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JUNE 2021

The Valley of Death and the Business of Asset Management

Working Paper

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While Marc Andreessen, well-known Silicon Valley investor and entrepreneur, famously observed that "software is eating the world," combating climate change will require deploying hard assets to replace greenhouse gas producing infrastructure. To cite one example, the UN's Intergovernmental Panel on Climate Change (IPCC) calculated that an annual investment of $2.4 trillion until 2035 will be needed in the energy system alone to limit temperature rise to 1.5 °C. By any measure, we are falling far short of mobilizing this quantum of capital. There are many explanations for this gap: clean energy is still too expensive relative to conventional energy, or put differently, returns are too low for clean energy; a lack of carbon pricing and generous subsidies for fossil fuels distort market flows; clean energy is still seen as risky technology; investors worry about uncertainties of clean energy support policy. To address the financing gap, there have been likewise a range of proposed solutions. Some solutions involve greater government investment through direct funds, blended finance structures, and new financing entities such as green banks. Other solutions have sought to change investor behavior through greater disclosure or through different investment vehicles such as green bonds or through Environment Social and Governance (ESG) funds.

Is the core of the problem a lack of capital or the need for greater innovation? Is innovation needed in finance or in technology? These questions come together in the problem of how to finance the "Valley of Death" in capital-intensive early stage clean technology companies: the period of time needed for a company to go from a pilot plant to achieve sufficient scale and costs in manufacturing to reach commercial viability. While some of the new infrastructure will come from technology that is currently available, to achieve carbon neutrality–if not carbon negative goals–will require deployment of innovative technology at scale. Certainly, some development and deployment of new technology will come from established companies with adequate access to capital. However, the industrial system of innovation has increasingly tended to rely upon the role of the entrepreneurial world of inventors and startups. And history has shown that it has been very difficult for early stage clean energy manufacturers to attract enough capital to achieve commercial viability. They face a classic "chicken and egg" problem. Initial production costs are high because they do not have sufficient scale, but without scale they cannot lower costs. As a result, so-called "Cleantech 1.0" proved to be a disaster for most venture capital firms. An MIT study concluded that US venture firms lost over $10 billion on cleantech investments from 2006-2011, most of which had been made to manufacturers of equipment.[1] Other than the success of Tesla, government efforts to support clean energy manufacturing also came to tears. The US Department of Energy's loans to Solyndra, the bankrupt solar manufacturer,[2] became a debate topic in the 2012 presidential election; a Chinese firm wound up purchasing battery maker A123 that had received US government grants to expand its manufacturing facilities.[3] While there has been some improvement in venture allocation to manufacturers, the Valley of Death problem has remained real. It is not surprising that the proposal for a federal Clean Energy Deployment Agency (CEDA) that would support first commercial manufacturing plants reemerged in the 2020 election.[4] If the private sector isn't able to finance clean tech manufacturing who else will?

This paper argues that the problem of financing clean energy stems from the need to fit into silos built to finance other sectors of the economy. An early stage company that has invented a new solar technology may start with venture capital financing, but then will need different financing for scaling up its manufacturing and still different kinds of financing to deploy solar parks. These financing silos are specialized because of regulation and because

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[1] Venture Capital and Cleantech: The Wrong Model for Clean Energy Innovation, MIT Energy Initiative Working Paper, 2016 (MITEI-WP-2016-06.pdf) (accessed March 12, 2021).
[2] Key Facts: Solyndra Solar, Department of Energy (accessed March 14, 2021).
[3] New York Times, Wanxiang Group Buys American Battery Maker (nytimes.com) (accessed March 12, 2021).
[4] Bipartisan Policy Center , Establish a Clean Energy Deployment Administration (accessed March 14, 2021).

of the perception that specialization will achieve greater returns from dedicated expertise. To understand these financing silos, one needs to understand that financing and investing are two sides of the same coin. Therefore, one needs to understand the motivations and structures—and the business—of investing. As currently configured, the investment "architecture" is poorly aligned with financing a low carbon world. There is nothing inherent in, or unique to, the risks in financing capital intensive climate change solutions other than the vestiges of these investing silos.[5]

The first section of this paper provides a summary of the general structure of the investment world, including the difference between asset owners and asset managers; asset management as a business, including compensation structure; the role of consultants; the responsibility and typical behavior of fiduciaries; and the implications of foundation, pension fund and endowment behavior on the investment world.

Using this framework, the second section of the paper explains why the venture capital business model is inconsistent with the needs of financing capital intensive clean technology startups and why there are relatively few clean tech companies funded in limited geographies in spite of a wealth of research institutions across the country.

The paper will then review the issues of project financing, a technique designed for larger scale projects with proven technology and therefore inconsistent with financing innovative technology. It will cover the stages of development of a project and the return requirements of different financing silos (development equity, project equity and project debt) both before and after construction. Projects are often sold several times to entities with ever lower costs of capital because of the structure of investing silos, even though this creates inefficiencies (higher costs) for clean energy customers.

Next, the paper highlights the relative lack of growth equity–the funding needed as a bridge between venture capital and project finance–used to finance scale in operations and manufacturing. The paper contrasts the limited amount of capital from growth investors in clean energy with biotechnology. The biotech sector has few difficulties in capital formation even though taking a drug from molecule to manufacturing requires a similar amount of time and money as a new solar or storage idea. There has been a recent flood of money from "blank check" SPACs (Special Purpose Acquisition Companies) into clean tech growth companies. In a later section, the paper discusses whether SPACs represent a sea change in growth capital to the sector.

The paper reviews two recent innovations in the clean energy finance–Green Bonds and YieldCos–argues that neither innovation has done much to address fundamental problems in financing clean energy.

The paper concludes with some thoughts on i) the costs–and benefits–of fitting clean energy into traditional investment silos; ii) some policy implications for government officials, including how market development policies may shorten the valley of death and improve capital formation; iii) how traditional investment silos are changing in light of low expected returns and how some investors see opportunity that arises from operating at the edges of silos; and iv) how perceived risk of climate change may burst the "climate bubble" in capital markets which will lead to revaluation of companies and redirection of capital flows.

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[5] Please see research by Soh Young In, "Financial Innovation for Energy Innovation", http://bjwa.brown.edu/26-2/financial-innovation-for-energy-innovation/ and "Financing Energy Innovation: The Need for New Intermediaries in Clean Energy", https://www.mdpi.com/2071-1050/12/24/10440 (both accessed March 29, 2021).

The paper's main point is that, as a business, the asset management world has acted rationally to create investment products where there are investable opportunities. Investing and financing derive from demands in the real economy; they do not create it. While there are indeed inefficiencies and obstacles exist in financing clean energy that stem from the extant investing architecture, without a change in the political economy, we can expect only marginal changes in investing flows and in the investing architecture. These initiatives may be good for asset managers but will do little to mobilize sufficient capital for energy transition nor change behavior of mainstream investors. To be clear, marginal changes are better than none; by reducing the friction costs associated with the current architecture, they will increase the flow of funds into clean energy. However, only strong market signals from the real side of the economy offer the promise of a fundamental change in investment flows, and with it, changes in the investing and financing architecture.

A Short Summary of the Investment World

The purpose of investing is to generate returns to satisfy future liabilities. An individual may be worried about paying for a child's college tuition, a home mortgage, or for retirement. A corporate pension fund needs to generate returns to satisfy future retiree obligations or an insurance company needs to have sufficient assets to meet future claims. In theory, this investment pool should find its way into real projects that generate returns in excess of their cost of capital. In so doing, the stock of capital will increase, creating more societal wealth. The more capital available to invest, the cheaper the cost of capital for financing.

While stock and bond markets have been functioning for centuries, the last forty years have seen dramatic changes in the structure of the investment world. Where individuals could once look to companies to provide a fixed pension or to banks for their savings accounts, where large companies would look to banks for the bulk of their debt requirements, there has been a steady trend towards disintermediation of traditional institutions where individuals and companies are exposed directly to markets. Most companies now offer defined contribution plans–where the company commits to providing a yearly amount of money while an employee is working–rather than providing a defined benefit; the employee, not the company, now bears the risks as to how to invest the money in markets to ensure a comfortable retirement. Likewise, more than 80% of corporate debt now comes from bond markets rather than from banks.[6]

Multiple forces drove disintermediation. As in the pension example, some disintermediation stemmed from a desire to shift risk from institutions to individuals; banks sought to transfer risk from their own balance sheets to bond investors; governments deregulated financial markets to lower costs of capital; investment banks saw opportunities for earning fees from increased trading flows. Disintermediation continues today as FinTech companies seek to pick off highly profitable business segments from traditional financial institutions.

Disintermediation has propelled the growth of institutional investors in the market as large investors got even larger, as more and more assets transferred to markets from traditional intermediaries. While there are discount brokers and endless cable shows on personal finance, the percentage of assets owned by institutions instead of

[6] Federal Reserve, Financial Stability Report, November 2019, p. 19, accessible on https://www.federalreserve.gov/publications/files/financial-stability-report-20191115.pdf (accessed March 18, 2021).

individuals has continued to increase. More than 80% of US stocks are owned by institutional investors.[7] Most individuals who own stocks own them through mutual funds, often through their 401k accounts. The growth of institutional investors created an asset management industry, the business of money management. Asset managers are typically not asset owners. Asset managers invest the money of asset owners. Just in the same way that individuals invest through mutual funds, large asset owners, such as endowments, pensions funds and insurance companies often do not invest themselves; they pick asset managers that do the investing on their behalf. Asset owners pay asset managers to manage their money.

Another major change in investing has been a proliferation of asset classes and investment styles. 40 years ago, a pension fund or endowment would typically allocate 60% of its portfolio to US stocks with the remainder in bonds.[8] Today, there are dozens of separate asset categories, including large and small US stocks; developed and emerging markets debt and equity; high yield debt, real assets, including real estate, timber and oil and gas; infrastructure; mortgage securities; specialized industry funds, including biotech; geographical funds, including China; and many types of private equity, including different stages of venture capital and large buy-out funds. The argument for different asset categories is that increased diversification with non-correlated returns will help portfolio performance. The other argument spurring greater specialization is the same as in medicine: the greater the specialization, the more skilled the practitioner, and thus, better performance. More recently, in the wake of concerns about equity and the environment, some asset owners have allocated assets to dedicated ESG funds, although there is debate among asset owners and asset managers as to whether ESG represents a distinct asset class or a discipline that should be used in evaluating all assets. While it is the most sophisticated and largest asset owners that initially adopt new asset classes and investment styles, the asset management industry often will bring the products to more and more investors, including retail investors, in an effort to collect more assets. In general, the greater the amount of assets under management, the greater the profit to the manager.

These different asset classes emerged *in response* to–and subsequently *enabled*–changes in the real side of the economy. A combination of factors came together in the 1970s that posed considerable challenges to the U.S. economy. Arab oil producers imposed an oil embargo in 1973[9]; another shock to oil prices occurred after the Iranian Revolution.[10] Japan posed a major competitive challenge in many manufacturing sectors. These factors, in turn, created another challenge: stagflation, the odd combination of wage and price inflation with low economic growth.[11] These forces encouraged companies to rethink their corporate strategies. In one prominent example, the Boston Consulting Group developed one of the most popular approaches that segmented business units based upon growth and cash flow:

> The 1970s were years characterized by a strong turbulence. The crisis of the 1973-1975, triggered by a strong increase in oil prices…put into question the very principle of strategic planning. Under these conditions, the B.C.G matrix came, at the right moment, to help a confused management. The indications of the matrix gave to the presidents…of major companies a tool to strategic control planning and capital budgeting. They were able to allocate resources having a clear image of the strategies: support "cash cows," investing [in] "stars" and…abandoning "dogs."[12]

[7] Tax Policy Center, Who Owns US Stock? Foreigners and Rich Americans; Pensions & Investments Online, 80% of equity market cap held by institutions (pionline.com) (both accessed March 12, 2021).
[8] PEW Trusts, State Public Pension Investments Shift Over Past 30 Years (pewtrusts.org) (accessed March 18, 2021).
[9] Department of State, Office of the Historian, Milestones: 1969–1976 (state.gov) (accessed March 29, 2021).
[10] Federal Reserve History, Oil Shock of 1978–79 (accessed March 29, 2021).
[11] Economy Watch, Stagflation In 1970s (accessed March 29, 2021).
[12] "The Rise and Fall of the B.C.G. Model" http://conferinta.management.ase.ro/archives/2014/pdf/13.pdf (accessed March 29, 2021).

