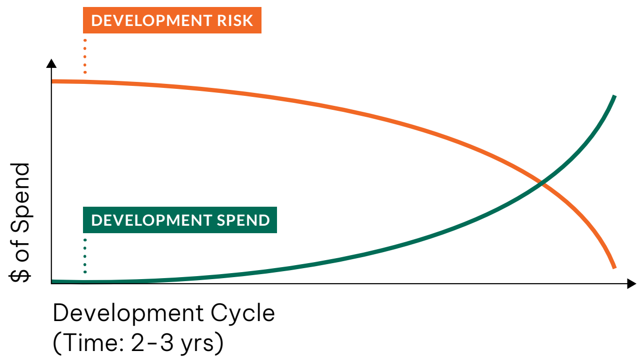
[44] This section describes one of the bottlenecks to the proliferation of Climate solutions. Additional barriers to meeting 2050 climate targets include: (a) an immature ecosystem around climate solutions, (b) credit risk of underserved communities, and (c) difficulties in the ability to monetize tax benefits for less established developers or riskier projects.

In addition to typical development risks (e.g., permitting, offtake) applicable to proven solutions, for nascent technologies, the uncertainty around the project costs, competitiveness, and the ability of the project to raise capital for a FOAK project, add significant additional risk to the development process.

7.2. Part Science, Part Art

The order in which these activities will/should be performed and the risks associated with each step of the process will depend on the technology, location, regulatory regime and market conditions. It is typically a balancing act between capital at risk and retiring important risks first.

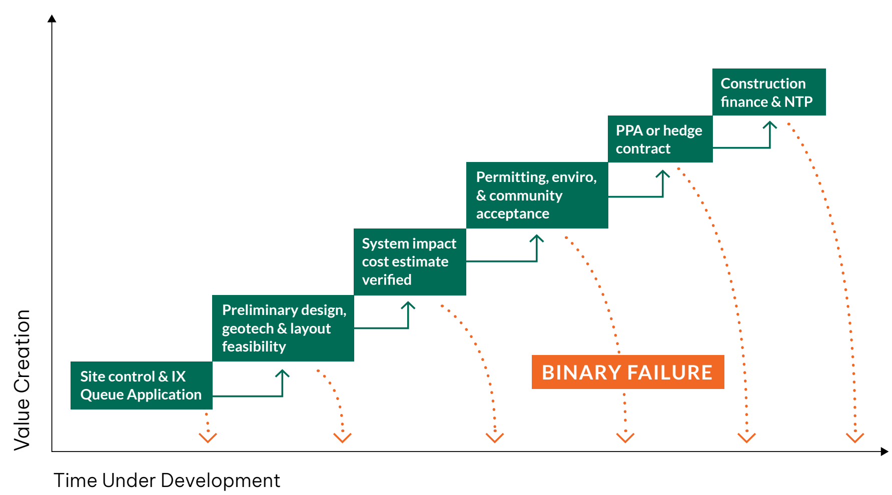
Figure 13. Development Risk vs. Spend



Source: https://www.leveltenenergy.com/post/project-development-essentials

Unlike Project Finance, where binary risks are typically frowned upon, most of the steps in the development stage can result in a binary result (e.g., permits may be refused or delayed, public may oppose the project, interconnection approvals may result in upgrade costs that render the project uneconomical, the developer may not be able to secure an offtaker for the project, or attract capital providers).

Figure 14. Steps in the Development of a Project



Source: https://www.leveltenenergy.com/post/project-development-essentials

Part of the art for a developer — an eternally optimistic human being — is to know which risks are likely to be highest in a particular situation, how to sequence the activities to retire the highest risks for the lowest costs, and, when issues arise — and they often do — knowing how to separate the deal breaker from the bump in the road.

7.3. Risks and Costs are Compounded for Nascent Technologies

In addition to typical development risks (e.g. permitting, offtake), for nascent technologies, the uncertainty around (a) the project costs (detailed FEED study is often needed to accurately estimate project costs) and their competitiveness and (b) the ability of the project to raise capital for a FOAK project add significant risk to the development process.

7.4. How Big of a Check is Needed to Develop a Project?

Project development costs include the following:

- Overhead for the development team.
- Environmental assessments.
- Design and Engineering firm, geotech studies.
- Securing site options.
- Legal (for permitting, commercial and financial agreements).
- Deposits for Interconnection application, where applicable.

A rule of thumb to evaluate the reasonableness of development costs is around 5% of total project costs. Actual costs range from less than $1mm (for very small repeat developments such as residential solar projects), to tens of millions for larger complex projects.

7.5. Why Developers Have a Hard Time Attracting Capital for Development Stage

Development stage funding for standalone projects is typically structured as a milestone based convertible debt instrument, with the assets (including contracts, permits, if finalized) as collateral. Part of the rationale for the structure is to stage funding until specific risks are retired, and the ability for the lender/investor to step in and take control of the project (and complete development) in case of a default. If the project is completed, the lender/investor either receives the proceeds of a development fee funded by the construction stage capital providers, and/or converts the loan into an equity interest in the project.

While the structure makes sense in principle, it offers limited protection. There is often a significant risk that:

- The project never reaches completion for reasons unrelated to the skills of the developer (in which case the collateral is of limited value).
- From the perspective of the long term construction capital providers, the long term project economics are too tight to justify a development fee that accurately compensates the risk premium for the development stage investor.
- Construction stage capital providers are not willing to compensate development stage capital providers until construction risks are retired. After all, their much larger invested capital is reliant on developers' structuring efforts (and much smaller amounts at risk). They would often want construction/completion risks to be retired before developers start earning fees.

As a rule of thumb, the chances of success for a development stage project are around 50%. Percentages are:

- Significantly higher (and costs lower) for small scale standardized proven projects (such as residential or commercial solar projects), where the main risks are around securing customers.
- Lower (and costs significantly higher) for controversial large projects or nascent complex ones. The risk/return profile of investments in development stage projects is not a strategic fit for Project Finance capital providers, particularly given the binary nature of such investments, except in the context of a large portfolio of operating projects, where part of the capital generated by the portfolio can be used to fund the development of projects earlier in their lifecycle pipeline.

Thus, VCs may in theory be a better source of funding when looking at the risks of these investments. Returns, however, typically are not in line with expectations, particularly given the push from construction stage capital providers for a longer time-framed equity stake in the project as a primary source of repayment. In addition, due diligence on development stage projects requires an expertise that few VCs are equipped to handle.

Practically speaking, technology providers that develop projects (with a smaller development budget) in house have an easier time including these expenses in their overall operating budget than standalone developers. But large development budgets, standalone projects, and independent developers all have a hard time being adequately funded.

