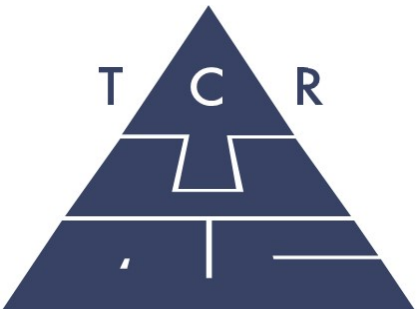

Final Report

Strategies for Investing in Clean Energy Technologies

Traditional and Novel Mechanisms for Accelerating Development and Deployment

Prepared for: **Meta Platforms, Inc.**

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EXECUTIVE SUMMARY

The challenge presented by climate change will require the development and rapid scaling of a broad complement of solutions. While key enabling technologies, notably wind and solar power, have already been deployed at scale, achieving an affordable and reliable net zero power grid will require the development of additional technologies. Crucially, this next generation of clean energy technologies will need to progress from demonstration to diffusion at a much more rapid pace than we have seen previously.

Though the public sector may be best suited to support the earliest stages of technical development (e.g., grant funding) and late stages of mass diffusion (e.g., tax incentives, regulatory standards), there is an opportunity for corporates to help bridge the gap between the two. Mid- to late-stage Technology Readiness Level (TRL) technologies benefit from the creation of early markets, commercial demonstrations, and market signals on performance and cost characteristics and may offer the highest leverage opportunities for corporate interventions. In particular, interventions that can catalyze additional investment beyond a sponsor's direct financial commitment may be particularly well-suited to the corporate sector in light of individual firms' more limited ability to fund innovation programs on the same scale as the public sector. While all have unique merits, the selection of an ideal intervention depends on a range of factors, including the characteristics and development stage of the target technology and the sponsor's desired outcome and level of commitment.

This report presents and discusses financial mechanisms corporate buyers can use to support the development and deployment of clean energy technologies. The first chapter discusses two well-established approaches – prizes and purchase commitments. The second chapter discusses more novel approaches, including novel variations on the basic structure of the advanced market commitment, novel financial hedges, new ideas related to tax equity and sponsor equity, and novel ideas designed to support early-stage R&D efforts.

Prizes and Purchase Commitments

Prizes are a useful mechanism to spur breakthrough innovation, stimulate or create new markets, and source solutions for some of the world's most challenging problems. They can take on many forms based on the desired outcome but can typically be bucketed into two general categories: ex-ante prizes, commonly referred to as inducement prizes, and ex-post prizes. Ex-ante prizes are designed to stimulate activity or innovation in a specific field, and awards tend to be established prior to an invention taking place. They typically have longer timelines, are more capital-intensive, and are best suited to encourage innovation. Ex-post prizes are awarded to an existing invention and typically involve government or corporate procurement or patent buy-out of a specific idea or invention.

Prizes are best suited to supporting technologies at TRL 3 to 7 and are most successful when the following criteria are met: (1) a clear and measurable goal, (2) a defined timeline, (3) a large pool of diverse problem solvers, (4) backing by a reputable institution (to bolster publicity and attract more competition and funding); and (5) a diverse and unbiased panel of judges with expertise in the prize's subject area. While successful in many contexts, prizes most often fail when they set unrealistic or unclear goals or when they have prohibitive funding requirements that prevent applicants from either participating or demonstrating success.

A highly successful prize can produce spillover benefits and mobilize large amounts of public and private funding into the prize's field. Among the benefits of prizes are that they are usually open to any participant and tend to attract a wide array of potential problem solvers, they tend to generate publicity and can drive public interest in a particular technology or field, and they only reward success. Several examples of successful and unsuccessful prizes are discussed in section 1.3.

While prizes are designed to spur innovation or the development of novel solutions, they are not a direct incentive for deployment. Thus, prizes are sometimes used in combination with other mechanisms, such as purchase commitments, where the prize stimulates early-stage technical development and a follow-on purchase commitment provides a path for further development and commercialization.

Purchase commitments are a broadly defined category of mechanisms in which an off-taker (or a group of off-takers) makes a conditional commitment to acquire future output for a specific technology or solution. Purchase commitments can take on a variety of forms, including milestone-based payments, advanced market commitments, bi-lateral contingent purchase orders, and preferred supplier agreements, all of which are discussed in detail in section 1.4.

Technologies suited to purchase commitments may range from TRL 4 to 9 but ideally share properties of modularity or unitized output, and performance characteristics that are well-understood and observable ex-ante. For earlier stage technologies, purchase commitments are generally structured with broader eligibility and less specific success criteria, both of which may become more targeted when applied to later TRLs. Ultimately, the flexibility of this mechanism makes it a highly useful tool that may be employed across a wide variety of circumstances and easily combined with other mechanisms to maximize impact.

The primary benefit of purchase commitments is their ability to catalyze investment, often far beyond the scale of the contingent commitment, by providing a signal of future market demand. Depending on their size and scope, these commitments have demonstrated the ability to induce investments in manufacturing capacity, develop entirely new markets, and precipitate multi-million-dollar capital raises for market entrants.

While these broad categories of interventions have historically proven effective in many instances, going forward, there is ample opportunity to explore novel approaches that can build on the lessons learned from prior experience.

Novel Strategies

As mentioned previously, the transition to net zero will require the rapid development, demonstration, and deployment of new clean energy technologies. The urgency and scale of this challenge will require a willingness to test novel approaches to support and fund innovation. Chapter 2 describes several less well-understood approaches designed to maximize decarbonization per dollar spent, including novel variations on the basic structure of the advanced market commitment, novel financial hedges, and new ideas related to tax equity and sponsor equity, among others. Though each of these approaches may have merit, the right mechanism will be technology – and TRL – dependent.

Section 2.2 discusses two variations on the basic structure of the advanced market commitment. These more novel conceptions of an advanced market commitment are intended to provide earlier

financial support and greater direction to potential suppliers, with clear incentives and milestones for their research and development over time. For example, one variation that corporate sponsors could offer is an "accelerated" advanced market commitment, in which some portion of the committed funds is prepaid upfront to potential suppliers. These upfront payments provide early-stage companies with, not only working capital, but also a stronger value proposition to leverage with investors in the form of demonstrable revenue. Among other potential benefits for the corporate, providing this early support could give them an opportunity to negotiate favorable terms for future purchases as a concession for taking upfront risk or to influence innovation on specific performance parameters of interest.

Opportunities for the use of novel financial hedges are discussed in section 2.3. The concepts of forward price contracting and financial hedging are well understood in the energy industry. One form of forward price contracting, the power purchase agreement (PPA), has been used extensively since the 1980s by independent power producers to de-risk projects by locking in a fixed price for future output. Virtual PPAs, introduced in 2015, provide many similar benefits but are purely financial instruments, removing the requirement for physical off-take by the buyer. PPAs are well-suited to situations in which a single commodity is sold with a clear and liquid market for both buyers and sellers. While these agreements have been critical to the development and deployment of wind and solar projects, other financial mechanisms may be better suited to providing market certainty in cases where a single commodity or clear liquid market is not involved. Situations in which more novel hedging mechanisms may be beneficial include market stacking (where several complex value streams exist, as in the case of energy storage); complex regulatory markets where the procured commodity is only part of the revenue; and situations in which the "procurer" does not directly participate in the market. Corporates could help facilitate the creation of these more novel financial hedges by, for example, creating a fund that is used to collateralize derivative contracts. While a single corporate purchaser could do this alone, a consortium of corporations pooling resources would likely be more effective at achieving scale. The consortium could define investment objectives and themes at the inception of the fund to direct investment into projects that best align with their climate or other objectives. This strategy has the potential to provide broader benefits to the market by creating an avenue for projects that do not fit well within the traditional PPA paradigm to secure financing.

Tax equity is one of the key levers provided by the U.S. government to scale up renewable energy, particularly wind, solar, and storage. Two of the largest sources of tax credits are the Investment Tax Credit (ITC) and the Production Tax Credit (PTC), which allow investors in renewable energy projects to claim a credit against their federal income tax based on either the cost of the project (for the ITC) or the electricity generated (for the PTC). A drawback of the tax credit system is that a relatively high tax liability is needed in order to gain value from the tax credits. Many renewable energy developers lack the tax liability to take full advantage of the credits awarded to their projects and, as a result, turn to outside entities to supply capital in exchange for the tax credits. Prior to the recent passage of the Inflation Reduction Act (IRA), only the investors in a renewable energy project were eligible to take advantage of the tax credits associated with that project. However, following passage of the IRA, tax credits can now be monetized and sold to another taxpayer, which opens up alternative sources of capital that are simpler and less risky than traditional tax equity relationships. Section 2.4 discusses two ways a corporate partner could get involved to help make the most of this change in tax law: directly purchasing tax credits and creating a marketplace for tax credits. In the case of the latter, a company, particularly one with deep software development capabilities, could develop an online

marketplace for the purchase and sale of these credits to improve the ease with which these transactions can occur, thereby lowering barriers to renewable funding and deployment. A transparent, liquid market could reduce transaction costs and reflect the full value of the credits by attracting buyers who are in the best position to benefit from purchasing tax credits.

There are additional opportunities for corporates to support clean energy technologies through sponsor equity, which are discussed in section 2.5. These include through direct investment, through coalition forming, and through fund creation. In the case of renewable energy projects, sponsor equity is often used to fund the initial stages of development and construction. One of the key benefits of sponsor equity in renewable energy projects, which often have a higher degree of uncertainty and risk than traditional energy projects, is that it can help to de-risk the capital stack. By providing a significant amount of sponsor equity, the sponsors can help mitigate some of the risks associated with the project, making it more attractive to other investors. In this way, a corporate could utilize sponsor equity to enable commercial-scale development of a novel technology that might otherwise struggle to get necessary funding. In doing so, a corporate sponsor with a large energy demand could potentially use these relationships to secure net zero energy for its own facilities and thereby contribute to any net zero goals it had set for itself. The corporate sponsor may also benefit from positive public perception of their direct contributions to the energy transition.

Chapter 2 closes with a discussion of several novel ways corporates can support technology research, development, and demonstrations (RD&D). Early RD&D funding is key to a technology's long-term success and ability to bridge the common "valleys of death" that typically appear between the research and proof-of-concept phases, as well as between the demonstration and adoption phases. While traditionally the realm of the public sector, there are opportunities for corporates to accelerate RD&D efforts, including the creation of a testbed, creating an accelerator program, participating in a joint development agreement, and offering low-cost loans. These ideas, and successful examples of each, are discussed in detail in section 2.6. Additionally, corporations can support other opportunities for researchers and entrepreneurs or experts from different fields to exchange knowledge (learning by interaction) and, in some cases, may be able to build information, modeling, or visualization tools that can accelerate the tempo of innovation.

CHAPTER 1: Prizes and Purchase Orders

1.1: Executive Summary

The challenge presented by climate change will require the development and rapid scaling of a broad complement of solutions to enable a global transition to Net Zero by 2050. While key enabling technologies, notably wind and solar, have been deployed at scale, achieving Net Zero will require the development of additional technologies to complete a portfolio of affordable, reliable clean energy resources. The next generation of clean energy technologies will need to progress from demonstration to diffusion much more rapidly.

Considerations for Corporate Purchasers

Given their tighter resource constraints, shorter investment timelines and stronger emphasis on positive returns, individual corporate buyers will not supplant the role of the public sector in accelerating the development of clean technologies. However, their ability to pool resources across peers and partners and quickly iterate to refine interventions to maximize impact can make corporate buyers a powerful driver of progress. While the options for intervention are numerous, those that can catalyze investment, and thereby impact, beyond a sponsor's direct financial commitment may be particularly well-suited to the corporate sector in light of individual firms' more limited ability to fund innovation programs on the same scale as the public sector.

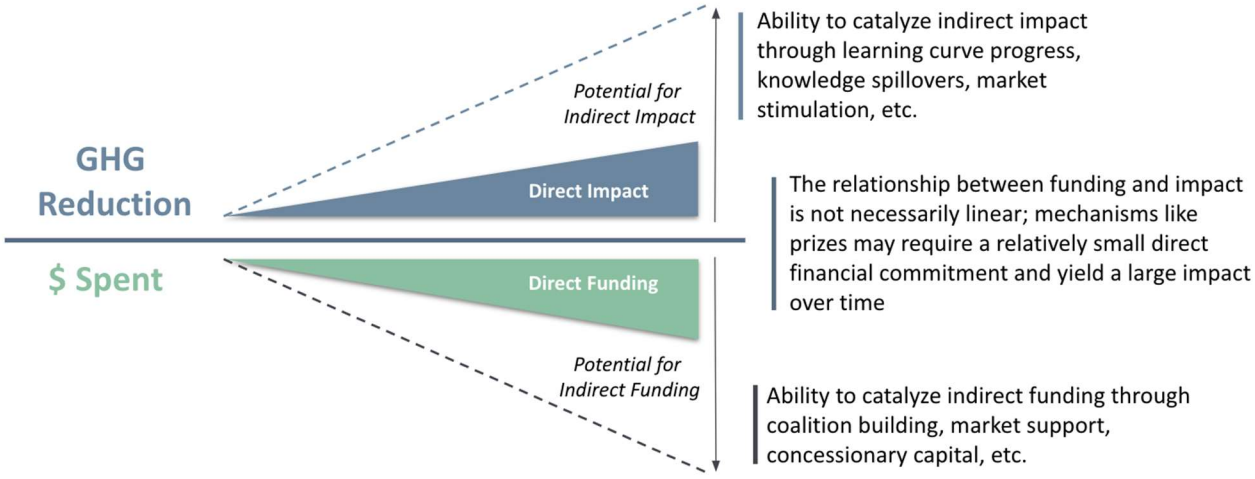

Figure 1: Considerations for corporate purchasers

While exceptions certainly exist, mid- to late-stage Technology Readiness Level (TRL) technologies, where the creation of early markets, commercial demonstrations and market signals on performance and cost characteristics are most beneficial, may offer the highest leverage opportunities for corporate interventions.

Prizes and Purchase Commitments: Experience & Key Considerations

Though the public sector may be best positioned to deploy interventions aimed at the earliest stages of technical development (e.g., grant funding) and late stages of mass diffusion (e.g., tax incentives, regulatory standards), there is an opportunity for corporations to help bridge the gap between the two.[1] Corporations' inherently market-oriented nature may make them well-suited for interventions targeted at later stages of commercialization due to the strong alignment with their own economic incentives and their ability to move quickly to take advantage of emerging market opportunities. They may also play a role in encouraging innovation for earlier stage technologies through prizes, milestone-based programs and other joint development efforts. While all have unique merits, the selection of an ideal intervention is contingent on a range of factors, including the characteristics and development stage of the target technology and the sponsor's desired outcome and level of commitment.

Prizes are an extremely useful mechanism to spur breakthrough innovation, stimulate or create new markets, and source solutions for some of the world's most challenging problems. They can take on many forms based on the desired outcome but can typically be bucketed into two general categories: ex-ante prizes, commonly referred to as inducement prizes, and ex-post prizes. Ex-ante prizes are designed to stimulate activity or innovation in a specific field, and awards tend to be established prior to an invention taking place.[2] They typically have longer timelines, are more capital-intensive, and are best suited to encourage innovation.

Prizes are best suited to supporting technologies at TRL 3 to 7 and are most successful when the following criteria are met: (1) a clear and measurable goal, (2) a defined timeline, (3) a large pool of diverse problem solvers, (4) backing by a reputable institution (to bolster publicity and attract more competition and funding); and (5) a diverse and unbiased panel of judges with expertise in the prize's subject area.[3] A highly successful prize will produce spillover benefits and mobilize large amounts of public and private funding into the prize's field.[4] While there is some degree of freedom in designing a prize, it is crucial to ensure strong alignment between the desired outcome and critical parameters, such as size and timeline.[5] Prizes may also be used in combination with other mechanisms, such as purchase commitments, where the prize stimulates early-stage technical development and a follow-on purchase commitment provides a path for further development and commercialization.

Purchase commitments are a broadly defined category of mechanisms in which an off-taker (or group of off-takers) makes a conditional commitment to acquire future output for a specific technology or given solution. Their primary benefit is their ability to catalyze investment, often far beyond the scale

[1] Kaufman et al., 2021.

[2] National Academies of Sciences, Engineering, and Medicine, 2020.

[3] Bays et al., 2009.

[4] Hendrix, 2014.