While oil prices eased in the 1980s,[13] other challenges arose. Increasing trade and market liberalization policies ranging from China and Korea to Argentina to a wave of privatizations of state owned enterprises only further increased global competition. Corporate executives such as "Neutron Jack" Welch at G.E. and "Chainsaw Al" Dunlop sold off "non-core" assets and slashed employee headcounts to reduce costs and improve profitability to improve shareholder value, while outside corporate raiders threatened to take over companies if they did not likewise take scalpels to their businesses. Carl Icahn took over TWA in 1985 and sold off assets. T. Boone Pickens attempted a takeover of Gulf Oil in 1984; in response, the company sold itself to Chevron. These trends have accelerated as China has become the world's workshop and technology has allowed for creation of virtual companies. The increased focus on shareholder value has led to sale of non-core operations, outsourcing, and a greater emphasis on capital efficiency. Indeed, many hedge funds use ROIC (return on invested capital) to determine which companies should be owned long or sold short. "Capital light" companies are generally far more highly valued than those that manufacture things.[14]

The sale of non-core businesses and threat of corporate raiders fostered the growth of the below-investment grade, high-yield (or junk) bond market, developed by Michael Milken, and the explosive growth of the leveraged buy-out private equity market. High-yield bonds as an asset category and private equity as an asset category only came about *because of* developments in the real side of the economy that created enough investable opportunities. Likewise, emerging market debt and equity as asset categories–as well as the broader field of international investing, including private equity and venture capital in addition to stock and bonds–emerged in response to global liberalization policies. These new asset categories brought a rich set of fees for the asset management industry.

Understandably, the proliferation of asset class opportunities has, in turn, created an infrastructure for selecting different asset categories. Since many asset owners are fiduciaries, it is not surprising that they hire third party consultants who advise them on asset allocation; nor is it not surprising that the asset allocation of many asset owners doesn't stray very far from "benchmarks" proposed by consultants. Consultants have also devised tools for asset owners to evaluate the performance of asset managers. Hence, as an example, US stock managers are ranked against the performance of other US stock managers relative to the S&P 500; bond managers against the Bloomberg Barclays Aggregate Bond Index; or international equity managers relative to MSCI EAFE. In private markets, such as in private equity, managers are ranked against each other, on a percentile basis.

It is easy to understand the challenge faced by asset owners. As fiduciaries, they are at risk if they vary too much from the asset allocations of their peers, including expanding the number of asset categories in which they invest. Moreover, they are all seeking to invest in the best performing asset managers based upon historic performance data. The consequence of so much diversification and mirroring of behavior is often mediocre performance. Further, it is often the case that an asset manager that has superior investment performance over one period will underperform in the next. But searching for enhanced performance is a beast that can never be slayed. It can lead to asset owners considering new asset categories from asset managers, to finding new managers, to deciding to reduce costs by investing in index funds. Passive investors (low cost index funds and ETFs) now own nearly half of

[13] MacroTrends, Crude Oil Prices - 70 Year Historical Chart (accessed March 29, 2021).

[14] In the U.S., economic value-added has largely moved from manufacturing to innovation, brands, distribution and services, abetted by investors that are able to assess the relative global capital efficiency of different companies. Apple does not manufacture its computers or phones. Manufacturers of jet engines look to service revenues for the bulk of their profits rather than to manufacturing. It is hard to assess the challenges of financing clean technology manufacturing companies against this backdrop of declining manufacturing overall, although this question is beyond the scope of this paper.

US stocks.[15] The search for performance has led to an increasing number of "quant" oriented trading funds who use models to trade based upon historical relationships between individual stocks or macroeconomic factors. Together, passive and quantitative investors account for the majority of trading on the New York Stock exchange.[16]

One of the ironies facing asset owners is that in spite of the enormous effort that they go to in identifying asset categories, selecting asset managers and then in evaluating asset manager performance, the biggest driver of portfolio returns is asset allocation (i.e., how much of the portfolio is in, say, stocks versus bonds) rather than in security selection (which stock or bonds are selected by the asset manager). And because most CIOs of large asset owners are likewise evaluated on the basis of performance relative to other assets owners, asset allocations don't usually vary much between large asset owners: it is safer to stay with the crowd. Nonetheless, change can occur. Perhaps the biggest change in the search for performance in the last few decades has been the "endowment" model, adopted by David Swenson at Yale, and now copied by many other endowments, which has emphasized "alternative investments"–hedge funds and private equity–and significantly reduced allocation to traditional bonds and stock managers. For much of their history, hedge funds and private equity offered superior returns for similar reasons. Hedge funds didn't offer performance *relative* to the S&P 500; they offered *absolute* returns, marked every month. Where a typical equity manager needed to hold a portfolio similar to the S&P 500 but would look for outperformance by under or overweighting certain stocks, a hedge fund could concentrate positions or avoid entire sectors. Other hedge funds recognized that with increasing concentration of investment focus, there was less inefficiency *within* each asset category but much less *between* categories. Likewise, private equity managers could invest in companies that they liked and through control positions could wring out inefficiencies in businesses that they owned.

It is important to understand that the asset management business is exactly that: a business. Regulated public stock and bond managers are largely paid based upon the amount of assets that they manage, not directly on the basis of their underlying investment performance; only if an asset owner is unhappy and takes assets away from the manager does compensation materially suffer. Since in mature, liquid markets it is difficult to get outperformance relative to the market, there is always the threat of the asset manager deciding to use an index fund where fees are very low (asset management fees for public stock and bond managers are low). The average mutual fund fee for an active stock manager is 1.2%[17], whereas the average fee for index funds is 0.14%[18]. As a consequence, scale matters. The vast majority of funds that invest in large capitalization stocks and bond funds are very large so as to afford their investing infrastructure. In another irony, however, the larger the fund, the more difficult it is for the fund to outperform the market—it becomes so large that it must buy big enough positions in big enough stocks that it begins to mirror the market. The bigger business opportunity for asset managers has been in unregulated, alternative asset categories where the compensation arrangements are based upon performance. A typical private equity fund charges a management fee of 2% of assets under management and a "carried interest" (carry) of 20% of profits above a benchmark (around 7%).[19] In contrast to a public bond or stock fund that would require many billions of assets under management to represent an attractive business, a new private equity fund requires much

[15] CNBC, Passive investing now controls nearly half the US stock market (cnbc.com) (accessed March 18, 2021).
[16] The Economist, Briefing, March of the machines - The stock market is now run by computers, algorithms and passive managers (accessed March 18, 2021).
[17] The average expense ratio paid by mutual fund investors today is half of what it was two decades ago. Between 1999 and 2019, the asset-weighted average fee for mutual funds overall fell from 0.87% to 0.45% (whereas the asset-weighted average expense ratio for active funds was 0.66% in 2019, a decline of 3% from 2018). Key driver for the trend of falling fund fees has been a shift by investors to lower-cost funds, including index funds and ETFs; see Morningstar, 2019 U.S. Fund Fee Study.
[18] ICI Research Perspective, Vol. 26 No. 1, Trends in the Expenses and Fees of Funds, 2019 (ici.org), March 2020, (accessed February 15, 2021).
[19] Financial Times (ft.com), Private equity clings to '2 and 20' fee model, August 11, 2016, accessed February 16, 2021.

less scale, although in the past couple of decades, private equity firms have raised “mega” funds[20] of $8-10 billion in their core buyout areas. Moreover, large private equity firms have diversified, not only by adding new sector funds–in one example, KKR has added “TMT” (Technology, Media, Telecom), health care, energy, infrastructure–but also into new businesses, including hedge funds and debt.[21] Each of these verticals have themselves raised funds of several billion dollars. Not surprisingly, several large private equity firms have gone public where investors value their stocks based upon the ability of the firm to keep growing assets under management–where there are stable management fees–and predictable realization events as portfolio companies are sold. The bigger and more diversified the private equity firm is, the greater the potential value of its stock.

For the asset owner, the growth of these giant private equity firms poses a conundrum. On the one hand, the private equity firms argue that by virtue of their size and brand, they can hire the best people and have superior access to deals. Moreover, there is institutional stability–the firms are much less reliant upon a brilliant investor. An asset owner may have the confidence that an established firm will stand behind a new fund or asset class. For a fiduciary, there is safety in numbers; no one can criticize an asset owner for being an LP in a fund being managed by a name brand private equity firm. On the other, however, large funds, to put large amounts of money to work, need to invest in larger deals. As a result, their returns may resemble overall returns in the stock market. And while a large firm is less reliant upon a star performer, an asset owner may see the benefit of investing with one. In practice, an asset owner has constrained choices when it comes to private equity: pick a fund from a major private equity complex; compete to get into a top performing fund that is smaller in size; or participate in a first-time fund started by a new investing group. For many asset owners, however, investing in first time funds is too risky. They are concerned about unproven team dynamics and lack of an investment track record. The easiest decision is to decline participation in the first fund and hope to participate in the second fund once success in the first has been proven.

A cynic would say that the asset management industry has done well for itself as a business, but much less well for asset owners. The vast majority of active stock managers underperform the market. Only 29% of managers outperformed the market in 2019, down from 37% in 2018 which was the average underperformance for the prior 15 years.[22] While as an asset class, private equity may have outperformed the market, the structure of most private equity funds isn’t aligned with the interests of asset owners. Consider a large buy-out equity fund that typically invests in sizeable, relatively mature and stable businesses; such businesses can support meaningful debt. The businesses typically have established niches in markets and in scale. In short, they are good businesses whose performance can often be enhanced, at least initially, by operating improvements brought on by the private equity firm and through changes in executive compensation. However, under the structure of most funds, the private equity firm will not earn its carry until the asset is sold. In considering when to sell an asset, private equity managers need to balance rates of returns (the higher the returns, the better the relative performance and therefore the ability to attract more assets in subsequent funds) with the aggregate amount of carry dollars to be paid to themselves. Given that improvements in the business above its organic growth are typically temporal, it’s not surprising that the median holding time of assets at private equity firms is 4.9 years.[23] While the asset owner may gain an attractive return on the money invested, the business has now been sold, and cash returned to the limited partner (LP) asset owner who must now find another asset manager who will invest the money. An asset owner might have been very happy to have continued holding an investment in an attractive business even if its returns declined over time.

[20] PitchBook, What are mega funds? (accessed March 21, 2021).
[21] KKR, Private Equity (accessed March 21, 2021).
[22] Morningstar, How’d Active Funds Do in 2019? So-So; Barron’s, More Clients Considering Early Retirement, but Are They Ready? (both accessed March 21, 2021).
[23] Pitchbook 2020 Annual US PE Breakdown, (pitchbook.com); for 2019 see Pitchbook, PE firms aren’t keeping portfolio companies as long as they used to (both accessed March 21, 2021).

Similarly, hedge fund compensation arrangements don't always align with the interests of asset owners. While on the face of it, the hedge fund offers the benefit of absolute returns, provided on a monthly basis, with the carried interest only paid based upon performance, what can happen in practice is that hedge fund managers can get paid substantial payouts during periods of good performance, and then incur no penalty (they don't need to returns fees) in subsequent periods of poor performance. This kind of compensation structure can encourage short term, high-risk trading strategies.

While the asset managers haven't always served the interests of asset owners, asset owners themselves haven't served their own interests either. They have tended to mirror the decisions taken by peers which has led to lemming-like behavior. Asset owners may complain about the fees charged by private equity managers, but very few are prepared to build their own direct investment activities; as Limited Partners (LPs), they can delegate investment decisions to third party managers who are General Partners (GPs) rather than incur the legal (and political risk) of making such decisions themselves. More fundamentally, the biggest failure of asset owners is that they have attenuated the connection between their assets and their liabilities. Asset owners are also liability owners. However, most asset owners–whether they are individuals or institutional pension funds or insurance companies–have presumed that by maximizing the return on their assets, they will satisfy their eventual liabilities. Put simply, asset owners have helped create an *asset management* industry, not an *asset-liability management* industry. This is one of the key reasons why the investing architecture is poorly aligned with the financing of clean energy. Asset managers–even those that invest in private, "illiquid" assets–can trade in and out of assets; they will only consider climate liabilities as they impinge on nearer term financial prospects of the assets that they manage. Liability owners have no such luxury; like the Cat in the Hat, they can't easily shed their problems.

A very long bull market–driven by sustained reduction in interest rates–has covered over the sins of underperformance, high fees and misalignment between asset managers and asset owners. The Wallace Foundation, with an endowment of $1.5 billion,[24] is a typical mid-sized endowment where there is a small in-house team that sets asset allocation and then selects asset managers and evaluates manager performance. It incurs about 2% in fees each year. When market returns are double digit, paying 2% in fees is tolerable. It may be an altogether different story for the asset management business if market returns are lower.

Until the prospect of lower returns changes the structure of the asset management industry, clean energy financing needs to fit into the investing silos that have been created in the last 40 years. Some years ago I met with David Swensen[25]. He wanted to know more about renewable energy. At that time, it was possible to purchase an operating wind or solar park that had a 20 year power purchase agreement with an investment grade counterparty for a 8-9% yield which seemed very high for the low risks of the project. I told him that returns were "bond-like," given that technology was mature, revenues were highly certain and operations and maintenance costs were likewise well-known. "Is it a bond?," he asked. No, I replied. "Then it's equity?," he asked. Yes, I answered. "Is it public equity?," he pressed. No, I replied. "Well," he said, "if it's private equity, 8-9% is too low for our private equity bucket. We are targeting much higher returns." At one level, his answer didn't make any sense to me. Why wouldn't Yale want an 8-9% asset as part of its portfolio? But given the logic of the investment world, it made complete sense.
A wind or solar park didn't fit into the architecture. Renewable energy projects weren't in any asset class.