8. "Are We There Yet"? Other Bottlenecks to Meeting 2050 Targets

Our research identified the following additional barriers to the deployment of climate infrastructure:

An immature ecosystem around climate solutions

The ecosystem around innovative climate solutions lacks experienced developers, expertise in evaluating technology and market risks in nascent sectors, certification bodies, supporting infrastructure, as well as operational experts, as illustrated in the following examples:

- When looking at the early days of onshore wind generation projects, the biggest source of uncertainty for project underwriting had more to do with wind studies and associated long term probabilistic production estimates than turbine performance. It took some time (and errors) for these estimates to become more reliable.
- In the case of offshore wind generation, the lack of Jones Act compliant installation and service vessels, port infrastructure and transmission infrastructure contribute[45] to the difficulties of scaling the offshore wind industry in the US.
- The lack of a fully developed charging infrastructure is a bottleneck to the proliferation of electric vehicles.
- For agriculture projects or nature based carbon market offsets, accurate measurements of GHG reductions are essential (and in their infancy) tools to allow the development of such markets.

Credit risk of underserved communities

Mainstream Project Finance capital providers' stringent credit criteria are misaligned with the credit of the communities most impacted by the climate crisis. The issue is particularly relevant for distributed solutions targeting the low- and moderate-income ("LMI") market, and/or unrated commercial and industrial customers.

Tax equity: Reserved for the Elite?[46]

Most special purpose entities formed for the purpose of construction and implementing a climate solution do not have the capacity to utilize the clean energy tax credits (ITC, PTC, Section 45Q), and consequently enter into partnerships with tax equity providers, who can monetize these tax credits. Tax credits are however subject to recapture risk (by the government) in certain instances, including termination of the partnership, or subject to certain performance levels. As a result (as well as given the imbalance between availability of tax equity and demand for it), tax equity tends to be easier to obtain for known, established developers, and commercially proven technologies where providers are confident about expected performance levels. For smaller, less established developers, or riskier projects, availability of tax equity remains an issue.

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[45] Complex and lengthy permitting processes are another major factor.
[46] This gap may be addressed depending on the outcome of the Build Back Better Act.

Prime

9. Can Catalytic Capital Bridge the Gaps Identified?

Many tools will be necessary to unlock the trillion dollar scale of annual investment required to rise to our global climate challenge, and while unprecedented amounts are being raised to support climate solutions, our research shows catalytic capital is critical to bridge the gaps identified – and is needed in multiple forms.

In contemplating potential solutions, we first explored[47] how other initiatives have either attempted or are currently attempting to fill in some of these gaps. Our early ideas around catalytic capital interventions are not intended to compete with existing efforts, but rather to complement many other public and private actors with private, philanthropic or other catalytic support.

For the purposes of this research effort, we adopted the Catalytic Capital Consortium's definition of catalytic capital:

> *"Investment capital that is patient, risk-tolerant, concessionary, and/or flexible in ways that differ from conventional investment, and whose aim is to unlock impact and additional investment that would not otherwise be possible."*

We then looked at different ways catalytic capital could be structured and deployed to ease the barriers discussed in this report. The first approach brings catalytic capital into the fold (potentially blending it with finance-first capital in an investment vehicle) to fund 100% of the third-party funded costs of a project (in all but one case as a bridge to finance-first capital once the risks are retired). The second approach injects catalytic capital selectively to retire specific risks or improve returns, typically alongside independent finance-first capital. Each approach takes different forms when attacking each of the four gaps previously discussed, as laid out in the tables below.

[47] See Appendix E.

9.1. Approach 1 - Wholesale Risk Reduction, via Pooled Capital to Fund 100% of Costs

The main advantage of this approach is its simplicity vis-a-vis the solutions provider, complemented by speed of execution. This not only enables the deployment of hard-to-fund projects, but also accelerates the deployment process with simple catalytic solutions. Each of the proposed solutions below addresses a specific gap, and most of these financial products could be structured using a "blended finance" approach: blending (a) capital accepting below market financial returns with (b) risk-tolerant capital, as well as (c) finance-first capital.

Table 3: Possible Catalytic Solutions in a Wholesale Risk Reduction Approach

Gap targeted	Solution	Financial products	Capital per project	Summary
FOAK projects	Bridge to performance	Project equity, potentially with warrants in the solutions provider	$10-$70MM	Fund construction of FOAK projects until completion and comissioning, plus ramp up to steady state operations — Finance once steady state, then sell equity. May be combined with DOE LPO or similar loans or loan gaurantees at the start of contruction.
	Bridge to market readiness	Project equity	$10 - $70MM	Fund contruction of FOAK projects, sell when specific policy, regulatory, market or design risk is passed.
Demonstration projects	Fund demonstration projects	Project equity with warrants, growth equity	$20 - $70MM	Fund demonstration projects in combination with grants where available and self-funding by company.
Projects in the development stage	Fund development costs	Convertible loan, growth equity	<$30MM	Fund project development for both proven and nascent solutions. Loan is paid off at the start of construction and/or converts to project equity.
Early deployment of small, distributed projects	Bridge to scale	Project equity	<$10MM	Aggregation of small projects—sell to frontier or mainstream investors once aggregated.
	Bridge to equity	Pledge fund	<$50MM	Origination, diligence and underwriting of tax equity investments in small projects on behalf of tax equity.

Source: Prime Coalition

Prime

9.2. Approach 2 - Surgical Intervention

This approach focuses on surgically deploying the minimum amount of catalytic capital where needed. A variety of financial products can be used to retire specific (and typically single-issue) drivers of risk and/or return that make it prohibitively difficult for finance-first capital providers to participate. The advantage of this approach is the allocation of a scarce, precious resource for a very specific purpose, in a manner that complements finance-first investors and/or lenders. While these solutions are applicable at any of the early deployment stages and for any project size, from a practical purpose, they are likely to be more useful for larger projects (where Approach 1 may be too onerous), within the capital stack of Approach 1 products, and/or for a next generation of project (e.g., FOAK (2-to-n)).

Table 4: Possible Catalytic Solutions in a Surgical Intervention

Target	Financial Products	Risk Retired	Capital per project	Summary
Insurance	First loss equity	Completion risk Credit risk	TBD	Provide the first loss catalytic capital to insurance providers to help expand the universe of risks covered and reduce exclusions for insurance products.
FOAK (2-to-n) projects, or as part of the blended pool for demonstration projects and FOAK	First loss equity	Technology market risk Low risk-adjusted returns	Depends on risk — to be sized as needed. (Likely between $1 MM - $30MM)	Provide the first loss subordinated equity tranche to fund constrction of projects. Subordination can be specific to certain risks or thresholds, depending on needs. This has the added benefit of improving returns for finance-first investors.
	Guarantee	Technology risk	TBD	Technology provider would provide performance warranties for equipment (e.g., guarantees a certain yield or availability). Given technology provider is unlikely to be creditworthy, catalytic investors could provide a guarantee to investors and lenders backstopping technology provider's warranties.
	Below market debt	Low risk-adjusted returns	> $30MM	Provide below-market debt to fund project construction. Such debt would boost overall equity returns to levels commensurate with the risks for finance-first investors, while still being senior to equity.
	Contingent equity	Technology risk	$10-$30MM	Provide contingent equity to cover potential construction cost overruns. While structured as equity, these are effectively contigent grants for projects.
	Carbon offset pool/Advance market commitments	Market risk Low risk-adjusted returns	TBD	Creating a vehicle to pool voluntary purchases of CO_2 offsets and offer "offtake" arangements.

