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EFI FOUNDATION

ENERGY FUTURES FINANCE FORUM

A FRAMING REPORT

Increasing the Quality of Investments for Deep Decarbonization

The EFI Foundation is a 501(c)(3) nonprofit organization dedicated to educating the public on issues relating to harnessing the power of technology and policy innovation to accelerate the clean energy transition. The EFI Foundation is based in Washington, D.C.

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Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, the EFI Foundation builds on the prior work of the Energy Futures Initiative, a nonprofit organization co-founded by former Secretary Moniz in 2017. Reports by the EFI Foundation and the legacy work of the Energy Futures Initiative are available for download at **www.efifoundation.org**.

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Introduction

Successfully implementing and achieving the global clean energy transition is often considered to be primarily a technological challenge, with the primary focus being the discovery of new means of making and using energy without greenhouse gas (GHG) emissions. Less understood is the massive investment and capital markets challenge of raising the finances needed to deploy well-proven, cheap, and serviceable decarbonization assets. The Energy Futures Finance Forum (EF³) offers policy recommendations reflecting an investor's perspective that decarbonization investments must be blue chip.

The financial challenge would be consequential even if the business proposition for investing in decarbonization were robust. The inseparable intertwining of public policy and the economics of decarbonization assets, however, magnify this challenge, which is already formidable. The emission of GHGs is fundamentally a pollution control problem—a global negative externality. Such externalities pose economic issues because it is less costly to pollute than to mitigate pollution, and GHG emissions are no exception. Abating emissions of GHGs or any other pollutant must be either compulsory or profitable.

Unfortunately, advanced countries with high and robust GHG emissions pricing and/or emissions control regimes are not major contributors to the world's gross domestic product. Absent the robust and accurate pricing of GHG emissions that could create the cash flows that make GHG abatement profitable and attractive to investors, governments, including the U.S. federal government, have supported policy pathways in two general categories: the establishment of supply-side financial incentives, such as federal grants and tax credits, and demand-side market forcing mechanisms, such as state renewable portfolio standards or low carbon fuel standards programs.

These alternatives to a carbon price or legal limitations on emissions must be robust and long-lasting enough to ensure profits for owners of decarbonization assets and enable successful access to debt and equity markets. In short, with the right policies, these assets will become investment quality or investable. On the flip side, if policy mechanisms are nonexistent, weak, and impermanent, rational lenders and investors will eschew decarbonization debt or equity exposure in favor of less problematic asset classes. This scenario is generally the case with today's policies—their insufficiency has given decarbonization assets an investment quality problem. Moreover, confidence in the long-term stability of financial incentives is crucial but lacking. Understanding and addressing the policy deficiencies that undermine the investment case for decarbonization assets is essential for the clean energy transition and achieving net-zero carbon goals by midcentury.

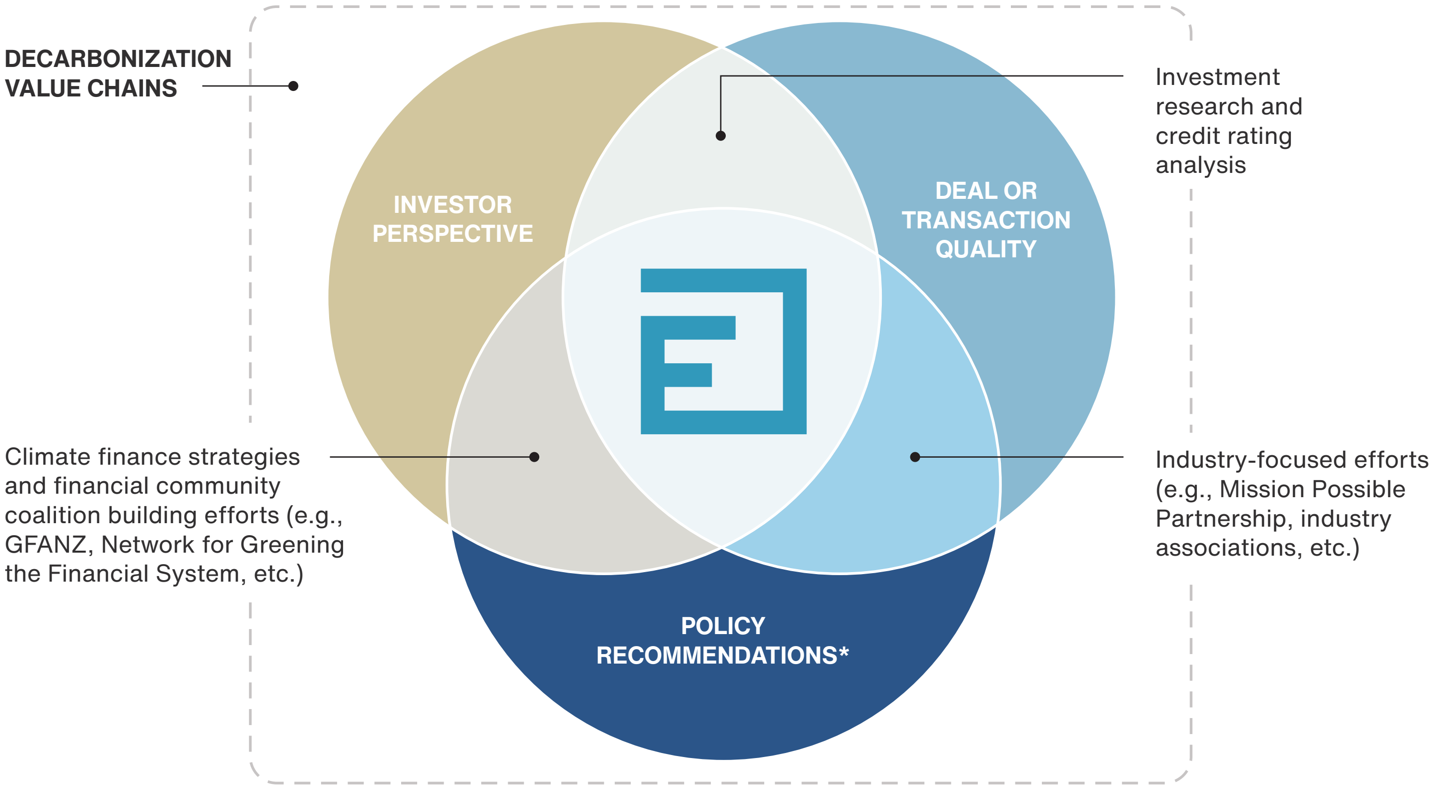
EF³ was established to analyze investor barriers to at-scale private financial capital flows to assets needed for the energy transition and to develop policy and financial sector recommendations to overcome these barriers in the United States and globally. EF³—a program within the EFI Foundation—considers an all-of-the-above strategy as its fundamental framing and focuses on the mechanisms that can improve the investment quality of clean energy.

The Energy Futures Finance Forum (EF³) was established to analyze investor barriers to at-scale private financial capital flows to assets needed for the energy transition and to develop policy and financial sector recommendations to overcome these barriers in the United States and globally.

From a financial markets perspective, all-of-the-above means enabling access for all decarbonization technologies and deploying those solutions across economic sectors, including fuels, industrial processes, electricity generation, supply chains, and efficiency and conservation beyond a narrow power sector focus. Improving the investment quality of decarbonization value chains will help enable industry players to gain access to the largest pools of private capital—global, publicly traded debt and equity markets—which are of the same order of magnitude as the expenditures needed to achieve net zero by midcentury.