It also meant that financing costs for the project were higher than they needed to be.

[24] Wallace Foundation, 2019 Audited Financial Statements (wallacefoundation.org) (accessed March 21, 2021).
[25] David Swensen manages Yale's $27 billion endowment, David F. Swensen, B.A., B.S., '80 Ph.D., '14 L.H.D. (accessed March 21, 2021).

Venture Capital: Financing the Beginning

Venture capital investing as a discrete business of investing began slowly after World War II; Fairchild Semiconductor was the first major technology company financed by venture capitalists in 1959.[26] Most VC firms were located in what later became known as Silicon Valley, since they were geographically close to the growth of the semiconductor industry that developed around Stanford University. While through the 1960s and 1970s, the venture capital industry was small in scale, it developed the basic infrastructure that exists today. First was the creation of a number of independent investment firms specializing in venture capital spread along Sand Hill Road. Second was the fund structure in which the investment firms would act as GPs and third party investors would be LPs. The fund compensation structure, made up of a management fee and carried interest (representing 20% of profits), became the standard among the much larger leveraged buy-out fund private equity firms that arose later. Third was fund size. Because of the perception that there were few attractive investment opportunities and high risk of failure, GPs (and their LPs) sought to limit the size of funds and to spread risk by making many investments. Hence, while by 1980 there were 650 venture firms, in 1978–a peak year in fundraising–the industry raised $750 million in new funds.[27] Since then, the industry has seen successes–in the 1980s, Apple, Compaq, Genentech, and LSI; the internet boom of Amazon and Google; and more recently, social networking sites of Facebook and Twitter–as well as busts, including the bursting of the internet bubble in 2001 and the failure of the clean tech 1.0.

Venture capital has grown up. It is an established part of the private equity allocation in a typical endowment portfolio, although its share of the private equity "bucket" is less than 10%.[28] Nonetheless, the early history of the industry–as a business–informs its investing behavior. Venture capital is perceived as a risky business, with only a limited number of investable opportunities. For at least the last two decades, conventional wisdom is that only one out of ten deals will be a "home run" (10X the money invested); the successful deal will offset losses incurred by the others. As a consequence, while there are a few very large venture funds, most are small; the median fund size is $100 million.[29] Given fund compensation structures, the path for wealth creation for partners of venture firms requires receiving carry from multiple funds. The math doesn't work otherwise: a one in ten chance of a successful deal in a small fund where investments are spread among dozens of companies simply won't generate enough profit. While, of course, generating profits from good investments is a sine qua non on the path to partner wealth creation, getting the next fund is also dependent on how the venture firm's returns compare *on a relative basis* to other firms. Asset owners seek to own venture firms ranked in the top quartile of performance. Historical data suggests that investing with venture firms with lower relative performance underperforms the S&P.

All of these elements of the venture capital business–and business practice–have developed over decades: for investing in software, IT, or for a new consumer product. The venture business was not set up for investing in capital intensive clean tech companies. The failure of Cleantech 1.0 stemmed directly from trying to fit clean tech investments into an investing structure designed for something else. While there has been some improvement in the amount of venture financing to clean tech manufacturers, there are fundamental weaknesses in the investing structure that inhibit capital formation.

[26] HBS Working Knowledge, Done Deals: Venture Capitalists Tell Their Story: Featured HBS Arthur Rock (accessed March 21, 2021).
[27] Arun Rao, A History of Silicon Valley, 2013, Chapter 6 (scaruffi.com) (accessed March 21, 2021).
[28] PNC Insights, 2020 State of Endowments: Past, Present & Future; larger endowments managing above $1 billion, such as university endowments, generally have a higher private equity allocation: the Harvard Endowment Fund has a private equity allocation of 23% (Harvard University Financial Report Fiscal Year 2020, p. 9, harvard.edu); Yale's Endowment allocates about 10% in private equity (Yale Investments Office); Stanford's Endowment has a private equity allocation of 30% (Stanford University Investment Report 2020, p. 7, Stanford-University-Investment-Report-2020.pdf) (all accessed March 21, 2021).
[29] Crunchbase News, There Are More VC Funds Than Ever, But Capital Concentrates At The Top, March 7, 2019 (accessed February 17, 2021).

First, a small fund size fundamentally limits the amount of capital available to finance a company through the valley of death. Bringing a new clean tech manufacturing company to commercial scale will cost many hundreds of millions, inconsistent with funds which may only average $10 million per deal.[30] Second, fund structures encourage venture firms to harvest successes: i) since the greatest point of price appreciation potential is during a company's "S" curve where its growth takes off, holding an investment too long is a mistake; ii) profits are only paid to venture firms if a "realization" (i.e., a sale or distribution of stock to LPs after an IPO) event occurs. And showing success helps raise the next fund. It is not surprising, then, that venture firms prefer investments in "capital light" businesses, such as software. Not only do they require less capital, it is easier to know within a few years whether the business will be successful. The journey to commercial success for a clean tech manufacturer may take a decade.

This paper is not the first to argue that the traditional venture capital business model is inconsistent with financing clean tech manufacturing, and thus, inhibits the flow of capital to the sector. Yet, the business model may also explain other observed data in financing. In software and IT, there are a few geographies with existing "ecosystems" of universities and companies. In clean technology, capabilities are dispersed around many parts of the US, across national labs and various universities. In contrast, whatever cleantech investing is taking place is limited to a few geographies. The management fee of 2% is intended to cover the running costs of a venture firm; wouldn't then the economics of a small fund inherently reduce the size of the investment team and the travel budget? If so, wouldn't that explain why most investments are not far from where the team can drive? Moreover, the data indicates a dramatic shift in year to year industry focus of clean energy venture investing–from wind in one year to storage the next, as an example. Might the evaluation criterion of relative performance explain this result? Woe to an investment firm evaluated on a relative basis to stray too far from what other firms are doing. If other firms are investing in storage, one might conclude, I better invest in storage, too.

Taken together, these elements of the venture capital business model may result in an intense focus on a limited number of companies–in geography and in sector. And to ensure the best chance of being able to raise the next fund, a venture firm needs to compete with other firms to get the "best" deal. Deals that are not perceived as "best" may not attract any VC investment interest at all. VC firms may compete on the basis of their brand endorsement or on promises of providing support to management in staffing, in mentorship, and in making corporate introductions. However, a willingness to pay a high valuation for equity is often critical for a VC's success in getting the opportunity to invest in a desired deal. Indeed, it is often the company that establishes a valuation, with VCs facing limited room for negotiation. In practice, VC valuations are counter-intuitive. Given the inherent risks of investing in early stage companies, one might expect that VCs would use conservative forecasts of results and sober estimates of exit prospects for each company in their portfolios. Instead, the typical VC valuation assumes that each company in its portfolio will largely achieve its forecasted goals and exit through an IPO or private sale in a future year at multiples that exist in today's market. This future number is discounted to today at a return that the VC hopes to earn on the investment.

While this approach to valuation helps VCs win desired deals, the question remains as to whether this approach increases the chance for company failure: indeed, is the "one out of ten" article of faith in the industry inherent in investing in early stage companies or is it a self-fulfilling prophecy? The typical VC business model induces a portfolio of many investments at high valuations, managed by a small team paid for by a fund's management fees. Is an unintended consequence of this structure a focus on urgency: an intense focus on which companies appear to be winners, while cutting off time and money to those that are laggards? Once a company loses its venture

30 Statista, VC-backed companies: global deal size by stage 2020 (accessed February 17, 2021).

sponsorship, it is likely going to die. This focus on winnowing winners and losers is ill-suited for capital intensive clean manufacturing companies. Not only does an investment in a software company cost less money, it also takes much less time to see whether the company is gaining commercial traction. In contrast, a clean manufacturing company not only needs backing to fund its technology–and then its manufacturing capability–it may also take considerable time to determine whether the product will achieve commercial success. In an alternate world where there was a different business model–where there was less need to raise the next fund, where funds were not evaluated relative to each other–perhaps there would be more reasonable valuations and more time given to companies that may take longer to succeed. Such a world would be more favorable for clean manufacturing companies.

Project Finance: Financing Deployment

There were a number of reasons for the failure of Cleantech 1.0. Market conditions changed. Solyndra may have had an innovative technology, but costs for conventional solar manufacturing declined faster as Chinese manufacturers scaled up. Similarly, policies changed; where climate change had enjoyed bipartisan support, it increasingly became a partisan issue. Venture firms found that the energy industry was more difficult to disrupt than other sectors; it not only enjoyed more political support, its customers were often cautious. After all, energy is a commodity that, but for externalities, is well-supplied by fossil fuel companies. These factors made the valley of death even longer.

One other reason for the failure of Cleantech 1.0 stemmed from silo investing. Venture investors may have had expertise in early stage company investing, but knew little about how the equipment being produced–new types of solar panels, for example–were going to be financed. Many clean energy projects are funded through a specialized technique called *project finance.* Project financing is distinct from corporate financing. Where corporate financing raises debt and equity from the assets and cash flow of the entire business, project financing relies upon the cash flow of only a single project.[31] In technical terms, most project debt is "non-recourse," meaning that there is no parent to support or guarantee the debt.

Project finance is used for clean energy projects for several reasons. First, many projects are developed by small firms–often just a small group of people–because developing projects is an entrepreneurial activity where spending as little money as possible to develop a successful project can bring substantial profit to a few people. These small development teams do not have sufficient capital to finance a project using their own balance sheet. Project finance allows a team without much money to build a large wind or solar park based upon future cash flows coming from the project. Second, even companies that have meaningful assets and cash flows often aren't willing to use their own balance sheets to finance projects. They don't see themselves as banks, and more importantly, project financing may be cheaper. Raising equity at the project costs less than using their corporate equity. Third, many customers don't want to own (and finance) their own projects. Just in the same way that SolarCity revolutionized the residential solar industry by offering a residential lease, companies likewise often want to procure clean energy "as a service." Since energy is an operating expense, companies are reluctant to use their capital budgets to pay the high upfront costs of clean energy, even though ongoing costs may be lower. Entering into a lease or a contract to purchase clean power enables a company to get the benefits of lower costs immediately, while procuring clean energy as an operating expense.

[31] Project Finance - A Primer on the Project Finance Industry (corporatefinanceinstitute.com) (accessed March 21, 2021).

Project finance would seem an elegant solution for project developers and for customers. However, the technique is ill-suited for innovative technologies. Since the providers of project debt and equity can look only to the cash flows from the project for payment, new technology poses meaningful risks: how long will it take for the project to be built? How much will it cost? Will it perform as predicted? What about ongoing operations and maintenance costs? While an innovative solar panel, for example, might be cheaper than a more conventional panel, at the project level–using thousands of panels–the project itself might not be cost competitive if it can't raise as much cheap debt as its conventional alternative. Banks–mostly from outside the U.S.–are the largest source of project debt.[32] In contrast to other loans which are sold to others outright or can be securitized, project loans often remain on bank balance sheets for many years. Loans which remain on balance sheet require a certain amount of regulatory capital to support them. Given the limited number of project lenders and relative illiquidity of secondary markets, banks approach project lending very conservatively. Banks need to observe new technology for many years before it is deemed "bankable." And unless developers know that a technology is bankable, they will not waste their time developing a project with innovative equipment. The limited number of project lenders also means that banks will allocate capital to larger developers and larger projects since these opportunities are more profitable. Smaller loans require more regulatory capital underlying them and cost as much to execute as bigger loans. Developers also know that without project debt, there will not be project equity available since debt is needed to provide the required leveraged rate of return to project equity investors.

Venture firms were unaware of these obstacles in project financing. The alternatives for an innovative solar manufacturer unable to get project financing were unappealing. If developers were unwilling to use the equipment, then VCs might be asked to fund a company's own development efforts. Further, if banks were unable to provide sufficient debt financing, then VCs might be asked to come up with additional debt and equity financing to fund the construction of the project themselves. Since project returns would be less than typical venture returns–a project producing power under a contract to an offtaker should be less risky than an earlier stage company manufacturing the equipment–this additional financing would reduce returns in a fund. Moreover, there would be no certainty as to when–or the number of projects needed before–a bank would determine that the technology would be bankable. It is not surprising, then, that many companies failed. They couldn't get VCs to come up with this additional funding to get to bankability.

