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Guidebook for Early Climate Infrastructure

How Climate Technology Developers are Approaching First-of-a-Kind Projects

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Introduction

A constellation of emerging climate startups are facing their hardest challenge: how to deploy their first projects.

The early-stage climate technology ecosystem is flourishing, and an increasing number of entrepreneurs and scientists are bringing forward startup companies with promising solutions for some of our hardest challenges. Many of the climate problems that once seemed nearly impossible to address—decarbonizing cement, storing low-carbon power for days, replacing high-temperature heat in heavy industry—now have alternatives demonstrating viability in pilot projects around the globe.

It is essential to climate stability that these new technologies are scaled up from pilot size to infrastructure-scale. In the latest International Energy Agency Net Zero Roadmap, 35% of the emissions reductions necessary for limiting climate change will come from technologies not yet on the market.[1] However, the bulk of climate impact will come from deployment of technologies at a large-scale.[2]

This scaleup is most challenging at its threshold, where the first facilities present technology, operational, customer, and construction risks that make them a challenging fit for any traditional source of lower-cost capital like project or infrastructure finance. Increasing attention has been given to this first-of-a-kind gap from investors, but startups have limited visibility on the levers they can pull in advance of their first commercial-scale project to smooth their trajectory.[3]

Founders of breakthrough technology companies rarely embark on their journey expecting to become project developers. However, without natural development partners like those driving forward wind and solar projects who will bring the technology to market, these early teams must rapidly build the permitting, contracting, financing, and operating expertise to bridge the roles of both technology providers and project developers.

So, what's an early-stage climate startup to do?

In an effort to provide guidance and reference points for early-stage climate technology startups whose first full-size projects are just over the horizon, I interviewed dozens of leaders in climate tech companies, investors, and other key stakeholders to identify patterns in how successful recent climate projects mitigated key risks and what actions startups can take to smooth the way for their first-of-a-kind endeavors.

This paper lays out how project financiers think about project risk factors, and explores how four specific companies reduced these risks through thoughtful approaches to project development. It is my hope that this report will be useful as a guide for startups approaching project scale, that it will be part of a flourishing ecosystem of literature on early climate infrastructure, and that it will be worth updating in the very near future because of the many more projects and creative mechanisms that will be deployed in the next few years.

1 International Energy Agency, "Net Zero Roadmap: A Global Pathway to Keep the 1.5 C Goal in Reach," (2023 update) September 2023.
2 For more on technology impact at scale, see Dawn Lippert, Danya Hakeem, and Ramsay Siegal, "The Commercial Inflection Point Scale for Climate Tech Startups," Elemental Excelerator, May 11, 2022.
3 Karine Khatcherian, "Barriers to the Timely Deployment of Climate Infrastructure," Prime Coalition report, May 2022.

WHAT MAKES EARLY CLIMATE INFRASTRUCTURE SO CHALLENGING

Why financing is key

For low-carbon infrastructure projects, often more than half of the cost of the output (whether renewable electricity, green cement, or sustainable aviation fuel) is driven by the cost of financing, a combination of interest rates on debt and yield to equity investors.[4] Roughly 40% of the cost of renewable energy projects can be attributed to costs of financing.[5] Lowering these costs is critical to the competitiveness of these solutions and the rates at which they displace incumbent carbon-intensive technologies.

To be competitive and profitable at scale, climate founders must shift from venture capital and growth equity funding with an embedded cost of capital in the 25-40% range to project finance funding closer to the 10-15% range. The infrastructure funds and banks that offer lower cost project financing trade the uncapped upside of equity investments for more reliable cashflows, requiring allocation of responsibilities to creditworthy counterparties and bounding of risks through detailed project specific documentation. They are typically only willing to back new technologies after they have demonstrated a history of strong operational performance and revenue generation.

Though limited, alternative lower cost sources of capital for climate-related projects exist. Platforms that offer better terms because the lender or grantor desires impact, rather than purely returns, can help founders conserve equity capital. Startups can focus on grants and other public sources of support to reduce the costs of their projects. However, the pools of capital available from government or philanthropic funders are too small to fully support the trillions of dollars of climate infrastructure necessary.[6] In the future, more creative sources, like blended concessionary capital or advanced market mechanisms that guarantee offtake, might further smooth the path to scale in coming years. Some startups will find partners that can bridge multiple roles or investment phases, including investors who can provide a combination of company equity and project capital or developer partners who seek to secure upside by bringing in their own project capital and taking on more project risk.[7]

These financing mechanisms can relieve some of the difficulty of scaling climate tech, but founders must build with the assumption that they will need to primarily rely on more traditional sources of capital as they scale. Climate startups will need to speak the language of risk mitigation rather than upside maximization, as is ideal for attracting venture capital.

In order to fruitfully build to scale, climate technology developers need to think creatively about how they can de-risk their projects well in advance of the project beginning. In many cases, actions taken years before breaking ground can be the most impactful on the ultimate success of individual projects and the venture more broadly.

4 International Energy Agency, "The Cost of Capital in Clean Energy Transitions," December 17, 2021.
5 Project cost splits between financing, opex and capex detailed in page 50 of Nat Bullard Annual Presentation "Decarbonization: Stocks and flows, abundance and scarcity, net zero," January 31, 2024.
6 Mark Gongloff, "$266 Trillion in Climate Spending Is a No-Brainer," Bloomberg, November 13, 2023.
7 For more on funds that invest in both companies and projects: Albert Wenger, "Building out the Climate Capital Stack," Union Square Ventures blog, February 16, 2023.