[5] Ibid.

of the contingent commitment, by providing a signal of future market demand.[6] Depending on their size and scope, these commitments have demonstrated the ability to induce investments in manufacturing capacity, develop entirely new markets and precipitate multi-million-dollar capital raises for market entrants.[7] Target technologies may range from TRL 4-9, but ideally share properties of modularity or unitized output and performance characteristics that are well-understood and observable ex-ante. For earlier stage technologies, they are generally structured with broader eligibility and less specific success criteria, both of which may become more targeted when applied to later TRLs. Ultimately, the flexibility of this mechanism makes it a highly useful tool that may be employed across a wide variety of circumstances and easily combined with other mechanisms to maximize impact.

While these broad categories of interventions have proven effective in many instances historically, there is ample opportunity to explore novel approaches going forward that can build on the lessons gleaned from prior experience.

1.2: Prizes and Purchase Commitments

1.2.1: Overview & Applicability

While rapid innovation is central to avoiding the catastrophic outcomes of global climate change, mass diffusion of these new technologies is equally critical. In its latest report, the International Energy Agency deemed that only two of the 55 components of the global energy system that are crucial to achieving Net Zero by 2050 are presently on track for the types of performance and cost improvements necessary for deployment at scale.[8] In light of the extent of progress yet to be made, a concerted effort is necessary across the public and private sectors to advance and commercialize these technologies.

As seen in Figure below, technology push interventions are typically best suited to earlier TRLs.[9] At these first stages of development, the viability of the underlying technology, especially with regard to commercial applications, is often unproven, making it difficult for potential off-takers to determine its value, if any. As such, interventions intended to create early markets are less well-suited. Even for technologies that may have strong potential for commercial applications in the future, the uncertainty around the timeline for commercialization at the earliest stages of development can leave off-takers exposed to the risk that the market may have shifted, or the technology may have been leap-frogged by the time commercial delivery is possible. Therefore, interventions that entail actual purchases or ongoing commitments are likely to be more effective at later stages of development.

While purchase commitments are typically utilized in later stage demonstration phases (TRL 7 and higher), we will also highlight examples where corporate purchasers intervened in earlier phases of

[6] Ho & Taylor, 2021.

[7] Bowen, 2019.

[8] International Energy Agency, 2022.

[9] Kaufman et al., 2021.

development to provide contingent support for incremental improvements along the development path, as reflected in Figure . These types of interventions often utilize a system of milestones in the earlier phases to direct the R&D efforts of the solution developer and to limit the downside for the purchaser. This type of milestone-based scheme can be coupled with a purchase commitment for the eventual output or may be structured as part of a broader purchasing program, as in the cases described below of Liatris and Stripe, respectively. These earlier commitments to developing technologies may imply a higher degree of risk for corporate purchasers as the technology and execution risks are likely far more significant than those associated with later stage solutions. In light of this, corporate purchasers should be prudent when scaling the size of these early financial obligations and specific when defining milestone criteria. However, the risk profile of these earlier engagements should not necessarily deter corporates, as they may offer the potential to exert considerable influence over solution design in line with their own needs and may enable them to capture longer-term upside through preferential purchasing terms, equity ownership or other means agreed between the parties.

Beyond the stage of development, the degree of modularity of the solution may also be an important determinant of whether these types of interventions will be effective. This relationship may be driven in part by the capital intensity of delivering complex systems, the relatively small and contingent nature of the off-taker's commitment, and the ability to attract outside capital in light of these dynamics. For contingent purchasing, the off-taker's commitment is effectively cancellable if the solution does not meet defined success criteria, which for a complex and highly integrated system may be difficult to determine until after its completion. Additionally, the lack of modularity also implies that the solution is less portable and therefore likely to have a smaller pool of alternative buyers if the original off-taker does not fulfill its commitment. As such, it may be exceedingly difficult to attract the capital necessary to fund the project on the basis of securing a contingent purchase commitment. This contrasts with a more modular solution for which price and performance characteristics may be reasonably well understood through prototyping prior to a larger investment (e.g., constructing a full-scale manufacturing facility) and for which there is likely a higher probability that alternative buyers are accessible if the contingent purchase does not materialize.

1.2.2: Types of Prizes and Purchase Commitment Mechanisms

These interventions may take a variety of forms. Those that we will focus on in the following section are briefly outlined below:

1. ***Prizes and Contests***: Prizes are a longstanding method to spur innovation and drive competition among a large and diverse pool of applicants. With a measurable goal and clear timeframe, prizes can provide vital support and funding for technologies in TRL 3 to 7.

2. ***Purchase Commitments:*** Purchase commitments may take many forms but share the same basic structure. An off-taker (or group of off-takers) makes a commitment to acquire future output for a specific technology or given solution. Several common forms are outlined below:

    a. ***Milestone-Based Payments:*** Under this mechanism, an off-taking entity agrees to make defined payments to participants if specific milestones are met within a designated time frame. The participants are otherwise responsible for funding any development

required to achieve milestone objectives, and off-takers bear no financial obligation should milestone objectives not be met on the published timeline. This mechanism may be the precursor to a contingent or binding offtake agreement between the two parties.

b. ***Advanced Market Commitments:*** Historically utilized by the public sector, advanced market commitments are binding agreements that provide an initial market at a guaranteed price/quantity for an emerging technology once it has been developed. They are often outcome-based (i.e., avoid detailed technical specifications), but specify particular performance and cost targets. Notably, they are also agnostic to the provider of the technology.

c. ***Bi-Lateral Contingent Purchase Orders:*** Negotiated between a specific supplier and off-taker, these arrangements most closely resemble traditional purchase orders. The key difference is the inclusion of various criteria which must be met in order for the agreement to remain in force.

d. ***Preferred Supplier Agreements:*** Similar to bilateral contingent purchase orders, these agreements exist between an off-taker and a designated supplier. These arrangements typically do not include specific criteria that the supplier must meet, but rather provide flexibility to off-takers by avoiding the need to firmly commit to a specific quantity at the time of the agreement.

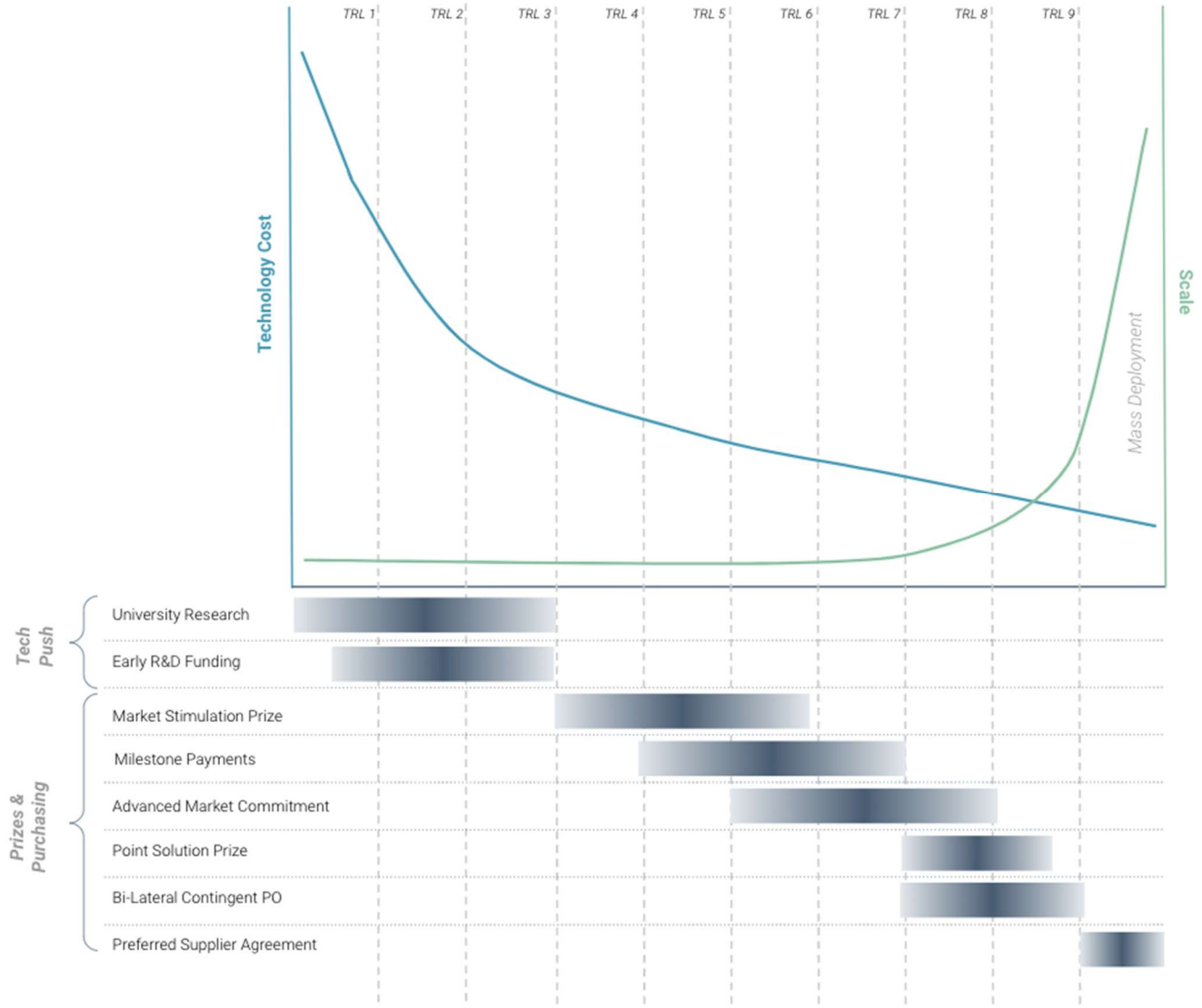

Figure 2: Innovation Interventions & TRL

Credit: *Columbia & ADL Venture*

1.2.3: Selecting the Appropriate Intervention

Determining the appropriate intervention is highly context specific. Among key considerations, the upfront identification of a clear, well-specified and achievable goal is paramount to the success of any intervention. From the perspective of a potential sponsor, clarity on the desired outcome is necessary in order to assess the potential universe of viable solutions, their relevant stages of technical readiness, and the extent of the need for technical and/or financial support to achieve desired goals. For potential suppliers, the specification of a well-defined goal is critical to determining whether sufficient alignment exists between their capabilities and desired outcomes and to efficiently directing resources towards achieving these ends. While a clear understanding of the desired outcome is essential, the means by which it is achieved do not necessarily need to be narrowly specified. In many cases, associating a high degree of technical specificity with a demand-pull intervention may prove antithetical to the desired end. For instance, in the case of Operation Warp Speed (OWS), launched in 2020, the desired outcome of accelerating the development and deployment of 300 million doses of a safe and effective Covid-19 vaccine was clearly defined. For candidate selection, the program adopted an intentionally broader strategy "to build a diverse portfolio of vaccine candidates based on distinct platform technologies…intended to provide a range of options, potentially accelerating the development and mitigating the risks associated with the challenge of developing a safe and effective vaccine on OWS's timelines." The novel mRNA approach, which had not previously been used for a licensed vaccine, was one of the platforms that ultimately proved successful.[10]

Figure below provides a simplified framework for directional recommendations for selecting an appropriate intervention; while not included as an explicit step in the decision tree, the framework relies on a baseline assumption that the sponsor has identified a clear and achievable goal at the outset of the exercise. The considerations at each branch of the decision tree are framed as binary outcomes; however, in reality most of these dynamics will fall along a continuum. For example, grant recipients may be willing to bear some degree of financial risk or sponsors of milestone programs may eventually be willing to commit to an offtake agreement once interim performance hurdles have been satisfied. Another consideration that sponsors should bear in mind when selecting or designing an intervention is that these dynamics may change over time for a particular technology and that these mechanisms are not mutually exclusive. As many of the examples below will illustrate, interventions often take a hybrid form. Examples may include advanced market commitments that offer contingent purchase orders to suppliers prior to larger binding agreements or prize competitions that award an initial milestone payment to a group of finalists before proceeding to competition for the larger prize.

Once the desired outcome has been defined, there are several other factors that a sponsor must consider when designing the appropriate intervention for a given context. The universe of potential solution providers or relevant technologies will both depend on how the outcome is defined and will in part dictate how this outcome can best be achieved. In the case that there are few viable solutions or potential suppliers, a more targeted approach may be better suited to an expedient outcome. Conversely, a large pool of potential solutions or providers may make interventions aimed at market stimulation or demonstration of multiple relevant technologies more attractive in order to avoid

[10] United States Government Accountability Office, 2021.

picking winners before a dominant option has clearly emerged. Potential suppliers' willingness and/or ability to share in the costs and risks associated with developing a viable solution should also factor into the design of an optimal intervention. To the extent that suppliers are not able to share in the costs or are unlikely to be able to attract sufficient external funding, a grant or related mechanism that awards upfront capital will likely be the most appropriate intervention.

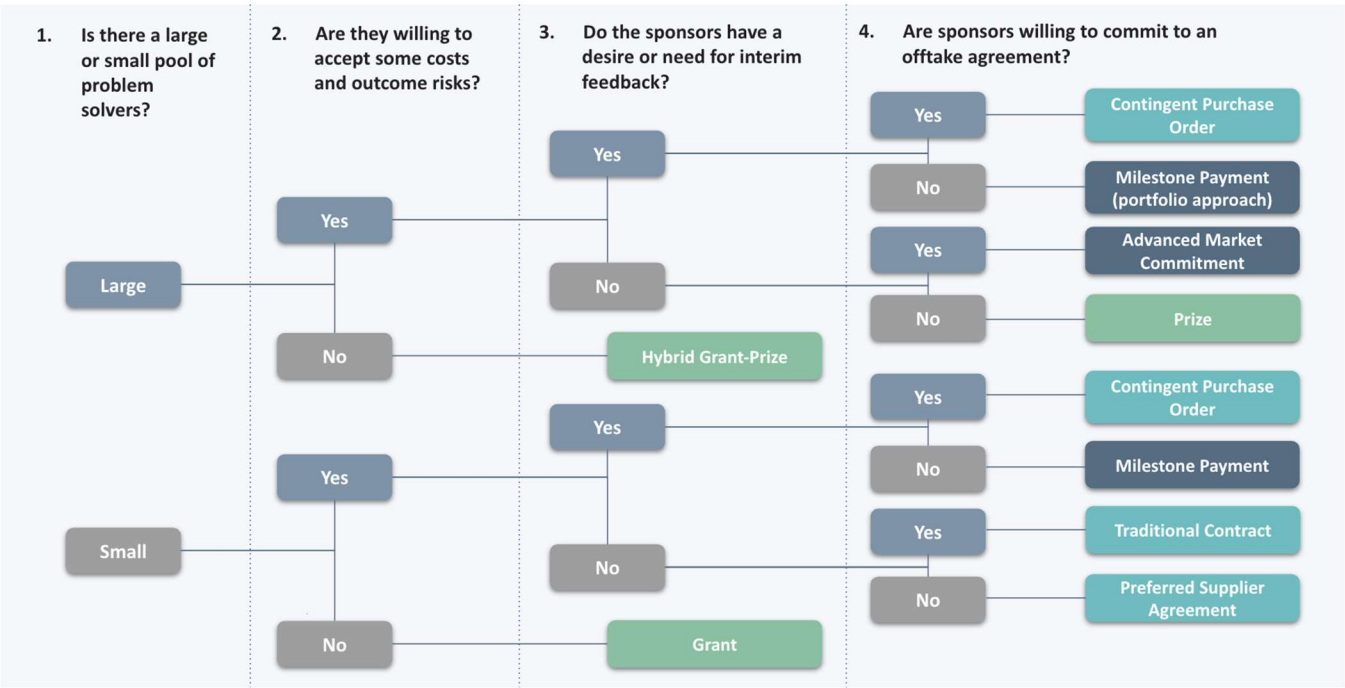

Figure 3: Simplified Framework for Intervention Selection

The final two criteria are driven by sponsors' preferences for early feedback on cost, performance or other parameters and the degree to which they're willing to commit to demand ex-ante. In cases where early feedback is desired, interventions can be structured with interim checkpoints to guide the development of a solution over time, as in the case of milestone-based schemes, or with a later-stage offramp prior to an acquisition decision. In either case, this type of structure provides sponsors with the ability to evaluate desired criteria prior to making a financial commitment to suppliers. The final key consideration is the form that this financial commitment takes. In some cases, sponsors may be willing upfront to commit to purchasing output, whether contingent or outright. However, in instances where there may not be appetite to commit to demand at the outset, there are multiple options, including prizes and milestones-based payments, that may be appropriate. As will be illustrated by the examples included throughout the text, these interventions are often employed in hybrid form, combining elements of multiple mechanisms based on the sponsor's desired outcomes and the specifics of the context.