Unfortunately, project finance has several drawbacks beyond bankability that hamper clean energy project deployment. First, project finance, as developed in the mid 20th century, was not invented for clean energy projects. Nor was it invented for companies that had limited balance sheets. It was, in fact, invented for large, well-financed natural resource companies that wanted to build large infrastructure projects (ports, pipelines) but sought to manage risks by creating a separate entity with non-recourse debt to the project sponsors. As a consequence, while the underlying concepts in project finance may be similar, each project tends to be bespoke, requiring extensive legal documentation and structuring. While large, utility-scale wind and solar parks can afford these costs, many distributed energy projects–fuel cell, storage, and some solar installations–are small; structuring costs alone can make the projects uneconomic.

Federal tax credits that support wind and solar projects also complicate project financing. Because so many developers are small businesses, they often don't have enough income to take advantage of the tax credits. However, projects themselves also don't generate enough income because of depreciation and interest expense.

[32] Müllner Jakob, International project finance: review and implications for international finance and international business, Manag Rev Q 67, 97–133 (2017), SpringerLink (accessed March 21, 2021).

Therefore, the only way to capture the value from the tax credit is to find a profitable third party corporation as a tax equity investor. The tax equity investor provides capital–which can represent 30-60% of the total capital "stack" of the project–in exchange for the tax benefits and a fixed rate. While it is called "equity," tax equity is very debt-like; in addition to a fixed rate, payments are made to tax equity investors before going to pay debt obligations. Because a project needs to be in operation for tax benefits to be realized, tax equity investors are as cautious about new technologies as bank lenders. Tax equity, then, is another obstacle to deployment of innovative solutions.

The market for tax equity is limited to a couple dozen banks and large corporations. As a consequence, it is expensive–more expensive than debt. Because of the limited amount of tax equity available, larger developers have an advantage; they can offer more financing business to banks or offer sufficient amounts of projects to offset a large corporation's tax liability. Smaller developers developing smaller projects often can't get tax equity in spite of attractive underlying economics. The projects don't get built.

The costs and availability of tax equity for renewable energy projects stands in stark contrast to the tax equity market for Low Income Housing Tax Credits (LIHTC)[33]. In another example of how renewable energy needs to fit into structures often set up for other purposes, renewable energy credits don't have a critical attribute that LIHTCs possess: banks get credit under the Community Reinvestment Act (CRA) for investments in LIHTCs,[34] but not for renewable energy credits. Since the intent of the CRA is to encourage banks to make loans and investments in disadvantaged communities but in a "safe and sound" manner, LIHTC may be a more attractive way to meet the CRA obligations than extending loans in those communities. Put simply, developers of low income housing find it easier to get tax equity and at much lower costs than developers of renewable energy projects.

Each piece of the capital needed to build a project has challenges. Project debt providers will lend to projects that use proven technology; the tax equity market is limited in size. The last piece–project equity–poses its own set of obstacles to a developer since there are two types of equity needed. The challenges of availability and cost of project equity again stems from the need for renewable developers to fit into extant investing silos. The first amount of equity is needed for the development of the project itself: to fund the costs associated with identifying and securing rights or ownership to a site, performing environmental and engineering studies, seeking local community support and necessary approvals and permits, negotiating terms from equipment and construction providers, and arranging for offtake contracts for power or renewable attributes from government, utility or corporate counterparties. Relative to the capital and construction costs of the project, these development costs are modest, measured in the hundreds of thousands or low millions for a utility scale wind or solar project. The second type of equity is needed once all these preconditions in development are achieved. At that point, the project has a "financial close," and it proceeds into construction. For a utility scale project, the amount of equity needed for this phase is in the tens of millions; for a very large project, even more.

The risks of each phase of the project are different. For the development phase, the risks are binary. The project will be built–and the developer will likely make a profit–or it won't in which case the money spent on developing the project is wasted. While each step along the process of development makes a project more likely to proceed and therefore more valuable, a project can become worthless if a developer never gets a needed approval, finds an endangered species or can't sign a contract for an offtaker at a price that generates enough revenue to cover the project costs. Investing in this early phase of development is akin to venture investing. Since project developers

[33] US Department of Housing and Urban Development, Low-Income Housing Tax Credit (LIHTC) (accessed March 21, 2021).
[34] Federal Reserve Board, Community Reinvestment Act (CRA) (accessed March 21, 2021).

are using proven technology, there is no technology risk, but there is the risk that management isn't able to execute against plans or that the team isn't able to work together effectively. Because of the risks involved, required returns in the development business are high, typically 20-30% per year or more. Although the risks and returns are venture-like, most venture firms don't invest in development companies. Developers don't bring technology, IP, or a new customer offer to the market. Nor are most private equity firms interested in funding early stage development. In contrast to venture firms where limited partners expect "one in ten" results in the portfolio, private equity fund limited partners look to stability of returns across a portfolio. A development business is too risky. Moreover, as private equity funds have gotten ever larger, an investment in development doesn't put enough money to work to make a difference in portfolio returns. To be clear, there are some entities that invest in development activities, including some growth investors, a few private equity firms and corporations that want to outsource their development activities, but they are outliers. Investing in renewable energy development does not easily fit into existing investing silos.

The risks for equity in building the project are far different. By the financial close, a typical renewable energy project has minimal risks. The developer has obtained all approvals and negotiated a fixed price for construction and equipment. The developer has also obtained contracts which cover ongoing revenues and costs, including contracts for power and for operations and maintenance. Hence, at financial close, almost all of the economics of the project are locked in for as long as 20 years. For an equity investor at that point in the project, returns are much more "bond-like" than returns from an investment in a company. Returns will fall in a narrow bound of outcomes. Indeed, once a project is operating, insurance companies, some pension firms, and some infrastructure funds like these long-dated investments. Given much lower risks than a project in development, investors in completed projects accept a much lower rate of return, typically a levered 7-9%. It is nonetheless not always easy for a developer to find project equity at the financial close at terms that reflect these reduced risks. As a matter of investment policy or charter, many insurance companies, pension funds, and infrastructure funds are prohibited from investing in projects that have development or construction risk. These restrictions predate clean energy projects and were supposed to prevent these entities from investing in high risk developments of airports or other large infrastructure projects where development and construction costs are large and unknown. These risks are fundamentally different for renewable energy projects. Even though the development of a wind or solar project is risky, the money at stake is small; once a project is at financial close, construction costs are known, with risks bounded. In steps a private equity firm to provide project equity to build the project and to hold the project during the first year or so of operation. Once the project is thus seasoned, the private equity firm sells the project to a pension fund, insurance company or infrastructure fund that will hold it for the project's remaining life.

Hence, there can be multiple owners of a project during its life, each representing a different investment silo with different return expectations. The early phase of a project might be owned by a growth investor, the construction phases by a private equity firm, and a project in operation phase by an insurance company. Each entity may make money along the way as a project is sold. As an example, in negotiating with a power offtaker, a developer "prices" a project with an expected return of 13% to $100 million in project equity. The developer sells this project to a private equity investor at the financial close at 12% or $108 million; the developer would take a $8 million profit. The private equity firm funds the project and holds it for a couple of years, then sells it to an insurance company at a 9% yield. Selling the project at this lower yield gives the private equity firm a $33 million profit. To understand bond math is to understand this profit: there's an inverse relationship between bond yields and bond prices. Much as a bond, a renewable energy project using proven technology and operating under a power purchase agreement is a stable money machine that produces stable annual cash flows. The lower the yield requirements of an investor–

typically as the perceived risks of a project declines–the higher the value of the project since the lower discount rate increases the values of the future series of cash flows.

A developer needs to anticipate the various steps and return requirements of each kind of investor and try to develop a project which will generate enough returns for each investor. Given that projects take years to develop, anticipating future return expectations can also be a challenge. Multiple investors–representing different investing silos, each looking to earn a profit, spread over several years–creates inefficiency. Ultimately, this inefficiency manifests itself in the price of renewable energy a customer pays. It is the price per kilowatt of power that determines revenues for the project; given that other costs are known, the higher the requirement for returns on equity for all the investors along the way, the higher the price per kilowatt.

In short, structures of existing silos create inefficiency that renewable energy customers bear in the form of higher prices of renewable energy because projects change hands during their life. But inefficiency may go even beyond that. Is the final yield right, given the risk-return characteristics of projects? Utility scale wind or solar projects offer bond-like returns, although bond yields for utilities are less than 3%.[35] Recognizing that there is some equity risk in a project, is it possible that the 7-9% return requirements of long term owners of projects are too high? Might 5-6% be the right yield? If so, that would mean a considerable reduction in the cost of renewable energy. Where did this return requirement come from? Many asset owners, with the counsel of advisors and fiduciaries, have decided that infrastructure warrants being an asset category. However, renewable energy projects are not a separate asset category; they need to fit into the larger infrastructure category even though the risks are different. While required yields have come down as the number of investors interested in owning these assets has increased, yield requirements may be a consequence of investing silos that need to fit into a general infrastructure asset category where return expectations are–and given greater risks of airports, ports or toll roads need to be–higher. Put differently, have 7-9% returns been “pulled down” from overall traditional infrastructure expected returns of 10-15% rather than having been “built up” from utility debt yields? If so, fitting into the existing investing infrastructure built for other things has a real cost for renewable energy.

There’s one last obstacle created by project finance structures: they have inhibited growth of securitization markets for renewable energy. As part of the broader trend of disintermediation, securitization allowed lenders to bundle smaller loans into bonds that could be sold to investors. While the Great Recession showed the perils of excesses mortgage securitization–banks had little economic stake in the risky mortgages that originated and then sold to others–securitization plays an important and continuing role in financing credit card purchases, automobiles, and aircraft. Securitization is one of the reasons why corporate lending has migrated increasingly away from banks to bond markets. Longer dated, fixed rate loans pose a difficulty for banks which rely upon short term, floating rate deposits for funding. Unless hedged (and hedging costs are expensive), an increase in interest rate means that a bank must pay more for its deposits while the value of its asset (a long dated loan) goes down. Given that a bank’s capital is highly leveraged, this sort of mismatch of rate and maturity can create serious, if not existential, financial risk. Rather than banks holding a long dated asset against short term liabilities (deposits), securitization allows a bank to sell a long dated loan to an institutional investor such as a pension fund or insurance company that has long dated liabilities.

After the 2008 financial crisis, global banking regulators further tightened reserve requirements for bank lending for long dated loans and for smaller loans. These restrictions were not intended to harm lending to clean energy

[35] Municipal Bond Investor Weekly, bond_investor.pdf (raymondjames.com) (accessed March 21, 2021).

projects per se, but nonetheless further constrained the flow of lending to many projects. Because renewable energy projects are long-lived, banks are therefore reluctant lenders. In addition, loans to distributed energy solutions can be small in size; the average cost of a residential solar system is $15,000 to $25,000. Securitization would seem to be an obvious answer in place of bank-led project financing. Unfortunately, a number of features of project financing have inhibited the growth in securitization for clean energy. While the residential solar industry has embraced the benefits of securitization, for many years, major residential solar developers used their privileged access to tax equity providers and banks as a barrier to entry to smaller companies. Rather than in other sectors of the economy where companies compete on the basis of product or service quality–where customers have many choices for financing–solar companies used their access to financing as a competitive advantage.

Securitization markets turn financing into a "utility," widening access to debt for a variety of companies. Securitization, however, requires a bond rating. In order to establish a rating, rating agencies need considerable historical data on equipment performance and customer behavior. Unless a growing industry can provide enough of such data, it is difficult to get a rating. Solar industry leaders were initially reluctant to provide this data. Securitization also requires standardized contracts, ideally, as in the case of mortgages, across an industry; while the documentation across different projects is similar, major solar companies were also initially reluctant to standardize contracts. Beginning in 2016, the solar industry began to embrace securitization. Since then, there have been a couple of dozen deals; at $2 billion per year,[36] solar securitization barely registers in the $800+ billion overall securitization market[37]. Few other clean energy solutions have achieved the size, data requirements and standardization allowing developers to gain access to the liquidity and cost advantages of bond markets.

If developers have limited access to bank financing and securitization markets are nascent, we can hardly be surprised that–except for larger projects using proven technology–it is a financing desert for deployment of innovative clean technology solutions.

Growth Investing: A Missing Link?

In other sectors of the economy, successful early stage companies are purchased by larger companies, or if they wish to remain independent, may seek additional capital from growth investors before going public. Growth investing is a specialized investing silo that is distinct from venture investing. VCs invest in companies that are pre-revenue; capital that is invested goes to product development, engineering, business development, and marketing. VCs are typically taking both market and technology risk. In contrast, a typical private growth fund investor looks for companies that have generated revenues from an established market, with proven unit economics. In contrast to a venture investor, a traditional growth investor will take neither technology nor market risk. While a company may have limited history, the business has achieved repeatable and scalable operations; capital that is invested goes to further customer acquisition, product enhancements, or to additional operational scale. As a result, capital invested is usually considerably larger than a VC investment. While there are cleantech companies–typically service companies–that fit these criteria, the stereotypical manufacturer of an innovative solar panel would not. The company would neither have achieved scale in manufacturing, nor (thanks to problems in obtaining project financing for deployment) commercial success.