How to think about project risk factors

From the vantage point of a traditional project investor
Co-authored by Guy Van Syckle III
For detailed questions and strategies, see Appendix A

In their path of building towards scale, climate founders can benefit from putting themselves in the shoes of a project investor. Understanding how project finance and infrastructure investors consider risks will enable startups to develop projects for speed to deployment and profitability. While these questions could fill a report of their own, a few of the most important elements to prepare for in the early stages of project planning are:

Technology: Many climate startups are scaling exciting novel technologies that promise to do things in ways that are impossible to do with existing technologies. However, project investors want to see that the underlying technology being deployed has been well-proven and ideally demonstrated multiple times at a commercial scale. Startups can help mitigate this risk by using existing technologies and/or components wherever possible, running as large of demonstration-scale projects as possible, using components well proven in other industries, leveraging large manufacturers for their supply chain, and/or exploring technology insurance options like New Energy Risk.[8]

Development and construction: Startups that have proven themselves effective at rapidly improving technologies at a small scale require a different skill set to develop and construct a full-sized project. To mitigate investor concern about development capability, startups should seek to bring on a highly experienced development team with backgrounds in related technologies, partner with top EPC companies, and explore partnership terms that shift some risks associated with development to partners in the project or to the customer. Optimizing the project size will also be critical—startups should weigh economies of scale in a larger project, size of project feasible with their current corporate resources, and the standardization of project size to improve replicability with a variety of follow-on clients.

Operations and maintenance: Similar to challenges around development and construction, project investors may have serious concerns about the capability of a startup to operate and maintain a project for its lifetime without a history of doing so successfully. Startups could address these concerns by assigning operational obligations for the project to partners or customers at project completion, though potentially trading off returns to the startup or benefits of data collection to de-risk financing of future facilities. Startups can also develop "warm backup" relationships in which key partners commit to stepping into project operation in the event that the startup is no longer able to operate and secure warranties from component manufacturers that cover performance.

Feedstock supply: Fluctuations in input costs could endanger a project's profitability. If a project requires zero-carbon power in order to operate, the feasibility of constructing or soliciting that power could prove a major challenge in a time of long interconnection queues,transmission congestion, or limited suitable nearby land. To reduce challenges around renewable sourcing, startups can pursue collaborations with renewable energy developers and their customers to increase confidence in the certainty and creditworthiness of offtake or can consider building higher costs of power into their project budget in order to be an attractive offtake for those

8 New Energy Risk provides performance insurance solutions to technology developers without long-term performance data at commercial scale.

projects. Startups can mitigate risks associated with feedstock supply, by siting projects in locations where multiple sources of feedstocks are available, negotiating multi-year agreements with key suppliers, and structuring customer agreements to allow a passthrough of energy and input costs.

Labor: Projects may require highly experienced workers with skillsets that are niche or in relatively high demand, like specialized electricians or engineers. Labor shortages or high labor costs may mean delays and erosion of returns. Integrating labor as a key element of site selection can help ensure that startups benefit from existing workforces, lower-cost labor, or skilled labor with customers or partners. In addition, startups may benefit from existing workforce development or upskilling programs or partnerships with local vocational schools or community colleges to train workers in the capacities needed for the facility's operation.

Revenue certainty: Project investors would find it easiest to underwrite revenue from a facility where demand is nearly certain, with long-term contracts in which customers are held to purchasing output at a set price for the entire duration of the facility. However, this is rarely an option for climate tech companies. Depending on the type of market its output will be sold into, startups could adopt several strategies to minimize revenue risk. Those selling into commodity markets, where prices fluctuate and long-term supply agreements are rare, could explore a revenue guarantee contract with a bank or commodity trader to ensure backup in case of market changes. Companies with a large but low-margin market can focus on initial sales to smaller higher-margin sectors (for example, using carbon recycling to produce high-value fragrances in advance of a larger market for fuels). Startups can also aim to secure LOIs with customers or customer coalitions with specifics around revenue and quantity, even if these are not fully binding offtake contracts.

Contract/customer reliability: Continuing from the previous challenge, customer creditworthiness is a top concern for investors when considering offtake and revenue certainty. While partnering with larger highly creditworthy customers would be a step towards reducing the risk of a customer bankruptcy, this is not always an option in industries where bankruptcies are common and few large players are highly regarded by rating agencies (e.g., the airline industry). In these cases, startups could build facilities that could serve alternative customers and develop agreements with customers that offer strong protection in the case of customer termination (ex. specific liquidated damage amounts paid in event of customer default). A startup should at least have a clear picture of the credit exposure they are taking with customers and regardless of size and perceived customer heft ask for a diligence package on financial health (e.g., 3yrs of audited financials) as this will ultimately be requested by any project financier.

Policy dependence: Thanks to the generous funding opportunities in the Inflation Reduction Act, grants, tax credits, and loan guarantees at the federal level are driving a tremendous amount of climate related investment activity in the United States.[9] State and local governments have offered incentives as well to encourage climate infrastructure to be built in their territories and to create jobs and taxable revenue. While startups should take advantage of these opportunities wherever possible, they should also be cautious about building a long-term business model that relies on repealable or partisan incentives that could be overturned by future administrations. There should be a path to unsubsidized profitability in the global markets.

9 Casey Crownhart, "How a half-trillion dollars is transforming climate technology," MIT Technology Review, August 16, 2023.

Case studies

Startups that have developed commercial-scale climate projects over the last few years have done so in a myriad of creative ways. Through a series of interviews in late 2023 through early 2024 with some of the most promising climate tech companies, we have collected four case studies of thoughtful approaches to financing that address the risks outlined above.

In an effort to explore how different types of climate tech projects have different types of risk mitigation levers accessible, this study examines four substantially different types of companies:

- Fervo, generating zero-carbon power
- Monolith, producing decarbonized commodities
- Rondo, manufacturing and deploying a novel heating source for heavy industry
- Via Separations, installing industrial efficiency and decarbonization components

Fervo Energy

Fervo Energy is commercializing a breakthrough enhanced geothermal technology, leveraging lessons and technology from the shale revolution in the U.S. to drill horizontal stimulated geothermal wells that minimize project surface footprint and enable 24/7 carbon-free electricity production in geographies where geothermal resources are not accessible with traditional production methods.