1.3: Prizes & Contests

1.3.1: Overview

Innovation is key to continued economic growth in any sector, and an often underrated tool that can facilitate breakthrough innovation is prizes and contests. Having existed for centuries, prizes and

contests take on many different forms as a means to democratize problem solving.[11] Traditionally, prizes bring together a diverse group of problem solvers in order to accomplish a clear and measurable objective within a reasonable time frame.[12] Prizes are designed to spur innovation or the development of novel solutions in particular fields, but they are not a direct incentive for deployment, especially if the prize outcome does not benefit consumers. Further, prizes tend to work best when supporting R&D efforts for technologies that are early in development but not at their initial nascent stage (i.e., at TRL 3 and 7). While prizes cannot always substitute for robust research funding or ensure the development of a high-quality workforce, they complement those efforts by sourcing competition that ultimately drives down costs and spurs innovation in an otherwise stagnant field.[13]

1.3.2: Types of Prizes

Prize structure and reward can take many forms, but there are two general categories to define prizes: Ex-ante and Ex-post.

Ex-ante, or inducement prizes, are designed to stimulate activity or innovation in a specific field, and awards tend to be established prior to an invention taking place. They typically have longer timelines, are more capital intensive, and are most beneficial for spurring innovation.[14] Ex-ante prizes include point solution prizes, where a specific and well-defined challenge is identified, but the solution requires innovation and often does not exist/is not known, as well as market stimulation prizes which are designed to spark innovation in a new or stalled market.[15]

Ex-post prizes are awarded to an existing invention and typically involve government or corporate procurement or patent buy-out of a specific idea or invention.[16] Though several notable historical examples exist (e.g., the 18th-century Longitude prize), modern-day examples of the successful utilization of ex-post prizes to encourage innovation are more limited, thus this type of prize will not be discussed at length.

1.3.3: Target Audience and Setting Goals

It is paramount to understand the potential applicants and their motivations when creating a prize. There is an allure to prizes that even notable government grants fail to achieve. Prizes tend to draw from a wider array of stakeholders and reward fewer applicants. There is something psychologically attractive about becoming an exclusive winner of something prestigious or highly beneficial. As such, it is important to distinguish what types of problem solvers your prize may attract and if there are enough to stimulate a competitive discourse. It is equally important to consider the target goal in

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[11] Hendrix, 2014.

[12] Bays et al., 2009.

[13] Kalil, 2006.

[14] National Academies of Sciences, Engineering, and Medicine, 2020.

[15] Bays et al., 2009.

[16] Gans, 2007.

relation to the applicants who may be applying. It is exceedingly difficult to set up a goal for success unless you are on the way to achieving it. Therefore, prizes typically are best suited for technologies that are relatively well understood to enable sponsors to define a clear target outcome. While prizes generally involve the further development or novel application of existing technologies, they also entail significant R&D efforts as their goals are typically ambitious and the challenges addressed are significant.[17]

While many/most prizes target earlier-stage innovation, there is an opportunity to set specific and targeted problem statements for technologies that are already commercialized at TRL 9. This reinforces the idea that the tempo of innovation, even for technologies that are already in-market at scale, can be accelerated by addressing the biggest cost drivers. For example, balance of system costs in solar could be a focus of targeted problem statements now that significant cost has already been taken out of the cells and modules.

1.3.4: Benefits of Prizes

The benefits and positive externalities of successful prizes are manifold; some of the most notable benefits are that prizes are often open to any participant, they have the potential to reduce administrative costs and burdens for the participants, and they only reward success. Prizes also allow the government or other entities to establish a goal without being overly prescriptive or determining who is in the best position to achieve success too early or insularly. In other words, prizes are a method to even the playing field.[18] The collaboration and competition that is created through prizes also plays an important role in driving down costs through advances in technologies and the sharing of ideas. This specific benefit is advantageous not only to prize competitors, but to others developing or purchasing similar technologies.

Another advantage of prizes is that they tend to generate publicity and can drive public interest in a certain technology or field. Prizes can offer positive feedback loops to support continued innovation. A recent study by the Royal Agricultural Society of England found that people who won prizes were much more likely to receive and renew patents. Further, doubling the prize purse led to upward of a 33% increase in patented innovations.[19] Prizes can inspire and stimulate, and their flashy nature brings together a variety of stakeholders beyond traditional grant proposals.

1.3.5: Conditions Under Which Prizes Succeed & Case Studies

As alluded to above, prizes are considered successful when they incentivize innovation and generate spillover benefits.[20] These benefits might include additional post-prize investment in a relevant sector, the creation of new industries and sectors, increased publicity in an up-and-coming sector, etc., all of

[17] Kay, 2018.

[18] Hendrix, 2014.

[19] Ibid.

[20] Hendrix, 2014.

which have the potential to exceed the value of the prize itself.[21] In order for prizes to generate this level of success, it helps if they meet certain criteria.

A prize will primarily need a **balance of structure and freedom** in its problem and solution criteria to allow participants to be creative while meeting a measurable objective. This is often achieved by outlining specific success criteria, while leaving the means by which a solution can achieve the stated ends largely unprescribed. Defined success criteria can help to direct both applicants' R&D efforts and judges' ultimate selection decisions, while less defined means can help encourage creative solutions. If the prompt is well defined, successful prizes will also often have a high level of **publicity** to source a competitive pool of applicants, to provide reputation benefits to winners, and to drive innovation during and after the prize's completion, as well as significant **investments and support** from reputable companies and high-profile individuals. Additionally, the use of **intermediaries or prize platforms** makes the application and judging process easier for both applicants and judges alike. Finally, as prizes are meant to democratize problem solving, it helps greatly if there is a diverse **panel of judges** who can avoid biases and remain objective while judging the competitors.[22]

As stated above, it is crucial to have a well-defined goal that is accomplishable within a given timeframe.[23] The goals of the prize and the timeline are inextricably linked because the habits and desires of consumers and producers can change over the course of a prize's duration. For example, if a prize is set forth with the goal of seeding a market transformation, it is imperative to examine consumer habits and market trends in order to succeed.[24]

Some examples of successful prizes include several American-Made Challenges, select X-prizes such as the Ansari XPRIZE and the NRG COSIA Carbon XPRIZE, the ProblemSpace Building Material Challenge, the RMI Global Cooling Prize, and the Kaiser Design Challenge: Small Hospital, Big Idea.

American-Made Challenges

As of 2022, there have been 39 American-Made Challenges launched; 18 completed, and 21 open/in progress.[25] Initiated by the National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy (DOE), they are broadly successful because of their low barriers to entry, low-risk conditions, and the well-regarded institutions that run the challenges. Due to NREL's and DOE's high profile and wide reach, the prizes attract a diverse set of domestic innovators with technologies that range from ideation to TRL 6. Other notable reasons for the success of the American-Made Challenges include the opportunities that they create for public-private partnerships to leverage government investment and grow new businesses, solutions, and opportunities. Through these challenges, most competitors – and surely the winners – are granted access to a valuable and extensive network of collaborators, other

[21] Ibid.

[22] Ibid.

[23] Bays et al., 2009.

[24] Davis & Davis, 2004.

[25] U.S. Department of Energy, 2022.

innovators, investors, and laboratory facilities.[26] In addition to the direct resources that the applicants are offered, the validation from DOE and NREL typically helps startups obtain private sector funding.

Since launching in 2018, the American-Made Challenges has awarded about $100 million in cash and incentives to candidates in more than 30 prizes in solar, water, geothermal, hydrogen, and more.[27] The American-Made Challenges have proven to be one of the speedier means of supporting startups and innovators, in part due to the financial prizes and in part due to the validation by NREL and DOE that the American-Made Challenges enable.

ProblemSpace

ProblemSpace is an open innovation platform built by ADL and sponsored by DOE that helps entrepreneurs build traction and secure commercial opportunities through innovation challenges often sponsored by corporations, such as electric utilities. Once problems are identified, solutions are sourced from thousands of ventures worldwide. The applications are reviewed by ADL experts and a diverse panel of judges through rounds of questions, interviews, and techno-economic analyses. This process establishes the relationship between the corporate and startup with a foundation of mutual respect and trust, overcoming an otherwise dangerous stumbling block for many entrepreneurs. The ProblemSpace platform is also low risk for most applicants and typically leads to growth opportunities for entrepreneurs.

A successful example of a ProblemSpace challenge was launched in partnership with Sto, a $2 billion provider of exterior wall systems, to design requirements for the Building Materials Challenge in 2019.[28] This was one of the first open innovation challenges ever run in any segment of the $1 trillion U.S. construction sector. Over 400 startups applied, and three winners were ultimately selected.

Beyond the recognition provided by the contest, Sto entered both a joint development agreement and purchase agreement with winner Liatris, a pre-seed start-up that mass produces high performance insulation that is non-toxic, non-flammable, environmentally friendly, and easy to install. By awarding just $180,000 in up-front seed funding to Liatris, Sto was able to position the company to generate an additional $4 million in follow-on funding, the vast majority of it non-dilutive.[29] The challenge also resulted in a longer-term relationship between the two partners that focused on joint development and contingent purchasing and will be discussed later in the chapter. Furthermore, the Building Materials Challenge triggered a wave of follow-on activity in the construction industry by other large-cap players such as Cemex, St. Gobain, Suffolk Construction etc., all of which had a contingent purchase element to them. The Building Materials Challenge was unique from other construction-related innovation initiatives in that it was built around customer validation and product-market fit. The longer-term demand signaling has not only helped Sto directly leverage its limited R&D budget (most building

[26] Ibid.

[27] U.S. Department of Energy, 2022.

[28] ProblemSpace, 2022.

[29] Ibid.

materials companies spend 1-2% of revenue on R&D) but will likely enable it to benefit from other ecosystem innovation much more broadly in the long run.

X-Prizes: Ansari and NRG COSIA Carbon

The Ansari XPRIZE, which spanned from 1996 to 2004, was the first and arguably the most successful XPRIZE. With a $10 million award, it challenged contestants to launch a spacecraft into space and achieve breakthroughs in low-cost spaceflight.[30] Previously a sector dominated by the government, the Ansari XPRIZE effectively launched the private spaceflight industry. Its success can be attributed to the intense media and public attention generated by the launch of the winning spacecraft, which attracted more than $1.5 billion of private and public funding into the industry.[31] Another major driver of success, which is a hallmark trait of inducement prizes, was the strategy of paying out for results and not effort. Other effective prizes have ensued – the $15 million Off-Grid Energy Access XPRIZE strives for universal clean energy by creating off-grid, home energy systems that are sustainable and affordable.[32]

In 2015, NRG and COSIA launched the $20 million NRG COSIA Carbon XPRIZE with the goal of turning CO_2 emissions into usable products.[33] The prize was designed to inspire the development of new and emerging CO_2 conversion technologies as a means to turn one of the planet's biggest liabilities into an asset. The teams were judged on how much CO_2 they were able to convert and by the net value of their products. Winners were announced in 2021, and some of the finalists' products included concrete, alcohol, plastics, fish feed, and others all made from CO_2.[34] Similarly to other successful prizes, the competitors were offered support along the way not in monetary means, but through access to test facilities, the opportunity to collaborate and share ideas with other competitors, and through an ecosystem of innovators, engineers, industry partners, entrepreneurs, and potential funders that all aided the competitor's long-term success. Ultimately, the winners received the prize purse, introductions to new investors, future partners and collaborators, as well as the opportunity to prove and showcase the success of their ideas.

Kaiser Design Challenge: Small Hospital, Big Idea (2011-12)

The Kaiser Design Challenge was launched by healthcare provider Kaiser Permanante, a well-regarded leading healthcare provider committed to green building and sustainable design.[35] The goal was to "conceptualize a new approach to delivering inpatient care to our members in new or underserved communities" with a focus on reduced life cycle costs, innovation to improve health care, flexibility,

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[30] Ansari X Prize, 2022.

[31] Ibid.

[32] Hoyt & Phillis, 2007.

[33] X Prize Carbon, 2022.

[34] Ibid.

[35] Schwartz, 2011.

and efficiency.[36] With a somewhat vague yet thought-provoking competition prompt, Kaiser took a risk, yet gave participants creative license. In the case of a design-based award, open-ended prompts are often successful because there tends to be a good deal of variation between competitors. Unlike specific technical prizes, design prizes thrive when they are not overly prescriptive.

The competition sourced more than 108 design concepts from around the world, and after an 11-month review process, three finalists were selected.[37] Eventually, Kaiser determined that two of the three finalists could produce a result greater than the sum of their parts if they collaborated. The reward provided a $750,000 cash reward, which is relatively small compared to traditional prizes; however, the reward also included an opportunity for the winning designer(s) to contract with Kaiser to turn their designs into a reality.[38] This is an example of a prize partnering with a form of a contingent purchase order which provides the winners with a higher chance of success post-competition, and the institution holding the prize becomes more invested in the applicants' success.

1.3.6: Conditions Under Which Prizes Fail & Case Studies

Prizes most often fail when they set unrealistic or unclear goals or have prohibitive funding requirements that prevent applicants from either participating or demonstrating success.[39] When prize objectives are vague, innovation often fails due to its failure to identify a starting point or due to a general lack of direction. It is especially difficult to launch prizes in sectors that require significant capital expenditure, and few prizes have succeeded in capital-intensive fields. Prizes are also notably no substitute for long-term basic research as mentioned above, and as Tim Harford of the Financial Times points out, "Even a $100 zillion prize wouldn't buy you the next Internet—it's just too disruptive a concept."[40]

When prize criteria are vague or unclear, it often sources the wrong talent and applicants end up putting too much time and resources into a prize that might not be aligned with their solution. Additionally, prizes often do not include a proxy for improvements in price-to-performance ratio.[41] This can result in the best performing teams winning the prize competition but at too high of a cost.

Google Lunar XPRIZE (2007–2018)

Perhaps the most public prize failure was that of the Google Lunar XPRIZE, which was announced in 2007 as an inducement prize for space competition. Organized by XPRIZE and sponsored by Google, the Lunar XPRIZE challenged privately funded teams to land a lunar rover on the Moon, travel 500 meters, and transmit back to Earth high-definition video and images. After several extensions to the

[36] Ibid.

[37] Saito & Serrano, 2012.

[38] Ibid.

[39] Smart, 2018.

[40] Kamenetz, 2008.

[41] Kalil, 2006.

original 2014 deadline, XPRIZE announced that, due to fund-raising and regulatory challenges, the prize concluded with no winner.

The failure of the Lunar XPRIZE showed the difficulty of launching prizes in sectors that require significant capital expenditure to achieve innovative breakthroughs, such as space exploration. Finalist teams in the Lunar XPRIZE, led by researchers and small to medium-sized companies, fell short of their $50 million benchmark to cover the costs of their lunar missions.[42] Several teams also struggled to clear regulatory hurdles and were not able to gain governmental approval to send their payload to the moon.[43] These takeaways can be implemented toward a future prize to ensure its success. Organizers of prizes in capital-intensive sectors should make fundraising easier by raising the profile of the prize so that it is more attractive to private funders.[44] Organizers of prizes that contain regulatory hurdles should anticipate these challenges and offer more comprehensive resources to contestants. Despite the many shortcomings of the Google Lunar XPRIZE, its impact on the space sector was noteworthy: it established the first space companies in India, Israel, Malaysia, and Hungary, created 280 new jobs, and ushered in technological advances in miniaturization and 3D printing.

Archon XPRIZE

Other prizes fail not because of a lack of solution, but because they are outpaced by innovation. The Archon Genomics XPRIZE was a $10 million prize awarded to the first team to accurately sequence 100 whole human genomes. The Foundation set a goal to sequence a genome for $10,000 or less, but companies developed capabilities to do it for less than $5,000 per genome. Eventually, the Archon XPRIZE was canceled, demonstrating the importance of identifying under-researched spaces that are not actively being pursued by well-funded members of the scientific community.[45]

The Super-Efficient Refrigerator Program (SERP)[46]

In the mid-1980s, several large U.S. utility companies, including Pacific Gas & Electric (PG&E), and Southern California Edison (SCE), were investigating ways to increase energy savings from refrigerators while phasing out chlorofluorocarbons (CFCs), per federal regulations.[47] The result was a consortium of 24 utilities that called itself SERP. Based in Washington, D.C., SERP was the first of many initiatives

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[42] Smart, 2018.

[43] Ibid.

[44] Kalil, 2006.

[45] Howes, 2022.

[46] Note that while this prize failed to meet the originally set goals within the set timeline, it resulted in long term success that can be seen in current refrigerator designs that use around 25% less energy than the winning design.