[36] Finsight, Solar ABS Bond Issuance Overview; Mercom Capital Group, Total Corporate Funding in Solar Sector Increased 24% with $14.5 Billion in 2020 (both accessed March 21, 2021).
[37] SIFMA, Securitization (accessed March 21, 2021).

Developing companies need to "graduate" from one investing silo to the next to finance the next stage of their growth. Mixing metaphors, each link in the investing chain needs the next one in maturity to take the company further. The lesson of Cleantech 1.0 for VCs was that downstream links were weak or absent. The dearth of growth investors in clean energy was one of the reasons that VCs had to commit much more capital than their usual VC commitment during Cleantech 1.0 to support manufacturers. Then stepping into the shoes of growth investors, VCs realized that the next link–project financing for deployment–didn't exist either. While there has been a modest increase in the flow of growth investment to clean energy companies, there are few growth investors willing to take the risk of funding the scale up of a clean tech manufacturer.

While the typical private growth equity investor looks to companies that have generated sales and established unit economics, there is a major exception to the rule: biotechnology. Biotechnology growth funds have invested billions[38] into VC backed deals. These are funds that are businesses, charging LPs a management fee and carry. The capital requirements of a biotechnology company that seeks to manufacture its product is considerable. While there have been a few recent large (>$100 million) venture backed biotech deals,[39] most venture deals are far smaller; average round sizes are $20-30 million.[40] These venture investments fund drug development and laboratory space and specialized equipment and phase 1 clinical trials. A pilot 100 liter cell culture might cost $10 million. However, as the stakes go up as a drug proceeds to later trials, venture firms turn financing over to growth investors who will pay higher valuations and put more capital to work. Indeed, knowing that there are ample growth investors waiting to take on the next stage of growth draws in earlier stage investing by VCs. A phase 2 trial can cost between $7-20 million; a phase 3 trial can cost between $12-50 million. For manufacturing, a 1,000 liter facility can cost $40 million; a 10,000 liter plant can cost $200 million. And then there are the running costs supporting the business for the years until it can start making sales. The typical time from discovery to market is ten years.[41] And there are considerable risks along the way. Only a third of drugs make it to phase 3,[42] and of those, about 40% fail.[43]

Capital formation works in biotech. Not just in terms of investor performance,[44] but in terms of social outcome. As the British Biotech Growth Trust put it in a recent investor presentation,[45] this period has been a "Golden Era" in innovation. There has been a 50% increase in late stage pipelines therapeutic products from 2014-2019. Three quarters of the pharmaceutical industry's late stage development pipeline and 90% of next generation biotherapeutics are being developed through emerging biopharma. The industry is tackling everything from migraines to cystic fibrosis to breast cancer.

The time scale and amount of capital–and arguably risks–required for a biotech company to go from idea to commercial manufacturing is similar to what it would take for a new solar company. The success of capital

[38] Murphey Richard, Top biotech venture capital funds of 2018, 2019 and 2020, https://www.baybridgebio.com/blog/top_vcs_2018.html (accessed June 26, 2021).

[39] There were 52 "mega-deals" (>$100 million) in 2019 (Nature Biotechnology | Europe's biotech renaissance); across the entire healthcare industry, 27 privatae equity deals were greater than $1 billion in value (Bain & Company | Healthcare Private Equity Market 2019: The Year in Review).

[40] Average round size in 2019 was $28.3 million; Nature Biotechnology | Europe's biotech renaissance.

[41] The Pew Charitable Trusts, From Lab Bench to Bedside A Backgrounder on Drug Development (pewtrusts.org) (accessed March 21, 2021).

[42] Reuters, Success rates for experimental drugs falls (accessed March 21, 2021).

[43] BIO, Biomedtracker, Amplion 2016, Clinical Development Success Rates 2006-2015; Oxford Academic, Biostatistics, Estimation of clinical trial success rates and related parameters (oup.com) (both accessed March 21, 2021).

[44] In 2019, 52 biotech companies went public, witnessing on average a first-day gain of 16%, which drove the major biotech indices and ETFs to gain between 9.8% and 13.7% (Nasdaq | 3 Top-Performing Biotech Funds for 2020) (accessed March 2, 2021); and that was before the biotech industry hit all-time highs in terms of equity financing, IPOs and post-IPO performance in 2020 (LifeSciVC | The Biotech Paradox of 2020: A Year In Review) (accessed March 2, 2021).

[45] The Biotech Growth Trust PLC, Annual General Meeting of July 2020, Investor updates (biotechgt.com).

formation in biopharma begs a related pair of questions: why is there no "valley of death" for biopharma? Or what makes clean tech manufacturing different from biopharma? While traditional growth investors shun both technology and market risk, biopharma is an exception. Investors are willing to take technology risk because the economic prize of a successful drug is worth the risk: if a drug is successful, there is little market risk. There is no valley of death because venture investors hand off to growth investors who fund companies through their long period of clinical trials and manufacturing scale up. While the manufacturing processes–and margins–of making a new solar panel are certainly different from the biotech industry, the larger part of the relative failure in capital formation in clean tech manufacturing is due to market uncertainty. A successful new drug for cancer faces a fundamentally different market outlook than a new solar panel. A solar panel produces a commodity–electrons–which needs to compete with both "brown" and "green" electrons. Will government support policies continue? Will there be a cost of carbon? What will happen to prices of fossil fuels? Asking growth investors to take both technology and market risk is simply a bridge too far. It stretches the investing silo too much. Without growth investors ready to do later stage funding, venture firms are less likely to make investments in early stage companies. There's no point in even going on the onramp.

There are exceptions to the rule. Rivian, the electric vehicle manufacturer, has raised $8 billion since 2019 from a series of strategic and growth investors, including Amazon, Ford, Cox Automotive, T. Rowe Price, Blackrock and Fidelity.[46] Given that China, the world's largest car market, recently ordered that most cars sold there by 2035 need to be electric–and more recently, GM's announcement that it will only make zero emissions vehicles by the same date[47]–growth investors in electric vehicles face less uncertainty about market risk than in other cleantech areas.

Innovations in Stock and Bond Markets: YieldCos and Green Bonds

In addition to liquidity, public stock and bond markets usually offer superior valuation over private markets because they attract the broadest number of investors, including small retail participants. YieldCos and Green Bonds are recent innovations in markets. This paper argues that neither one adequately addresses the financing gap.

YieldCos: Trying to Bring Efficiency to the Value of Renewable Energy Projects

Operating wind and solar parks are capital intensive assets that generate stable cash flows over a long life. In that way, they have economic characteristics similar to other infrastructure assets in the economy. The difference, however, is that conventional energy infrastructure–such as natural gas pipelines–and real estate, such as offices, hotels or shopping centers–receive special tax treatment that helps them equity finance their businesses through publicly traded stocks: Master Limited Partnerships (MLPs)[48] in the case of energy infrastructure, and Real Estate Investment Trusts (REITs) in the case of real estate.[49] While they are structurally different, in economic terms they are similar. Both MLPs and REITs have only one level of taxation: they are not taxed at the corporate level, only at the investor level. Further, they are required to pay out the vast majority of annual cash flow (80%) to their investors in the form of a dividend. As a consequence, they are valued by investors on the basis of current and anticipated

[46] Bloomberg, EV Startup Rivian Said to Reach $27.6 Billion Value on New Funds (accessed March 21, 2021).
[47] The New York Times, G.M. Wants to Make Electric Cars. China Dominates the Market (nytimes.com) (accessed March 21, 2021).
[48] Tax Guide To Master Limited Partnerships (forbes.com) (accessed March 21, 2021).
[49] The Taxman Cometh: REITs and Taxes (forbes.com) (accessed March 21, 2021).

dividends. MLPs and REITs enjoy broad institutional and retail investor interest. Having only one level of taxation and publicly traded stocks give these companies a low cost of equity capital. There are dozens of publicly traded MLPs and REITs on the New York Stock Exchange and NASDAQ. REITs are part of the S&P 500. They are purchased by dedicated mutual funds, and are owned as part of large capitalization stock holdings by asset managers.

MLPs and REITs are generally not available to renewable energy projects in spite of their economic similarities to other infrastructure assets. In the case of MLPs, the statute makes it clear that "natural resources and energy" are eligible for MLP treatment, "except from renewable sources." While there have been multiple efforts in both houses of congress to amend the statute that would permit MLP treatment for renewable projects, these efforts have proven unsuccessful.

Creating a renewable energy REIT may be more promising. In theory, there is more flexibility in the determination of which assets may be deemed "real" as opposed to "personal" property; any real property could be eligible for REIT. Under the REIT statute, it is the IRS or Office of Tax Policy at the US Treasury that make such a determination. Over the last decade, there has been a steady increase in the types of REIT-eligible assets beyond office buildings, hotels or shopping centers. Cold storage warehouses (not just the buildings, but also the equipment inside), railroad tracks and transmission towers are REITs. So are LED billboards. It was not surprising, then, that during the Obama Administration, several advocates argued that wind and solar parks ought to be deemed real property. After all, if an LED billboard—which has electricity running through a wire in an electric frame up to a glass panel that is lit—is real estate, then the reverse ought to be true for a solar park as well. After much deliberation, the Obama Treasury did offer guidance that while the metal frames of a solar installation could be considered real estate, the solar modules were not. The Treasury Department apparently did not want to increase tax preferences. Needless to say, since metal racking represented a minor part of the cost of solar park, this guidance did not unlock solar REITs.

With dim prospects for renewable projects receiving MLP or REIT treatment, several bankers proposed a structure—which they called a "YieldCo"—that mirrored the same structural advantages. These would-be publicly traded stocks owned operating wind and solar assets that would pay out the bulk of their cash flow to shareholders each year in the form of dividends. While they would be structured as regular "C Corporations" as opposed to the special tax advantaged structures of MLPs or REITs, because of the tax benefits enjoyed by renewable energy projects, YieldCos were unlikely to pay much tax at corporate level. Some bankers called the structure a "synthetic MLP."

YieldCos were wildly successful instruments—at least for a while. While many renewable energy projects are developed by small, independent developers, there were a number of utilities and independent power producers that had developed and owned operating wind and solar parks. The benefit to these companies was clear. First, by carving out these assets into a separately traded entity, the assets were valued on a different basis than they would be as part of the overall corporation which would have a mix of other activities; Nextera, for example, had a regulated utility business, a non-regulated renewable energy development business in addition to owning operating renewable energy projects. After all, as project returns are "debt like," the cost of equity should be less than corporate equity. As the name suggested, YieldCos were valued on the basis of their yield. Assets were valued in the way that bonds are valued: the lower the required yield for a fixed stream of coupon payments, the higher the bond value. Under the structure developed by bankers, a developer, having developed a project at a yield of, say, 11%, would sell its projects to a YieldCo at a yield of 7-8%. If the project was worth $1,000 at 11%, the same project would be sold to the YieldCo at a value 25% greater. However, since YieldCos were valued on the basis of current and future dividend yields—and sold with the expectations that dividends were going to grow at 15% per year—

YieldCos were trading at 3-5%. What this meant was this same project originally valued at $1,000 might now be valued at the YieldCo at nearly $1,900. Again, this increase in valuation for a project with the same cash flows is the consequence of bond math: if investors require a lower yield, the value of the bond (or in this case, the renewable energy project) increases. The second reason companies sponsored YieldCos was the possibility of revaluation of the parent company. Because bankers required corporate sponsors to retain at least 50% ownership in the assets—to ensure alignment of interests in operations—the value of retained interest in the projects might benefit the sponsor's own stock price. Half of a project valued at $1,900 at the YieldCo might boost the value of the parent that owned the other half. The third benefit to the sponsor was that it finally had identified a long term owner of the project which would pay the lowest yield for the project. Rather than trying to figure out which insurance company or pension fund that might own the project after it was operating and at what yield, a developer now would know. It could look to its YieldCo. This insight would enable the developer to be more competitive in submitting bids to renewable energy customers. In short, YieldCos were an innovation that sought to reduce the inefficiency that existed between investing silos of development and long term ownership.

Investors of YieldCos also liked them. They represented stable cash flows with none of the risks of operating companies.

Of course, YieldCos worked for investors as long as the relationship between the different yields–at what the developer could develop projects, at what yield the YieldCo would purchase projects from the developers, and at what yield the YieldCo would trade)–remained intact. Given that YieldCos needed to pay out 85% of their cash flow in the form of dividends each year, they would need to keep raising equity to pay for new projects. Since bankers promised that dividends would grow every year by 15%, YieldCos would need to keep purchasing projects. As more and more YieldCos came into the market, the demand for projects would increase meaning that the yields on those projects would decline (the higher the price, the lower the yield). Likewise, developers would be unable to develop projects at the same 11%-type yields if YieldCos succeeded in bringing more transparency to the required yields of long term owners; lower purchase prices for renewable power would mean lower yields on projects. And if YieldCo investors began to worry about whether the YieldCo would be able to keep growing dividends at 15% through continuing to buy projects at the same yields, prices of YieldCos would decline.