Source: Prime Coalition

9.3. A New "Climate Transition" Approach

To successfully bridge early deployment gaps, the finance sector needs a new "climate transition" approach that blends elements of and expertise in (a) Project Finance structuring and risk management, (b) late stage venture/growth investing, and (c) catalytic capital deployment.

Today's projects are trying to fit their needs into the traditional project financing or venture capital mould, which is problematic because:

- The point at which an early deployment should be structured as a project (as a proof of concept for later iterations) is earlier than the point at which the project meets requirements of traditional Project Finance capital.
- The risk/return profile for these transactions doesn't fit with either VC or Project Finance (returns are too low for VC, risks are too high for Project Finance).
- Many of these transactions require some level of support from catalytic capital.
- The expertise needed to assess project development, construction and operating risks lies with Project Finance experts, whereas the expertise to assess technology and market risks lies with VC/growth investors.

9.4. Looking Beyond Funding Gaps: Programmatic Toolkit

Beyond existing asset classes and risk/return considerations, one of the main reasons it is so hard for companies or developers to cross early deployment gaps is that companies and capital providers alike must navigate without a compass. Programmatic tools that could support a catalytic capital investment ecosystem include:

9.4.1. Accelerator for Projects

Creation of an ecosystem/accelerator to facilitate access, third-party cooperation, education of VCs and growth stage companies on Project Finance, and provision of technical assistance. Target users would include technology companies and project developers. The accelerator would provide:

- Technical assistance (development, project and financial structuring).
- Access to ecosystem (sources of capital, corporates, EPC contractors, partners, government).
- Education programs.

In addition, enabling this ecosystem would have the additional benefit of allowing:

- Companies to understand the needs of financiers as a first step to developing a more effective relationship.
- Capital providers to get involved in the planning stages of climate projects ahead of a capital raise and better understand underlying technology risk.
- Corporations or EPC firms to get familiarized with the solution/technology as a soft way to facilitate future offtake agreements or EPC wraps earlier than when they otherwise would.

9.4.2. Early Stage Deployment Validation Advisory Group ("Seal of Approval")

Establishment of an advisory group consisting of engineers, operations experts, contractors, industry users, market experts, and relevant government entities that would opine on:

- Whether a project meets its proposed stage (e.g., demonstration vs. FOAK — i.e. appropriate prior relevant step/objective has been completed).
- Realistic expected cost reduction pathway when contemplated.
- Expected market adoption (availability of long-term contracts).
- Whether a proposed project is replicable (permanent FOAK or expected to be first of many).

10. Endnotes

The objective of this report was to assess the bottlenecks and opportunities to enable and/or accelerate the deployment of climate solutions. New investment vehicles and government support have emerged since our research commenced, as the ecosystem is evolving on a daily basis, and the analysis should remain dynamic. In addition, our work primarily focused on the US capital providers and projects. We recommend a similar analysis be performed on other OECD countries as well as developing economies. When looking at how catalytic capital may bridge the gaps, no assessment of the impact of a particular solution is included in the research, nor does the paper make a recommendation about where and how such an effort should be housed.

Prime

Appendices

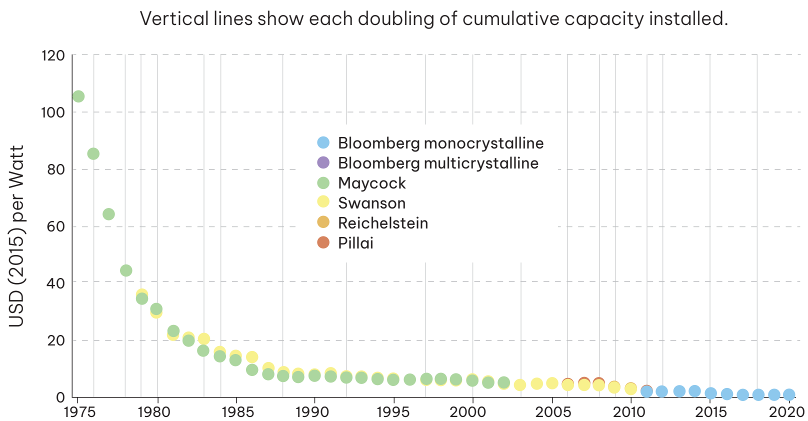
Appendix A: The Solar Example

The solar sector is a great illustration of the long lead times[48] from innovation to adoption. Today, it is easy to forget that generation of electricity from solar panels was once considered "risky" and "innovative." In the 1970s, the energy crisis prompted research and innovation in alternative technologies in the US, including the Solar Energy Research, Development and Demonstration Act of 1974. With energy prices dropping in the 1980s, however, the effort around renewable technologies slowed down significantly and didn't really restart until the early 2000s. For solar to become mainstream in the mid 2010s in the US, it took a combination of:

- Chinese government subsidies for solar panel manufacturing and deployment;
- The Solar Investment Tax Credit enacted in 2006;
- Early support from certain Utilities entering into above market offtake agreements;
- DOE Loan guarantees supporting the first large scale installations in the US in 2010-2011;
- Progress in adjacent technologies (e.g. inverter safety, performance); and
- Installed costs subsequently dropping over 70% in a decade.[49]

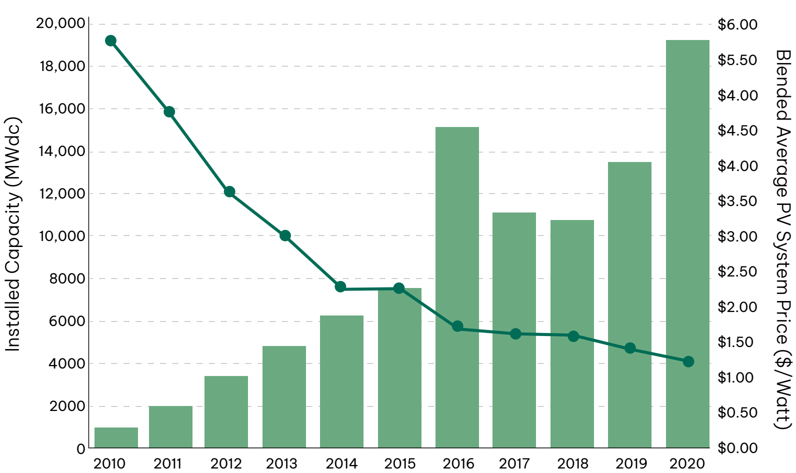
Since then, solar has had an average annual growth rate of 50 percent[50] in the last 10 years in the U.S.