[47] Eckert, 1995.

under the "Golden Carrot" program to develop and market more efficient technologies.[48] The long-term goal of the Golden Carrot initiative was to allow utilities to pool the rebates offered to customers for efficient appliances to provide a clear market signal for manufacturers to produce more energy-efficient products.[49] To accomplish the goal of reaching 25% less energy consumption in refrigerators, SERP launched a prize that would award a manufacturer that was able to design, competitively price, and market a CFC-free and energy-efficient refrigerator. The reward was $30 million, and SERP did not fund any R&D efforts.[50]

In 1993, Whirlpool Corporation won the challenge with a refrigerator that was a slightly more evolved version of their current model. In order for Whirlpool to claim its reward, it had to sell 250,000 of its efficient refrigerators by 1997.[51] Unfortunately, as energy prices fell, consumers did not want to purchase energy-efficient appliances, and Whirlpool ceased production of the appliance.[52] While SERP was not able to promote the commercial development of efficient refrigerators due to the changing external environment as energy prices decreased, the prize was highly effective in inducing innovation. Similarly designed refrigerators made up a third of the U.S. market in 2004, and each consumes half as much electricity as typical units did prior to 1993.[53]

1.4: Purchase Commitments

The following section provides a deep dive into the four purchase commitment mechanisms outlined above, including an assessment of when each may be most effective, illustrative examples, and the various benefits and limitations of each.

1.4.1: Milestone-Based Payments

Applicability & Criteria for Success:

Milestone-based payments are best suited when possible solutions are at an earlier stage of development and a singular dominant technological path has not yet been identified. Depending on the level of funding, the milestone-based approach can support development efforts across a portfolio of potential solutions, increasing the likelihood that at least one solution will meet the desired criteria.[54] In order to be successful, the administrator of the program should have sufficient technical

[48] Ibid.

[49] Ibid.

[50] Ibid.

[51] Eckert, 1995.

[52] Davis & Davis, 2004.

[53] Ibid.

[54] National Aeronautics and Space Administration, 2014.

knowledge to define milestones and effectively evaluate a solution's progress against them. Milestones must also strike a balance between being overly prescriptive, thereby limiting the means available to achieve the desired outcome and being overly abstract so as to prevent clear delineation between success and failure. Because the technologies most likely to benefit from this mechanism are earlier in the development cycle, this balance can be more difficult to strike than for those targeted at later-stage technologies.

Examples:

NASA Commercial Orbital Transportation Services Initiative

The first of a dual-phase NASA program targeting the development of domestic space transport providers, the Commercial Orbital Transportation Services (COTS) challenge allocated up to $500 million in milestone-based payments for the demonstration of partners' space transport capabilities.[55] The program used broad functionality as the foundation of the program's solicitation (specifications were less than 3 pages), allowing for more creativity in respondent proposals. By the conclusion of the program in 2013, two firms, SpaceX and Orbital SK, had developed the desired proficiencies and secured long-term contingent contracts from NASA totaling over $3 billion for the commercial re-supply of the International Space Station.[56] NASA estimated that the cost of developing SpaceX's Falcon 9 rocket alone using traditional government contracting and oversight mechanisms would have neared $4 billion, a sum ten times the amount paid out to SpaceX under the COTS program.[57] In both successful cases, NASA bore less than half of the total investment necessary to develop the desired capabilities. Beyond the massive savings to NASA, the program also supported the growth and development of the nascent U.S. commercial launch services industry, which was non-existent prior to the COTS program and is now market leading.[58]

Sto & Liatris

After selection as a winner of the Building Materials Challenge (see above), Liatris, an insulation startup, entered into a multi-year agreement with challenge sponsor Sto Corporation, a construction materials and products company. By structuring this broader agreement with a multiple-phase milestone structure, including a definitive long-term purchase order at a fixed price upon successful commercialization, Sto was able to provide clear guidance to Liatris on its commercial requirements, which Liatris used to direct its R&D and product roadmap and demonstrate commercial interest to private and public-sector investors. Liatris is now on track to deliver its first commercial product to Sto in late 2023.

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[55] National Aeronautics and Space Administration, 2017.

[56] Ibid.

[57] Kaufman et al., 2021.

[58] Bowen, 2019.

At the time when the agreement was signed, Liatris' specific material and process for the product to be used in Sto systems was at TRL 2. The initial development agreement was intended to advance the technology to TRL 4 so the company could have a viable demonstration of a higher margin niche product that would attract additional private investment and non-dilutive (e.g., government grant) capital. The agreement then has formal purchasing and scale up milestones tied to attainment of higher TRLs, with the intention of at minimum, enabling a preferential path to buying a differentiated product, while also offering option value to make larger strategic investments in manufacturing and technology scale up.

QuantumScape & Volkswagen

QuantumScape is a solid-state battery company that is developing EV batteries that can be smaller, lighter, and faster charging than today's lithium-ion battery backs. Since 2012, QuantumScape and Volkswagen have had a strong collaborative relationship that evolved from testing and evaluation to small equity investments to a joint venture agreement. The joint venture agreement began small, with a total investment of $3 million by the parties in 2018 but was expanded as QuantumScape met technical milestones. The joint venture agreement was amended in 2020 with a $200 million investment by Volkswagen, $100 million of which was contingent on meeting certain technical milestones.[59] In March 2021, the parties announced that said technical milestones were met, unlocking the additional $100 million in funding.[60] The specific terms of the purchase commitment at the point the technology is ready for commercial deployment in Volkswagen vehicles has not been made public, but Volkswagen's intent is for QuantumScape solid state batteries to provide a competitive advantage to Volkswagen if and when the technology is deployed in mass-market electric vehicles.

Volkswagen maintained the rights to terminate its participation in the joint venture if QuantumScape was unable to complete the development of the solid-state battery cells in the timeframe required by the joint venture agreement. However, if QuantumScape is ultimately able to commercialize its solid-state battery technology, Volkswagen will see upside because of its 50% stake in the joint venture. Volkswagen can benefit from years of collaboration with QuantumScape to be early to market with a potentially transformational technology.

QuantumScape was able to leverage the partnership with Volkswagen to raise an additional $700 million in capital by merging with a Special Purpose Acquisition Company (SPAC) in late 2020.[61] As with most other SPACs of that period, QuantumScape's market capitalization has subsequently declined, but the market validation and investment from Volkswagen were central to the growth story QuantumScape successfully marketed to investors at the time. Because the joint development agreement does not prevent QuantumScape from selling its technology to other automobile OEMs, the market viewed the relationship with Volkswagen more positively still.

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[59] Securities and Exchange Commission, 2020.

[60] BusinessWire, 2021.

[61] Korosec, 2020.

Key Benefits for Innovators and Off-takers and Limitations on Efficacy:

Milestone-based payments benefit innovators by effectively creating a first market for incremental degrees of development for a given solution, while also de-risking development of multi-component systems. These programs have the potential to attract private funding earlier than might be expected for a more nascent technology, as they are indicative of longer-dated future demand. In the case of the NASA COTS program, the announcement enabled multiple start-ups, even outside of the selected participants, to raise significant VC funding to pursue a space launch program.[62] Importantly for these earlier technologies, this type of scheme can also de-risk larger projects by proving out component systems along the development path, while also providing early market feedback as to the characteristics valued by potential end customers.

For funders, the contingent nature of capital provided by a milestone-based program can reduce information asymmetries and better align incentives with recipients. Information asymmetries are more likely to exist with newer, less understood technologies, which may provide innovators with an advantage relative to capital providers when assessing the likelihood of a desired outcome.[63] Using performance milestones to create off-ramps if innovators are unable to deliver committed capabilities, effectively eliminates the risk introduced by this asymmetry. NASA demonstrated the effectiveness of this mechanism by exercising its option to discontinue support of an initial participant, Rocketplane Kistler, when it was unable to meet a milestone, thereby freeing $170 million of contingent funding.[64] The fixed nature of the payments also creates a strong incentive to manage costs and focus effort where most aligned to program goals.[65]

While effective at advancing technological development, milestone-based payments alone may not be enough to bring technology to full commercialization. While NASA deemed the COTS program an overwhelming success, its final report also surmised that the potential for long-term contracts provided by the second phase of the program was also critical in driving private funding to the two participants.[66] From a corporate procurement perspective, another drawback of a milestone-based payment program is the administrative burden created by its operation. Depending on the solution being pursued, there may not be sufficient technical expertise in-house to define milestones or assess success for an emerging technology. This can be ameliorated by bringing in outside expertise, as NASA did with the VC community, but this has the potential to add to the cost and overhead of the program.

1.4.2: Advanced Market Commitments

[62] Ho & Taylor, 2021.

[63] Kremer, 2008.

[64] National Aeronautics and Space Administration, 2016.

[65] National Aeronautics and Space Administration, 2017.

[66] National Aeronautics and Space Administration, 2014.

Applicability & Criteria for Success:

The typically large size of these commitments makes them especially useful in situations where incentivizing capacity is a key goal.[67] While they may also be targeted at earlier-stage technologies, advanced market commitments are particularly well-suited to mid-range technical development where the pre-existing base of R&D is sufficient to effectively articulate the definition of success.[68] According to Ho, the existing knowledge base should be well-developed enough for sponsors to roadmap for 5-7 year outcomes and understand existing market or supply chain failures that have hindered commercial development to date.[69] Desired outcomes, rather than specific technical requirements, are typically better suited as success criteria, as these commitments tend to have longer horizons and superior technologies may emerge over time.[70] Also, given that these commitments are not made with a specific technology provider, there should also be multiple viable players with the necessary expertise to feasibly build out sufficient capacity to serve the target market. Otherwise, a bilateral arrangement would likely be preferable.

To successfully execute an advanced market commitment, the sponsoring organization(s) must make a commitment that is deemed credible by the market and is sufficiently large to encourage private investment. Therefore, any entity considering launching an advanced market commitment should ensure requisite funds are sufficiently insulated from changes in business priorities, economic conditions, etc.

Examples:

Gates Foundation & Vaccines

In 2007, the Gates Foundation, in concert with five national governments, committed to funding $1.5 billion of advanced demand for pneumococcal vaccines targeted at developing markets. The program was designed to provide 10-year contracts to firms with eligible vaccines, committing to large annual tenders at a fixed price of $3.50/dose, which was in excess of manufacturing costs.[71] In effect, the program de-risked private firms' investments in R&D efforts and capacity construction by providing per-dose subsidies and guaranteed demand. Additionally, the program was structured such that multiple firms participated in tender offers, creating long-term price competition and de-risking supply chains, both of which would be increasingly important as the program and associated funding wound down.

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[67] Kremer et al., Advance Market Commitments: Insights from Theory and Experience, 2020.

[68] Ho & Taylor, 2021.

[69] Ibid.

[70] Department for Business, Innovation, and Skills, 2011.

[71] Kremer & Williams, Incentivizing Innovation: Adding to the Tool Kit, 2010.

While it is not possible to know the counterfactual, best estimates suggest that the program saved 700,000 lives as of 2020 resulting from the successful creation of 3 vaccines and the immunization of 150 million children.[72]

Frontier Fund & Carbon

In April 2022, Stripe, a global payment processing platform, launched the Frontier Fund through which it will fund nearly $1 billion of carbon removal by 2030. Funds are provided by Stripe, a number of large corporates, and Stripe customers that have opted to allocate a small percentage of transactional revenue processed on Stripe's platform to the program. The technology-agnostic pledge seeks to provide market support to a range of potentially viable technologies that could ultimately provide high-quality, low-cost carbon removal at scale. The Frontier Fund utilizes a novel bifurcated purchasing strategy for the providers selected. A metric designed by the program to capture the degree of certainty with which a unit of carbon removal can be measured and verified determines the size of the commitment.[73] Frontier will make larger commitments for technologies with a higher degree of confidence, while still supporting less verifiable, potentially more novel solutions with smaller pre-purchase agreements. This strategy is intended to support innovation at all stages while limiting downside risk.

As of December 2022, the Frontier Fund made its second round of purchases from seven companies totaling $11 million and provided research grants of $250,000 each to two additional companies. In the cases where Stripe agreed to pre-purchases, agreements are structured as a fixed price for a given quantity of carbon removal by a specified date. For example, Arbor Energy and Resources signed an agreement to provide 667 metric tons of carbon removal and storage by December 2026 for $333,333. Prices, quantities and timelines all vary by company. In addition, most contracts include a conditional renewal provision that provides the option for a larger follow-on purchase if several generic and project-specific milestones are met.[74] The follow-on provision includes only a minimum aggregate purchase amount (e.g., $1 million in the case of Arbor) without committing to a specified quantity or price per ton. However, the future purchase is subject to most-favored-nation pricing, with the supplier committing to provide Frontier and its members with the lowest available purchase price available for any given quantity.[75]

As part of the second selection round, the Frontier Fund also provided research funding to two companies in much earlier stages of development for their respective carbon removal technologies. As outlined in the agreement with one such firm, Nitricity, these funds are intended to support the design and execution of various experiments to optimize the key parameters of their solution, in addition to a pilot demonstration. Upon successful completion of experimentation and demonstration, the

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[72] Kremer et al., Advance Market Commitments: Insights from Theory and Experience, 2020.

[73] Frontier, n.d.

[74] Frontier, 2022.

[75] Stripe Inc., 2015.

agreement also includes a conditional follow-on purchase should the firm meet additional performance milestones.[76] Unlike the Gates Advanced Market Commitment described above, the Frontier Fund operates with a much more flexible approach that utilizes different contractual arrangements to support technologies across a range of TRLs. The willingness to provide research funding can support the development of earlier TRL technologies, while the consistent use of contingent purchasing with defined milestones for both early and later stage technologies helps to maintain the emphasis on innovation irrespective of TRL.

Key Benefits for Innovators and Off-takers and Limitations on Efficacy:

A primary benefit of advanced market commitments is their ability to leverage private markets to shoulder the R&D costs necessary to create a viable product and to do so at scale. This guaranteed early market enables investors to realize a return before a self-sustaining market develops organically, thereby unlocking capital earlier. Given that advanced market commitments are effectively an open call to innovators, this ability to catalyze capital is not limited to a particular firm nor necessarily even to firms directly eligible to benefit from the tender agreements. If sized commensurately with past examples, these commitments have the potential to advance the entire supporting ecosystem necessary to commercialize a solution, including investments in supply chains, manufacturing capabilities, and so on.[77]

Another benefit of these provider-agnostic commitments is their ability to avoid technology lock-in and limit risk through diversification, which is especially important when targeting mid-range technical solutions where a dominant path has not yet emerged amongst all possible solutions.[78] Even with the Frontier Fund's initial purchase, three distinct categories of technology (direct air capture, enhanced weathering, and synthetic biology) received purchase commitments.[79] Given that the fund is structured such that it only specifies an aggregate commitment over a given time period, there is longer-term flexibility to make increasingly larger purchases if dominant technologies emerge. Similar to prizes, advanced market commitments' open call for innovation has the ability to generate substantial public attention and inbound interest. Beyond the potential to attract innovators from non-traditional backgrounds and disciplines, this may also reduce the burden on an off-taker to perform extensive research into the full-scope of potential solutions, conduct outreach, and perform diligence prior to selecting a singular provider ex-ante.

The primary drawback of this mechanism is the scale of funding required for success. While it may be possible to replicate the results achieved by the Gates example and others with commitments that are orders of magnitude smaller, we presently do not have these more limited historical use cases to evaluate. Beyond the need to raise or acquire significant resources to fund the commitment, the longer

[76] Stripe Inc., 2022.

[77] Ho & Taylor, 2021.

[78] Organisation for Economic Cooperation and Development, 2011.

[79] Frontier, 2022.

time horizons of advanced market commitments may present additional challenges for corporates, as certainty that the funds can be protected and not re-allocated to other business priorities that may arise over time is essential. Similarly, the large-scale, long-horizon nature of advanced market commitments creates potential challenges from a design perspective.[80] Program administrators must carefully consider whether to utilize price targets, demand guarantees, or other mechanisms to support the early market. Poor program design could either render the program ineffective due to a lack of compelling incentives or expose the administrator to financial risk if the economics of the desired outcome shift considerably over the life of the challenge.[81]

As illustrated by the two examples included above, there are many possible designs that sponsors may adopt for an advanced market commitment. While historical examples are limited and there is no strict rubric, successful program design should include the definition of a clear target outcome and the calibration of all other design decisions (e.g., ideal number of recipients, average size of award, contract structure, etc.) should be undertaken to address the key barriers that have impeded the achievement of this outcome to date or may continue to in the future. In some cases, these barriers may be largely technical, while in others misaligned incentives, supply chain failures or other forces may be at play. In the case of the Gates vaccine advanced market commitment, the program was designed to address a market failure whereby drug companies are under-incentivized to develop vaccines specific to developing countries given those populations' lower ability to pay.[82] The advanced commitment provided both a long-term purchasing commitment and a per dose subsidy that provided drug companies greater certainty that they could generate a positive ROI from a pneumococcal vaccine specific to the developing world. While the program intentionally supported multiple firms, the tender offers for each needed to be sufficiently large to justify their large-scale investments in development and production. Conversely, the dominant barrier impeding the target outcome of the Stripe Advanced Market Commitment is largely technical in nature. Accordingly, the program provides smaller awards to numerous potential suppliers representing a diversity of technologies. Follow-on purchases are contingent on the successful completion of numerous milestones related to the further technical development of each solution along a roadmap designed to result in lasting, measurable, and cost-effective carbon removal.