Indeed, the YieldCo bubble did burst when interest rates began to rise and yield-oriented stocks declined. YieldCo investors became worried about the sustainability of YieldCo math. The YieldCo fallout claimed SunEdison. SunEdison had been an early issuer of YieldCos. The company—a mix of silicon manufacturing, renewable solar development, and owner of solar projects—viewed YieldCos as a way to separately highlight and capitalize its operating solar projects from the rest of the company. The high value of the retained interest in solar projects boosted the value of the SunEdison stock which encouraged the company to raise corporate debt to expand its development activities, including the purchase of a large wind developer. When the YieldCo market unraveled, SunEdison lost 95% of its market valuation in a year and subsequently went into bankruptcy.[50]

After the bubble burst, most YieldCos were restructured or repurchased. The idea of creating a publicly traded stock that would most efficiently value operating renewable energy assets remains a good idea. YieldCos, however, stand as a cautionary tale of trying to fit renewable energy into financial instruments developed for other sectors.

[50] Reuters, Solar developer SunEdison in bankruptcy as aggressive growth plan unravels, April 21, 2016 (accessed March 9, 2021).

Green Bonds: Greenwashing or New Source of Financing?

In 2007, the European Investment Bank issued the first "green bond."[51] Dubbed a "Climate Awareness Bond," the proceeds of the bond were dedicated to renewable energy and energy efficiency projects. Soon thereafter, the World Bank issued a SEK 2.3 billion green bond;[52] the IFC issued a $1 billion green bond in 2013.[53] Following these benchmarks, the green bond market exploded in size, from $10 billion in 2013, to over $40 billion in 2015,[54] to over $300 billion in 2020.[55] The overall market for green bonds has exceeded $1 trillion.[56] While sovereign and development banks dominated issuance in the early years–and still represented more than half of all green bond proceeds issued in 2020–major US and international corporations have issued them, including Apple, Toyota, EDF, and PepsiCo. Green bonds, as the Economist put it, are "the stars of climate finance."[57]

Green bonds make a promise that the money raised will be dedicated to green projects. There are standards and principles that issuers must follow to earn a "green bond" brand. Some green bonds issuers segregate the funds; others need to account for the use of proceeds. A skeptic would ask since the bonds are using the same fixed debt capacity of the issuer as a non-green bond–again, from a credit standpoint, the bonds are identical–if there were attractive green projects to be funded, why wouldn't they be funded anyway? The evidence that there are incremental corporate environmental projects funded by green bonds is mixed. In a study for the Bank of International Settlements, Ehlers, Mojon and Packer (2020)[58] conclude that green bond issuance does not translate into lower carbon intensity, measured as emissions relative to revenues. Indeed, most green bonds are issued by companies that are already less carbon intensive than average. Flammer (2020)[59] suggests that corporate green bonds have signalling value, arguing that an initial green bond issuance presages improvements in environmental performance and CO_2 emissions reduction. Moreover, it may be that by virtue of issuing a green bond, some clean energy projects get higher visibility than they would otherwise receive.

Issuers no doubt get the benefit of virtue signaling, irrespective of whether there are incremental projects funded. In addition, there may be a marginal economic benefit to issuers of green bonds. Even though they are identical to non-green bonds in terms of their credit, green bonds may save an issuer a few basis points in interest costs. The reason for any interest rate advantage is the rise of ESG-related funds that represent a rapidly growing category of investing. Some asset owners have decided to allocate a portion of their portfolios to ESG funds. As a business, asset managers have eagerly embraced this increase in interest by establishing more and more ESG funds. There are now more than 6,000 dedicated "ethical" funds and nearly $40 trillion in assets have some sort of ESG framework.[60] ESG investors may be willing to pay a modest premium for green bonds which accounts for the interest rate savings to borrowers.

In spite of their popularity and size of issuance, have green bonds unlocked financing for clean technology? The short answer is no. From a credit perspective, more than 90% of green bonds are identical to the regular bonds that

[51] Climate Awareness Bonds (CAB) (eib.org) (accessed March 9, 2021).
[52] 10 Years of Green Bonds: Creating the Blueprint for Sustainability Across Capital Markets (worldbank.org) (accessed March 9, 2021).
[53] Press Releases (ifc.org) (accessed March 9, 2021).
[54] publicationpensionfundservicegreenbonds201712-rev.pdf (worldbank.org) (accessed March 9, 2021).
[55] Nasdaq, ESG-Related Bond Issuance Surges in 2020 (accessed March 9, 2021).
[56] Greenbiz, $1T milestone for green bonds underscores larger fixed-income shifts (accessed March 9, 2021).
[57] The Economist, The meaning of green - What is the point of green bonds? | Finance & economics (accessed March 9, 2021).
[58] Green bonds and carbon emissions: exploring the case for a rating system at the firm-level (bis.org) (accessed March 9, 2021).
[59] Corporate Green Bonds by Caroline Flammer | SSRN (accessed March 9, 2021).
[60] Bloomberg Professional Services, Transforming ESG: A roadmap for creating global standards; The Forum for Sustainable and Responsible Investment (ussif.org) (both accessed March 9, 2021).

companies issue.[61] The entities that are issuing them, therefore, already have high credit ratings and ready access to bond markets. The remaining bonds are mostly solar securitizations where investors are relying upon credit rating analysis of underlying cash flows. Green bonds, thus, are not a new credit instrument. They do not make it easier for innovative solar manufacturers to raise money to finance factories, nor help finance their first solar parks. Green bonds, however, generate higher fees for bankers than traditional bonds. And ESG funds, likewise, are more expensive than traditional funds. Green bonds are good for the asset management industry. Whether they make a difference in clean energy finance is much less certain.

Fitting into the Silos: What Has It Cost?

Simply put, the extant investing architecture was not designed for financing capital intensive clean energy. As capital formation appears successful in other innovative sectors of the economy–including IT, biotechnology, health care, and communications–it suggests that, at least elsewhere, specialized silos of investing and finance achieve the twin objectives of generating returns for investors and channeling capital to growth sectors of the economy. Start up companies tap venture financing; as they grow, they graduate to growth investors; as they mature, they are able to tap large and liquid stock and debt markets to finance large scale expansion. Again to mix metaphors, one financing link in the chain is linked to the next. In contrast, the financing links for innovative capital intensive clean energy companies are misshapenned, missing, or weak. Working back from financing of deployment, if project financing techniques make it difficult for adoption of new technology, growth investors will be reluctant to make scale up investments in manufacturing since they may worry about the ability to get to market. And if growth investors shy away from making investments, venture investors may well be concerned about making even an initial investment if there is risk that the next phase in financing may be difficult to complete.

Capital intensive clean tech companies have tried to fit their financing into the existing architecture, however ill-suited it is for the purpose. It should be clear by now that even for mature technologies and for utility scale renewable energy projects, the hand-off from developer financing to private equity to long term asset owner is inefficient and results in higher costs for clean energy customers. Costs of project equity may be too high because MLPs and REITs are not permitted for renewable energy projects. Other capital costs of projects may be too high because of the reliance upon banks and the constraints of the tax equity market. Costs may be prohibitive for smaller projects. Documentation and legal costs can be considerable; it may be difficult to tap bank, private equity and tax equity providers. And current structures make it enormously difficult for innovative companies to get financing at any cost.

The solar industry's success stems from its ability to fit into financing and investing silos already invented. The solar lease that revolutionized the residential solar market followed many other leasing business models. Large utility solar parks fit into traditional project finance structures used for other infrastructure projects. And most recently, solar securitization mirrored other vehicles for securitizing auto loans and credit cards. While it took time from existing products silos to adapt to solar, once established, solar had the benefit of much more ready access to capital. Using a biology analogy, the cell recognized solar as a friendly protein and could admit it through the cell wall.

[61] Green-bonds-PP-f3-lr.pdf (earthandwatergroup.com) (accessed March 9, 2021).

The further away a financing opportunity is from existing product silos, the more difficult it will be to finance. From a public policy standpoint, trying to fit into silos built for financing other sectors of the economy means higher costs for renewable energy, inadequate capital formation for innovation, and less economic development opportunity in the real side of the economy. More disturbing in the battle against climate change are time delays as asset managers themselves try to adapt their structures to financing a new sector. Beyond that, investors lose opportunity to invest in assets that will generate returns to satisfy their long term liabilities.

Policy Implications

Several policy implications emerge from a better understanding of the investing architecture. First, as the biotech example makes clear, growth investors are prepared to commit substantial capital and assume considerable technology risk if they believe there will be a commercial market at the end of their efforts. Recent evidence from EVs reinforces this same conclusion.[62] Growth investors have been the weakest link in the chain in financing capital intensive clean tech companies. Growth investors provide the scale up capital for manufacturing and for bridging the valley of death. As a consequence, while there are structural problems associated with the investing architecture, the fundamental problem of mobilizing capital is less the architecture and more the lack of commercial market certainty. Put differently, the asset management business looks to earn fees from money that it puts to work. Without enough scalable investable opportunities, the asset management industry will not make the effort to evolve to accommodate and understand clean energy assets. It is not generally a chicken and egg problem: if only there were more capital, there would be more projects; if there were more projects there would be more capital. It is much more the latter than the former. As such, the more governments–and companies–announce emissions reductions commitments, the greater the confidence investors will have for eventual commercial markets for the companies in which they invest. Second, it is hard to know how much the difficulty in funding clean technology deployment–which retards earlier company capital formation–is due to the inherent risks of clean tech and how much is due to the anachronistic reliance upon project financing and private bank lending. Government policy that would open up MLPs or REITs for project equity would lower the costs and increase the availability of project equity. Moreover, it would be in the interest of REITs and MLPs to use their scale of assets to lower debt costs; any savings in interest costs would benefit their equity. Since REITs and MLPs would act as aggregators of projects, they would have sufficient market power to enforce greater standardization of contracts and sharing of data that would enable public securitization of debt. As it is now, developers are diffuse in number and either see advantage in their own proprietary contracts and data or are subject to the greater market power of utilities or government entities that set their own contracts. Beyond lowering the cost of project equity and facilitating lower-cost public debt for projects using mature technologies, MLPs or REITs might provide financing for projects that use innovative technology. In the same way that high yield (below investment grade) bonds developed after the investment grade market matured, so too, is it possible that investors might seek out high yielding MLPs or REITs for projects that took on more risk.

Further, government-sponsored green banks can play a role in project financing by filling gaps in private sector project debt availability. The New York Green Bank, for example, instead of offering a subsidy, offers credit to project developers who face a problem of availability of credit, not its costs.[63] Many smaller projects–even up to

[62] US News and World Report, Investing in the Electric Car Industry, https://money.usnews.com/investing/stock-market-news/articles/investing-in-the-electric-car-industry (accessed March 10, 2021).
[63] Investment Strategy - NY Green Bank (accessed March 10, 2021).

$50 million–have challenges in getting project debt from banks. After the 2008 Great Recession, new bank capital regulations have made it very expensive for banks to make “riskier” loans.[64] While these rules weren’t intended to hurt smaller renewable energy projects, they have often had that effect since in addition to being small, projects loans need terms of 15-20 years (also deemed riskier, and therefore requiring more bank capital in reserve to support the loans) and still have the perception of technology risk after many bankers remembered the clean energy financing bubble of the early 2000s. In addition to size, another gap that green banks can fill is the challenge for banks to invest time in developing new financing structures or understanding new business models. As an example, while commercial banks had gotten comfortable with lending to the individual residential solar market, they were leery of lending to community solar projects where there were multiple customers with different credit scores and where the panels were located offsite from where customers lived.[65] Once the NY Green Bank demonstrated that these loans were creditworthy and large enough, the Green Bank stepped out of the way and let the private financing sector take over.

Put differently, green banks accelerate financing by doing the work to fit clean technology into the existing investing architecture; having done so, there is ample human and financial capital for subsequent capital formation. Another policy implication, then, is whether there are other government steps that could facilitate use of existing channels of financing or speed up the time between one step of financing and the next. As examples, if the Department of Energy gave a “Good Housekeeping” seal of approval to emerging technologies (“it works” or “the cost reduction roadmap seems reasonable”) would this accelerate VC and subsequent growth investment? Or if it offered a performance guarantee on equipment to facilitate bankability of a project? Could government provide data on its own energy efficiency programs and require that its vendors do securitization of debt? And in so doing, standardize contracts that would also facilitate future securitizations?