Figure 15. Evolution of Solar PV Module Costs



Source: IEA, Evolution of solar PV module cost by data source, 1970-2020, IEA, Paris

Figure 16. U.S. Solar PV Price Declines & Deployment Growth



Absent the catalytic effect of the tax credits, offtake agreements and DOE loan guarantees, would solar be a mainstream investment today? Could these timelines have been accelerated further?

Source: IEA, Evolution of solar PV module cost by data source, 1970-2020, IEA, Paris

[48] "The History of Solar." n.d. Gov.energy.eere.www1. https://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf
[49] Part of the decline in solar installation costs can be attributed to improvements in efficiency, economies of scale in production, optimization of installation costs, standardization of structures, financing and documentation.
[50] According to the Solar Energy Industries Association.

Appendix B: Project Finance 101

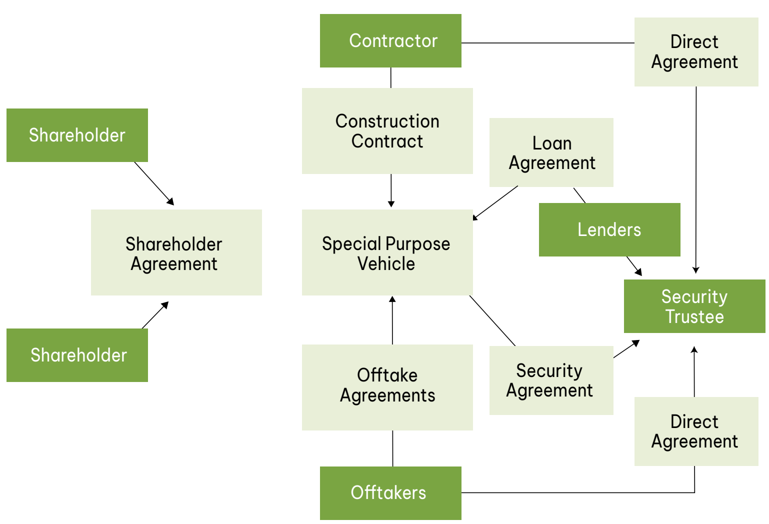
What are the barriers for Project Finance investors and lenders to step into the capital provider role for project deployments? As a starting point, anything that is getting done for the first time is bound to come with some element of uncertainty and risk, and the one thing project financiers dislike above all else (well, apart from the words "FOAK" and "trendy") is uncertainty. Fear of the unknown drives a reluctance to invest in first time projects. Will it work as planned? How can one assess whether the project will deliver expected results in the absence of precedent?

This fear is for the most part rational, and has its source in the concept and structure of a Project Finance transaction. What is a Project Finance transaction? In its most basic form, it is a standalone structure that contractually allocates risks to the party best able to manage it, attempts to avoid binary risks, and uses high levels of limited recourse debt to reduce the overall cost of capital.

Project finance transactions typically consist of the following:

- One or more shareholders (equity providers) own a special (single) purpose vehicle (the Project Company). The Project Company owns the assets (consisting of actual hard assets as well as contractual rights and obligations, permits, etc.)
- The Project Company's lenders will partially finance the construction of the project on the basis of the projected cash flows of the project. Assets are typically pledged as security for the lenders.
- Shareholders commit to fund the balance (a fixed amount) of the construction costs of the project via pre-determined equity injections in the Project Company, also on the basis of the projected cash flows of the project. The debt is usually off balance sheet for the equity providers.

Figure 17. Typical Project Finance Structure



Source: Dentons

The most basic premise of Project Finance is the concept of risk allocation to the party best able to bear such risk. As such, in an ideal world, the Project Company would allocate:

- Construction completion and performance risk to a creditworthy contractor through a "turn-key" EPC (Engineering, Procurement, Construction) contract.
- Supply risk through "firm" supply contracts that guarantee a steady supply of feedstock, fuel or other necessary resources.
- Market risk to a creditworthy off-taker through a "firm" long-term sales contract with pre-defined pricing and volume purchasing obligations.
- Operations and maintenance ("O&M") risk to an O&M provider.

Basic underwriting criteria for a Project Finance transaction also include “proven technology” and “Tier 1” equipment suppliers. Projects structured in accordance with these principles are expected to have fairly predictable cash flows and generally quantifiable risks, resulting in higher leverage and cheaper cost of capital. Conversely, as risks increase, cost of debt increases and the debt to equity ratio (and consequently equity returns) decrease, while return expectations increase.

Track record of capital providers attempting to release one or more of these principles has been mixed. In terms of revenue forecast risks, for example, investments in merchant gas fired power projects in the late 1990s/early 2000s have had a long history of failures as the underlying marginal cost of production changed with commodity price fluctuations, whereas the reliance by wind and solar project capital providers on production forecasts linked to weather or insolation data, has been easier[51]. Today, many of the 20-year utility offtake agreements have given way to shorter corporate or residential offtakes, or financial hedges. In all these cases, it took several projects being structured and completed before these “exceptions to the rule” (another form of FOAK project) became more mainstream.

One of the first (implicit) rules of Project Finance is that, once a notice to proceed for construction has been issued, binary risks are assumed to be retired. The remaining risks, at that point, should be around variability of cash flows and not whether or not the technology will work or whether there is a market for the product.

Another more explicit rule is that of risk allocation to the party most able to bear such risk. These two concepts will be essential to keep in mind as we go through why certain projects are harder to fund than others.

[51] While early wind forecasts were later shown to be overstated, predictive technology had since made progress - at least on an average probabilistic basis, leading to more accurate (and more commonly accepted) forecasting.

Appendix C: Project Finance Deal Breakers

Technology risk

Technology risk from a Project Finance investor/lender perspective evolves around:

- Construction or implementation risk: will the project be completed on time and at a pre-agreed cost?
- Commissioning risk: once completed, is the project running up to its expected capacity and delivering a product that matches specifications (typically at a point in time)?
- Performance risk: will the project perform as expected over the duration of its life? Is it consistently delivering a product matching customer's specifications? Is it delivering the expected performance (e.g., annual quantities, yield, efficiency, predictive hit rate, etc.)?