Aside from similarly sized commitments to a stated future goal, the Gates vaccine program and Frontier's carbon removal commitment share little in common from a structural perspective. However, in both cases the program sponsor carefully calibrated elements of program design to address critical impediments to the desired outcome.

1.4.3: Bi-Lateral Contingent Purchase Orders

Applicability & Criteria for Success:

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[80] Kremer & Williams, Incentivizing Innovation: Adding to the Tool Kit, 2010.

[81] Kremer et al., Advance Market Commitments: Insights from Theory and Experience, 2020.

[82] Nayar, 2011.

This type of agreement is typically best suited for technologies that are near commercialization (TRL 8-9) with few, if any, remaining technical hurdles. Contingencies are generally defined around finer points of performance and specific cost targets based on the counterparty's existing technical approach. These types of arrangements are most usually formed with firms that have a higher degree of strategic fit with the off-taker's core business, such as securing a key input or a competitive advantage in a new market. To successfully mobilize private capital, the contingent agreement should either be of sufficient size or duration to signal future demand large enough to justify any capital investment necessary to scale up production. A higher degree of strategic fit with a core goal of the off-taker in itself can serve as a compelling signal if the market can be persuaded that it will be an area of future investment beyond the scope of the specific purchase order.

Given the conditional nature of these agreements, they are likely to be more effective at attracting private capital to a supplier if the investment required to deliver the solution is not specific to the off-taker. Otherwise, the classic hold-up problem, in which the off-taker's bargaining power is enhanced once a specific investment has been made, will be exacerbated and investment discouraged.[83]

Examples:

Providing Long-Term Off-Take Stability to Facilitate Rapid Supplier Scaling - TSMC, Volkswagen, Reliance

The most common and straightforward mechanism in contingent purchasing is a large-scale and longer-term supply contract, which could also be referred to as a blanket purchase order, master purchase agreement, or master supply agreement depending on the industry it is used in. The key consideration behind all such agreements is that they provide a supplier, which could be an emerging company or an established player breaking into a new market, with a reasonable level of certainty to plan capital and supply chain investments, without putting the purchaser at risk under a structure that is strictly "take or pay." A typical MPA will have the following key terms:

- Length that significantly exceeds the usual procurement window for a given industry
- Some type of deposit or guaranteed short-term commitment up front that is non-retractable
- The ability to guarantee larger purchase quantities under some type of rolling forecast as the relationship evolves and shows successful progress

When deemed highly strategic, this type of supply deal may also be accompanied by a significant corporate investment and/or joint development & technology licensing partnership. One of the first examples of this type of transaction in clean energy was in 2010 between Stion, a U.S. thin-film solar start-up, and Taiwan Semiconductor (TSMC), the world's largest manufacturer of computer chips which was establishing a new solar business unit.[84] TSMC invested $50 million in Stion and also licensed its technology while issuing a five-year purchase commitment where 80% of the first year of production

[83] Che & Sakovics, 2004.

[84] Stion was a U.S.-based company that began manufacturing in 2011 and ceased operations in 2017 citing foreign competition.

volume was guaranteed. Other start-ups funded by Stion's lead investor, Khosla Ventures, have continued to utilize similar deal structures, including Quantumscape with Volkswagen for EV batteries. The graph below shows a typical progression of guaranteed purchasing and contingent purchasing in this type of situation.

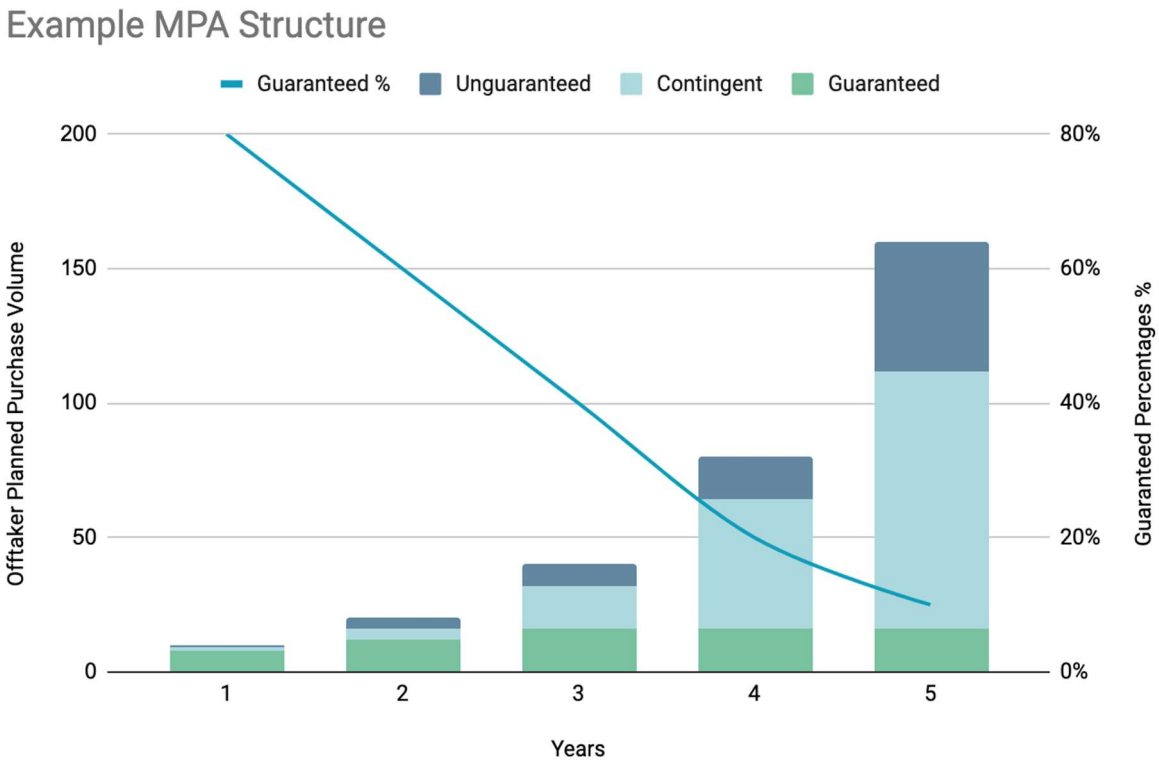

Figure 4: Hypothetical MPA Structure and Progression

Key Benefits for Innovators and Off-takers and Limitations on Efficacy:

Bi-lateral contingent purchase orders or master purchase/supply agreements can be employed as a signal of bankable future demand that provides credibility to the supplier and limits risk for the off-taker. These arrangements can be leveraged by the supplier in conversations with investors to illustrate a feasible path to near-term revenue even before a commercialized product is in the market, as well as provide clear specifications for product-market fit. The primary benefit to the off-taker is the ability to utilize this high-leverage, low-risk mechanism to improve the likelihood that a specific technology will achieve commercialization without bearing all of the financial risk associated with obtaining scale. Because the agreements are between two specific firms, the contingencies can also be much more narrowly defined, particularly in the beginning of the agreement, ensuring the off-taker knows exactly what will be delivered if the contract remains in force. Also, in cases where these agreements are made with partners that have known strategic value, bilateral agreements that help partners achieve initial scale can help cement a mutually beneficial long-term relationship either through delivery priority, exclusivity, favorable pricing terms, etc.

While highly useful across a range of circumstances, the drawback of this mechanism is the indirect nature of catalyzing meaningful investment, deployment, or learning across an industry more broadly. Unlike other mechanisms outlined, these arrangements are made with a single supplier, and therefore are less likely to attract new entrants in the same way as the broader, provider-agnostic mechanisms described above. Lack of an identical or similar second source can often limit the planned procurement ramp, especially in current market conditions where supply chain fluctuations are common even in mature businesses. Furthermore, engaging with nascent technology providers that can disrupt the economics or other key performance specifications, will usually require that provider to raise external scale-up capital, for which the contingent purchase order is a strong but not definitive success criteria for such raise.

Depending on the maturity of the overall market for the specific technology, another potential risk of this approach is that the off-taking firm is effectively picking a winner. In more mature markets where the technology and merits of all players are well understood, this risk is reduced; however, when considering novel technologies, this type of mechanism may increase the likelihood of betting on the wrong horse. Depending on the process undertaken to identify the supplier, entering into a bilateral agreement with a single, selected partner may also result in overlooking lesser-known or non-traditional solutions. Conducting extensive due diligence may lessen these risks, as may selecting a portfolio of potential partners as opposed to a single supplier.

1.4.4: Preferred Supplier Agreements

Applicability & Criteria for Success:

Preferred supplier agreements should be utilized only when an off-taker has a very high degree of certainty that the counterparty can deliver on critical cost and performance characteristics. As such, they are typically most beneficial when a technology is fully proven and commercially viable but would benefit from a higher degree of demand certainty in order to scale. Given that the quantity for purchase is typically not specified upfront, these agreements are most impactful for critical goods or services (i.e., being the preferred supplier of a product that the off-taker will likely only require small quantities of in the future is less likely to motivate investment).

Example: Gamesa, Dominion & Hai Long Offshore Wind Project

In January 2020, Dominion Energy designated Siemens Gamesa (and specifically its SG 14-222 DD turbine) as its preferred supplier for its 2.6 GW Coastal Virginia Offshore Wind project. Following the agreement, Siemens Gamesa began exploring manufacturing options to support the project, ultimately announcing plans to construct a $200 million facility in Virginia. Once completed, this will be the first offshore wind turbine blade facility in the U.S.[85] Similarly, Hai Long Offshore Wind Project in Taiwan designated Siemens Gamesa as the preferred supplier for 3 planned projects, totaling over 1 GW of capacity. On the heels of that preferred supplier agreement, Siemens Gamesa announced plans to

[85] Siemens Gamesa, 2021.

triple the size of its existing facility in the region to support demand from the Hai Long projects and future demand in the region.[86]

Key Benefits for Innovators and Off-takers and Limitations on Efficacy:

This type of arrangement can be very effective at driving capacity investments by suppliers without necessarily requiring a firm commitment from off-takers upfront. These more open-ended agreements enable credible demand signaling while providing significant flexibility in terms of the ultimate quantity purchased and timeline for acquisition. In the case of the offshore wind projects above, this may have been the preferred form of purchase commitment due to its ability to limit the off-takers exposure in the event a project is delayed or canceled without necessitating the specification of multiple unknown contingency clauses upfront.

The drawbacks of this mechanism are very similar to those identified for bilateral purchase orders in that they are unlikely to spur investment across multiple players or the broader supply chain ecosystem. This mechanism also clearly entails picking winners amongst a range of potential solution providers, which could similarly result in overlooking other promising alternatives in markets that are less mature.

1.4.5: Common Benefits of Purchase Commitments

The flexible nature of purchase commitments makes them a useful tool for corporate purchasers seeking to achieve a range of desired ends. In certain instances, like the Gates Advanced Market Commitment, they may provide the support necessary to stimulate an initial innovation and invest in the capacity necessary to deploy it at scale (without necessarily encouraging further iteration on initial design). In other cases, such as the milestone-based joint venture agreement between QuantumScape and Volkswagen, the contingent financial awards provided incentive for continued development and validation of QuantumScape's core technology over time. In both cases, however, these interventions successfully stimulated capital flows necessary for the development and/or commercialization of the target technologies. Beyond their ability to stimulate investment, strategies of this nature have other related benefits. For the off-taking entity, these contingent agreements can limit downside risk. Contingent arrangements only require a financial outlay if the criteria defined by the off-taking entity are met. While milestone-based programs involve capital at risk for purchasers if suppliers fail to meet later-stage technical milestones, the staggered nature of these payments or investments still serves to limit downside relative to an upfront lump sum outlay. A closely related benefit is the ability for sponsors and suppliers to define and agree to success criteria upfront. This not only limits risk for off-takers, but also provides a greater degree of transparency to innovators as to the performance characteristics most valued by the market and the price that it is currently willing to bear. These are crucial insights that can help innovators direct R&D efforts and outside investors' direct capital more efficiently.[87]

[86] Siemens Gamesa, 2022.

[87] Ho & Taylor, 2021.

CHAPTER 2: Novel Strategies for Corporates to Accelerate Decarbonization

2.1: Introduction

To achieve Net Zero, a global economy in which remaining net emissions do not exceed the earth's sequestration of carbon (e.g., by oceans and forests), the public and private sectors will need to undertake efforts to advance the rapid development, demonstration, and ultimately deployment of a range of new and established technologies required to shift away from a fossil-based electricity generation.

As described in the previous chapter on prizes and purchase commitments, traditional corporate procurement mechanisms such as power purchase agreements (PPAs) may not maximize decarbonization impact per dollar spent, particularly for novel technologies such as long-duration energy storage or hydrogen. Tools such as prizes and purchase orders, if employed effectively, can direct the effort of technologists toward increasing the tempo of innovation to decrease the cost and improve the performance characteristics of novel technologies.

However, the urgency and scale of this challenge will also require a willingness to test novel approaches designed to speed the innovation and uptake of these critical technologies. This paper describes several less-understood approaches to maximizing decarbonization per dollar spent by a corporate. The right mechanism will be technology – and TRL – dependent, but the strategies described here – advanced market commitments, financial hedges, tax equity, sponsor equity, test beds, and more – should be considered by corporates seeking to achieve the greatest decarbonization from their energy budgets. Given that these strategies are novel by design, this paper draws less from academic literature and more on interviews with entrepreneurs, experts, and this team's lived experience working to accelerate the pace of innovation in clean energy as well as financing and deploying clean energy technologies.

Support for *innovation* will be critical to the development and demonstration of novel technologies, as well as to their continued evolution over time in order to realize the cost reductions and performance improvements necessary to transform a novel technology into an effective and economic solution at scale. Support of *deployment* efforts will also be essential to the global Net Zero transition, as the need for renewable energy is massive and growing and can only be addressed by the physical deployment of a portfolio of technologies, both existing and novel, at scale. Corporate purchasers have the opportunity to play a role both in advancing the tempo of innovation and accelerating deployment at scale. This paper will consider non-traditional roles that corporate purchasers may play in supporting R&D for given technologies, in addition to financial innovations they could pilot to encourage deployment efforts.

Direct support for R&D efforts is critical for innovation and the advances necessary to move a novel concept from ideation to commercialization. The public sector has historically played a crucial role in providing funding on a large scale for early-stage innovation across a wide spectrum of sectors, including energy. While the private sector will not supplant this role, especially at the earliest stages of

technical development, corporations can nevertheless meaningfully contribute to supporting the continual development of promising technologies over time. This support may take a variety of forms, from direct funding to providing support for test facilities, incubator programs and a number of other means of facilitating early demonstration efforts. Additionally, corporations can utilize other means, such as procurement contingent on incremental price or performance improvements, to encourage and support the continual development of even fully commercialized technologies over time.

When developing strategies to accelerate deployment, techniques to manage project-level risk can make projects more financeable or bankable and lower the cost of capital to deploy more projects at scale. Reductions in project risk can unlock increasingly large and affordable pools of capital to fund projects. Risks associated with the deployment of renewable technologies exist in numerous forms and to varying degrees of acuteness, depending on the technology. Understanding and managing these risks is important when considering how to design innovations to incentivize deployment, as the private capital necessary to finance projects is risk-averse and requires compensation for varying degrees of risk assumed. Several common types of risk are outlined below:

> **Market Risk (e.g., electricity prices, asset utilization):** The economics of energy generation and energy storage projects are tied to prices of electricity markets, commodity markets, and grid services markets; as such, they are therefore exposed to market fluctuations. In particular, price and demand changes can hurt the bottom line of the generator, either through a lower market clearing rate or through lower quantity. In some cases, the technology might face risk from multiple markets, such as a hydrogen electrolyzer relying on both an input market of electricity and an output market for hydrogen.
>
> **Operation / Generation Risk:** Operational risk can arise from a variety of sources, including equipment failure, human error, natural disasters, cyber-attacks, and regulatory changes. In each case, the overall productivity of the generator is lower than expected.
>
> **Technology Risk**: With any new technology, there is a risk that the technology will not function as expected. This could be for a range of reasons, most commonly due to problems scaling a prototype into a commercial-scale setting.
>
> **Execution Risk:** Execution risk refers to the risk that a company will not be able to execute its plans or strategies as intended. Potential reasons include financial constraints, regulatory hurdles, and competitive pressures. These competitive pressures may be exacerbated in a dynamic market, such as that for clean energy solutions, as each emerging technology will be competing against multiple others vying for a role in the clean energy portfolio of the future, in addition to more static technologies.