The fourth policy implication from understanding the current investing infrastructure goes to innovation. Bill Gates and others have argued for major increases in R&D and innovation expenditures in such public-public collaborations as Mission Innovation[66] and Breakthrough Energy Coalition[67] to “correct a major shortcoming--namely the ongoing failure of the private marketplace to invent, develop and scale more affordable, secure and clean energy technologies for public benefit.”[68] Advocates of this approach argue that the solution to this market failure is largely greater government investment in innovation together with some new sources of private venture capital from philanthropic and family offices. However, without a better understanding of the chains of financing which follow innovation investments, this approach will likely not achieve its potential. There may be more innovative company formation, but these businesses are likely to falter in the next phase of financing and deployment. Moreover, large commercial markets draw in innovation and capital. After all, “Moore’s Law” is not a law of physics, it is a law of markets. Behind the predictable declines in cost and improvements in semiconductor performance are both invention and small innovations in processes spread over large production. The lesson from Solyndra was that declining costs from scale deployment of “good enough” technology proved superior to an innovative technology.

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[64] The Financial Panic of 2008 and Financial Regulatory Reform (harvard.edu) (accessed March 10, 2021).
[65] Community Solar for Your Home - NYSERDA (accessed March 10, 2021).
[66] Mission Innovation (mission-innovation.net) (accessed March 10, 2021).
[67] Our Story (breakthroughenergy.org) (accessed March 10, 2021).
[68] Teryn Morris, “How the US Government Could Execute Bill Gates’ Vision for Energy Innovation,” Greentech Media, December 2, 2015. See more recently, Varun Sivaram et al, Energizing America: A Roadmap to Launch a National Energy Innovation Mission, Columbia Center on Global Energy Policy, 2021.

In sum, government policies that stimulate end markets would encourage more investment by growth investors, together with policies that enable REITs /MLPs and Green Banks to free up more project financing would likely achieve more success in financing a company through the valley of death than a large, federal Clean Energy Deployment Agency that would fund scale-up manufacturing. It is also possible that rather than an innovation push approach, more capital will be mobilized for early stage enterprises by starting with deployment-related policies, creating demand pull. CEDA and Mission Innovation address the symptoms of the financing gaps; these other policy measures would work on the cure. At a minimum, government emphasis on policies on market development and on financing projects would reveal which parts of the chain of capital formation are flawed and in need of government intervention. As it is now, it is hard to disentangle the different pieces: how much of the problem is a lack of investment in innovation, how much is the need for government funding to scale up manufacturing, how much is the problem of financing. This paper argues that while there are structural problems in investing and financing that manifest themselves in the valley of death, there is adequate capital to address the climate crisis. The structural problems have been overwhelmed by historic uncertainty about whether the size of the investment prize is worth the trouble.

Has the Tide Turned?

In the last year, there has been significant change in market sentiment in favor of clean energy. Tesla's market value exceeds the combined values of the next nine car makers.[69] The stock of Sunrun, the largest residential solar company, has increased over 1,000% in the last year. Clean energy ETFs, after remaining flat in price since 2016, have nearly increased 4x in 2020.[70] Propelling this increase in stock prices are several factors. First, costs for solar, storage and other clean energy solutions continue to decline; indeed, the more that is produced, the cheaper it becomes. Second, demand for these solutions continues to increase. Not only have a number of U.S. states announced carbon emissions targets, 23% of the Fortune 500 have also plans to curb their emissions.[71] Third, with the election of Joe Biden, investors expect more aggressive energy and climate policies that will benefit clean energy companies.[72]

The most dramatic illustration of investor interest has been in clean energy SPACs (special purpose acquisition companies). First created in the early 1990s,[73] a SPACs is a "blank check" company that raises money from an IPO that has a limited amount of time in which to acquire a private company. If the SPAC finds a private company target, the private company then effectively goes public through a reverse merger into the SPAC (called "de-SPACing"). One public policy argument behind SPACs is that retail investors have the opportunity to buy into private equity types of investments with downside risk: investors not only vote to approve the acquisition, they can redeem their shares at the IPO price if they don't like the deal. After a long period of dormancy, the SPAC market reemerged in 2014, with 12 SPACs raising $1.8 billion.[74] However, in the last few years, the numbers have skyrocketed. In 2020, there were

[69] Tesla valuation more than nine largest carmakers combined: Why? (cnbc.com) (accessed March 10, 2021).
[70] Whereas clean energy ETFs experienced double digit losses in the first three months of 2021 (ETF.com | Wind Turns On Clean Energy ETFs) (accessed March 12, 2021).
[71] Deeds Not Words - The Growth Of Climate Action In The Corporate World.pdf (naturalcapitalpartners.com); 23% of the Fortune 500 have made a real climate commitment (fastcompany.com) (both accessed March 12, 2021).
[72] Here's how Biden's presidency could be a boost for impact investing (cnbc.com) (accessed March 12, 2021).
[73] The term "SPAC" was coined by David Nussbaum, CEO of EarlyBirdCapital (the successor of the now defunct GKN Securities Corporation) in the early 1990s; see Daniel S. Riemer, Special Purpose Acquisition Companies: SPAC and SPAN, or Blank Check Redux?, 85 WASH. U. L. REV. 931 (2007), https://openscholarship.wustl.edu/law_lawreview/vol85/iss4/5 (accessed March 12, 2021).
[74] Reid Hoffman, Reinventing the SPAC | LinkedIn (accessed March 12, 2021).

248 SPACs IPOs raising $83.3 billion.[75] SPACs cut across different industry verticals, including homeland security, consumer products, media, sports and entertainment. Burger King went public through deSPACing.[76]

In the last year, there have been several clean energy and climate-related SPAC transactions. Nikola, which developed concepts for zero emission fuel cells vehicles, went public through deSPACing.[77] At the time of the announcement in March 2020, the company was valued at $3.3 billion, even though it had recorded $117.5 million in losses in the third quarter of 2019 and had less than $500,000 in yearly revenue.[78] Its value was based largely on future orders of $10 billion. In conjunction with the acquisition by the SPAC, the company raised $525 million in a private placement led by Fidelity, the Boston-based investment giant, providing a total of $700 million to the company to help build its manufacturing facility and its fueling infrastructure.[79] After reaching a valuation of $13 billion, Nikola is currently valued at $9 billion.[80] More recently, EVGO, the largest private fast charging network, went public through another deSPACing valuing the company at about $2 billion. Its 2020 revenues were $18 million; the company was valued based upon estimates of 2025 cash flow.[81] The combination of proceeds from the SPAC and a private placement amounted to $575 million which will be used to finance EVGO's build out of its network. Driving this change in investor sentiment has been the flood of money pouring into ESG funds. In 2020, $347 billion flowed globally in ESG-related funds, with more than 700 new funds under launch.[82] In the U.S., ESG-related funds raised $51 billion in 2020, more than twice the amount raised in 2019. The U.S. represents less than 20% of the $1.65 trillion global assets in sustainable funds.[83] The shortage of sustainable investment opportunities accounts for the high valuations of clean energy stocks.

Given this powerful wave of funds coming into the sustainability space, has the clean energy finance problem been solved? If capital-intensive companies such as Nikola and EVGO are able to raise hundreds of millions to finance manufacturing and infrastructure build-outs, is the valley of death a problem of the past? There are good reasons to conclude that the flow of funds into sustainability funds will continue. According to a recent Morgan Stanley report, 95% of millenials favored investing in sustainability in 2019, up 9% from 2017.[84] Some estimates forecast that nearly 60% of mutual fund assets will be ESG funds by 2025.[85] Asset owners are asking asset managers for more ESG products. Given that fees for ESG funds are generally higher than for traditional funds, asset management firms are rushing to fulfill demand (although more lower cost index funds and actively managed ESG strategies have recently become available).[86]

While recent change in investor sentiment shows promise for financing clean energy, it is not yet clear that we can declare victory over the valley of death. The SPAC experience itself presents its own promise and peril. Many of the companies that have been taken public through SPACs are early stage, high risk propositions. And again, most of the companies are not clean energy-related. As an example, Momentus Space, a space transportation

[75] Harvard Business Review, The SPAC Bubble Is About to Burst (hbr.org) (accessed March 21, 2021).
[76] The New York Times, Burger King to Return to Public Markets (nytimes.com); Harvard Law Review, SPAC-and-Span: A Clean Exit? (harvard.edu) (both accessed March 12, 2021).
[77] Forbes, Nikola And Hyliion Partner With SPACs; What's Next For EV Trucks? (forbes.com) (accessed March 12, 2021).
[78] Wall Street Journal, Nikola's Losses Widen as Executives Try to Regain Momentum, Develop First Truck - WSJ (accessed March 12, 2021).
[79] Nasdaq, Electric vehicle startup Nikola set to begin trading under symbol NKLA following SPAC merger approval (accessed March 12, 2021).
[80] Yahoo Finance, Nikola: Rewarding Push Into Hydrogen (yahoo.com) (accessed March 12, 2021).
[81] Seeking Alpha, EVgo: Charging Too Hot (NYSE:CLII) (accessed March 12, 2021).
[82] Bloomberg Green Insight, The $490 Billion Boom in ESG Shows No Signs of Slowing (accessed March 12, 2021).
[83] Ibid.
[84] Morgan Stanley, The Case for Sustainable Investing (accessed March 12, 2021).
[85] Bloomberg, Almost 60% of Mutual Fund Assets Will Be ESG by 2025, PwC Says; Financial Times, ESG funds forecast to outnumber conventional funds by 2025 (ft.com) (both accessed March 12, 2021).
[86] Morningstar, Where to Find Low-Cost ESG Funds (accessed March 12, 2021).

and infrastructure company went public through deSPACing in 2020. It went public with no revenue, based on development of a transport and service vehicle and the concept of the first hub and spoke model in space. Momentus is not expected to earn a profit until 2023, but was valued at .6 x 2025 revenue or $1.2 billion.[87] By any conventional valuation technique, this number is, if one forgives the pun, atmospheric. One appealing reason why companies are interested in going public through a deSPACing is that, in contrast to a "regular" IPO, companies are able to provide their own forecast of future results and discuss them with prospective investors. Under the constraints of traditional IPOs, companies rely upon equity research analysts providing forecasts and need to be cautious about "forward-looking statements." Whether this greater investor visibility into company forecasts explains high valuations for deSPACed IPOs is difficult to fathom: do investors put more faith in management's forecasts or in those prepared by Wall Street analysts?[88]

Will SPACs emerge as a primary means of growth company equity financing? There are two possibilities. The first possibility is that SPACs represent a speculative bubble. And as in the case of other bubbles, this bubble will end when markets realize how much risk some of these newly public companies entail. Whether it be in shortfalls in execution of the business plan, in scaling up production, turnover in management, or delays in obtaining key contracts–it seems inevitable that some of these companies will stumble. When they do, their stock prices will collapse, casting a pall on others and chilling market interest in funding the next set of deals. After all, there is a reason why public and private markets have existed: companies need to achieve a degree of maturity in private markets before going public. Public market investors are not venture investors. However, until the bubble ends, investors will keep playing the game because it makes them money.

What has fed the bubble is the SPAC structure itself. The SPAC sponsor makes a pitch to investors about the sponsor's ability to find a target. From the SPAC investor's standpoint, it is a low risk proposition. If the sponsor is unable to find a target, the investor gets its money back. If the sponsor finds a target, the investor votes for the merger and has the opportunity to redeem shares at the original purchase price if the investor doesn't like the deal. If, however, market participants view the target as being attractively valued, the SPAC investor effectively owns shares in the target at a discounted price. If upon announcement of a target, the SPAC share price appreciates, the investor can sell the SPAC shares in the market before the deSPACing transaction takes place. Or the SPAC investor can wait and sell the shares later after the deSPACing and the investor has shares in the operating company. Thus, for the SPAC investor, the downside is the opportunity cost of getting its money back if the sponsor can't find a target. However, this cost is effectively an option premium on buying an in the money call on a high-flying IPO.

For the SPAC investor to make money requires another step in the structure. Once the sponsor finds a target, the target and the sponsor arrange a "PIPE" (private investment in public equity) offering in which major institutional investors commit to buy shares in the target upon the merger. The PIPE proceeds, together with the proceeds from the original SPAC, provide the target with substantial financing for its business plan. As the term suggests, this offering takes place privately, with no disclosure to the SPAC investors as to the target or the PIPE. It is only after

[87] CNBC, Momentus: The latest space stock MNTS through SPAC deal (cnbc.com) (accessed March 12, 2021).