In typical bankable projects, technology risk for large projects is allocated to a creditworthy and reputable EPC contractor, who will commit to deliver a turnkey project at a fixed price and by a certain date. The EPC contractor will also typically provide some level of performance guarantees (e.g., minimum production or yield guarantee), backed by liquidated damages sufficient to keep lenders whole. Absent a turnkey contract, the special purpose company constructing and operating the project would be exposed to delays, cost overruns, and performance risk, in an environment where its only source of capital stems from debt and equity commitments made at notice to proceed.

Having a turnkey EPC contract provides a single point of responsibility for the design, engineering, procurement and construction of the project. The contractor typically subcontracts various components to other companies (e.g., an engineering firm, an equipment supplier, construction company), and acts as the conductor — ensuring each subcontractor delivers on its responsibilities — and taking finger-pointing risks in exchange for a fee (typically a markup of the costs).

Today, most of the innovation for climate solutions is transformational (i.e. new ways of doing things) rather than incremental (e.g. improving efficiency of an existing solution), and in the hands of small thinly capitalized start-ups. But while these start-ups are in the best position to innovate, they often find themselves constrained at the deployment level. With no deep pockets to fund first deployments and no balance sheets to stand behind potential performance guarantees, these companies fall into the deployment valley of death for first time projects. Even assuming all else were to be adequately structured and non-technical risks adequately mitigated, why would a third party (e.g., EPC contractor) take responsibility for a project they have not previously built or delivered and/or a start-up's learning curve? Why would it take responsibility for a design it did not create, equipment that still needs to demonstrate it will perform, and associated costs? The lack of long term performance data at a commercial scale makes it very hard for EPC firms and capital providers alike to bank on such a technology's performance.

In addition to the fundamental question of performance of a specific innovative technology, there are additional technical risks that arise out of the deployment of certain technologies:

- Long term availability of spare parts, operating know-how and IP: most Project Finance investments have a minimum of 10 year, and usually a 20 to 30 year investment horizon. Will the technology company still be a going concern during the life of the investment? Will it be able to guarantee long term availability of spare parts, fundamental hands-on operating know-how, and 40 IP? For instance, when Bloom Energy started deploying fuel cell projects on a Project Finance basis, the biggest concern for project capital providers related to the need for the fuel cell technology to have periodic system refurbishments and replacements during the contract term. Would Bloom Energy still be a going concern 10-15 years later to replace the fuel cell stacks?

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- System integration: certain technologies, even when proven, may be unable to plug into, or risk negatively impacting existing infrastructure, systems and technologies. For instance:
  - Internet of Things, distributed storage and/or demand side management software and hardware need to be integrated within the host's existing infrastructure, and may impact the grid. The technology may have been tested independently and in simulations, but there is a risk that it may negatively impact existing systems once commercially deployed.
  - Similarly, technologies that bolt on to existing projects or tightly coupled systems run the (actual or perceived) risk of impacting existing operations or causing the entire system to fail in case of a failure. Via Separations, a Prime Impact Fund portfolio company, produces a filtration system (membrane) capable of reducing the energy required to separate chemicals by 90%. The system would be a bolt on to existing industrial processes (pulp, chemical, petrochemical), and could be structured as a service (pay for production). Despite a modular system intentionally designed to avoid disruptions to existing processes, the first commercial scale deployment will be important to get project financiers (and host facility owners) comfortable with this risk.
- Integration between various technologies: many of today's anticipated solutions (e.g., carbon capture and usage projects, or green hydrogen/ammonia projects) consist of the complex integration of multiple potentially FOAK technologies. The Kemper gasification demonstration project is the poster child of this risk. Combining coal gasification, carbon capture and use, and combined cycle power generation, the project started with an expected cost of $2.4 billion that increased to over $7.5 billion before being scrapped.

Market risk

The norm for Project Finance transactions is for the special purpose company deploying the solution to enter into long term purchase agreements, committing to minimum volume offtakes, ideally at a fixed or minimum guaranteed price.

Yet, as mentioned earlier, climate solutions are not only centered around utility or large corporate customers, where long term offtake agreements with creditworthy parties are common. Most of the solutions needed to be in compliance with the Paris Accords impact markets that have either been operating in a status quo for years, or not fully developed yet, and in both cases not accustomed to Project Finance structures and long term offtake agreements.

As an example, carbon sequestration projects would require a source of revenue for the project company to remove and sequester CO_2. Absent conversion to a product of marketable value, sequestration projects would have to rely on carbon credits (a market where long term agreements and predictable pricing are not yet available) and state and federal incentives (Section 45Q tax credits) as their source of revenue. Even in the scenario where the CO_2 is intended to be converted to a product of marketable value, the offtaker, a special purpose entity with an innovative conversion technology, may be an equally thinly capitalized company that does not yet meet creditworthiness standards.

Similar concerns arise in the production of commodities when the early cost of production is higher than that of less green incumbents (often with fully depreciated facilities). How can the project be economical when the price-setting producer is cheaper and with deeper pockets? For FOAK projects, how can the facility compete when costs are still higher or more uncertain than for subsequent ones?

The issue is also particularly relevant in the context of manufacturing facilities. Economies of scale are particularly important for manufacturing facilities, where purchase orders rarely account for the full production capacity over a long term.

Finally, even when offtake agreements are available, the creditworthiness of such offtaker can make or break the transaction. It is easier for capital providers to rely on the credit of counterparties rated highly by the traditional rating agencies (e.g., Standard & Poor's and Moody's), or customers with high FICO scores. It is much harder to assess the credit quality of small commercial institutions, the LMI market, or municipalities whose budgets are set by annual appropriations.

In all these instances, absent long term agreements, getting project capital providers comfortable with the market or revenue risk is likely to prove difficult.

Regulatory and policy risk
Climate projects are subject to a variety of regulatory, permitting and policy risks that can impact the viability of projects and/or result in significant delays. For example:

- Large offshore wind projects require reviews by and authorizations from a variety of federal and state agencies, including the Army Corps of Engineers, the National Marine Fisheries Service, the Fish and Wildlife Service, the Bureau of Ocean Energy Management, the Coast Guard, and the Environmental Protection Agency. The Vineyard Wind project, an 800MW offshore wind project off the coast of Maine, was finally approved in May 2021 after years of permitting delays.
- The profitability of storage and demand side management projects is oftentimes reliant on the ability to stack multiple revenues and/or mitigate demand peaks, which are at the mercy of regulatory design and policy changes.
- The lack of clarity, consistency and long term visibility associated with government policies and incentives makes it hard for technology innovators and project developers to rely on these regulations and policies, particularly for long lead time climate infrastructure projects. As an example, development and construction of large scale climate projects spans multiple years, yet, they rely on tax incentives and policies that are subject to each administration's views on climate.[52] Similarly, the long lead times between demonstration and adoption of climate solutions make it hard to reliably plan for business models that may or may not be available by the time the technological innovation is proven. The Build Back Better Act is one of many illustrations of the difficulties and delays associated with government incentives. In what is arguably one of the most climate friendly government and public support environments in decades, over a year after the first plans to extend PTCs, ITCs, and expand Section 45Q tax credits, the bill is yet to be passed.