At different stages along the path to commercialization, technologies will face different combinations and varying degrees of the types of risk enumerated above. Generally speaking, those facing more established technologies tend to be fewer and better understood, and therefore easier and cheaper to manage. In the case of more established technologies, such as solar PV and onshore wind, mitigation mechanisms (e.g., PPAs) can sufficiently address the dominant risks associated with project development in order to unlock other capital necessary to fund the project.

In instances where existing mitigation methods are not well matched to project risks, financial innovation could play a crucial role in speeding deployment. Further, financial innovation may also have an important role to play in advancing the deployment of established technologies to the extent that identifying a PPA counterparty is or becomes a bottleneck. The table below includes a number of mechanisms that this paper will discuss in more detail in the following sections. The various risks that each is best suited to address are shaded in green and, among other considerations, may help guide where each intervention can be most impactful in accelerating deployment.

Table 1: Novel Strategies as Risk Mitigants

		Primary Market Price Risk	Ancillary Market Price Risk	Operation / Generation Risk	Execution Risk	Technology Risk	Rationale
Tempo of Innovation	Prizes & Contests						Prizes signal that an off-take market will likely exist for later stages of the technology given the demonstrated interest by the prize sponsors
	Contingent Purchase Orders						Contingent purchase orders reduce price risk as off-takers specify a price they would theoretically be willing to pay for performing technology
	Test Beds / Labs						Test beds and labs can help mitigate early stage tech risk by providing early demonstration opportunities for developing technologies and facilitating gradual iteration in a controlled environment
Deployment	Accelerated Advanced Market Commitment						AMCs provide upfront price certainty well in advance of delivery. Accelerated payments can also shift some of the operational, technology and execution risk from the project developer to the sponsor
	Power Purchase Agreement						PPAs provide effective downside protection to project owners for unfavorable movements in energy prices
	Hedging / Insurance						While insurance / hedging can be designed to protect against different risks, including technology risk, revenue puts most effectively shift risks of unfavorable output or price conditions, both in primary and ancillary markets if hedged in aggregate
	Tax Equity						If the project from which the corporate partner is purchasing tax credits fails to execute as expected, the partner may be unable to claim the anticipated credits
	Sponsor Equity						Investors face exposure to all aspects of the project's risk, particularly without a PPA to avoid energy price risk

Note: Ancillary market risk is intended to highlight the distinction between strategies that address price risk in a single market (e.g., energy markets) versus those that may be more effective in situations where technologies face potential price risk across multiple markets (e.g., energy, frequency, and capacity markets)

2.2: Advanced Market Commitments

For some technologies that are not yet fully commercialized, uncertainty about future demand may make it difficult to justify the investments necessary to achieve scale. As a result, firms underinvest in capacity, and technologies that could have broad market potential at scale may stagnate. This problem is more acute when increasingly large upfront capital investments are required, as heavy discounting of uncertain future cash flows makes it difficult to achieve a positive return on investment when initial outlays are large.

2.2.1: Potential Roles for Corporates

For technologies where market uncertainty has led to underinvestment, an advanced market commitment may be able to mobilize capital by reducing uncertainty concerning future demand.[88] Through an advanced market commitment, the sponsoring organization commits to supporting a specified quantity of future demand (defined as either units of output or cumulative spend) for technologies that can meet defined cost and/or performance criteria.[89] Though typically large in size, the contingent nature of these commitments may provide a more favorable risk profile for sponsors looking to advance novel technologies without taking on equity-like risk. As opposed to bi-lateral contingent purchase orders, advanced market commitments are effectively an open call to innovators and are not directed to any singular supplier or highly specified technical solution.

Outside of the Frontier Fund, launched in 2022 by a consortium of corporate sponsors to advance carbon removal solutions, the most notable examples of advanced market commitments have been sponsored by the public sector and have largely focused on health technologies, notably vaccines.[90] Despite the lack of a meaningful track record of private sector examples, this market-based mechanism may be a useful tool for corporate purchasers with a particular interest in advancing the deployment and further development of novel technologies. Two possible variations on the basic structure of the advanced market commitment described in the last chapter are proposed below. These more novel conceptions of an advanced market commitment are intended to provide earlier financial support for potential suppliers and greater direction with clear incentives for their research and development efforts over time.

One variation that corporate sponsors could consider is offering an "accelerated" advanced market commitment in which some portion of the committed funds is prepaid to potential suppliers upfront. This may include prepayment for RECs, carbon credits generated by a project, or another form of project output. These upfront payments could theoretically provide early-stage companies not only with necessary working capital, but also with a stronger value proposition to leverage with investors in the form of demonstrable revenue.[91] While the broader advanced market commitment creates certainty that an early market for a technology exists, these directed prepayments signal the sponsor's confidence that a specific firm is well-positioned to capture some portion of that committed demand. Prepaying suppliers may offer a more efficient way for sponsors to direct capital toward the firms that they deem most likely to deliver. Providing this early support for selected technologies could also give

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[88] Kremer et al., Advance Market Commitments: Insights from Theory and Experience, 2020.

[89] Kremer & Williams, Incentivizing Innovation: Adding to the Tool Kit, 2010.

[90] The Frontier Fund was launched in early 2022 with the stated goal of purchasing $925 million of carbon removal by 2030. The intention is to support technologies with high-volume, low-cost future potential. Purchase agreements signed to date provide a price per ton ranging from $230 to $1,600 , a significant green premium over the <$100/ton the program ultimately seeks to achieve.

[91] According to data compiled by Wing Venture Capital, 67% of companies that raised their Series A in 2017 were already generating revenue, compared to 11% in 2010.

sponsors an opportunity to negotiate favorable terms for future purchases (e.g., most favored nation pricing) as a concession for taking upfront risk.

An advanced market commitment could also be designed to include interim milestones for incremental improvements in either performance or price over time. One possible structure could separate demand into staggered tranches, each with price and performance thresholds that become increasingly aggressive. Potential suppliers could theoretically be allocated demand as part of an earlier tranche and excluded from later rounds for failure to keep pace with price or performance improvements. Designing an advanced market commitment in this way could incentivize not only deployment, but also innovation as a condition precedent of participating in future allocations.

2.2.2: Potential Benefits to Corporate Purchasers

Corporate sponsors may reap several potential benefits through sponsoring advanced market commitments, ranging from the satisfaction of internal climate goals to generating positive public interest. The election of the underlying technology of interest can be made based on the sponsor's unique objectives and anticipated future needs. For earlier stage technologies, an advanced market commitment can offer corporate purchasers the opportunity to secure future output of a desired technology that is not currently fully commercialized. Sponsors could also theoretically employ this mechanism for later stage, commercialized technologies to incentivize innovation on specific performance parameters or encourage new entrants at a lower price. The flexibility of the mechanism and its specification criteria provide corporate purchasers the opportunity to determine whether to place emphasis on price, quantity delivered, technical characteristics, or some combination thereof. These specification criteria may also have the ability to influence how target technologies evolve over time by directing the efforts of potential suppliers hoping to participate in this demand in the future.

Large commitments of this nature have the ability to attract private capital, potentially materially in excess of the sponsor's initial financial commitment. Specification criteria outlined in the solicitation may also help to steer external capital more efficiently to achieve the cost and performance objectives outlined in the solicitation.[92] Assuming that these commercialization efforts succeed, the sponsor can then acquire the eventual output, compliant with desired success criteria, without having committed any additional capital to the development efforts required to deliver the solution. For large advanced market commitments designed to support multiple suppliers (i.e., not a winner-take-all structure), it is also possible that numerous relevant solution-providers will benefit from these external capital flows. By stimulating funding to support the demonstration or commercialization of a given technology across multiple firms, this strategy may also create favorable conditions for longer-term competition, which in turn increases the likelihood of cost declines resulting from increasing the tempo of innovation.

Another benefit of this strategy is its straightforward, market-oriented, and highly flexible nature. While advanced market commitments may not be well suited to every situation, their inherent flexibility (e.g., size, structure, time horizon, etc.) makes this mechanism more easily adaptable to

[92] Ho & Taylor, 2021.

sponsors' needs than others that may be governed by strict regulatory regimes or more highly dependent on other market actors.

2.2.3: Outstanding Questions and Considerations

Given that the basic mechanics of this strategy are well-understood, the most important questions facing a potential corporate sponsor will center around program design, including target outcome or technology, time horizon, size of commitment, and defined success criteria. Once the desired outcome has been identified, decisions as to the appropriate timeline, success criteria and associated level of specificity, and nuances of the structure should all be calibrated so as to maximize the probability of success in the context of the stated goal.

Structuring an advanced market commitment with either an accelerated payment schedule or interim milestones would add nuance to program design. Committing to prepay for future output will likely require a higher degree of diligence on the part of sponsors, as they will need to assess ex-ante whether a potential supplier is likely to meet specified success criteria in the future versus assessing more developed technology ex-post. Sponsors can alter elements of program design to limit the downside risk that the pre-purchased future output does not materialize or falls short of the success criteria. Options include limiting the size of prepayments to any singular supplier and relative to the overall commitment, restricting eligibility to suppliers with more mature technology, or placing additional conditions on the receipt of prepaid funds. For an advanced market commitment with interim milestones, sponsors will need to repeat many of the decisions made at the overall commitment level for each tranche of demand. These would include considerations like relative sizing and temporal spacing of tranches and tradeoffs between cost and performance improvements.

2.3: Financial Hedges

The concepts of forward price contracting and financial hedging for commodities can trace their modern roots in the U.S. back to the mid-19th century agricultural commodity markets of the Midwest.[93] Since that time, these concepts have evolved and expanded to cover a much broader spectrum of underlying assets and to employ an increasingly complex range of financial instruments. One form of forward price contracting, the PPA, has been used extensively since the 1980s by independent power producers seeking to lock in a fixed price for future output and to thereby significantly de-risk projects.[94]

PPAs are well-suited to situations when a single commodity is sold with a clear and liquid market for both buyers and sellers, such as well-established renewable energy technologies. For sellers, signing an off-take agreement at a fixed price can help facilitate securing financing, often at a lower cost of capital due to the lower risk associated with future cash flows. For buyers or off-takers, the contracts provide price predictability, as well as additionality and other environmental benefits for renewables projects. Virtual PPAs, introduced in 2015, provide many similar benefits, notably increased certainty for sellers and renewable energy credits (RECs) for buyers, but are purely financial instruments that are cash-

[93] Permanent Subcommittee on Investigations, 2009.

[94] Yescombe & Farquharson, 2018.

settled and eliminate the requirement for physical off-take by the buyer.[95] Since the time of their introduction, virtual PPAs, as well as other longer established hedging mechanisms, have provided a popular alternative to physical PPAs as illustrated in Figure .

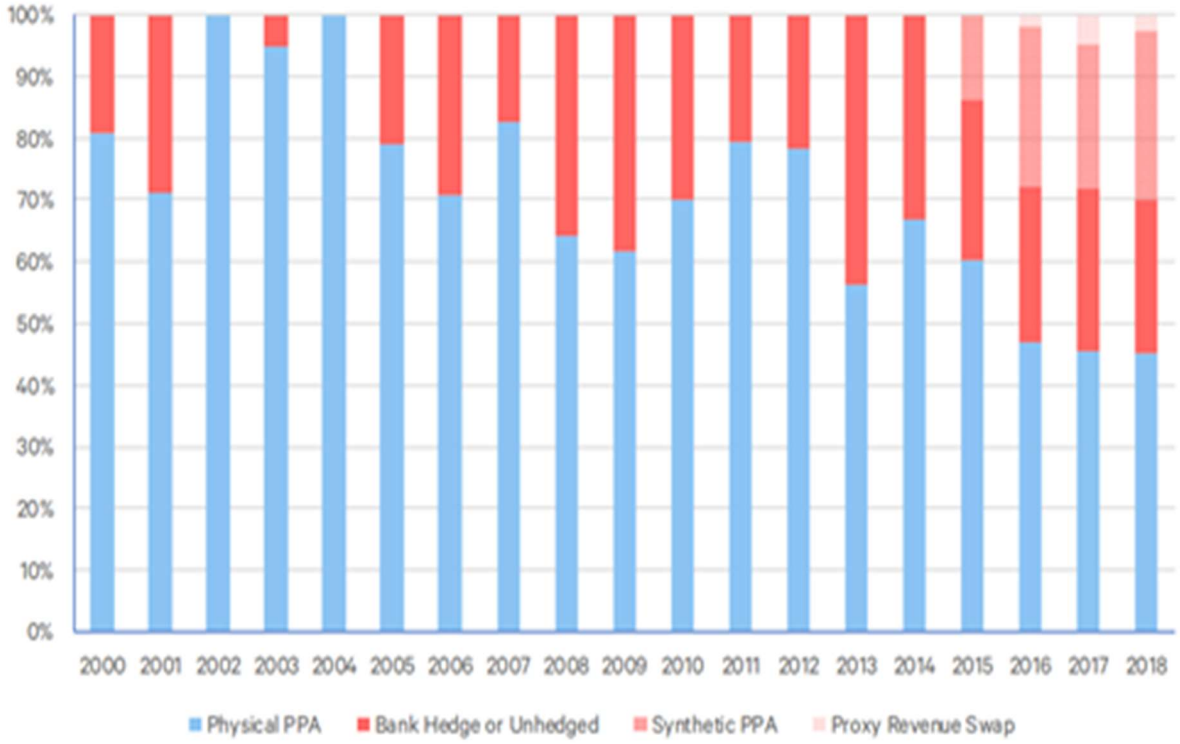

Figure 5: Percentage of U.S. wind capacity installations by financial structure

Credit: *Bartlett, 2019.*

2.3.1: Cases Where Traditional Off-Take Agreements May Be Insufficient

While these agreements have been critical to the deployment of wind and solar projects, other financial mechanisms may be better suited to providing market certainty in cases where a single commodity or clear and liquid market is not involved. Cases where more novel mechanisms may be necessary could include:

1. ***Market stacking, where several complex value streams exist as in the case of energy storage (e.g., ancillary, energy, capacity, etc.)***

   In these cases, bi-lateral commitments with a single fixed price lack the flexibility and nuance likely necessary to adequately capture the multiple value streams provided by a project. Given that a wide spectrum of market, grid, and system conditions may affect both pricing and output, a more holistic approach that considers their effects across all relevant value streams may provide developers with greater certainty around the project's comprehensive value.

[95] Kansal, 2019.

2. ***Complex regulatory markets where the procured commodity is only part of the revenue (and perhaps a minority)***

   In certain markets regulators have created pricing regimes that compensate distributed energy resources for benefits they provide to the grid beyond energy alone. For instance, New York's Value of Distributed Energy Resources (VDER) program compensates projects based on when and where they provide energy to the grid. These payments are determined based on time- and location-variable energy pricing and a range of other pricing for other ancillary services, such as capacity and environmental considerations.[96] In these cases, a traditional PPA that is priced based on the value of energy alone would fail to account for the full revenue potential of a project.

3. ***When the 'procurer' does not directly participate in the market, for example:***

   a. ***Support for green hydrogen (but not a hydrogen buyer)***

   b. ***Transmission***

   The lack of direct participation in the market by the corporate purchaser precludes the use of physical bi-lateral off-take agreements. A cash-settled agreement (akin to a virtual PPA) would also be ill-suited for these infrastructure-related plays, as a corporate counterparty would not benefit from offsetting any related risk or be able to claim RECs from these projects.

In the cases described above, a downside hedge in the form of a revenue floor could be more appropriate than a PPA to make more projects bankable and decrease the cost of capital. Utilizing a revenue floor, as opposed to a long-term virtual or physical off-take agreement, may provide project developers a greater degree of certainty over a larger portion of a project's long-term value by expanding downside protection beyond a single value stream. By utilizing this type of hedge, developers could effectively guarantee that the cumulative receipts from all functions of a given project or asset do not fall below a defined threshold. Additionally, in cases where the 'procurer' does not directly participate in the market, this could provide a means to facilitate project deployment by de-risking project economics without the need for direct involvement in the exchange of goods and/or services. Figure below illustrates the differing payout structures for traditional PPAs and a theoretical revenue put.

[96] New York State, n.d.