EF³ will provide rigorous, unbiased analysis and thought leadership, coupled with broad and continuous stakeholder engagement, to form policy recommendations at the intersection of finance and clean energy to drive deployment and diffusion of essential technologies. Other climate finance-oriented groups have done valuable service by raising awareness of climate needs and risks on the part of corporate management teams, investors, and the public. EF³ is taking a far more granular approach, working to identify the factors that could block, diminish, or minimize the decarbonization investment efforts and targets of even the most well-intentioned lenders, investors, and corporate boards. EF³ will examine environmental, financial regulatory, and tax statutes and regulations; decarbonization asset costs and performance; investment market flows; corporate internally funded investment patterns; and the criteria by which investors, fiduciaries, debt rating agencies, and equity investment analysts evaluate decarbonization asset investability. By focusing on increasing project investment quality sufficient to enable the implementation of a range of deals, the program will be complementary to ongoing global climate finance and sectoral decarbonization efforts (*see* **Figure 1**, *next page*).

Figure 1: **DIFFERENTIATION AND COMPLEMENTARITY: EF³ SITS AT THE INTERSECTION OF POLICY, DEAL QUALITY AND THE INVESTOR PERSPECTIVE**



*includes both type (i.e., legislation, regulation, administration) and focus; depth (i.e., energy and environment) and breadth (e.g., tax code, labor, treasury, etc.)

Through its research and engagement activities, EF³ will help facilitate international, national, and industrywide efforts to scale up investments to decarbonize the economy. The EF³ team brings experience and expertise across the energy landscape, including energy finance and project development, macroeconomics, strategic management, policy, regulation, and technology. The program leverages and expands upon the research capabilities, convening power, and credibility of the Energy Futures Initiative (EFI).[i]

This paper describes the motivation and implementation framework for EF³. It discusses the essential investment barriers facing the clean energy transition and the approach of EF³ to help address those challenges.

i The Energy Futures Initiative (EFI) advances technically grounded solutions to address climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, EFI conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. The EFI Foundation (efifoundation.org) is the 501(c)3 nonprofit affiliate of EFI, following a broadly similar remit as EFI. EF³ will be carried out under the auspices of the EFI Foundation. EFI, EFI Foundation, and EF³ each maintain editorial independence from their public and private sponsors.

Motivation: The Financial Demands of the Clean Energy Transition

Globally, the energy sector accounts for about 75 percent of total greenhouse gas (GHG) emissions.[1] The sector's ongoing transformation to 2030 and beyond to midcentury is essential for meeting net-zero global climate mitigation targets.

According to a 2021 United Nations report[2]: "Over the next decade, every aspect of national energy systems will be affected by changes in climate and energy policy, and financing, continuous technological advancement, and shifts in energy supply and demand. … The energy transition can thus no longer be limited to incremental steps. It must become a transformational effort, a system overhaul, based on the rapid upscaling and implementation of all available technologies to innovate for the future." Clearly, there is an urgency to increase the pace of decarbonization, both to make substantial and lasting emissions reduction by 2030 and to reach net zero by midcentury.

Numerous studies have documented the substantial investments that will be required for this transformation as well as for the modernization of publicly and privately owned energy and energy-related infrastructures.[3,4,5,6] These estimates primarily focus on the need to replace aging infrastructure while managing the influx of "smart," connected, higher efficiency and lower GHG-emitting systems and components. These requirements are compounded by the need to make energy infrastructure more reliable and climate resilient.

Simply replacing retiring infrastructure with low-carbon equivalents, while necessary, is insufficient given the relatively low capital stock turnover rates of durable assets. At the same time, closing existing energy infrastructure via unplanned shuttering would result in stranded assets en masse, in turn creating widespread economic distress and aversion to future investments. This risk raises many policy questions about how to accelerate turnover rates as part of a just transition.

Another pivotal issue: Simply developing the decarbonization *solutions* that we need is a different matter from having the decarbonization *industries* we need. We now have adequate available pathways to advance major changes needed for a net-zero economy. Many of the mission-critical solutions, however, have not been deployed at a commercial scale or even at a first-of-a-kind (FOAK) installation, much less having been demonstrated and deployed at enough installations to create a viable industry.

Improved gigawatt-scale nuclear fission plants, for example, are currently being built around the world, and 50 megawatt (MW) to 150 MW scale fission reactors have been advancing for decades. The technology is not a problem per se. However, the U.S. has not built a single new 50 MW to 150 MW scale civilian fission reactor, much less built the foundations of a commercially viable small modular reactor industry—which would ostensibly require building greater multiple units apiece of several different designs.

Another example is found in two principal technologies for carbon capture, where the processes of scrubbing carbon dioxide (CO_2) out of a mixed process gas or waste gas stream date from the 1930s and 1950s. Several hundred million metric tons of CO_2 are removed annually (though usually vented to the atmosphere) in industrial facilities such as natural gas processing plants, fertilizer plants, and coal-to-chemical plants. The U.S., however, has deployed only one coal-fired power plant with a carbon capture system and no carbon capture technologies in gas-fired power plants, pulp mills, cement plants, steel mills, industrial steam boilers, or oil refinery process units. Again, founding a carbon capture industry would require building multiple instances of carbon capture in each of these industrial settings by multiple vendors.

> **"Over the next decade**, every aspect of national energy systems will be affected by changes in climate and energy policy, and financing, continuous technological advancement, and shifts in energy supply and demand. ... The energy transition can thus no longer be limited to incremental steps. It must become a transformational effort, a system overhaul, based on the rapid upscaling and implementation of all available technologies to innovate for the future." **— From a 2021 United Nations report**

Theme Report on Energy Transition: Towards the Achievement of SDG 7 and Net-Zero Emissions, 2021, https://www.un.org/sites/un2.un.org/files/2021-twg_2-062321.pdf

A pivotal part of setting the foundation for new clean energy industries is the development of the upstream portions of the value chain, for example the development of scale-efficient manufacturing to build parts and entire subassemblies on a low-cost, standardized basis. Building multiple units using primary technologies is essential for understanding both the design and the typical specifications of standardized components; this effort will enable the deployment of supporting factories.

The scope of capital spending required to establish clean energy industries also is magnified by the capital requirements in the downstream portions of the value chain, which include transportation, distribution, and waste disposal. For example, decarbonizing transportation will require new infrastructures for charging and fueling electric vehicles and fuel cell vehicles. Widespread deployment of smart and distributed electricity generation and storage systems also will require new infrastructure investment in transactive transmission and distribution systems enabled by digital control systems and sophisticated energy management systems supported by broadband communication capabilities.

In addition, the impacts of climate change (e.g., sea level rise, extreme temperature variability, etc.) will require that new infrastructures have enhanced resiliency. Further, energy security concerns have become a prominent factor as shifts in the energy mix influence the balance of power across and within geographic regions. Simultaneously meeting these needs—and many more—will require substantial increases in investment, as well as innovation in the architecture of infrastructure systems.

The energy transition's environmental and economic rewards can be considerable if the transition is thoughtful, sequenced, and appropriately supported. The requirement to deploy existing—and to develop new—clean energy solutions at scale and speed could lead to revolutionary opportunities for promoting economic growth, improving energy system resilience and reliability, and ensuring greater energy security and prosperity. The development of new industries can create high-quality jobs and contribute to building a more competitive economy.[7,8] The United States is well-positioned to develop innovations and industries in clean energy given its wealth of resources (i.e., natural, engineering, human, scientific, financial, educational, and institutional). However, all this development is predicated on the idea that sufficient capital is available to fund this vital transition.

The Macroeconomic and Capital Markets Challenges of Sourcing the Required Financing

A major obstacle, perhaps *the* major obstacle, is finding the several trillion dollars per year of financial capital required to pay for deploying new clean technologies globally in addition to their upstream supply chains and downstream infrastructure. The challenge is made more difficult because the world will need to finance this new clean investment while simultaneously continuing to perform essential maintenance on upstream and downstream legacy energy systems until they are no longer needed for global energy system reliability and resilience.