Business scaling risk
Project Finance transactions require intensive and costly multi-months diligence, structuring and documentation efforts, rendering individual small distributed projects uneconomical. For capital providers to justify spending the time and effort analyzing and structuring these projects, there needs to be (a) a large market opportunity for the solution in question, and (b) a pipeline of similar opportunities actionable in the next 12 months that aggregates to more than $50mm in investments, to allow for the amortization of these costs across a larger number of transactions, and the standardization of the diligence and documentation efforts.

There is a risk that the pipeline in question does not materialize over that timeframe or that the portfolio of projects ends up being too heterogeneous to be levered, in both cases impacting the profitability of the investment.

[52] Sunset dates for production tax credits ("PTC") and investment tax credits ("ITC") for wind and solar projects were extended multiple times at the very last minute, triggering cycles of delays and under-investments during periods of uncertainty.

Insufficient returns

Project finance is categorized by VCs and tech companies as a "cheap source of capital." With sometimes over 70% of the capital being provided by debt and numerous examples of renewable projects trading at equity returns in the single digits, developers often hope that these newer climate solutions can be funded with similarly low expectations of returns (and high leverage).

The reality is that, contrary to popular belief, Project Finance capital providers are actually, for the most part, rational investors. As such, the amount of debt that lenders are willing to provide to a project, the interest rate they would charge, as well as investors' return expectations are all a function of the actual or perceived risks of a transaction. Higher risks will mean higher expectations of return, unfortunately often coinciding - for FOAK projects, with higher (or less certain) costs.

It is not unusual, for early projects with some expected variability in either costs or revenues, for investors to expect returns in the high 20s - early 30s. One way to understand this is to go back to the Project Finance fundamental theorem of risk mitigation. When a risk is not sufficiently mitigated contractually, "low risk" capital providers will simply reject the deals. Others will run sensitivity analysis around expected returns in several scenarios. When the band for these sensitivities is wide enough, the starting point (base case) for returns has to be high enough to absorb such variability. Projects with a sub 15%[53] starting point IRR will most likely fail these sensitivity tests.

At the same time, as mentioned earlier when looking at the headwinds facing climate solutions, costs tend to be higher in the early days of the deployment of a solution than once it is widely adopted, thus further stressing returns.

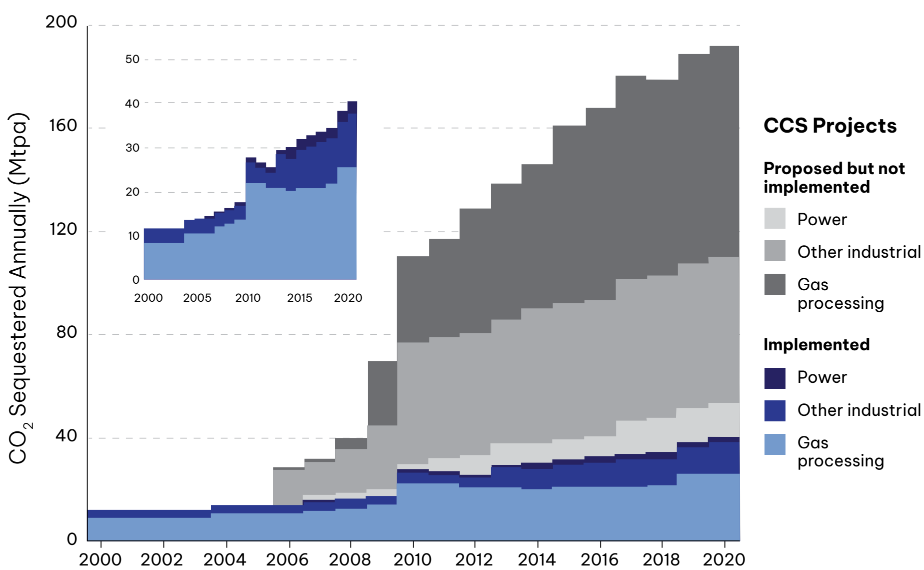
[53] Number for illustrative purposes. Return expectations will be in line with risks.

Appendix D: FOAK Case Studies

Study 1. Letter evaluating factors of success/failures of U.S. carbon capture and storage projects using empirical and expert assessments[54]

In this study, released in 2021, the authors evaluate the general track record of more than 149 CCS projects of all types that have been proposed or built worldwide, with a target to be operational by 2020. Out of these, more than 100 were terminated or put on indefinite hold, as shown in Figure 18. The distribution of success by type of projects highlights gas processing projects — that happen to have the most mature carbon capture application — as best performing (75% implemented). The corresponding figures for other industrial projects and power plant projects are approximately 60% and 10%, respectively.

Figure 18. Global Proposed vs. Implemented Annual CO_2 Sequestration (main figure), and Global Implemented Annual CO_2 Sequestration by Type (inset).



Source: Ahmed Abdulla et al 2021 Environ. Res. Lett. 16 014036

The authors then do a deeper dive of the 51 projects proposed or constructed in the U.S. over the past 20 years, using both statistical methods and interviews with experts to attempt to characterize drivers of failure or success. While we do not necessarily believe the statistical methods to be highly relevant (nor the sample size representative), the conclusions of the study are nevertheless interesting. According to the authors:

- "Projects with larger capital costs are more likely to fail," as "billion-dollar engineering infrastructure projects often encounter difficulties with financing, site preparation, supply chain management, or system integration. Consequently, these projects are often commissioned over-budget and behind schedule, if not abandoned altogether." The authors point out that none of the 14 projects with the highest budgets went forward (13 were abandoned while the 14th abandoned plans for CCS, reconfiguring the project as a combined cycle natural gas power plant instead).
- "High levels of technological readiness improve the chance of project success."
- "Credibility of revenues such as bilateral offtake agreements strongly increase the odds of project success."
- Credibility of incentives is ranked as the 4th important variable of success.

[54] Ahmed Abdulla et al 20221 Environ. Res. Lett. 16 014036.

Study 2. Case studies commissioned by the American Energy Innovation Council, examining the role of demonstration projects in the commercialization of new clean energy technologies
These case studies,[55] dated as of June 2020, outline and contrast (a) the "Mixed Success of the Carbon Capture Demonstrations," and (b) the "Successful Demonstration of Utility Scale Solar Photovoltaics."