Fervo was founded in 2017 by Tim Latimer and Jack Norbeck, who met while graduate students at Stanford. Its pilot project, launched in Nevada in 2021 and operational by November 2023, was backed by Google to support its renewable energy goals, generating 3.5 MW for local data centers. The Nevada project was chosen and structured to de-risk the drilling innovation at the core of Fervo's breakthrough. Fervo drilled two wells at an existing geothermal power plant and is selling its geothermal brine to the power plant operator, who manages power production from the site. Though this project validated Fervo's technology, producing a flow rate significantly above expectations and continues to generate revenue, it was not a full commercial-scale project.[10]

First-of-a-Kind Project Details

- ***Location:*** Southwest Utah
- ***Timing, scale, & structure:*** The project will be constructed in two tranches, reaching a full size of 400 MW by mid-2028. The first tranch, expected to come online in mid-2026, will produce 90 MW.



Fervo's Utah project

10 Details on Fervo demonstration plant performance: Jack Hunter Norbeck and Timothy Latimer, "Commercial-Scale Demonstration of a First-of-a-Kind Enhanced Geothermal System," Earth ArXiv, July 18, 2023.

- ***Customers:*** Power will be sold to community choice aggregators and utilities in California.

- ***Community engagement:*** Fervo has developed significant community and political engagement capacities in Utah and will employ roughly 150 people on-site during peak project development.

- ***Strategy:*** Through this commercial-scale project, Fervo hopes to fully de-risk the operational and development capabilities of the company, as well as the production of the technology at scale. Fervo plans to focus full development capacity on developing this site until it is fully operational, then develop multiple others in tandem with the learnings from this site.

- ***Market positioning:*** So far, Fervo has shown that it can drill a well at half the cost and in 70% less time than during its pilot development.[11]

Financing

To fund the Utah development, Fervo has raised several equity rounds, including a recent $244M financing led by Devon Energy.[12] The company has conditionally secured a $100M construction loan to cover a substantial portion of the project costs from an impact-oriented lender. This allows them access to a lower cost of capital than corporate equity or than they would currently be able to secure from a traditional project financier, based on the jobs created in rural areas by the Utah project. Fervo recently received a Department of Energy grant of $25M through the enhanced geothermal demonstrations opportunity, supporting the Utah project development.[13] Fervo is pursuing lower cost of capital financing options to cover the remainder of the capex for its facility.

Risk mitigation levers

- ***Gaining support from government officials and local community***: Fervo has been highly effective at establishing government backing, both through funding channels like the DOE grant and public declarations of support from officials, including Secretary of Energy Jennifer Granholm and Utah Governor Spencer Cox.[14] The company has made a concerted effort to engage the local community in its project development, minimizing risks of community opposition to project development stages. When Fervo submitted an environmental assessment for drilling to the Bureau of Land Management, the mayor of Milford, the town next to their project, filed a letter of support for their development efforts. Fervo's leadership team credits much of their success to the decision to build out a government and community engagement capacity internally early in project development, as well as their choice of local government affairs partner.

- ***High-quality offtake:*** Fervo's Utah project will sell the electricity it generates to California utilities and community choice aggregators through power purchase agreements (PPAs). 53MW of offtake agreements have been announced. In this regard, Fervo can benefit from two external mechanisms: the established nature of renewable energy PPAs as a way to compensate renewable energy developers, and policy mandates

11 Review of Fervo drilling performance: Kareem El-Sadi et. al, "Review of Drilling Performance in a Horizontal EGS Development," presented at Stanford University 49th Workshop on Geothermal Reservoir Engineering, February 12-14, 2024.
12 Jov Onsat, "Fervo Raises $244MM for Advanced Geothermal Energy Project," RigZone, March 7, 2024.
13 Jishnu Nair, "Fervo Energy one of only 3 companies selected for millions in geothermal funding from DOE," Houston Business Journal, February 14, 2024.
14 Maria Gallucci, "Fervo breaks ground on next-generation geothermal plant," Canary Media, September 26, 2023.

in California that require electricity providers to procure a minimum amount of non-weather dependent zero-emission baseload power.

- ***Deep development experience:*** Fervo brought on talent with deep experience building projects in related industries, including natural gas extraction, which helped reduce risks around project execution. While the company is deploying its first project, its team has over 85 years of collective energy experience. Bringing on this talent from a more established industry has also caused the company to explore project structures and strategies more common in other industries.

- ***Optimized location:*** In selecting the project location in Utah, Fervo optimized for several factors, including labor and material availability driven by oil and gas operations in the Uinta Basin, Department of Energy subsurface studies that significantly reduced the cost of surveying sites, and eager offtake nearby in the California market.

- ***Multi-phase project:*** By breaking down the project into multiple, separately financeable phases, Fervo reduced their initial development capital needs while maintaining an opportunity to reduce their cost of capital over time. By not locking in the entire financing up front, they will be able to further demonstrate their ability to execute in the first 90MW phase and find lower-cost sources of financing for the remaining 310 MW.

Monolith

Monolith is scaling up a methane pyrolysis process that transforms methane into carbon black and low-carbon hydrogen. Compared to conventional processes for producing ammonia and carbon black, Monolith's approach reduces CO2 emissions by 97%. Monolith was founded in 2012 by Rob Hanson and Pete Johnson, who brought deep experience in building renewable projects and a vision for a large-scale endeavor that addressed carbon emissions from the chemicals industry, along with Bill Brady, who had led one of the largest carbon black producers. They acquired their core IP from a company that successfully ran a pyrolysis facility in Canada but had been shut down during a period of high natural gas and low oil prices. This successful production history gave the executive team and investors confidence that the plasma technology could be successfully deployed.