A fundamental dimension of the challenge to financing global decarbonization is the magnitude of funds required. If much of the financing required for decarbonization assets can be accomplished with investment capital diverted from spending on high-emitting energy systems, the quantity is relatively small compared with the size of the global economy and thus achievable with moderate effort. Conversely, if capital requirements are outsized in the context of global savings and investment, coupled with only a modest amount freed up from high-emitting energy systems, then the challenge is considerable. Therefore, an order-of-magnitude estimation of how much capital is needed to fund global decarbonization is essential to determining what kinds of policy mechanisms are needed to marshal funds effectively.

While there have been few coherent attempts to estimate the global macroeconomic and capital markets challenges of financing decarbonization,[ii] we summarize the current literature and data along two dimensions to determine global and U.S. capital requirements. The two dimensions are forecasted total and incremental annual clean energy system spending and annual capital amounts freed up by reduced fossil spending that could lower the net incremental clean energy financing need. From this summary, we determine the significance of the net financing required compared to annual new global and U.S. capital market investment flows and the significance of that net need from an annual global (and U.S.) savings/net fixed capital formation context. We conclude that the net

ii Most climate/energy models are "partial equilibrium" energy sector models that estimate the costs of balancing energy supply and demand, with the attendant emissions and impact on the atmosphere. They are not "general equilibrium models" of the macroeconomy. Such partial equilibrium energy sector models can determine the higher capital and operating costs of energy investment systems that accomplish a climate result (i.e., limiting the rise in global temperature to < 1.5 degrees Celsius), but these models treat factors such as gross domestic product growth and financial market conditions as exogenous assumptions. Put succinctly, partial equilibrium models estimate cost but are insufficient to provide deep insight regarding the macroeconomic affordability or practicality of proposed climate solutions.

incremental clean energy system financing needs are consequential in the context of both global/U.S. recent annual savings/net fixed capital formation and new financial markets investment flows.

The broad outlines are clear: Policymakers must use the utmost care in designing decarbonization financing mechanisms that will attract a broad and deep set of investors to support the global decarbonization project, while maintaining global (and U.S.) energy reliability and resilience.

Total and incremental forecast annual clean energy/ decarbonization capital expenditures

The capital spending requirements for the clean energy transition are massive, both for the U.S. and globally. In 2021, the International Energy Agency (IEA) estimated that average total annual global clean energy incremental expenditures required between now and 2050 are approximately $4.3 trillion/year versus average 2016 to 2020 levels of $1.4 trillion/year (constant 2019 USD). The result is an average incremental clean energy expenditure of $2.9 trillion/year compared to the baseline.[9] Comparable U.S. net incremental expenditures are forecast to be $200 billion to $300 billion/year,[10,11,12,13] (though various forecasts use different definitions and time frames; *see* **Appendix** *for further detail*).

Annual capital amounts potentially made available by reduced fossil fuel infrastructure spending

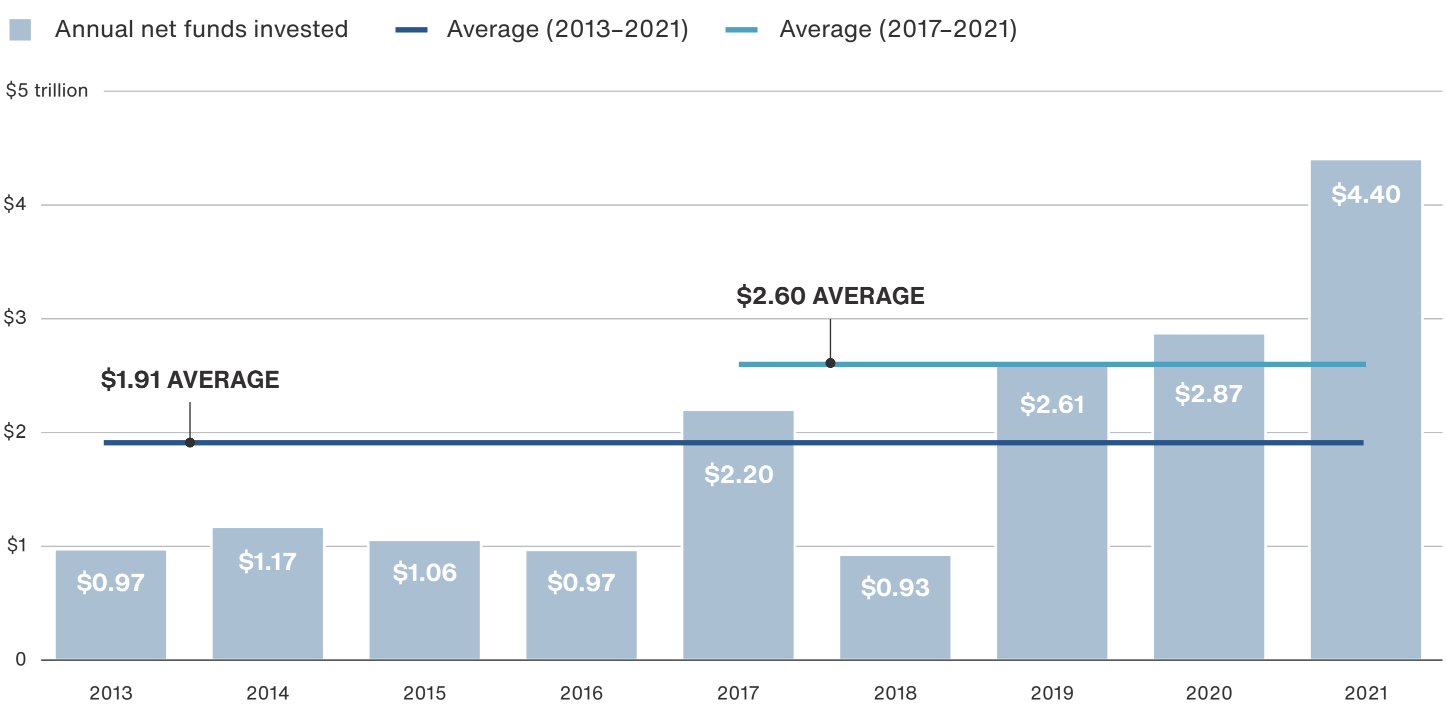
One line of thought posits that decreased fossil fuel infrastructure spending in response to the push for decarbonization investment could materially offset the global incremental $2.9 trillion/year capital requirement. The IEA estimates that total current annual spending on fossil capital expenditure is about $800 billion/ year, meaning that if this figure went to zero immediately, the net annual decarbonization spending requirement would be $2.1 trillion. The IEA's actual projections are a series of stepwise reductions in fossil capital expenditure: $300 billion/year to 2030, $400 billion/year 2031 to 2040, and $500 billion/year 2041 to 2050. What this cost reduction means is that capital diverted from fossil capital expenditure to decarbonization assets can close the annual spending requirement to 2050 from $2.9 trillion to $2.5 trillion (about 15 percent). Figures for the U.S. are more favorable, with reduced fossil spending mitigating 20 percent to 25 percent of the U.S. decarbonization financing requirement.

Comparing the annual decarbonization capital requirements to new investment flows

A primary channel for flowing new global savings into fixed capital asset investments is the professionally managed pools of institutional investor assets. Boston Consulting Group's *annual assets under management (AUM) report* shows net new funds contributed by asset owners, (e.g., pension funds, sovereign wealth funds, and individuals) into accounts managed by professional fiduciaries, such as fund managers and mutual funds. The magnitude of these net new funds averaged $1.9 trillion/year over a nine-year period (2013 to 2021) and $2.6 trillion/year over the most recent five-year period (2017 to 2021; *see Figure 2*).[14] The net annual incremental $2.5 trillion decarbonization requirement is similar in size to the available $2.6 trillion/year of new investable funds flow currently being deployed by institutional investors in *all* of the world's existing investment projects. To be clear, $2.6 trillion is already fully spoken for, being spent on airplanes, semiconductor factories, sewers, current fossil energy, and current clean energy, etc. The implication is that if the decarbonization capital requirement were to be entirely accommodated *without displacing other investments*, new savings flows to institutional investors could need to double to about $5 trillion.[iii]

The foregoing is not meant to suggest that managing the globally required $2.5 trillion is impossible. Instead, the new investment flow data in *Figure 2* underscore the message that this level of net incremental decarbonization spending is considerable in the context of the world financial system's demonstrated capacity. There simply is very little room for error in the types and levels of industrial policies and financial incentives governments around the world need for deep decarbonization.