The case study relating to Carbon Capture Demonstrations looks at 5 U.S. government supported large commercial scale coal gasification carbon capture and storage projects[56] between 2003-2015. Out of the five considered in the study, only two were built (Kemper County Project and Petra Nova), and only one (Petra Nova) worked (and captures only a fraction of the plant's flue gases). The authors of this study point out some of the challenges related to these projects, that ultimately led to the outcomes:

- Bespoke engineering.
- Reliance on anticipated economies of scale that were not realized due to cost overruns and schedule delays, as well as changing market dynamics by the time the projects were getting built.
- "Complexity challenges due to the integration of two major subsystems (a power plant and chemical separation)," including "marrying the culture of power engineers with that of chemical engineers."
- "Challenge of scaling up multiple systems at the same time."
- "Project contractors and equipment vendors are proceeding somewhat in the dark, with little particularized experience to guide them and no incentive to take financial risks."
- "The funding and schedule limitations imposed on the projects" did not correspond to the actual challenges of the project." "Government patience and interest ran out first."
- In Kemper's case, "construction began when only 10% of the final design engineering was complete."
- "Uniqueness is an inherent characteristic of the necessarily large CCS projects attempted, and, to some degree, will always be the case," since "each site location presents different characteristics in terms of coal type, transportation, process water availability, and proximity to CO_2 transportation and sequestration infrastructure."
- For the lone success story, the Petra Nova project, the authors point to the convergence of "a number of excellent design features, the oversight of an exceptionally able and motivated management team, the right location, and the use of modular construction for the tall units."

The case study relating to the solar projects looks at the loan guarantees provided to financial institutions (or direct loans) by the DOE's Loan Program Office for five large utility scale solar PV projects (using different technologies).

[55] Mackler, Sasha, and Eric Redman. 2020. "AEIC Scaling Innovation Project." Bipartisan Policy Center. https://bipartisanpolicy.org/report/aeic-scaling-innovation-project/
[56] These projects were also included in Study 1.

LPO-FINANCED UTILITY-SCALE PHOTOVOLTAIC PROJECTS >100MW

Name	Location	Owner(s)/Partners	MW Capacity	Loan Guarantee Amount (Millions)	Loan Issuance Date	Project Completion Date
Agua Caliente	Yuma County, Arizona	NRG Solar LLC & MidAmerican Renewables LLC	290	$967	August 2011	March 2014
Antelope Valley Solar Ranch	Lancaster, California	Exelon	242	$646	September 2011	April 2014
California Valley Solar Ranch	San Luis Obispo, California	NRG Energy Inc. & NRG Solar LLC	250	$1,237	September 2011	October 2013
Desert Sunlight	Riverside County, California	NextEra Energy, GE & Sumitomo of America	550	$1,460	September 2011	February 2015
Mesquite Solar	Maricopa County, Arizona	Sempra Energy, Sempra Generation & Consolidated Edison Development	170	$337	September 2011	June 2013
LPO FINANCED TOTAL			1.502 GW	$4.647 Billion		

Figure 19. LPO-Financed Utility-Scale Solar PV Projects

These projects were not only successful, but "sparked a decade-long boom in utility-scale solar photovoltaic power plant construction," and were the "final stepping-stone toward rapid commercial growth." The authors advance the following arguments as potential factors of success:

- The projects were the first demonstration at scale of technologies "that were already commercially proven[57] at smaller scale" (see Figure 19).
- The "scale-up of solar PV was achieved by deploying multiple modularly-manufactured panels."
- Part of the reason these projects were able to mobilize private investments was that "the lenders were reassured by the financial certainty of the government loan guarantee as well as the technical rigor of the due diligence review."
- Supportive state and federal policies after these demonstrations (including renewable portfolio standards and tax credits) were conducive to continued deployment and scale up of these technologies.

Study 3. Another Example: RedRock Biofuels[58]
RedRock biofuels is a case study that illustrates the difficulty and long timelines associated with capital raising, as well as the risks (including with respect to cost overruns) involved with FOAK projects. The company was incorporated in 2011, with plans to use waste wood biomass as a feedstock in a "proprietary integration of existing gasification, Fischer-Tropsch and hydroprocessing technologies" to make renewable jet and diesel fuels.

- 2011: Year company was incorporated.
- 2014- 2018: Red Rock biofuels was in the market looking for funding for the first commercial project.
- 2018: Raised $245mm in Oregon bonds.
- 2020: Requested additional $89-110mm in Economic Development Revenue Bonds[59] for "process technology changes and improvements to the facility." These were approved in June 2020.
- As of April 2021, project was 75% complete (60% including the new scope), and target completion date was stated to be Dec 2021 - Feb 2022.

Minutes of the Business Oregon Commission' meeting reflect the committee's concerns, among others, with the high leverage and absence of third party equity commitments, but ultimately leaves it to purchasers of the bonds to do their own diligence and assessment prior to investing.

[57] While the technologies were largely commercially proven, certain of these projects did include innovative components.

Appendix E: Sampling of Past and Present Initiatives[60] Attempting to Address the Issue

Sampling of initiatives attempting to address the issue

	Type	What	Focus and Limitations	Outcomes
Corporates (*) (e.g. ABB, GE)	Corporate guarantees + "bridge" project equity	FOAK	Inhouse technology only	Positive
U.S. Treasury	Tax credits or grants	FOAK (1-to-n), with high n; green premium	Ability to absorb or monetize tax credits	Positive
DOE LPO (*)	Loan guarantee, loan	FOAK (1-to-n) (overall risk)	Larger projects	Depends on metrics
DOE Applied Offices	Grants	Demonstration projects	Typically <50% of capital needed	Mixed track record
NY Green Bank	Loans	FOAK (2-to-n); small projects	No technology risk	Depends on metrics
Energetic	Insurance	Credit Risk	TBD	Depends on metrics
New Energy Risk	Insurance	FOAK (1-to-n); technology risk	TBD	Depends on metrics
Closed Loop Infrastructure Fund (*)	Below-market debt	FOAK	Small amounts, circular economy focus	Positive
Community Investment Guarantee Pool (CGIP)	Guarantee	Projects that benefit communities of color and low-income households	Credit, liquidity and performance risks, small amounts	Too new to rate
Breakthrough Energy Catalyst	Grants, below-market equity	FOAK (1-to-n)	Initial focus on 4 sectors	Too new to rate
OGCI Climate Investments	Equity (Project and Corporate)	Development	Limited FOAK tech deployments; TRL 7+	Too new to rate

Source: Prime Coalition

In looking at the outcome of various past and present efforts targeting certain of the gaps identified in this report, we looked at a combination of (a) ability to crowd in other investments, (b) financial viability of projects, and (c) catalytic impact on sector/technology/solutions targeted beyond a single project.

[60] Disclosure: Author has worked (as an employee or contractor) for the organizations highlighted with a (*).