Monolith's demonstration facility in Redwood City, California was constructed between 2013 and 2015 and funded primarily through company-level equity. The initial facility proved three important things: that the pyrolysis technology worked to produce carbon black at multiple grades, that Monolith's carbon black would be accepted by existing purchasers, and that the general economics were similar to what was expected. Though the reactor, which had the capacity for 190 tons of hydrogen and 700 tons of carbon black annually, was not profitable, it set the groundwork for Monolith to finance and launch a commercial-scale reactor.[15]

15 "Monolith Materials: Taking Methane Pyrolysis from Concept to Industrial Plant," ARPA-E presentation by Chris Mesrobian, Director of Technology, January 2021.

First-of-a-Kind Project Details



Monolith's current Olive Creek production site

- ***Location:*** Olive Creek, Nebraska

- ***Timing, scale, and structure***: Completed in 2021 after four years of construction, it was a more than 30 times scale-up from the demonstration plant, capable of producing 6kT of hydrogen and 14kT of carbon black annually, making it the world's largest methane pyrolysis facility ever built.

- ***Customers:*** The company sells carbon black through short-term contracts and sells hydrogen as ammonia to the fertilizer industry on a merchant basis. Publicly announced customers for carbon black include Michelin and Goodyear, which use Monolith's output in tire production.[16]

- ***Strategy for next facility:*** Monolith's second phase of Olive Creek will be a 12 times scale up, bringing production up to 194kT of carbon black and 275 kT of clean ammonia annually.For this expansion, they have partnered with Kiewit, one of the top contractors in the U.S., as the engineering, procurement, and contracting (EPC) lead.[17] Phase II is expected to enter construction in 2025, with production coming online in 2028. Beyond the Nebraska expansion, Monolith has 40 plants in development discussions in the US, Japan, and South Korea.[18]

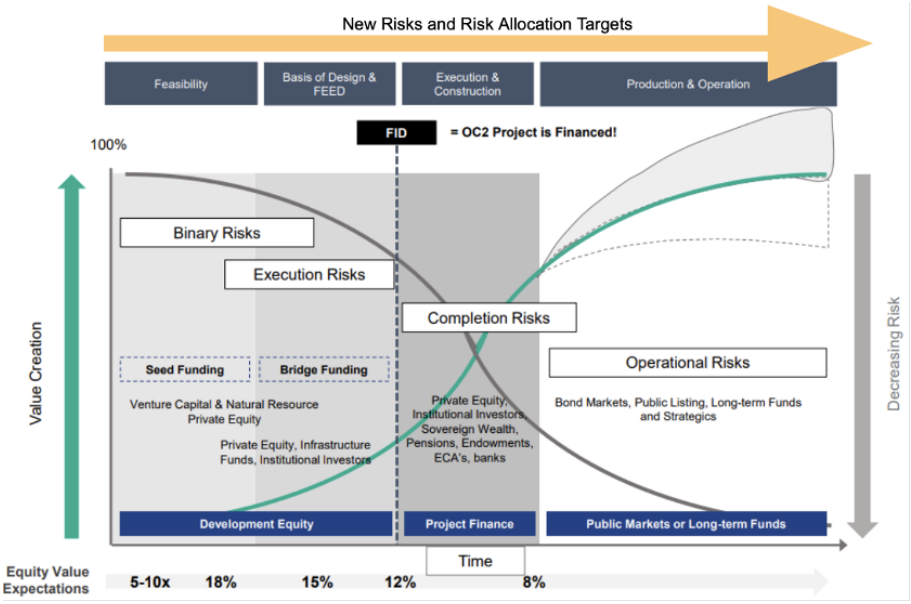
- ***Policy incentives:*** The new hydrogen production tax credit (PTC) provides the company with an additional (and certain) revenue stream, and to meet the regionality, additionality, and temporality requirements of the PTC, they will contract with renewable power developers.[19]

Financing

Monolith funded the early days of company development not with classic early-stage venture capital but with backing from private equity funds Warburg Pincus and Azimuth Capital Management. These funds provided them with an equity line of credit, a form of funding used more often in traditional energy investing. This involved a large amount of capital provided in tranches, which would be available to the company upon meeting key milestones. The financing structure allowed the executive team to reduce the time spent on continuous fundraising efforts and renegotiating the company's valuation through various potential rounds of venture capital financing. Instead, they could focus on executing and scale-up.

Monolith's pilot and first commercial plant were funded by corporate equity from these funds, as well as additional firms who joined additional equity rounds, including $300M equity financing in 2022 led by TPG Rise and Decarbonization Partners.[20]

16 "In Industry First, Goodyear Launches Tire with Monolith Carbon Black," Press release, May 10, 2023.
17 Engineering News-Record, "ENR 2023 Top 400 Contractors," 2023.
18 Climate Tech VC, "Monolith's Mighty Ambitions," July 22, 2022.
19 Department of Energy, "Clean Hydrogen Production Tax Credit (45V) Resources," December 19, 2023.
20 "Monolith Raises More Than $300 Million in Latest Funding Round led by TPG Rise Climate, Decarboniation Partners," Press release, July 14, 2022.



Capitalization structure over time: Monolith Materials

Monolith received conditional approval for a $1B DOE loan guarantee in 2021. This loan is expected to close later this year and will cover the majority of the costs associated with the Olive Creek Phase II project.