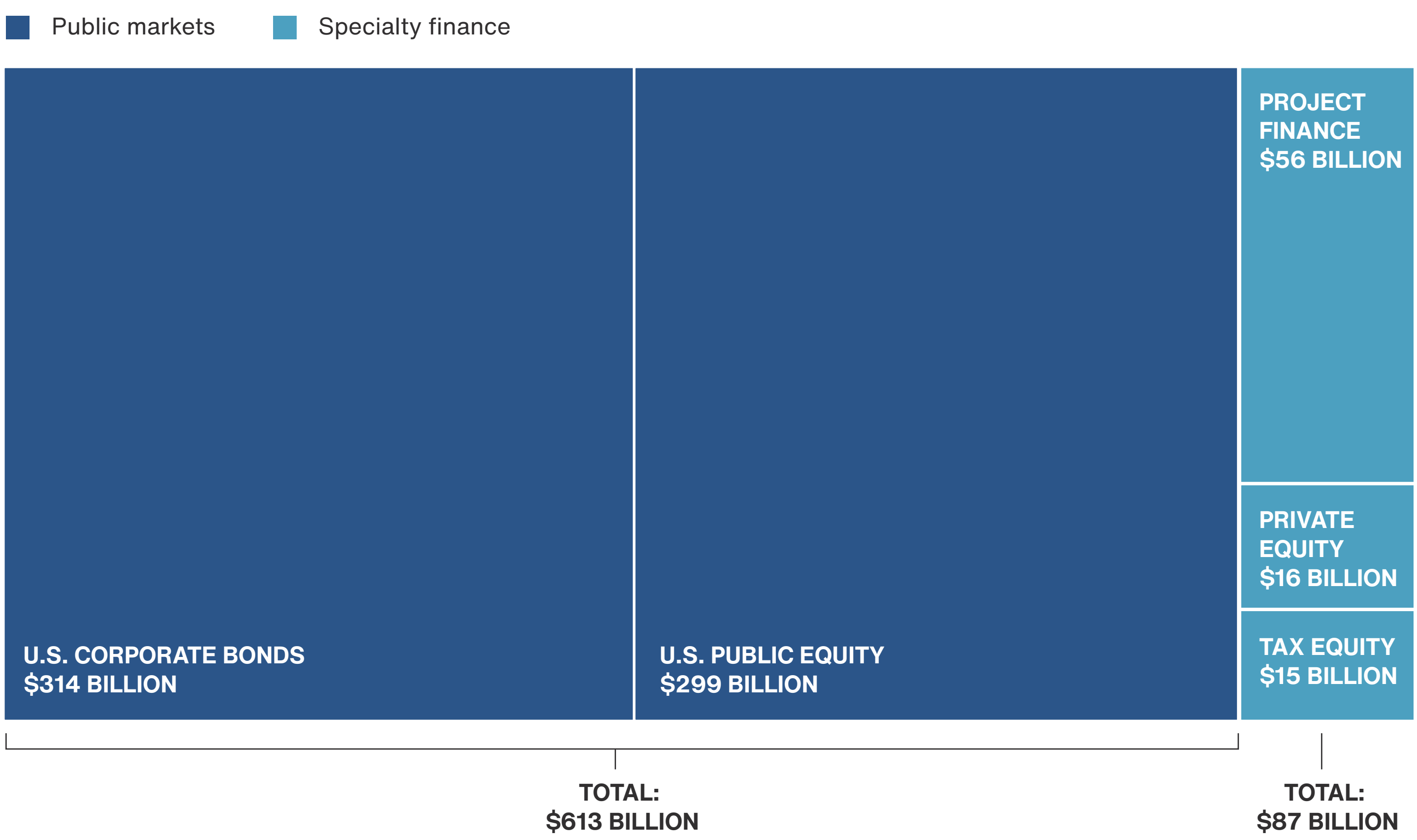
Figure 2: **NET NEW FUNDS FLOW INTO INSTITUTIONALLY MANAGED FUNDS WORLDWIDE, 2013 TO 2021**[15]



iii There are pools of capital outside of the world's institutional capital markets, but many of these pools are not available for long-term decarbonization investments. For example, the pool of individual checking and savings accounts in U.S. banks is arguably more likely to be deployed by banks on secured home mortgages than on business loans to decarbonization projects.

From the perspective of the U.S., current capital market volumes appear to be large enough to accommodate the annual $200 billion to $300 billion financing requirement. The estimate for new funds raised annually in U.S. markets[iv] is about $700 billion/year total (*see Figure 3*). Within that total the niche "specialty finance" markets of project finance debt and equity, tax equity, and private equity—transacting $87 billion/year (average 2017 to 2021) in the U.S.—are too small to by themselves raise an incremental $200 billion to $300 billion/year. The mainstream U.S. publicly issued and traded equity and corporate bond markets totaling $613 billion/year[v] (average 2017 to 2021) seem adequate—but only if decarbonization assets meet the high investment quality standards demanded by the sophisticated institutional investors who dominate these mainstream markets. That is, while the capital requirements for the U.S. are sizable, the dominant issue will be the investment quality of the decarbonization opportunities.

Figure 3: **SIZES OF PUBLIC MARKETS ($613 BILLION), SPECIALTY FINANCE ($87 BILLION), AND EACH OF THEIR CONSTITUENTS, 5-YEAR AVERAGE (2017 TO 2021)**[vi,16,17,18,19]



iv Exclusive of the U.S. Treasury and agency debt markets.
v Exclusive of corporate bond refinancing.
vi Due to data limitations, a 4-year average (2018, 2019, 2020, 2021) is used for U.S. Project Finance.

The U.S. macroeconomic savings/investment context for funding decarbonization

Capital markets are simply the conduit by which financial savings are channeled into new investment of productive capital equipment. An additional perspective on the global and U.S. decarbonization capital requirements of $2.5 trillion/year and $200 billion to $300 billion/year, respectively, is gained by considering global and U.S. statistics on savings and investment. The analysis of these spending levels is made more complex by the distinction between gross investment (or gross fixed capital formation) vs. net investment (or net fixed capital formation). Net fixed capital formation is the gross spending on new equipment, less the amount of capital asset consumption (assets that are at the end of their lifespans or were abandoned because of obsolescence).

On an economywide basis, 78 percent of U.S. fixed capital formation is offset by capital consumption (*see the top portion of Table 1*). Economywide fixed capital formation was $4,942 billion in 2021, but with capital consumption expense of $3,848 billion, the U.S. net fixed capital formation is $1,094 billion. This result, however, is an overestimation of the capital available to fund required decarbonization investments, since it includes the entire economy (including health care, defense, etc.). U.S. figures deriving gross and net capital investment for the macroeconomic sector most relevant to clean energy capital spending, the nonfinancial corporate sector, are provided in the lower half of *Table 1*.[vii] After eliminating federal, state, and local governments, the banking and finance industry, and residential housing, only about $2.2 trillion remains for corporate gross fixed capital formation. After accounting for capital consumption, the nonfinancial corporate net fixed investment available to be deployed toward decarbonization investments is $299 billion to $408 billion (*see also* **Box 1**, *next page*).