[88] There are subtle differences in the way–and to whom–forecasts are disseminated between traditional IPOs and SPACS. During the marketing of IPOs, only institutional investors have access to analyst forecasts that are delivered orally; analysts only publish their forecasts 25 days after the first trading date of the IPO. Because deSPACing transactions are technically structured as mergers and are subject to the vote of SPAC shareholders, management forecasts are included in the proxy statement; as such, they are available to retail investors at some point after the SPAC target has been announced and before the deSPACing transaction is effected. As a practical matter, this is a distinction without much of a difference since in both cases, the pricing of both IPOs and SPACs are determined by institutional investors. Further, by the time retail investors have access to either management forecasts in a SPAC or research analysts after an IPO, pricing has already been set and the stock has been trading. Upon the announcement of the target, the SPAC share price is effectively the share price of the target.

a merger agreement between the SPAC and the target, and after the PIPE commitments have been made, that the deal is announced publicly. Because it takes a couple of months for the merger to be completed, the institutional investors are making a forward commitment to purchase stock in the target. To compensate them for this risk, the investors buy the stock at a discounted price. To buy stock in the PIPE, these investors need to believe that the deSPACed stock price will be higher than what they have paid for it. They assume that shortage of high growth stocks will attract other institutional and retail investors who will bid up the price.

As long as all these pieces fit together, lots of people make money. The sponsors make money since they earn a share of the equity in the target; the SPAC investors make money based upon their ownership share of a company that now has attracted new capital through the PIPE from institutional investors who have established a discounted price; and the PIPE investors themselves who have purchased stock at a discounted price. The whole structure depends on the expectation of an eventual robust market once the deSPACing transaction is completed and the operating company, complete with its new capital, trades in the market. Without this assumption, the structure unravels. History suggests that public markets will eventually sour on very high risk IPOs. And once it does, the opportunity for growth capital in public markets for immature clean tech companies will end. But as long as there is the opportunity for investors to make money, the bubble will continue.

The second possibility is less cynical. Asset owners and asset managers are concerned about long term returns in the market. A recent survey of major banks and asset managers forecasted 5-7% annual long-term nominal returns on U.S. stocks.[89] This expected return is consistent with the long term premium of equity returns over risk free government bonds.[90] Such a low expected return poses a major challenge to asset owners and asset managers. Consider a state pension fund. The average return that state pension funds assume is 7.2% for the entire portfolio,[91] including holdings in lower yielding debt, meaning that the average pension fund is assuming that stock market returns will be higher than the recent forecasts. Similar problems exist for insurance companies or endowments where expected growth in assets is needed to offset future liabilities. If stock market returns are going to be lower, then endowments will need to trim spending, pension funds will need to increase funding, and insurance companies may need to raise equity. Against this grim outlook, asset owners are looking for ways to increase returns. Companies that have gone public through SPACs may be risky but they offer the promise of growth. Rather than SPACs being a speculative bubble, they may represent a secular change in the risk that asset owners may be prepared to take to achieve higher returns. Whether it is EV or a space infrastructure, investors may be willing to finance riskier companies in the public market than in the past. This would be good news for the costs and availability of risk capital.

Likewise, asset managers face challenges in their business model in a world of 5-7% returns. It was one thing for an endowment asset owner to pay 1 or 2 percent for an active management strategy when stock market returns were double digits. It may be an altogether different proposition when fees represent a major percentage of expected returns. A world of lower fees will challenge the underlying economics and assumptions of the asset management business whose development and growth occurred during bull markets. Indeed, most of the people today working in asset management have never faced a market with low expected returns. We can imagine some of the marginal changes that might occur in the asset management world: more industry consolidation to achieve scale so as to offer low fees to asset owners or continued efforts to define new asset categories. We could even imagine that

89 Morningstar, Experts Forecast Stock and Bond Returns: 2021 Edition (accessed March 12, 2021).
90 CFA Society, Bond Risk Premium White Paper (cfasociety.org) (March 12, 2021).
91 PEW Trusts, State Public Pension Funds Lower Assumed Rates of returns final 2020.pdf (pewtrusts.org); Bloomberg, Public Pension Funds Falling Short of Needed Returns This Year (both accessed March 12, 2021).

asset managers will blur the edges of their investing silos to improve their relative performance to other managers in how asset owners evaluate managers. As examples, a growth fund might take on more VC risk or a private equity fund might assume more technology risk. We don't know how much a lower returns world will lead to fundamental restructuring of the asset management business or to investment strategies of asset owners, but it is important to see that changes in financing of clean energy may be occurring against a backdrop of the challenges in the overall investment world.

In the meantime, in response to asset owner demand, a number of new climate related investment funds have been announced or established. Generation Investment Management set up a $1.0 billion Climate Solutions Fund with a focus on later stage VC and private equity growth; Brookfield has announced a $7.5 billion Climate Transition Fund which will invest in renewable power and investments that will reduce carbon emission; activist Jeff Ubben has set a $8 billion hedge fund on ESG investing. From a structural standpoint, few of these funds challenge the incumbent investing architecture. They fit squarely into traditional buckets of private equity, hedge funds, growth equity, infrastructure. Their compensation structures are likewise aligned with comparable investing products. TPG's $2.2 billion Rise Fund II charges a management fee of 1.75% with a traditional 20% carried interest. While some renewable funds–such as Carlyle's–are prepared to take some development and construction risk, for the most part, asset managers and asset owners seem to be most comfortable with remaining within established areas of specialization–albeit with a new industry focus. As such, these new funds are evolutionary steps within an existing structure rather than fundamental change in investing architecture.

We can expect that these evolutionary changes will accelerate capital to finance climate change, even if the SPAC bubble implodes. While U.S. energy policy could change yet again in a subsequent election, corporate and state level action are likely to be more durable, giving investors confidence that commercial markets for clean energy will be robust. In addition, the proposed EU Green Deal would require companies doing business in Europe to commit to scheduled reductions in Scope 1-3 emissions which will further create demand for climate change solutions. As such, more growth investors will be attracted to the sector, which in turn will draw in venture investors who will know that there will be investors ready to finance the next stage of growth. Moreover, having financed deployment of solar, the cycle time for project financing the next set of technologies will be shorter. As an example, carbon removal projects will likely be developed by independent developers. The customers who will want such projects–for use in cement or for enhanced oil recovery–will likely want to own the "service" (CO_2), rather than the equipment itself. Hence, developers will need to put together non-recourse project financings based upon offtake contracts for revenues. And as in the case of solar, these developers will need to rely upon tax equity as part of the capital stack; 45Q is a generous tax credit for carbon removal. Solar could also lead the way in eventual development of securitization markets for other smaller scale clean energy projects.

Less clear are the implications of investor pledges on achieving net-zero targets. Thirty of the world's largest asset owners with combined assets of $5 trillion[92] and 30 of the largest asset managers with $9 trillion under management[93] have committed to Paris Agreement-level decarbonization targets in their portfolios. Initiatives such as CERES[94]–which has 154 institutional investors with $24 trillion in assets under management–have made progress in reporting and advocacy but, up to this point, have not changed the underlying investing architecture. Will these

92 United Nations-convened Net-Zero Asset Owner Alliance – United Nations Environment – Finance Initiative (unepfi.org) (accessed March 12, 2021).
93 Net Zero Asset Managers Initiative - Home (accessed March 12, 2021).
94 Ceres, Commit to Climate (accessed March 12, 2021).

pledges stimulate corporate purchases of climate solutions in investor portfolios or create a market for carbon offsets as an overlay on portfolios?

If this evolution in the investing architecture goes well, capital formation in clean energy might replicate the success of the biotech sector. There will be tighter linkages in the financing chain from early stage venture investing to deployment. As a consequence, start up companies will have a much better opportunity to survive the valley of death. However, the capital requirements to address climate change are at a much greater scale than in biotechnology. More fundamental change in the economy–and in how the economy is financed–will be needed. No amount of money invested in new climate-related funds will move the needle. It is the mainstream that needs to change.

We can't expect the investment world to solve this problem. As a business, the asset management world has acted rationally. It has developed investment products based upon investable opportunities. Financing doesn't create demand for product or services–it facilitates, accelerates or enables the consumption of what a customer already wants. Merely providing financing for a car doesn't make a customer want a car; it allows a customer to avoid making a huge upfront payment. Likewise, the solar lease unlocked the residential solar market by providing solar power without taking on a personal loan or a mortgage. If customers didn't already want solar, the leasing solution itself would likely have had few takers. Whatever innovations have occurred in financing markets are derivative of the real side of the economy, not the other way around. In the community of people concerned about climate change, there is the persistent hope that financial innovation will unleash the needed capital to finance the transition to a carbon free world. Sadly, this is the world backwards through the telescope. There is ample capital and an asset management industry willing to put the capital to work. But it will follow market opportunities, not the other way around.

While corporate and consumer action can play a role in stimulating demand for clean energy solutions, it is only concerted government policy that can transform an entire economy. Only governments can implement a cost of carbon, establish regulations on emissions, eliminate or establish subsidies, impose carbon border adjustments, or create green banks. In addition, were governments to adopt a war footing posture, government procurement and direction of production would play a major role in restructuring the economy. It would no longer be a few clean energy companies trying to raise capital to compete with entrenched, large capitalized incumbents. Instead, every company, across various industries would be spending capital to reduce emissions. The financing and asset management world would react to these changes. Incumbent companies would use their ready access to financing to fund their own transitions. Asset managers would determine which companies would be winners and losers in the transition. Asset owners would increase asset allocations to higher-growth categories.

It's hard to forecast how the investing architecture would change in the face of strong policy action. It is possible that asset managers would propose brand new asset categories–global renewable energy projects, or carbon reduction or hydrogen production projects. However, as new asset categories would take place at the same time that investing flows would be dramatically changing in the overall market, it is likely that overall flows would be greater than those going into new asset categories. It is also possible that policy will drive more dramatic change in architecture. As an example, future clean energy projects may be embedded in broader community-based solutions that include health care, broadband access, wastewater management, and environmental services from land use. These projects would have different revenue streams, some private, some from government, with different credit counterparties. Some of this imagined community project's value can be internalized in the project's cash flows; other parts of the value are real but appear outside of the project in the form of property value increases or better health outcomes. Financing these projects would involve very different analytics, partnerships, and a better connection between long term assets and liabilities. While it is hard to see how the current asset management industry could finance this project, we can be certain that the asset management business will try to optimize itself to maximize its profits by directing investments to areas which represent the largest and most attractive investable opportunities.[95]

Although financing follows the real side of the economy, it is possible that investors could precipitate government action. In spite of efforts such as Risky Business–sponsored by Michael Bloomberg, Henry Paulson, and Tom Steyer–to highlight the risks of climate change to businesses and investors, it does not appear that capital markets have taken the financial costs of climate change into account in the valuation of stocks and bonds. Part of the problem may be the complexity of understanding the various interrelated pieces: offshore supply chains in Vietnam affected by sea level rise, water shortages in the U.S. Southwest, global migration, loss of value from Miami real estate, costs borne by local governments in building seawalls, as a few examples. Another may be the perception that climate change risk is still too distant to enter into valuation and security selection today. And then there is the dynamic of how money managers are evaluated. Investors may well believe that because markets are not appropriately valuing the financial risks of climate change, we are in a "climate bubble." However, unless you believe that other investors are going to take these risks into account, you would be ill-advised to structure your portfolio differently: you risk underperformance. However, as Chuck Prince, the then-CEO of Citibank put it in 2017 in the middle of the credit bubble, "as long as the music is playing, you've got to get up and dance."

What we know from other bubbles in markets is that they end, usually with an event. While it isn't possible for market participants to know what such an event will be or when the music will stop, when it does, markets move rapidly. And in doing so, revaluation of markets sends powerful messages to companies and to governments. Market action precipitates action in the real political economy. What also characterizes bubbles is that, in retrospect, the evidence of the bubble is hidden in plain sight. Keynes wrote that "animal spirits" rather than "the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities" drove market actors. Or, as the old Wall Street adage put it, that markets are driven by cycles of greed and fear. Whatever greed motivates the business of money management, the eventual fear of climate change may bring about the fundamental change in how money is investing. And that's what may make the difference.

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95 The investing architecture described in this paper started in the U.S. but has migrated to Europe. Certain products, including venture capital, private equity, and mutual funds have been exported to other countries and now exist in a number of emerging markets, although the architecture has had mixed blessings. On the one hand, creating an asset category for emerging markets has increased capital flows, but the number of countries deemed of interest to investors is limited. Moreover, the creation of the asset class has tended to link economies more than would otherwise since good (or bad) stock market performance in one country will tend to increase (or decrease) asset allocation which can lead to capital inflow or outflow in all the countries in the portfolio. The "Asian Contagion" of 1997 (Los Angeles Times, The Asian Contagion (latimes.com), accessed March 29, 2021) which led to a broad sell-off of emerging market equities around the world may have more taken place in conference rooms in Boston and in New York rather than in Asia as fund managers sold stocks in better performing markets to offset losses elsewhere and asset owners reduced their asset allocations to emerging markets.

Financing renewable energy in developing countries, then, needs to fit into the silos to the degree that they exist. And if they don't exist, it is very hard to get projects built unless there is government funding. It's hard to forecast what a change in architecture might look like, but a global renewable energy asset category for projects would help. It would create opportunities for standardization in contracts and for legal reforms; it would make capital more broadly available and at lower cost. And it would provide the ability to aggregate smaller projects.