Risk mitigation levers

- ***Leveraged de-risked technology:*** Monolith reduced the risk of fundamental technology failure by acquiring IP from a Norwegian company that had operated a methane pyrolysis facility at scale and combined this with innovations from several universities. Minimizing the fully novel aspects of their process reduced the risk that the technology would not perform as expected.
- ***Creative offtake backstop:*** Monolith initially met hesitation from investors about the pricing risk of selling a commodity like carbon black. Though investors were seeking long-term certainty in offtake, customers were accustomed to short-term contracts. To provide more certainty to investors, Monolith took a novel approach in structuring a revenue put with a large investment-grade counterparty in which the bank promised to provide revenue certainty. Though the Department of Energy was eventually able to take the pricing risk presented by Monolith's sales to the carbon black and ammonia markets after the Energy Act of 2020, the synthetic offtake helped them secure their initial commitment.[21]

- ***Hired deep development and finance experience:*** Monolith has brought on key leadership with deep experience in developing and financing projects at a similar scale to what their facility will become. Tim Rens, Chief Financial Officer, Russell Webb, Chief Operating Officer, and Phil Joyner, SVP of Manufacturing, have each spent three or more decades financing, developing, and operating energy and chemical infrastructure.

21 For more on discussion of DOE merchant risk capability: My Climate Journey podcast, "Ep. 197: Rob Hanson, Co-Founder & CEO of Monolith, and Jigar Shah, Director of the Loan Programs Office at US DOE," February 21, 2022.

- ***Strategic equity investors:*** Monolith's use of upfront funding from long-term private equity backers meant that the founders had to trust their investors and give up a significant portion of the company early.[22] However, these investors were ready to support the team in scaling and brought in support and knowledge from other infrastructure projects. Startups comfortable with having most of their incentive weighted towards scale may find this path an accelerant. Monolith also brought in other strategic equity investors, including NextEra, one of the largest global renewable energy developers, and SK and Mitsubishi, major industrial companies interested in the hydrogen economy.

- ***Distributed key risks:*** Monolith's leadership has focused on carefully delineating key risks at each project stage and negotiated with partners to distribute risks as much as possible.

- ***Multi-phase project:*** Monolith's production is economically most attractive on a large scale, with a project cost in the billions. To ensure that their cost projections were correct and to build investor confidence in their ability to execute, they built their Nebraska facility in two phases, which allowed the team to confirm project cost estimates, smooth development challenges like permitting and community support for the larger facility, and to build production data to help investors underwrite the second phase. Startups may benefit from building their facilities in multiple phases, with costs of capital significantly reduced for the subsequent phases.

Rondo

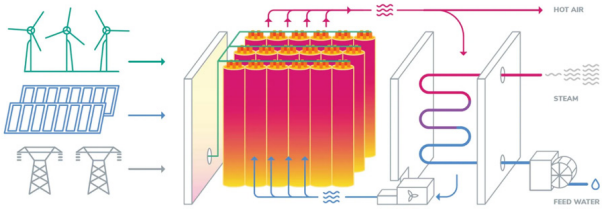
Rondo provides zero-carbon heat to industrial facilities through "heat batteries," or thermal storage systems that capture intermittent electricity and convert it into continuous high-temperature heat. Their systems can also be configured to deliver both heat and power and can be a drop-in replacement or an additional complement to existing equipment.

Their core innovation is storing heat from electricity in refractory brick, which has been used for centuries for industrial applications using heat from fossil fuels. By keeping the core technology as close to existing solutions as possible, Rondo benefits from the production infrastructure already in place to supply their systems. Rondo has partnered with Siam Cement Group for their manufacturing, and the companies are currently expanding production from 2 GWh/year to 90 GWh/year to create what they are touting as the world's largest energy storage manufacturing in Thailand.[23]

22 For more on founder and CEO of Monolith's reflections on equity line of credit approach: My Climate Journey podcast, "Episode 82: Rob Hanson, Monolith Materials," February 17, 2020.
23 Julian Spector, "Industrial heat startup Rondo to open world's largest battery factory," Canary Media, June 27, 2023.



Rondo heat battery at Calgren site



Rondo heat-as-a-service system

First-of-a-Kind project

- ***Location:*** At a Calgren Renewable Fuels facility in Pixley, California
- ***Timing, scale, and structure:*** 2Wh deployment, completed in 2023. It is the first electric thermal energy storage system in the US and the highest-temperature system in commercial operation, at above 1000 Celsius.
- ***Customer and value:*** Rondo's system provides heat as a service to its customer, helping Calgren produce low-carbon fuels incentivized by California's low-carbon fuel standard. Rondo's heat is provided at a lower cost to the customer than natural gas alternatives, and cuts the CO_2 intensity of the biofuel produced in half. The system was installed without requiring any downtime for the customer.
- ***Strategy for next projects:*** Rondo intentionally builds units of different sizes that are functionally identical in structure and can be easily expanded upward. Their publicly available spec sheet offers two sizes today, with 100 MW and 300 MW of storage, both of which are fundamentally the same set of bricks, installation, and heat transfer system as their 2 MWh system.[24]

Financing

Rondo has a large pipeline of potential projects, including many where the customer prefers contracting and financing under a heat-as-a-service or storage-as-a-service agreement as opposed to purchasing the system upfront. To meet this pipeline of distributed assets, the company has focused on "making project finance part of their design philosophy," hiring a full-time project finance lead, derisking the technology with the support of independent engineers and operating data, and structuring their projects as long-term offtake agreements with creditworthy customers.

For a company like Rondo, keeping transaction costs low across a portfolio of assets is key to securing project finance. Rondo aims to do so by minimizing differences across their projects, using similar customer offtake agreements across projects, and prioritizing working with sites where there is potential for multiple units to be deployed over time.

24 Rondo Energy website, "The Rondo Heat Battery Product Line."

In March 2024, Rondo received a substantial award from the Department of Energy Office of Clean Energy Demonstrations for up to $75M to install systems in Diageo North America distillation facilities in Illinois and Kentucky.[25] These systems will replace natural gas boilers used to produce beverages and liquors.