Table 1: **ESTIMATION OF U.S. ECONOMYWIDE AND NONFINANCIAL CORPORATE NET FIXED INVESTMENT**

All figures in $2021 billions	Estimate using U.S. Financial Accounts[a]	% of Gross Value	Estimate Using U.S. Net Income and Product Accounts (NIPA)[b]	% of Gross Value
Gross Fixed Capital Investment (Economywide)	$4,942	100%	$4,942	100%
Less Total Capital Consumption	($3,848)	(78%)	($3,848)	(78%)
Net Fixed Investment (Economywide)	$1,094	22%	$1,094	22%
Nonfinancial Corporate Gross Fixed Capital Investment[c]	$2,202	100%	$2,219	100%
Less Capital Consumption[d]	($1,903)	(86%)	($1,811)	(82%)
Nonfinancial Corporate Net Fixed Investment	$299	14%	$408	18%

a Financial Accounts of the U.S. Tables F2 and F103; **b** Financial Accounts of the U.S. Tables F4g, F4c, and F4f; **c** Right side includes REITS, and left does not; **d** Principal difference is that left side includes an extra $95 billion adjustment to capital consumption Table F3 and right does not.

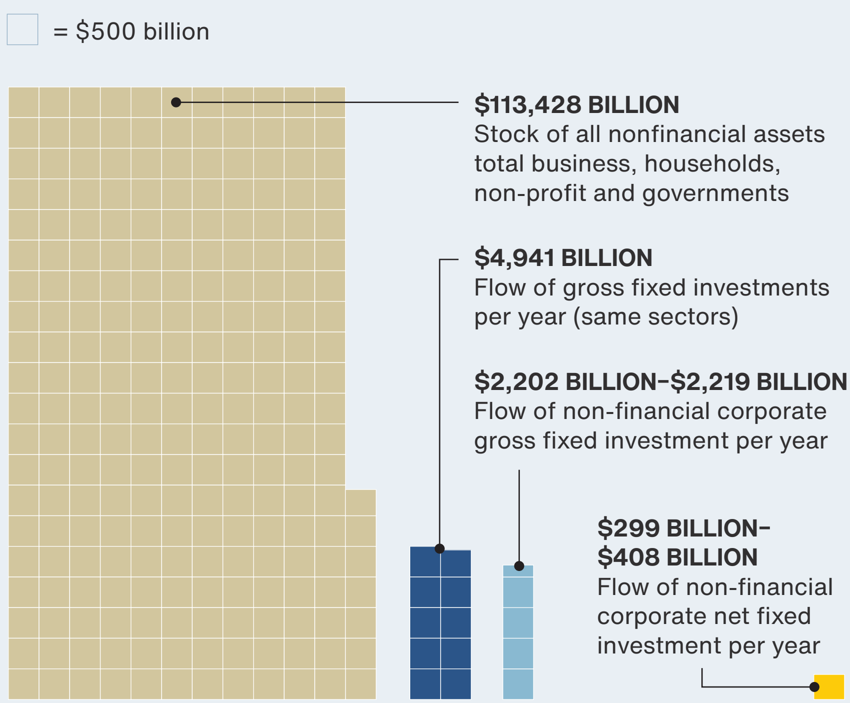
vii Two estimates are provided because the corporate from noncorporate spending is parsed slightly differently given the indicated data sources (U.S. Financial Accounts compared to U.S. Net Income and Product Accounts).

An incremental U.S. annual decarbonization investment of $200 billion to $300 billion would therefore be consequential since U.S. nonfinancial corporate net fixed investment is $299 billion to $408 billion. The conclusion is not that U.S. decarbonization is impossible; instead, it is that, as a nation, a set of tightly focused and highly informed policies is needed to help accommodate decarbonization spending with limited impact on other sectors of the corporate economy.

Box 1:

The decarbonization investment challenge in the U.S. in macroeconomic context: Stocks vs. flows; gross vs. net capital investment

In the National Accounts of the United States, the Federal Reserve shows annual net fixed capital formation (new capital build less allowance for existing capital worn out) in nonfinancial business to be $299 billion to $408 billion in 2021. Understanding that this figure represents net fixed capital flows available to all corporate sectors, not just energy and infrastructure, is essential. That this $299 billion to $408 billion value is only modestly larger than the $200 billion to $300 billion/year incremental investment for decarbonization assets in the U.S. puts the financing challenge into perspective.



Views from Across the Investment Landscape

EF³ undertook several rounds of in-depth, not-for-attribution interviews with corporate executives, financial community leaders, and main stakeholders to identify perspectives on substantial issues and challenges facing the clean energy transition. The interviews sought to garner views across the range of current and potential investor types (*see Table 2*) to develop an understanding of areas of consensus and divergence about why such financial actors participate—or choose not to—in decarbonization investments. More than 90 perspectives were gathered over 70-plus hours of conversation.

Table 2: **ENGAGEMENT IN CLEAN ENERGY INNOVATION BY INVESTOR TYPE**[20]

Investor type	Engagement in clean energy innovation
Venture capital	Interested in early stage investment in companies in return for ownership positions
Strategic capital (corporate investment in technologies)	Emerge as dominant source of funding in the applied research and technology demonstration phases
Private equity	Focus on companies with established revenue streams with opportunities for business performance improvement
Pension funds	Seek stable returns and focus on the deployment stage (with a few exceptions)
Sovereign wealth funds	Have long investment horizons; some have higher risk tolerance for the projects advancing national interests
Other passive investors (banks, insurance companies, mutual funds, or university endowments)	Have interest primarily in economic return at acceptable risk; some have reserve funds for clean energy investment for mostly technology deployment stage
Patient capital (high net worth individuals)	Show willingness to invest in early stage innovation with a high tolerance for risk in the service of broader social objectives

At the intersection of investment and the clean energy transition, five predominant themes emerged:

1. **There is a lack of consensus across financial actors as to the definition of energy transition investments.** Investors employ various nonuniform definitions and screening criteria to include/exclude holdings within portfolios, while a subset may co-mingle environmental, social, and governance (ESG) attributes within portfolio selection, potentially leading to underweighting of energy-related projects. As one asset manager put it: "… probably my biggest challenge is each client views [the energy transition] slightly different in their own world, in their own measures." Interviewees speculated that some of this viewpoint variation may be attributable to investor skill and experience. There was a consensus that while the investment community (writ large) has increased its knowledge base in recent years, it is still at the early stages of building the capabilities to assess the prospects of emerging clean energy transition projects (and carbon markets).

2. **Across many asset owners (including public pension funds and university endowments) and managers, there is a general perception that green investments lead to concessionary returns.** Although venture capital and growth equity investors do not share this view, given their placement within the capital stack, longer-term institutional investors expressed general discomfort justifying the risk-adjusted returns of clean energy projects. One asset owner offered this statement that summarized many views: "We've always gone into infrastructure or green projects somewhat reluctantly because the return profile was too low." Asset managers and asset owners both expressed the struggle of balancing impact—however, measured—with fiduciary duty.

3. **While there was a strong consensus across all financial actors that there is plenty of available capital for "good" (commercialized) projects, there was recognition that there are too few high-quality, investable opportunities.** Most clean energy transition prospects are concentrated in projects such as solar, wind, electric vehicle (EV) charging, and short-duration energy storage (e.g., lithium-ion battery), leading in some cases to depressed returns (risk-adjusted). Even so, asset managers are scrambling to place such opportunities within portfolios to meet the ESG investment trends, especially demanded by European asset owners (as they are generally seen as climate leaders compared to their U.S., Asian, and South American counterparts, though this trend is evolving). Conversely, other kinds of opportunities do not exhibit agreeable risk-adjusted returns and are not receiving adequate funding (e.g., carbon management, advanced nuclear, long-duration storage, etc.). While there is some indication that the sheer volume of capital flowing to decarbonization projects is causing a minority of institutional investors to become marginally more comfortable with risk exposure of new technologies, one asset manager put it succinctly: "… [If] a project [is] having difficulty finding capital, I think there's something wrong with the project."