Unsurprisingly, grants for demonstration projects had the least positive overall outcome, although these conclusions may be biased by the track record of large projects mentioned earlier in the report. David Hart, referring[61] to the technology Pork Barrel book, states that: "These projects rarely succeed in bridging the gap between proof of principle and market viability. Particularly when public investment is employed, once the spending spigot is turned on, its geographically concentrated fiscal benefits attract political support without regard to technological payoffs or commercial viability – large projects in particular are attractive to legislators. The Clinch river project ran for 14 years, absorbed more than $5 billion and was never completed (but was sustained because it provided contracts and jobs)." David Hart further states: "government funding is certainly needed for large projects in particular, but care should be taken that selection, funding and shutting down demonstration projects should be isolated from political influence."

The most positive outcomes were generated by:

- Corporates providing a blend of construction funding and corporate guarantees for FOAK projects;[62]
- Tax credits or grants (ITC, PTC) from the U.S. Treasury for renewable generation; and
- Below-market debt funding for FOAK projects focused on the circular economy.

While the financial viability of projects and ability to crowd in capital were positive for the DOE LPO and NY Green Bank initiatives, the impact on these efforts on the deployment of solutions at scale is mixed. The US DOE's program, in particular, was instrumental in rendering the U.S. utility scale solar sector mainstream, and some could argue in enabling Tesla's (and consequently electric vehicles) success. But the balance of the investments did not result in particularly meaningful follow-on opportunities, and if anything, cast a shadow on cleantech manufacturing projects. Insurance programs seem to have been helpful in crowding in debt capital into new frontiers, but the feedback was mixed as to the effectiveness and breadth of existing programs.

CGIP is currently piloting pooled guarantees from philanthropic organizations. If done right, this may prove to be a high leverage solution. However, from a lender/equity provider perspective, it may add a layer of unfamiliarity to the equation (e.g., how would capital providers underwrite the credit of a pooled guarantee from foundations? Credit committees may be uncomfortable with the ability to call on the guarantee, unless fully funded, which would negate its leverage).

[61] HART, DAVID M. 2017. "Across the "Second Valley of Death: Designing Successful Energy Demonstration Projects." Itif. http://www2.itif.org/2017-second-valley-of-death.pdf.

[62] Not necessarily for climate solutions.

Appendix F: List of Interviewees

Table 6: List of Interviewees

Name	Affiliation
36 MIT Alums @ MIT REF convening	MIT Sloan
Aaron Ratner	Nexus PMG/Vectr Ventures
Adam Forni	Google
Alex Lau	Carbon America
Alex Mitchell	LACI
Alexander Rozenfeld	Climate Impact Capital
Alfred Griffin	Generate/ex NY Green Bank
Alicia Barton	FirstLight Power
Alicia Seiger	Stanford University
Alok Mathur	GPFAC
Amanda Eller	Emerson Collective
Andrew Kessler	NY Green Bank
Bert Hunter	CT Green Bank
Brent Lewis	Carbon America
Brian Baynes	Verdox
Brian Von Herzen	Climate Foundation
Caitlyn Fox	Chan Zuckerberg Initiative
Charlie Lord	RENEW Energy Partners
Cheryl Martin	Harwich Partners
Christian Zabbal	Spring Lane Capital
CJ Warner	Sapphire Energy
Colin le Duc	Generation IM/Just Climate
Craig Sulzburgh	East Peak Partners
Dan Firger	Great Circle Capital Advisors
Dan Goldman	Clean Energy Ventures
Dave Chen	Equilibrium Capital
David Hart	ITIF

Name	Affiliation
Dawn Lippert	Elemental Excelerator/Earthshot Ventures
Derek Warnick	Electric Hydrogen Co.
Doug Schultz	DOE LPO
Eric Trusiewicz	BEV
Eve Hanson	Third Derivative
Hara Wang	Third Derivative
Ida Hempel	Just Climate
Jacques Guillet	Reliable Hydrogen
James Mackey	OGCI Climate Investments
Jason Jacobs	My Climate Journey
Jason Jay	MIT Sloan
Jason Segal	Javelin Capital
Jay Dessy	BEC
Jeff Eckel	Hannon Armstrong
Jeff McAulay	Energetic Insurance
Jeffrey Schub	Coalition for Green Capital
Jennifer Holmgren	LanzaTech
Jeremy Ley	NEM
Jessica Aldrich	NextEra Energy
Jessica Bailey	Greenworks Lending
Jetta Wong	JLW Advising
Jigar Shah	DOE LPO
Jim Baek	Community Investment Guarantee Pool (CGIP)
Jim McCrea	James McCrea & Associates
John Ravis	HamiltonClark Sustainable Capital
Jon Ellis	Crestmark
Josh Browne	Rho AI/Obantaria
Joshua Agenbroad	Third Derivative
Joshua Ruch	Chairman, Enerkem/RHO Fund Investor

Name	Affiliation
Kristin Barbato	Build Edison
Kumar Garg	Schmidt Futures
Lara Pierpoint	Actuate Climate
Libby Wayman	BEV
Linal Perera	Svante
Lincoln Bleaveans	Stanford University
Lorenzo Bernasconi	Lombard Odier Investment Managers
Lori Guetre	Carbon Engineering
Lou Schick	Clean Energy Ventures
Lynn Schenck	HBS
Mark Bruinooge	2040 Fund
Martin Keighley	CarbonFree
Mason Wallick	SEACEF
Matan Friedman	Generate Capital
Matt Kirley	NYSERDA
Melissa Uhl	Elemental Excelerator
Michael Bruce	Emerson Collective
Michael Leifman	Tenley Consulting
Mike Jackson	Earthshot Ventures
Mike Reynolds	Ultra Capital
Nan Ransohoff	Stripe
Noah Deich	Carbon180
Patrick Sieb	Investible, ClimateTech
Peter Davidson	Aligned Climate Capital
Peter Light	Lumen Energy
Ramsay Huntley	Wells Fargo
Ramya Swaminathan	Malta
Reuben Munger	Vision Ridge Partners
Richard Kaufman	Generate Capital / NYSERDA

Prime

Name	Affiliation
Rick Jones	Hartford Steam Boiler
Rick Schwerdtfeger	Leading Edge Equipment Technologies
Rob Day	Spring Lane Capital
Roberta Benedetti del Rio	Consultant to Just Climate
Ron Gonen	Closed Loop Partners
Ryan Orbuch	Stripe
Sasha Post	Additional Ventures
Scott Gardner	Carbonfree
Shreya Dave	Via Separations
Stuart Davies	ORPC
Tanay Mehta	Stripe
Thomas Kalil	Schmidt Futures
Thomas King	CrossRiver Capital
Thomas Long	Morgan Stanley
Tim Grosse	E Squared Energy Advisors
Tyson White	BEC
Will Coleman	OnRamp Capital

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