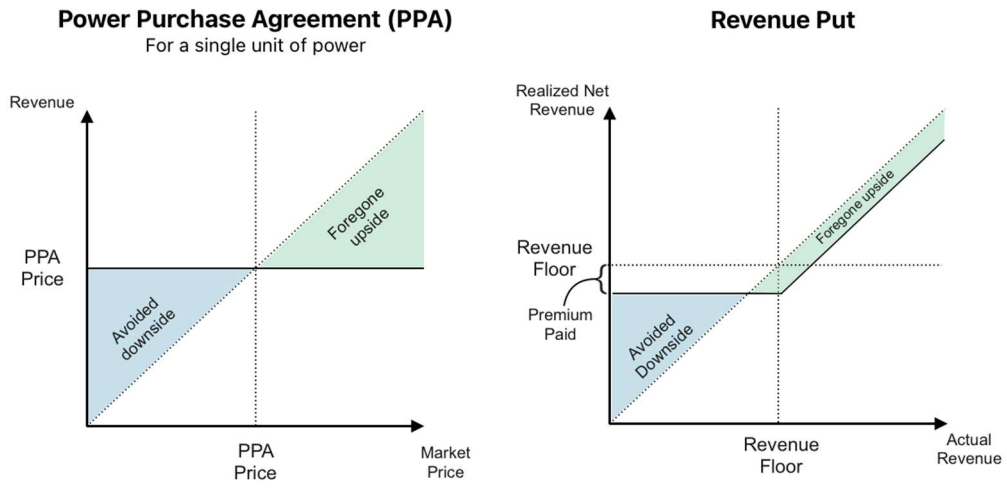

Figure 6: Traditional PPAs compared to Price Floors from a Project Developer's Perspective

A revenue put, an OTC derivative contract, could be a means through which this downside protection could be provided to the asset owner. Insurance products or other financial hedges may also be other viable mechanisms that could offer similar protection. While revenue hedges have not yet been used extensively for renewables projects, they are often employed in power markets more broadly for generators to control various types of risk. Several common mechanisms are described below.

Common Financial Hedges for Power Generation

Revenue Put: Typically utilized by gas-fired power plants, a revenue put is a cash-settled financial contract between a power provider and a financial counterparty that provides downside protection for the power plant over a specified term in exchange for an upfront premium paid to the financial counterparty. The contract specifies an annual revenue floor, which is typically sized to ensure that the plant will be able to meet its debt service and other fixed costs, less any other anticipated revenue sources. Revenue shortfalls are typically assessed based on a proxy calculation for the plant's theoretical net revenue, rather than the plant's actual revenue over the course of the year. Net revenue is calculated as the differential between power revenues and gas costs that a hypothetical power plant would realize throughout a year, based on published power and gas indices and predetermined assumptions for heat rate, capacity, and scheduled starts and stops.[97]

Heat Rate Call Option: A heat rate call option is a financial hedge used by gas plants that have a notional payout that is not tied to the plant's actual

[97] Budofsky et al., 2017.

performance.[98] Under this mechanism, the hedge provider and plant operator swap fixed and floating payments, the latter of which, known as the cash settlement amount, is determined based on published power and gas prices and a contracted heat rate, capacity, and operating expense amount. As the spread between power and gas prices tightens, the cash settlement amount becomes smaller, resulting in a larger net payment in favor of the plant operator, thereby providing downside protection against deteriorating market conditions. The converse is true as spreads widen, with the net payment shifting in favor of the hedge provider if power prices are sufficiently high. This ability to capture upside as spreads widen is effectively the payment for the hedge provider assuming the downside risk, as opposed to requiring an upfront payment as in the case of a revenue put.[99]

Proxy Revenue Swap: A proxy revenue swap is a cash-settled hedge between a project owner and a financial institution in which the hedge provider makes a quarterly payment based on a fixed annual revenue amount to the project owner in exchange for quarterly "proxy" revenue. Proxy revenue is calculated as the product of proxy generation (a set formula that converts the actual local irradiance or wind speed observed over the period into electricity output) and local hub price. This calculation is performed for every settlement period during the quarter. The resulting total is then netted against the fixed amount owed by the hedge provider and cash settlement made in the appropriate direction.[100]

Bank Hedge: Bank hedges have been used often in the wind sector and are contracts between financial institutions and project owners that can be settled physically or financially. The hedging effects are the same, but the description will focus on financial settlement for simplicity. Under the agreement, the hedge provider pays the project owner a fixed price for a fixed hourly amount of energy in exchange for the project owner's payment based on the floating rate established at the trading hub for the same fixed amount of power. While the hedge providers price certainty for a fixed amount of power, the project owner is still exposed to basis risk if prices at the node fall below the hub and volume risk if actual generation falls below the contracted fixed amount.[101]

2.3.2: Potential Roles for Corporates

Given that these types of contracts are typically written by sophisticated financial institutions, it is very unlikely that corporations would act as a counterparty to these transactions. However, corporate purchasers could help facilitate the creation of these financial hedges by raising a fund that is used to

[98] Ibid.

[99] Eberhardt & Szymanski, 2015.

[100] Brozynski & Tuenter, 2018.

[101] Bartlett, 2019.

collateralize derivative contracts (e.g., revenue puts). While a single corporate purchaser could do this alone in theory, a consortium of corporations able to pool resources would likely be more effective at achieving scale. This group of purchasers, or a designated third-party, could be responsible for sourcing projects, while a third-party would be responsible for writing contracts and managing risk at the overall fund level. Consistent with the management of a traditional investment vehicle, the consortium could define investment objectives and themes at the inception of the fund to direct the types of projects that would best align with their climate or other objectives.

By utilizing this structure, in which corporates are only responsible for providing collateral and a third-party financial institution is responsible for writing hedges and managing risk, the need for corporate consortium members to understand the nuances of individual markets that would be necessary to construct these hedge contracts is virtually eliminated. Rather, the third party, whether a bank or another financial institution, would determine the structure, term and revenue floor for each individual contract taking into consideration a range of project-specific considerations. By providing capital to collateralize these contracts, corporates may be able to encourage the broader or more rapid diffusion of revenue puts or other novel financial structures that may have the potential to de-risk the deployment of clean energy projects in the future.

2.3.3: Potential Benefits to Corporate Purchasers

This strategy has the potential to provide broader benefits to the market by creating a possible avenue to help projects that do not fit well within the existing PPA paradigm secure financing and by encouraging financial innovation for renewable deployment. As described above, there are several instances in which a traditional PPA may not provide enough certainty around future cash flows to enable developers to secure sufficient capital, or sufficiently cheap capital, to fund the project, which is unlikely to be deployed as a result, even if it could provide value to the system.

Just as technical innovation is necessary to avoid the most catastrophic outcomes of climate change, financial innovation also has an important role to play. Whether by supporting research and development or demonstration and deployment, vast amounts of capital will be required to meet this global challenge. The International Energy Agency estimated that annual global clean energy investment would need to reach $4 trillion by 2030 in order to achieve 2050 Net Zero objectives. This would roughly require a doubling of current levels of investment by the end of the decade.[102] While direct funding of R&D and investments in the deployment of novel technologies will undoubtedly play an important role, novel financing mechanisms that can de-risk investments and unlock other sources of funding could also be critical to realizing capital flows on the scale required to approach Net Zero.

2.3.4: Outstanding Questions and Considerations

Though financial hedging is not an inherently novel concept, the proposed application diverges materially from approaches currently utilized in the renewable energy procurement market. As such, further investigation into several key considerations outlined below should be undertaken.

Determining the appropriate floor and hedge term:

[102] International Energy Agency, 2022.

Establishing the appropriate revenue floor will depend on any number of factors, including project type, size, local market conditions, and future price expectations. Relative to more traditional mechanisms like PPAs, determining the appropriate revenue floor may entail more complex and nuanced calculations, as multiple value streams that follow different regulatory and pricing regimes could be in play. The term of the contract is also an important consideration. Revenue puts for power generation have historically had shorter terms of four to five years, which in most cases is shorter than the term of the project's debt financing.[103] Longer terms should help unlock more risk-averse capital sources, as revenues are guaranteed over a larger portion of the project's life and debt service, but option providers would need to be comfortable assuming market risk over a longer period of time.

Transaction costs:

There are often non-trivial transaction costs associated with writing hedging contracts, given their bespoke nature. The novelty of the applications described here may result in elevated costs as new forecasting and risk modeling, legal provisions, and pricing considerations may come into play. To the extent that some degree of standardization is possible over time, these costs should decline accordingly. Focusing an initial fund on a single technology-region combination may help speed the development of standardized legal terms and offers, thereby reducing transaction costs at the overall fund level.

Collateral sufficiency over time:

Corporate purchasers would be responsible for posting initial collateral to secure the option contract when written. In the fund approach outlined above, multiple hedges could be written against the consortium's pooled resources to reduce the overhead burden of posting collateral on an ad hoc basis as transactions close over time. This approach is predicated on the assumption that the fund manager would manage the operational complexity of maintaining segregated collateral accounts.

Once the underlying assets are operational, the fund manager would additionally be responsible for making periodic payments to project developers for any revenue shortfalls relative to the contracted floor. With prudent risk management by the hedge provider, option premiums should be sufficient to cover any outflows required to make revenue shortfall payments over the term of the hedges. However, in the event of a large or sustained unfavorable movement in prices, accumulated revenue shortfall payment could theoretically deplete available funds. One potential solution would be to have callable capital agreements with the corporate sponsors, which could result in additional funds paid in over time as needed. Another option would be to bring in another financial actor to assume the remaining uncollateralized risk above what is covered by initial margin requirements.

2.4: Tax Equity

Tax equity is one of the key levers provided by the U.S. government to scale up renewable energy, particularly wind, solar, and storage. Tax equity is rooted in tax credits made available by the U.S. government to incentivize renewable energy projects. The goal of these incentives is to make

[103] Thomson Reuters.

renewable energy projects more financially attractive to investors and to help drive the transition to a clean energy economy.

Two of the largest sources of tax credits are the Investment Tax Credit (ITC) and Production Tax Credit (PTC), which allow investors in renewable energy projects to claim a credit against their federal income tax based on a percentage of either the cost of the project (ITC) or the electricity generated (PTC). As of 2022, the ITC is set at 30% of the costs of the project, and the PTC is 2.6 cents per kWh, with inflation adjustments.

The drawback of the tax credit system is that in order to gain value from tax credits, you need a relatively high tax liability. Many renewable energy developers lack the tax liability to take full advantage of these credits, and so turn to outside entities to supply capital in return for the tax credits. Prior to the passage of the Inflation Reduction Act (IRA), only investors in renewable energy projects were eligible to take advantage of these credits. While there were more than 40 such entities that did so, 50% of tax equity was supplied by just two banks: JP Morgan and Bank of America.[104]

This represents a significant bottleneck in the funding of these projects, as those without relationships to those entities had a much more difficult time in securing that low-cost capital. Furthermore, tax equity providers invest in solar and wind projects with relatively low risk. The precise structure and risk profile varies, with one of the most common being the partnership flip. The flip feature of the structure allows the tax equity investor to sell its interest in the project to a new investor after a certain period of time, typically five to seven years. The new investor, known as the flip partner, steps into the tax equity investor's shoes and becomes entitled to the remaining tax benefits and cash flow from the project.[105] As a result of this structure, the tax equity investor is exposed to certain risks, including structural risks. This incentivizes tax equity investors to only undertake investments with minimal risk.

The Inflation Reduction Act recognized the limitations that this structure imposed on developers and instituted a number of changes to the tax credits system in order to lower barriers to development. One of the largest of these changes is the introduction of transferability. Credits can now be monetized by selling some or all of the credits to another taxpayer, which opens up alternative sources of capital that are simpler and easier than traditional tax equity relationships. It also allows for corporations with large tax liabilities to effectively act as tax equity investors by buying the tax credits, but without taking on the risks associated with investing directly.

Another significant advantage of the transferability piece is a lowering of transaction costs. Under the current system, the tax equity investors take a significant portion of the value of those credits. Experts suggest that 15-25% of the value is going to the tax equity partners, rather than being used by the project. It is now expected that the more liquid market for tax credits will enable lower transaction costs over time, potentially as low as 3% over the long run.[106]

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[104] Martin, 2021.

[105] Eberhardt, et al., 2022.

[106] Jenkins & Stokes, 2022.

Further de-risking involvement in tax credits, the Inflation Reduction Act also expands the availability of ITC and PTC structures into the future. Historically, uncertainty around the expiration of ITC and PTC programs has led tax equity investors to be more cautious around those investments.[107] By extending those tax credits, investments in the space and reliance on tax credits have been made significantly less risky. The table below shows the expected scale of the ITC between now and 2035 under the IRA:

Table 2: ITC, Pre- and Post-IRA, 2022-2035

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Pre-IRA	26%	22%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Post-IRA	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	26%	22%	0%

Credit: *Solar Energy Industries Association, n.d. (SEIA)*

In addition, the list of technologies eligible for tax equity of this type has broadened significantly. In addition to solar PV and wind, standalone energy storage has also been approved where it previously needed to be bundled with solar. Furthermore, newly introduced technology-neutral credits can be applied to any net-zero energy production facility, opening the door for innovative technologies.[108] Under these new rules, energy generation such as geothermal, wave power, and solar thermal technologies would all qualify[109] in addition to maintaining flexibility for novel zero-emissions energy technologies.

The story here is one of risk. Tax equity is a powerful tool for providing capital to renewable projects, but its usefulness is constrained by the risk appetite of the investors at play. Large banks that provide tax equity do so on the basis of it being a low-risk method for reducing their tax liability. Before providing tax equity, financial institutions traditionally require very high certainty that the project would qualify and generally will not invest in absence of that high certainty that an unwelcome notification from the IRS changes the project economics after the project has been deployed. In order to manage this risk, tax equity providers invest in large wind and solar projects with known specifications and technology, and with largely repeatable unit economics. While this works very well for incentivizing large-scale deployment of solar and wind projects, it does not contribute to the development of new technologies or the construction of novel solutions for energy generation and storage.

The passage of the IRA has opened the door for ITC and PTC programs to be used to enable the commercial deployment of novel technologies. In order to do so, however, the relatively higher risk must be addressed. The transferability component of the IRA has partially contributed to solving that problem, as an outside entity could purchase the credits from the developer without the tax partner

[107] St. John, 2022.

[108] Cooper & Hugenberger, 2022.

[109] DSIRE, 2022.

taking on the risk of directly investing in the project. However, there is some level of risk associated with relying on tax credits from projects that have some chance of not completing or underproducing.

2.4.1: Potential Roles for Corporates in Tax Equity

Corporate partners could get involved in two main ways:

1. ***Direct purchasing of tax credits.***

In this structure, a corporate partner could work with developers to purchase tax credits directly.

This allows the corporation to enable renewable deployment while simultaneously reducing its tax liability. This could be paired with purchasing RECs from the project for additional impact and benefit for the company.

In order to maximize impact, the corporate entity could focus on projects which would otherwise struggle to gain tax equity partners. This would include novel technologies, standalone storage, and other projects that are economically and environmentally valuable but potentially more uncertain than traditional commercial renewable deployments.

2. ***Marketplace Development***

For this solution, a company – particularly one with deep software development capabilities – could develop a marketplace for the sale of these credits in order to improve the ease with which these transactions can occur, thereby lowering barriers to renewable funding and therefore deployment. This structure would benefit from the corporate partner seeding capital by offering to purchase a large quantity through the marketplace, encouraging participation from developers and therefore attracting more companies looking to offset their tax liabilities.

By lowering these barriers across the board, the marketplace would enable developers to gain access to capital even if their technology is more novel and higher risk than the normal solar and wind projects that gain access to tax equity partners.

2.4.2: Potential Benefits to Corporate Purchasers

The tax equity structure presents a strong opportunity for impact while taking on less risk than directly investing in projects, as well as fewer losses than absorbing green premiums or issuing grants. A corporate purchaser would be able to enable technology development, commercial deployment, and emissions reductions through a system that would lower their tax burden. Furthermore, producing and managing a marketplace that enables renewable deployment has the potential to improve public perception as an added benefit.

2.4.3: Outstanding Questions and Considerations

It is important to consider that these are complicated legal structures, and credits can only be transferred once and so should be treated as a single sale, rather than an open marketplace for buying and selling. There is a great deal unknown about how the transferability will pan out in practice, with legal structures still forming around these systems. The legal and regulatory complications may cause corporates to be hesitant to enter the space and do pose a significant amount of risk for anyone looking to enter the space. A standard legal agreement for the sale or transfer of tax credits would significantly reduce this barrier and lower risk and uncertainty.

2.5: Sponsor Equity

Sponsor equity is a crucial component of project finance, particularly for renewable energy projects. Unlike corporate equity, which corresponds to investment in a corporate entity, sponsor equity represents the capital contribution *to a project*, possibly as a special purpose vehicle, made by the sponsors of a project, which are typically the companies or individuals that are taking on the primary responsibility for developing and implementing the project. Outside investors can take a role in providing sponsor equity, providing capital and adopting risk in exchange for a share of profits generated by the project.

In the case of renewable energy projects, sponsor equity is used to fund the initial stages of development and construction. This capital is critical for getting the project off the ground, as it is typically the first source of funding that is secured. The sponsor equity is also used to support the project during its operational phase, which can include funding ongoing expenses, such as operating costs and debt service payments, as well as providing additional capital for expansion or other growth opportunities.