Risk mitigation levers

- ***Optimize close to existing technologies:*** John O'Donnell, Rondo's CEO, has called their strategy "boring on purpose… innovate as little as possible."[26] Though their brick configuration is optimized for heat storage and transfer from electricity, the company has made a concerted effort to keep each element of their installations sourced from existing, creditworthy manufacturers and to minimize technology risks in their deployments. The company points to the performance of refractory brick in other industrial applications as key data demonstrating the validation of their core elements.

- ***Secure feedstock of renewable electricity through flagship partnership:*** In March 2024, Rondo announced a major partnership with EDP, a global renewable energy project developer and utility with a presence in Europe, North America, South America, and Asia.[27] In their announcement, Rondo and EDP highlighted the opportunity to co-locate wind and solar assets from EDP with Rondo heat batteries to provide fully decarbonized 24/7 heat and power supply contracts.

- ***Smooth scaleup challenges by reducing differences between products:*** Rondo is minimizing engineering and construction differences between their product offerings. Though Rondo's heat batteries come in different sizes, the difference is fundamentally in the number of bricks stacked and wires inserted, minimizing the risks of cost overruns or design changes as they shift to larger projects.

- ***Pursuing project finance early:*** Rondo has focused on designing for project finance very early in development to a much greater degree than many climate startups. This was somewhat spurred by CEO John O'Donnell's experiences in the solar thermal industry, in which he saw the challenges of adjusting toward infrastructure investor expectations late in company development. By building out project finance expertise early in the company's trajectory, Rondo has been able to fundamentally inform how they approach engagements with customers to maximize feasibility of financing facilities, as reflected in screening for high credit quality customers and considering key clauses in customer agreements early in the process.

Via Separations

Via Separations is decarbonizing industry by tackling emissions from separations, a key function that cuts across most industrial processes and accounts for about 15% of global energy consumption. Their novel graphene oxide membrane can withstand high temperatures and harsh conditions and is applicable to a wide range of industries including pulp and paper, chemicals, and food and beverage. Via systems can electrify processes that are currently fossil-fuel fired and reduce the amount of energy needed by 50-90%.

25 Department of Energy Office of Clean Energy Demonstrations, "Industrial Demonstrations Program Selections for Award Negotiations: Heat," March 2024.
26 My Climate Journey podcast interview with John O'Donnell, CEO of Rondo, recorded May 24, 2023.
27 Rondo Energy press release, "EDP & Rondo Energy partner to decarbonize industrial heat production, March 7, 2024.

The company was founded by Shreya Dave and Brent Keller, who met while completing PhDs in material science at MIT. Early in their partnership, they participated in the NSF Innovation Corps (I-Corps) program in which they conducted extensive customer discovery around separations with potential customers in a wide range of industries across the United States and Europe.

Via's installations integrate into larger industrial facilities, either fully replacing or supplementing existing components. Their first target market is pulp and paper manufacturing, where energy consumption is high and Via systems can reduce bottlenecks while electrifying and decarbonizing production.

Via built a modular and moveable pilot system, which they deployed through 4 pilot programs across 3 different customers between 2021 and 2022. The system collected 6,000 hours of field operating data, derisked the performance of its membrane technology, demonstrated consistent operational performance, and established its reputation within the pulp and paper industry.





Via's Project Kodiak (Jillian Wilson Photography)

First-of-a-Kind project details

Via's first commercial-scale installation is at an International Paper plant in Alberta, Canada, where the system concentrates black liquor, a key step in paper-making usually accomplished by burning fossil fuels. Construction started in May 2023, and commissioning began in March 2024. The installation can process 500 gallons per minute, 100 times the flow rate of its pilot. The cost per unit of capacity was roughly equivalent to its pilot because it was built with extensive instrumentation to report data and enable troubleshooting. Future systems with less instrumentation are expected to be nearly half the cost and double the capacity.

Via's system is built using a modular set of separation membranes, which allows it to be scaled up or down easily based on customer needs. Their initial revenue structure is based on performance and service fees, with the capability of selling the system directly to their customers if desired. Customers pay for electricity for the system and for the amount of material separated. Via hopes to build projects through repeatable agreements with efficiency-focused pulp and paper customers, many of whom have large portfolios. For these customers with larger portfolios of facilities, Via works with both facility operators and corporate parent companies to secure operator trust and reduce the corporate negotiations needed to develop new projects.

Financing

Via financed its first system through a combination of equity, equipment loans, and venture debt. $3.6M CAD of the system cost was subsidized with an award from the Canadian government through Natural Resources Canada's Investments in Forest Industry Transformation program.[28] Roughly a third of the system was financed with equipment loans from Atel, which allowed them to minimize the amount of equity needed for construction.

As their systems are modular and installed on existing industrial facilities, Via's fully commercial facilities will cost around $10-20M, depending on size. These facilities are much lower cost than many of the other climate infrastructure projects covered in this paper, making it challenging for project finance investors to finance individual facilities without high transaction costs eating into returns. To unlock project finance for future facilities, Via may explore financing a portfolio of assets under one line of credit and underwriting effort.

In March of 2023, the U.S. Department of Energy's Office of Clean Energy Demonstration announced an award of up to $46.6M to Via to decarbonize paper facilities in the United States.[29] This award could double the IRR of the early installations and speed up Via's deployments with key customers.

Risk mitigation levers

- ***Strong customer relationships:*** Via's founders Shreya Dave and Brent Keller spent extensive time in their early period of growth developing relationships in the pulp and paper industry through in-person site visits and engagement for detailed feedback. Today, their team has discussed opportunities for Via installations with 85% of the 114 pulp and paper facilities in North America. This rigorous customer-centered approach has helped them to build trust and visibility with their customers, and has translated to projects that maximize value to customers and to Via. Via has also made concerted efforts to build trust both with facility managers as well as with leaders at parent corporations.

- ***Data collection:*** Via has prioritized collecting performance data to increase customer confidence and to give investors greater confirmation for underwriting future installations. Both their pilot and first commercial facility were deployed with extensive capacity to collect data on production.