4. **Scaling technologies to commercial solutions remains a crucial barrier to certain solutions (e.g., carbon management, hydrogen, advanced nuclear, etc.) gaining access to large pools of capital.** There was an asset manager preference for smaller projects with lower capital costs that may also be amenable to rapid cost reductions through experience effects. As such, there was an emphasis on and interest in modular technologies (e.g., hydrogen production via hydrolysis, small modular nuclear reactors, and landfill gas capture opportunities). However, there was a persistent gap between solutions deployed at the pilot level and commercialized ones. Post-venture debt and equity investors are looking for 18 to 60 months of operational data on two to three facilities in locations close to operational scale to begin to become commercially comfortable with a technology/decarbonization solution. All financial actors that operate within the commercial solutions space questioned how these credible technology track records could be created in the near term.

5. **There is a strong consensus that the public sector needs to take the lead with supportive policies, mechanisms, and investments to induce more considerable capital flows.** All financial actors seek clear and durable signals that reduce the hold-up problem. As one asset manager asserted: "We think eventually, governments will be much more directive in terms of where capital needs to go for proper decarbonization." Indeed, public support takes multiple forms:
    - **Infrastructure:** The private sector alone cannot build the required infrastructure, bridging supply and demand for clean energy.
    - **Guidance:** Multiple investors called for industrial policy to set a direction so they can then allocate capital accordingly ("react and realign").
    - **Support:** There is a need for durable financial incentives usable by a variety of capital providers (e.g., direct pay tax credits, incentives for tax-sensitive entities, etc.), coupled with market rule updates that increase the returns for decarbonization assets (e.g., clean firm dispatch rules).
    - **Demonstration:** More and broader use of public funds is needed to develop credible technology/solution track records, especially for first-of-a-kind (FOAK) deployments (e.g., greater capacity for the U.S. Department of Energy (DOE) Loan Program Office (LPO) and greater demonstration appropriations building on top of the Bipartisan Infrastructure Law, CHIPS and Science Act, and Inflation Reduction Act).

Synthesis: The Investment Challenges to Clean Energy Scale-Up

Given the scale of capital expenditure required to achieve near-term and midcentury decarbonization goals in the U.S. and globally, coupled with investor perspectives across the capital stack, five facets of the investment challenge of clean energy scale-up emerge.

1. Accelerating deployment of existing commercial clean energy technologies

Investment in currently available clean energy technologies needs to increase the deployment rate by two to three times the historical trend; this increase will strain further application of previously successful business models. Establishing the trajectory to reach net zero by midcentury requires substantial progress in this decade, such as the goal announced by the Biden administration to achieve a 50 percent to 52 percent reduction in net greenhouse gas emissions by 2030 (relative to a 2005 baseline). Various modeling analyses agree on the need for dramatic scaling up of the deployment of solar, wind, and batteries to achieve the 2030 emissions reduction goal. Depending on scenarios, the solar and wind deployment scale may have to quadruple by 2030 compared to the current level.[21,22,23]

Achieving the necessary buildout rate will challenge conventional business and finance models. For example, additional large-scale buildout of onshore wind and solar will have to expand into areas that also will require new high-voltage and interstate long-distance transmission, raising issues with permitting and cost allocation.[24] Expanded deployment of solar energy will require expanded investments in distributed solar and battery storage facilities (e.g., commercial, industrial, and residential rooftop deployments.) New business models may be needed to facilitate pooling these investments into investable packages. For offshore wind, early deployments will need to incorporate transmission links to existing onshore transmission systems. This linking could involve utilizing transmission assets from retiring fossil fuel generating stations. As offshore wind moves toward gigawatt-scale deployment, a new backbone transmission system may be needed.

Policies must consider and address the entire value chain for deploying these technologies or risk shifting bottlenecks to elsewhere in the value chain. For example, tax incentives for solar and wind have resulted in meaningful investment interest in deploying renewables, yet shovel-ready projects must wait years to connect to the grid because transmission and distribution systems cannot handle the new resources.

A 2022 study from Lawrence Berkeley Laboratory reported interconnection queues of 1,400 GW of generation and storage capacity—93 percent of which included solar, battery storage, and wind energy—yet the Federal Energy Regulatory Commission reported those resources must wait an average of three years to connect to the grid.[25,26]

2. Commercializing advanced decarbonization solutions

Substantial investments and new public/private partnerships will be needed to commercialize advanced technologies with breakthrough potential, raising their investment quality. Breakthrough potential is measured along technical merit, market viability, compatibility (with existing systems), and consumer value/demand. Commercialization efforts (e.g., addressing technology risk, engineering risk, etc.) must be targeted appropriately to improve each dimension. Institutional investors find it challenging to justify the risk-adjusted returns of clean energy projects deploying innovative technologies, especially those that have yet to reach technical maturity.[27]

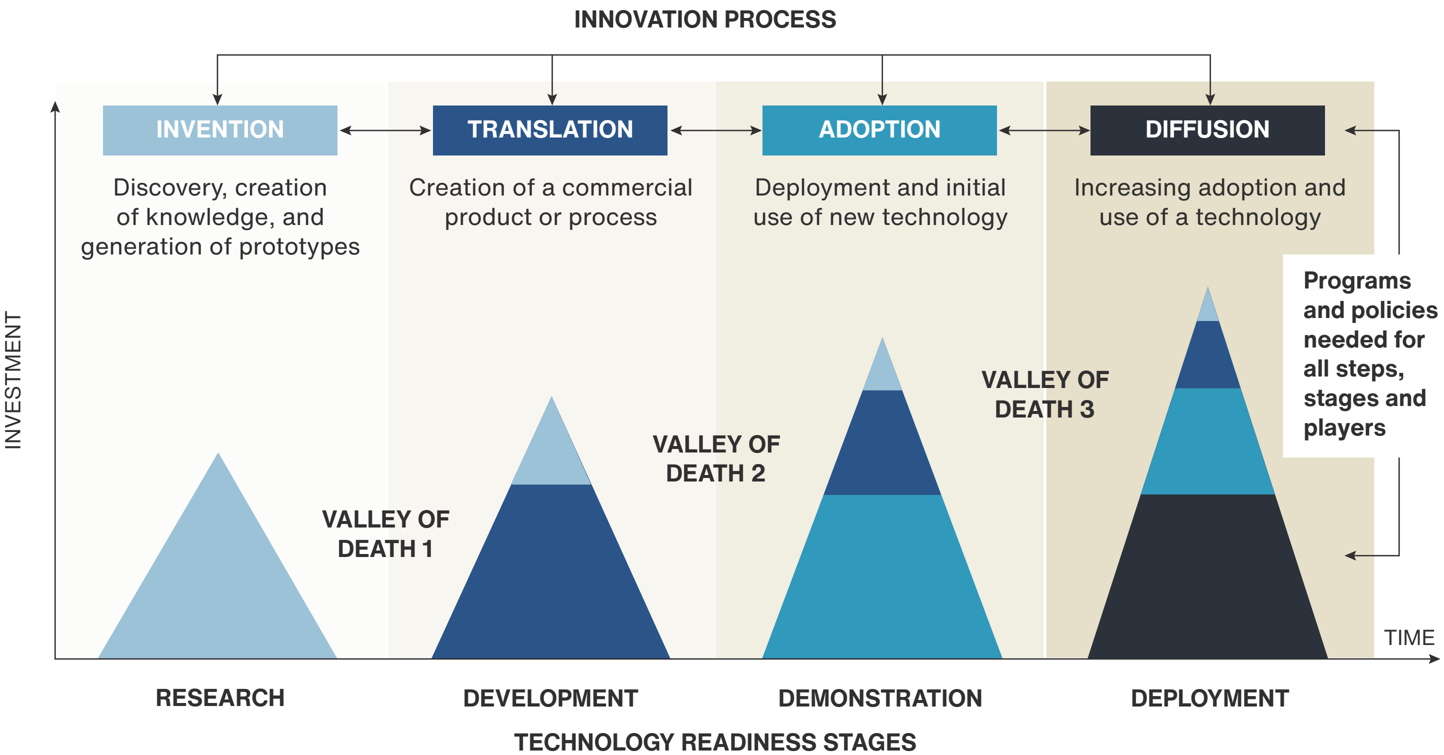
Meeting net-zero GHG emissions goals by midcentury will require going well beyond the scale-up of wind, solar, and batteries. It will require accelerating the development, demonstration, and ultimate deployment of various advanced technologies, including those with breakthrough potential. The International Energy Agency (IEA) estimates that as much as 34 percent of the net GHG emissions reduction by 2070 will require deploying technologies that are currently in only the prototype or demonstration phase.[28] Examples of breakthrough technologies and systems include:

- Longer-duration (daily, monthly, and even seasonal) energy storage technology options
- Very low global warming potential (GWP), ultra-high efficiency space heating and cooling
- Clean firm baseload power, such as advanced nuclear reactors and utility-scale geothermal
- Carbon management (carbon capture, use, and storage at scale; carbon dioxide removal; sunlight to fuels; biological sequestration)[29]
- Hydrogen-based energy carriers and fuels—including production of clean hydrogen and consumption for both heat and power applications
- Advanced grid management systems orchestrating diversity of distributed smart electrified loads and sources of supply

Since most of these technologies and systems are not fully mature, scaling up the deployment of these solutions and systems requires both federal support and the collaboration of public and private entities to mitigate technical challenges and risks (*see* **Figure 4**, *next page*). More specifically, many of these technologies have made great progress in laboratory proof of concept and in modestly sized demonstrations in the field, but generally have not yet reached the point of full-scale technical demonstration or initial commercial deployment. Recent legislation has empowered DOE to provide greater support for demonstrations and early commercialization by establishing such organizations as the Office of Clean Energy Demonstrations and bolstering the LPO capacity and breadth to finance promising projects.

Figure 4: **MOVING INNOVATIONS TO MARKETPLACE**[30]

Innovations move into the marketplace through a system of invention, translation, adoption, and diffusion. Technology readiness stages of innovation include research, development, demonstration, and deployment. This system and these stages require collaboration among numerous players, and the process can be nonlinear, often involving feedback gathered from learning by doing and using, which promotes continuous improvement. Appropriate funding is required to ensure promising solutions move through the system, the absence of which is known as the investment valley of death.



Note: Adapted from source: Energy Futures Initiative (EFI), 2018. Modified from Moniz, "Stimulating Energy Technology Innovation."

3. Defining decarbonization solutions clearly and consistently

In addition to economic considerations, accurate, consistent, and transparent measures regarding lifecycle GHG emissions are needed to assess the potential of clean energy investment opportunities. A focus on the measurement of lifecycle emissions has recently gained prominence following the passage of the Inflation Reduction Act (IRA), which included fees for methane emissions and lifecycle GHG emissions eligibility criteria for certain tax credits. This change is important because financial actors, regulators, and interested stakeholders often use differing impact metrics to assess the real and potential decarbonization attributes of a project or venture. The result is increased friction across parties, raising another barrier to the funding of a wider set of potential decarbonization solutions and increasing accusations of "greenwashing."

To better inform policies for incentivizing private investments in climate change mitigation, transparency of the methodologies used to determine and assess the emissions associated with essential technologies, infrastructures, supply chains, and a range of products and services is needed. These methodologies, including the range of data that support them, also must be translated into policies that ensure their accuracy and use by investors and corporations.

Requirements for such transparency are increasing. The EU, for example, promulgated a taxonomy for sustainable activities that required by the end of 2021 that "investors that offer funds in Europe described as 'environmentally sustainable' will need to explain how, and to what extent, they have used the taxonomy in determining the sustainability of the underlying investments. Such investors also must disclose the proportion of underlying investments that are taxonomy-aligned as a percentage of the investment, fund, or portfolio."[31]

In this context, in March 2022, the U.S. Securities and Exchange Commission proposed rule changes that would require a publicly traded company to include climate-related disclosures in its registration statements and annual reports to provide investors with consistent and comparable information for making investment decisions, as well as to provide consistent and clear reporting obligations for companies. The required information would include the company's governance of climate-related risk management and the impacts of climate-related risks on the company's business and financial statements, as well as direct and indirect GHG emissions (Scope 1 and 2), and emissions from upstream and downstream activities in its value chain (Scope 3) if the company has a Scope 3 emissions target. Overall, this proposed rule has received generally positive reactions from businesses and investors. Concerns have been raised, however, about operational issues of the rule, such as the inclusion of Scope 3 disclosure requirement and emissions measurement methodologies.[32]

4. Developing policy mechanisms to enhance decarbonization technology adoption

Policy mechanisms are needed to address the commercialization and scale-up, revenue, regulatory, infrastructure, financial, and reputational risks faced by decarbonization project developers and their associated investors. Addressing these risks requires wide-ranging government actions. These actions could include a focus on introducing new or revising existing policies/regulations that are aligned and coordinated with energy, environmental, and economic development goals. Such actions would be specifically designed to provide clear, predictable, and reliable investment signals to the market.

Economywide carbon charges have been advocated by economists as the most cost-effective approach for achieving deep decarbonization. A 2020 report by the Commodity Futures Trading Commission concluded that financial markets can efficiently channel resources to reduce GHG emissions only if an economywide price on carbon is in place that accurately reflects the social cost of emissions.[33] An economywide carbon charge would mobilize market forces to pursue least-cost solutions and motivate innovators to develop and provide new marketable solutions.

Such an economywide incentive does not exist in the United States. As such, proxy policy measures, such as federal efficiency standards and tax incentives, coupled with state and regional-level mandates, will need to be continued and expanded. Examples include the recently enhanced 45Q tax credit, which provides a credit of up to $85 per metric ton of CO_2 captured and stored, as well as recent announcements by California and New York that all new light-duty vehicles must be electrified by 2035.[34] In addition, expanded concessionary, first-loss, and low-cost public capital tools, such as commercialization and small-business grants, federal and state-level green banks, and the LPO program are needed. All these mechanisms—and more—are necessary to create and sustain the incentives necessary to progressively increase investor confidence in decarbonization assets.

5. Mapping and addressing greatest bottlenecks in clean energy value chains

The clean energy transition will require evolution and diversification of business models and supportive policies that address the entire value chain and are responsive to regional variations. The actions for energy transition must consider, address, and accommodate the interdependent challenges associated with infrastructure, supply chains, security risks, and resilience needs of energy systems, as well as the dynamics of energy industries and firms.

New clean energy technologies cannot make progress in isolation; rather, they depend upon extensive value chains, including upstream supplies of components and commodities, and downstream transport and infrastructure. Technologies cannot be scaled up without well-established infrastructure and supply chains. Primary issues of the safety and reliability of energy systems pose challenges to clean energy technologies to demonstrate that they do not compromise or adversely impact these essential requirements.[35]

Related issues include addressing the cybersecurity of physical and digital infrastructure; securing supply chains for essential metals and minerals needed for clean energy technologies and reducing their emissions to meet net-zero targets; and protecting intellectual property. Moreover, many of the issues faced by the energy sector are also highly regional in nature and would be better managed by strategies tailored to each region's specific needs. Noteworthy regional variation also exists in energy-use market applications. For example, more than half of the manufacturing industry subsector is concentrated in eight states.[36]

In many instances, the accelerated deployment of technologies will require a re-thinking of market structures and the roles of market stakeholders. The increase in distributed energy resources, for example, challenges the business models of traditional electric utilities. The energy transition also will require policies to address industrial organization (i.e., firm behavior and industry dynamic), including options for addressing the interdependent challenges that arise from infrastructure, supply chains, security risks, and resilience needs of energy systems.