One of the key benefits of sponsor equity in renewable energy projects is that it can help to de-risk the capital stack.[110] Renewable energy projects often have a higher degree of uncertainty and risk than traditional energy projects, due to a variety of factors such as the variability of renewable energy sources, the need for new technologies, and the potential for changes in government policies.[111] By providing a significant amount of sponsor equity, the sponsors can help to mitigate some of these risks and make the project more attractive to other investors. After sponsor equity is secured, other elements of the financing for the project then fall into place, including debt of various kinds.

A related role of sponsor equity in renewable energy projects is to provide a cushion against potential losses. If the project experiences financial difficulties or unexpected challenges, the sponsor equity can be used to absorb some of the losses and provide a buffer for the project's creditors and other stakeholders. This can help to protect the project from financial distress and allow it to continue operating and providing clean, renewable energy.

Similar to tax equity discussed above, sponsor equity has a risk problem when applied to novel technologies. Investors take on project risk with their capital, and as a result want to minimize that risk wherever possible. One of the primary ways by which they commonly do so is through a PPA. A PPA ensures that there is a contracted counterparty committed to buying the power generated by the plant once it is operational. This lowers the risk that the plant will be unable to sell its power at an economically viable price following its completion.[112]

An alternative to the PPA would be for generators to sell their electricity on the open market, often referred to as the merchant market. In a merchant market, power plants and other electricity generators sell their electricity directly to wholesale buyers, such as retail electricity providers, large

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[110] Feldman Equities, n.d.

[111] Byun & Kneip, 2022.

[112] Shea & Abbott, 2021.

industrial customers, or power exchange markets. In some cases, these wholesale buyers then resell the electricity to end users, such as households and businesses, while in the case of industrial customers, these entities would be the end users.

Merchant energy markets differ from regulated utility markets in that the prices of electricity are determined by supply and demand rather than by a regulatory body. This means that the price of electricity can fluctuate based on a variety of factors, including the availability of fuel, the weather, and the time of day, which in turn exposes the generator to price risk, but also to potential upside if electricity prices are higher than expected.

Securing a PPA for novel renewable technologies can be a challenging process, as these technologies are often untested and may not have a track record of performance. In addition, the terms of PPAs are typically long-term, so potential off-takers may be concerned about the potential risks associated with investing in untested technologies. Solar PV and wind are seen as low-risk technologies, but more novel solutions that are being developed such as geothermal have higher completion and operational risks.[113] Without a PPA, it becomes difficult to secure sponsor equity and therefore all other types of financing. When they are able to do so, the cost of capital can be much higher than for comparable projects.

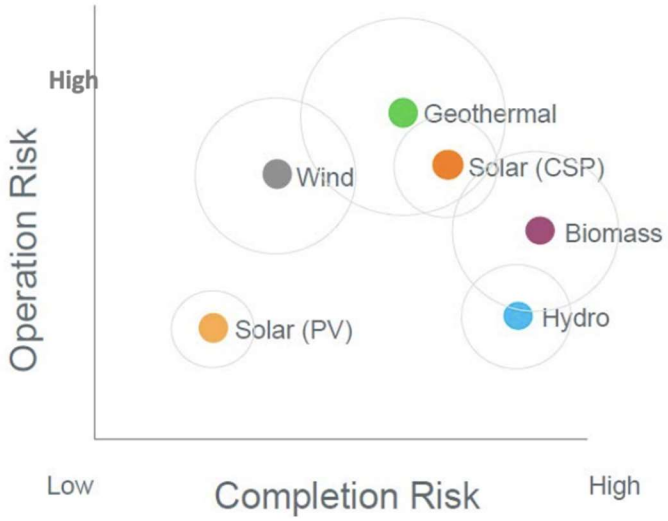

Figure 7: Financial Risk by Technology

Credit: *Feldman, Bolinger, & Schwabe, 2020.*

This creates a gap in the market. Renewable energy projects that are unable to secure a PPA can still be economically viable on the merchant market, but due to financing difficulties may still be unable to break ground. A corporate entity could fill a pressing need as well as take advantage of a potential financial opportunity by providing sponsor equity to these projects. The risk is higher than investment in a solar PV farm but will help enable novel generation technologies to scale and potentially contribute to the first commercial scale deployment of its type.

[113] Feldman et al., 2020.

2.5.1: Potential Roles for Corporates in Sponsor Equity

A private company can provide sponsor equity to a renewable energy project in several ways, both directly and through enabling other investors. Potential structure include:

1. Direct Investment

One option is for the company to invest its own capital in the project. This can be a good option for companies that have a strong financial position and are looking for opportunities to invest in renewable energy. In this role, they can directly identify and provide capital for the most promising technologies, catalyzing the rest of the capital stack and contributing to the deployment of net zero energy generators.

2. Coalition Forming

Another option is for the company to raise capital from outside investors, such as venture capital firms or private equity firms, and use that capital to provide sponsor equity for the renewable energy project. This can be a good option for companies that do not have the financial resources to invest in the project themselves but are able to attract outside investment. The corporate partner could add a significant amount of value by establishing a coalition that could provide due diligence for the novel technology and therefore contribute to de-risking the project for the other investors.

3. Fund Creation

A third option is for the company to form a partnership with other investors, such as other private companies, government agencies, or development banks, and use the combined capital to provide sponsor equity for the renewable energy project. This can be a good option for companies that want to share the risk and potential rewards of the project with other stakeholders. Given the scale of capital needed, creating a fund that would invest sponsor equity into a wide range of different projects would help lower transaction costs across the board and maximize impact.

2.5.2: Potential Benefits to Corporate Partner

A corporate partner would be able to utilize sponsor equity to enable commercial-scale development in a novel technology and could enable others to do the same. In doing so, a company with a large energy demand could use these relationships to generate net-zero energy for their own facilities, thereby contributing to any net-zero goals they had set themselves. Setting up a tax equity, PPA, or REC relationship with the developer could be possible additions when the relationship as an investor has already been established. Furthermore, being a direct investor in net-zero technologies could result in a strong public perception of their direct contributions to the energy transition.

Depending on the source of funds, the coalition and fund approaches outlined above would also limit exposure of third-party capital providers or consortium members to the risks associated with any single project. The diversification benefits offered by pooling and allocating funds across multiple projects may therefore lower barriers to attracting equity financing necessary to deploy both novel and existing technologies.

2.5.3: Outstanding Questions and Considerations

Investing in renewable or net-zero energy projects falls outside of the range of usual capabilities for many companies, and so would represent a departure from traditional ways of engaging with the renewable energy innovation world. Building up those capabilities or hiring firms who are able to do

so would likely be too high for an individual project basis, and so economies of scale quickly set in. Furthermore, these are by definition higher-risk investments and should be treated as such. These projects are designed to ensure maximum impact, rather than generate outsized returns, and so their financial status is likely less attractive. The scope of ideal projects and technologies remains to be determined but targeting first commercial scale projects for promising technologies should narrow the universe of potential projects.

2.6: Other Novel Strategies

Prizes and advanced market commitments are tools that can help spur innovation or encourage investments in capacity, but as the tangible awards are granted after the innovation takes place, they do not necessarily support early-stage R&D funding and breakthrough laboratory or test-bed discoveries.[114] While prizes and advanced market commitments will outline success criteria and establish goals for participants, innovators will often rely on private sector funding or support from a public entity such as DOE while they iterate and develop their solutions. Public funding is more common than private support in the early stages of technological innovation because of the public sector's ability to overcome tough market barriers and internalize externalities that often accompany innovation.[115] The lack of private investment in R&D stages is typically due to the problem of free-riders or spillover benefits that are generated prior to the deployment stage.[116]

There are several strategies, however, to de-risk the private sector's involvement in early R&D support, and private involvement will go a long way given the significance of R&D support to accelerate and continue encouraging innovation.

2.6.1: The Importance of R&D

Early R&D funding is key to a technology's long-term success and ability to bridge the common "valleys of death" that typically appear between the research and proof of concept phases, as well as between the demonstration and adoption phases.[117] Robust early-stage funding results in technologies that have stronger foundations and are thus able to perform better by the time they are scaling up.[118] Adequate funding and support can help propel novel concepts through or over the valleys of death and therefore accelerate their path to market.[119] Typically, corporates have incentivized deployment of novel technologies, but in order to more rapidly innovate and continue to develop new solutions to accelerate decarbonization, they need to incentivize innovation.

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[114] Kalil, 2006.

[115] National Academies of Sciences, Engineering, Medicine, 2016.

[116] Ibid.

[117] Ibid.

[118] Rissman & Marcacci, 2019.

[119] Ibid.

2.6.2: Potential Role for Corporates

As mentioned above, corporations can accelerate the critical R&D stages of novel technologies while mitigating potential risk associated with their involvement through a variety of novel strategies. The strategies explored below are some of the many possible routes that corporations can take to help accelerate innovation and support robust R&D support. Other novel approaches may include support for forums or the development of clusters connecting researchers and entrepreneurs or experts from different fields to enable the exchange of knowledge (learning by interaction) or building information, modeling, or visualization tools to help accelerate the tempo of innovation.

1. Create a Testbed

A crucial step for technologies to move from technology development to demonstration is to prototype their technology or test their idea. Overcoming this hurdle is often resource and time consuming, and many ideas will fail at this stage if the innovators do not have access to adequate facilities.[120]

Testbeds are facilities where entrepreneurs and innovators can test their ideas, and while they sometimes exist independent of the government, these facilities most commonly exist at National Laboratories around the U.S.

One example of an existing testbed in the state of California is CalTestBed, a voucher program that helps clean energy entrepreneurs gain access to critical testing facilities. It is run by New Energy Nexus and funded by the California Energy Commission's Electric Program Investment Charge.[121] CalTestBed provides $8.8 million in testing vouchers to 60 clean energy innovators with a TRL between 5–7 to use at one of 30 eligible testing facilities throughout California.[122] The program has formed partnerships state-wide and is able to utilize California's extensive network of public and private research institutions and labs to place innovators in the environments that they need to succeed. Since this crucial testing step can be a barrier for most entrepreneurs as mentioned above, the CalTestBed program directs some of its outreach efforts towards underrepresented communities to source a diverse network for the cohort. Ultimately the program provides access not just to testing facilities, but to an extensive network that includes California communities, venture capital firms, incubators, and corporates, which can lead to additional funding opportunities and potential partnerships.

A private entity might find this strategy useful if it has a network of testing facilities or if it has the resources that certain research fields might need to test their product or technology. If a corporation specializes in virtual reality or other related human and technology interactions, they might encourage innovators in that specific field to use their testing facilities in exchange for equity. Alternatively, the partnership between the private entity and the entrepreneur could lead to a pilot opportunity or contingent purchase order.

2. Create an Accelerator Program

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[120] CalTestBed, 2020.

[121] Ibid.

[122] Ibid.

Start-up accelerator programs support growth-driven companies through financing, education, and mentorship opportunities. Focused on early-stage startups, accelerators offer an immersive program that enables accelerated learning-by-doing and concentrated activity.[123] Many scholars have researched the effectiveness of startup accelerator programs and found that when graduates of accelerator programs are compared to a similar set of companies who have not participated in an accelerator program, they are more likely to reach milestones faster and receive funding sooner.[124]

One of the first startup accelerators to form in 2005 was Y-Combinator, and it has since evolved to be one of the nation's premier accelerators.[125] Their model invests $500,000 in every company selected and is made on 2 separate SAFEs. The first $125,000 is invested in a post-money SAFE in return for 7% of the company. The second $375,000 is invested on an uncapped SAFE with a Most Favored Nation (MFN) provision.[126] The MFN provision takes on the terms of the lowest cap SAFE (or other most favorable terms) issued between the beginning of the cohort and the company's next equity round. Both investments happen at the same time, and the company is expected to negotiate with investors later to repay the initial investments.[127]

The Y Combinator program has produced exceptional results with alumni companies including Airbnb, Stripe, Instacart, and Doordash, among many others; however, its model is one of many potential solutions. A corporate might find it valuable to create an accelerator program if they have certain internal problem statements that they are trying to address. The corporate could source startups specializing in solutions to their problems, and the culmination of the program could result in the corporate acquiring the solution in a pilot program or contingent purchase order.

3. Create a Joint Development Agreement

Joint Development Agreements, or JDAs, are partnerships between two entities that have complementary skills, resources, or knowledge bases whose collaboration is intended to produce innovation that is greater than the sum of its parts. When partnerships are created, innovation is accelerated, more doors may be opened, and more resources explored.

An example of a successful JDA is between Sto Corporation and Liatris Inc. As discussed in ADL's paper on Prizes and Purchase Orders, Sto is a large corporation in the building materials world that was looking to tap into growth markets in the next generation of building materials.[128] Sto launched a challenge on ADL's ProblemSpace platform in four challenge areas including one area focusing on fire-resistant materials. Liatris Inc, a company specializing in the mass production of high-performance insulation that is easy-to-install, environmentally friendly, non-flammable, and non-toxic, was selected

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[123] Hathaway, 2016.

[124] Hallen et al., 2017.

[125] Hathaway, 2016.

[126] YCombinator, 2022.

[127] Ibid.

[128] ProblemSpace, 2022.

as a winner of the fire-resistant materials category, and ultimately formed a JDA with Sto.[129] Liatris brought technical expertise and R&D capabilities, while Sto brought industry knowledge and the ability to manufacture at scale.

JDAs generally lead to successful results because the pooling of knowledge almost always results in increased innovation. JDAs could also be paired with any of the aforementioned strategies as well as a result of prizes or contests.

4. Offer Low-Cost Loans

Low-cost loans could be another method to accelerate the pace of innovation, as funding is often the biggest obstacle for entrepreneurs. Targeting TRL levels 8-9, this strategy would operate similarly to the DOE's Loan Program Office's (LPO) model but with the ability to support capital amounts less than $100 million, which is generally the minimum loan size considered by LPO.[130] A smaller amount of capital that could be offered through a corporate loan program would function as catalytic capital for novel technologies struggling to secure low-cost senior debt necessary to deploy the first 2-3 projects of a particular technology or application.

2.6.3: Potential Benefits to Corporate Partners

There are clearly many low-risk strategies available for private entities to step in and help support early-stage R&D all while collecting benefits for themselves and for those benefiting from the innovation. While public sector actors, such as national labs and DOE, will remain critical, corporations can also play a valuable role in accelerating innovation and deployment as a complement to existing government programs and the other novel strategies outlined throughout this paper.

2.7: Call to Action

Even corporations with the largest energy budgets have finite dollars to invest while procuring sufficient energy services to deliver core products and services to their end customers. Traditional energy procurement tools such as PPA were exceptionally valuable in increasing deployment over the last 20 years but are limited tools to drive innovation and deployment over the next 20 years.

The tempo of innovation can be accelerated through mechanisms that extend beyond prizes and purchase orders that include advanced market commitments that establish clear performance and cost goals for new technologies while providing market signals for ventures to secure funding. Co-development initiatives, corporate venture capital/accelerators, and test beds can accelerate innovation by bringing the strategic capabilities of the corporate to a new venture. As clean technologies reach TRL 8-9 and look to scale rapidly, the pace of deployment can be accelerated through novel mechanisms such as financial hedges, corporate tax equity, and sponsor equity to make projects more bankable and to lower the cost of capital. If the appropriate mechanism is selected for each technology and each TRL, corporates will be positioned to increase the decarbonization-per-dollar of their energy budgets.

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[129] Ibid.

[130] Richardson, 2020.

The largest corporate energy buyers individually can impact the pace of innovation and the scale of deployment, but that impact could be magnified by aggregating the purchasing power of multiple corporates. Historically, governments have been best positioned to accelerate cost reductions and deployment. An aggregation of corporate buying power may not necessarily have the same scale as government interventions, but if novel strategies are carefully mapped to technology and technology needs, corporates could have a disproportionate impact on decarbonization with their spending on cost and deployment.

GLOSSARY

Term	Definition
CFCs	Chlorofluorocarbons
COTS	Commercial Orbital Transportation Services
DOE	Department of Energy
LPO	Loan Program Office
MFN	Most Favored Nation
NASA	National Aeronautics and Space Administration
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
OTC	Over-the-Counter
PG&E	Pacific Gas & Electric
PPA	Power Purchase Agreement
R&D	Research & Development
REC	Renewable Energy Credit
SAFE	Simple Agreement for Future Equity
SCE	Southern California Edison
SERP	Super-Efficient Refrigerator Program
SPAC	Special Purpose Acquisition Company
TRL	Technology Readiness Level
TSMC	Taiwan Semiconductor
VC	Venture Capital

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