- ***Non-dilutive funding:*** Via has leveraged a range of opportunities to reduce project capital costs, leveraging both the Canadian and U.S. government's desire to increase efficiency and reduce emissions in critical industries as well as options to finance using equipment loans. This allows them to focus on using their venture capital on the fast-growing business, rather than their repeatable deployments. Pursuing these grants has an additional benefit of increasing diligence on their plans for deployment and scaleup thorough the rigorous review processes.

- ***Flexible installation size:*** Via can adjust the number of membrane modules installed as part of a system. Because of the modular nature of their installations, the company can optimize size not only for efficiency but

28 Natural Resources Canada press release "Government of Canada Invests in First-of-its-Kind Filtration Technology in Grande Prairie to Help Reduce Carbon Emissions," PR Newswire, June 13, 2023.
29 U.S. Department of Energy Office of Clean Energy Demonstrations "Industrial Demonstrations Program Selections for Award Negotiations: Chemicals and Refining," March 2024.

- also to meet the economic goals and capacities of their customers while achieving cost efficiency through the standardization of modules.

Takeaways for climate tech startups

The climate ecosystem is changing dramatically each year, and with increasing interest in FOAK facilities, new projects and financing options will continue to emerge. In this dynamic environment, startup leaders can learn from examples of FOAK financings; both recent ones like those explored in this paper as well as financings in the early days of solar, electric vehicles, and biofuel production in past decades.

The concept of "climate tech" covers an incredibly broad constellation of industries and project typologies. Segmenting the industry by type of project can help elucidate which projects have helpful insights to offer founding teams as they plan for scale. As laid out in Appendix B, grid-connected zero-carbon power producers or utility storage installations, large-scale industrial production facilities, small and modular industrial add-ons, and manufacturing facilities of climate components all face different opportunities and challenges as they seek to build and finance their early commercial facilities.

Key lessons from these case studies:

- ***Hiring is crucial.*** Venture-backed startups are often discouraged from focusing on hiring development roles until they absolutely need support for their buildouts, often after successfully proving out a pilot. However, in the survey of more than two dozen startups that led to this paper, nearly every company that had found substantial success credited much of it to bringing on talent early with deep expertise in managing projects. This was especially true when dealing with the complexities of land management, risks and legal division of responsibility, and nuances of customer agreements. Adding this talent early in the company's scaleup helps to inform the direction of the product and ensure that it is meaningfully deployable.

- ***Offtake should be approached creatively.*** These cases highlighted several different ways in which offtake could be leveraged to reduce risk, increase investor confidence, and magnify capital availability. Using a revenue guarantee as Monolith initially did can help "borrow" a much larger balance sheet to demonstrate certainty of offtake. Finding customers that value attributes the startup is able to provide over existing options (for example, Fervo's ability to generate zero-carbon baseload power) can motivate more secure and beneficial offtake relationships.

- ***Replicability over perfection.*** Though startups are striving to scale promising solutions, one of the best ways to de-risk failure is by increasing interchangeability, replaceability, and modularity. Rondo's efforts to make its project sizes as similar as possible and Via's efforts to modularize their installations help reduce uncertainty between deployments.

- ***No silver bullet option for financing First-of-a-Kind projects—yet.*** Though ideally new forms of project financing emerge that can take the substantial risks of first projects, investors and startups should recognize that most first projects, like the projects profiled in this guidebook, will need to rely on substantial startup equity. Startups should structure with an eye towards more risk-adverse project capital while taking a blended

approach between capital cost reducing opportunities like equipment financing and grants, multiple tranches of separately-financed construction, and low-cost partial loans where possible. At the same time, they should explore equity raises with partners who understand the long-term capital needs of project build out, and ensure that they are raising sufficient capital for project needs.

Appendix A: Key project risk factors and mitigants

	Key questions	Risk mitigation strategies
Technology	• What is being built? • What are the most likely points of technology failure? • How long has the technology been demonstrated for, and at what size? • What sort of data has been gathered, and can this provide assurance of performance and cost assumptions? • How much of the project relies on other nascent technologies?	• Use as many existing components as possible—instead of optimizing for breakthrough tech, optimize to limit new technology as much as possible. • Demonstrate the technology as close to commercial scale as possible before building the first full-scale facility, collecting extensive performance and cost data • Leverage large manufacturers for components, who can provide support if the technology fails while guarding your supply chain against dependence on a singular supplier. • Seek third-party validation from a respected independent engineer. • Consider technology insurance options.

	Key questions	Risk mitigation strategies
Development and construction	• What is the credit quality and experience of the team building the project? • Can you partner with a more experienced developer, or hire experienced developers? • Can someone else build the project if your company goes bankrupt mid-construction? • What is the supply chain outlook for the key components and risk of price spikes during construction? • What are the key permits required to deploy the solution? How long do they typically take? • What are potential risks from community opposition, and how can they be mitigated? • What might drive project delays, and how would this impact the project economics?	• Hire experienced developers from related technologies (oil and gas for geothermal, manufacturing, etc.) early to shape the approach to development. • Work with top EPC companies and collaborate on design plans, taking coaching from their decades of construction experience. • Negotiate terms with EPC partners in which the EPC takes responsibility for the design risk of the project, through higher liquidated damages amounts, higher performance thresholds, etc. • Explore options for surety bonds (insurance providers that guarantee project completion or payout to a customer in event of sponsor failure) early in project lifecycle. • Negotiate a contract with a price escalator to cover cost increases due to inflationary conditions and price shocks. • Design project in similarly sized modular units to increase project replicability and cost reductions between phases. • Seek opportunities for deployments to leverage existing permitting approvals. • Start local community outreach work early.

	Key questions	Risk mitigation strategies
Operations and maintenance	• Who is responsible for making sure the project works over the lifetime of the project? • What happens if the operator goes out of business? Who will ensure continued operation/delivery to the customer? • How reliable are projections of costs at scale, and how will the project margins work with higher costs?	• Secure component warranties from manufacturers that cover as much of performance as possible. • Have customers operate assets or be responsible for directly contracting operators. • Hire staff and leadership with deep operational experience. • Partner (or negotiate formal backup O&M agreement) with an experienced EPC who could step in to operate the facility in the case of developer bankruptcy.
Feedstock supply	• What is the availability of key commodity inputs that are required for the plant to operate and who is responsible for supplying them? • How is pricing variability in these inputs passed through to the customer? • To the extent the project is heavily reliant on renewable electricity or distribution capacity, what is the timeline to secure that supply? What barriers (like interconnection delays or permitting) might present challenges for the project? • If the decarbonization impact of a project relies on supply of zero-carbon electricity, what is the required levelized cost of this electricity to achieve profitability?	• Guarantee efficiency of the system to the customer, not the final price of output. Structure customer agreement with a pass through for energy or input commodity prices. • Consider access to multiple feedstock streams when evaluating sites. • Negotiate quality multiyear feedstock agreements with creditworthy suppliers. • Consider potential alternative feedstocks should prices spike. • Start collaborations with renewable energy developers early to increase confidence in project's certainty and startup's creditworthiness as offtaker for zero-carbon power. • Consider building higher costs of power into the project budget in order to be an attractive offtaker for renewable energy developers.

	Key questions	Risk mitigation strategies
Labor	• To what extent are the skilled laborers needed to construct and operate the facility available for hire in the target region? • What are labor costs like in the facility location, and how might these change if other projects are constructed? • What requirements are imposed on labor and workforce by funding from sources like the Inflation Reduction Act?	• Consider labor demographics when selecting the facility site. • Utilize skilled labor of partners and customers where possible. • Leverage automation opportunities where possible to reduce workforce requirements. • Consider how public funds and programs for workforce development could support facility development and operation.
Revenue certainty	• How credible are demand predictions for facility output? • s the output sold today, and if so, what are the current pricing structures (spot market t sales vs. long-term offtake agreements)? • How might price competitiveness of the output shift over the life of the facility? What competing solutions might emerge?	• Secure multi-year offtake agreements where possible, even if this requires taking price discounts vs spot price or the inclusion of price adjustments due to market conditions. • Secure a revenue guarantee with a commodity trader or bank, which would provide a backstop to offtake even if it adds additional costs to the project. • Focus on selling to initial markets with higher margins while scaling up to larger, lower-margin opportunities. • Have a path to sell product through alternative channels (ex: merchant vs. direct offtake).

	Key questions	Risk mitigation strategies
Contract/ customer reliability	• How creditworthy are typical customers? • What happens if the facility customers go bankrupt? • What happens if the customer wants to terminate the relationship? • How many potential customers are there for the output, and how flexibly can the facility switch between customers? • If the output is a commodity product, what happens if the market price changes dramatically?	• Screen customer credit quality early with potential project financiers. • If the project is an installation on a larger facility, design the project to be modular and movable to another site if there is a challenge with the customer. • Develop agreements with customers in which the customer is responsible for associated costs if they terminate the contract, with a clear schedule of termination payment amounts in excess of depreciated asset cost by period. • Avoid contract clauses that allow customer to terminate for startup bankruptcy, maintain cure rights for investors. • Position the product as a premium product offering more than just decarbonization (ex. higher capacity or better quality).
Policy dependency	• Would the viability of the project change if there were a shift in policy?	• Leverage sources of public funding thoughtfully and opportunistically, but evaluate the risk of any source going away with a change in government. • Pave a path to a globally market competitive output without subsidy. • Secure fixed multi-year contracts from offtakes that support the project in absence of policy support.

Appendix B: Scaling opportunities and challenges for different types of climatetech projects

Type of project	Example	Opportunities	Challenges
Zero-carbon power producer or storage provider	Geothermal, utility-scale storage Fervo, Form	• Power purchase agreements (PPAs) are an existing and well-understood mechanism for long-term offtake. • Offtake customers like utilities and major corporations are highly credible customers. • Green attributes (like renewable energy credits) are tradeable and another source of reliable income.	• Uncertainty on reliability of system and useful life compared to wind and solar projects. • Bespoke and lengthy offtake contracting cycle with uncertainty on how long-duration storage is valued.
Large-scale commodity producer	Decarbonized steel, cement, hydrogen, or aviation fuel producers. Carbon removal facilities selling into the burgeoning voluntary market Twelve, Monolith, Charm	• Large size of facilities more attractive to major project investors for whom overhead costs of evaluating a deal mean that a minimum project size must often be in the hundreds of millions of dollars to be compelling. • Can potentially leverage financing mechanisms around the commodity (like Monolith) or around the green attribute (like Twelve).	• Risk of major commodity price swings – like that in the lithium market. • Really big capital project to manage for a startup. Often competing directly with very mature project developers, hard to make costs that low. • Long-term offtake agreements are rare in commodity markets.

Type of project	Example	Opportunities	Challenges
Small industrial bolt-on or modular installation into existing facility	Industrial separations, industrial heat, carbon capture Via Separations, Carbon Clean, Rondo	• When bolting onto existing facilities, developers avoid a lot of risks around land and permitting. • Can build in a modular way that allows developer to recoup a lot of asset value if there's a customer issue and to be more certain of cost of each project.	• For the same reasons that a larger project can be much more attractive for an investor to spend time diligencing, small projects can fall under a minimum size that makes it difficult to finance.
Manufacturing facility of a climate good	Manufacture of utility-scale storage components Form, Rondo	• Manufacturing methods often de-risked. • Can leverage significant expertise from other manufacturing approaches. • Opportunity to partner with strategic manufacturers.	• Uncertain customer demand makes underwriting offtake challenging.