Energy Futures Finance Forum: Developing Policy Roadmaps to Increase Decarbonization Investment Quality

EF³ examines policies through the lens of a private investor, because—as is highlighted in this discussion—without substantial investment in decarbonization assets by such private actors, there is little chance of aggregating and investing the resources needed to meet U.S. decarbonization goals.

To be clear, the focus of this effort is on investors, not speculators—market actors that invest in blue chip, high quality, debt, and equity instruments. The attraction of institutional investors to blue chip investments is primarily driven by regulatory constraints and considerations, not preference. The regulatory regimes constraining these investors include, for example, the Employee Retirement Income Security Act of 1974 (ERISA) for public pension funds; a variety of insurance company capital adequacy regimes coordinated through the National Association of Insurance Commissioners; the 1940 Investment Company Act for mutual funds; and a variety of specific restrictions on institutional investor participation in partnerships and limited liability companies.[37]

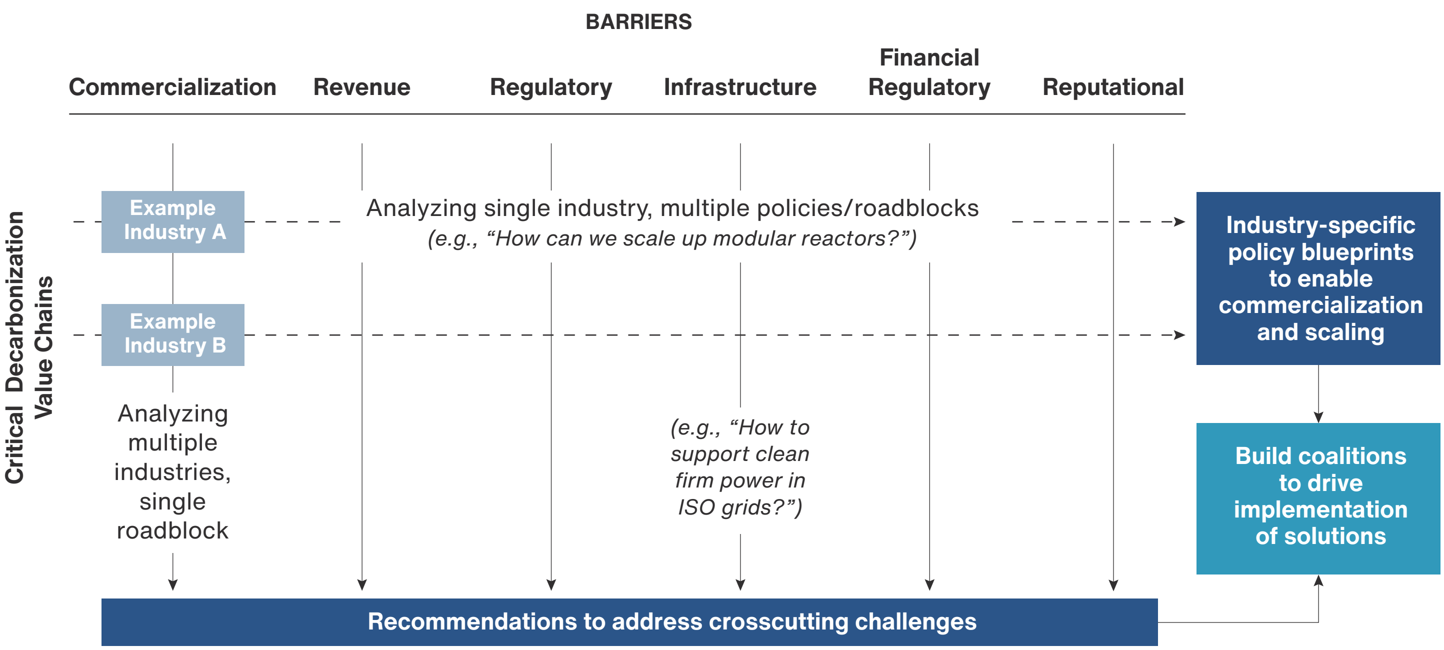
At the same time, policymakers are the most important audience of EF³'s analysis. The policy recommendations by EF³ are designed to help mitigate policy and regulatory hurdles that currently reduce the flow of institutional investor-controlled capital to mission-critical, decarbonization assets. Put succinctly, by focusing on investor needs, constraints, and options, EF³'s analysis and associated policy recommendations will be designed to ensure that pivotal decarbonization technologies and projects are also blue-chip financial investments.

EF³'s analytical approach iteratively examines the roadblocks to decarbonization investment from two vantage points (*see* **Figure 5**, *next page*). The first area of focus is on the multiple barriers across a technology-specific industry value chain (e.g., carbon capture and storage (CCS), advanced nuclear, hydrogen, etc.) EF³ will produce policy blueprints for at-scale deployment, centered on a prioritized agenda of minimum federal/state policy changes and minimum expenditures required to sufficiently increase investment quality of projects across the industry value chain. The second area of focus will be on crosscutting issues that affect many industries' value chains (e.g., tax incentive structure, infrastructure permitting, international carbon levies, etc.)

Each of these areas of focus has discrete merit. The best approach, however, is to view them as mutually reinforcing. The industry approach permits EF³ to mobilize groups of experts with deep industry-specific expertise, developing solutions that comprehensively address the needs of that industry. The multi-value chain approach to problem areas that cut across many decarbonization industries will help EF³ develop policy recommendations that meet the goal of technology neutrality and address the need for all-of-the-above technologies and projects that are pivotal to principal regions of the U.S. and the world.

Figure 5: **EF³ ANALYTICAL APPROACH**

The analytical approach of the program iteratively examines the roadblocks to decarbonization investment from two perspectives: an industry value chain perspective ("horizontal" analysis) and a crosscutting perspective focused on common barriers common to multiple industries ("vertical" analysis).



Perspective One: Technology-Specific Value Chains Analysis

EF³'s first perspective focuses on individual technology systems and their associated value chains that need to be fully scaled up to help achieve deep decarbonization. From a project finance/corporate capital allocation perspective, a six-risk dimension diagnostic will be applied to each link in an industry value chain.[viii] These risks are commercialization, revenue, energy/environmental regulatory, infrastructure, financial regulatory, and reputation (*see Box 2*). This horizontal industry-by-industry approach is essential for identifying all the steps in a single value chain, from upstream materials and component supply to construction, operation, and sales contracts for the main industrial asset to downstream infrastructure for transporting/disposal of products and waste materials. If one link in the chain is weak or broken, the entire value chain will lose access to the broader public markets and project finance.

Box 2:

The six investment risk diagnostic: How investors assess decarbonization opportunities

When assessing a decarbonization opportunity, the ultimate private capital decision-makers—capital commitment committees, investment committees, and/or board of directors—consider the project/investment itself, along with the interconnected upstream and downstream supply chain and customer base. These capital decision-makers use a broad set of criteria to determine the extent to which an investment strikes the right risk/reward balance according to their preferences and constraints. Central to this process is the identification and diagnosis of risks that exist along the entire value chain of an opportunity. If any one of these risks, wherever located in the value chain, is deemed too great given the expected returns, then the opportunity is rejected. The six risk dimensions considered are:

1. Commercialization risk: Is there a commercial deployment track record?
2. Revenue risk: Are there sufficient/stable revenues?
3. Energy/environmental regulatory risk: Are there changeable policies or daunting hurdles?
4. Infrastructure risk: Are there network or services limitations?
5. Financial regulatory risk: Is there unfavorable tax or financial regulatory treatment?
6. Reputational risk: Are there looming issues surrounding the social license to operate?

viii EF³ will frequently cite the ability of a decarbonization project asset to successfully project finance as a litmus test for policy. The term of art project finance means raising debt and equity solely based upon the creditworthiness and cash flow generation of a standalone energy, pollution control, transportation, or infrastructure project. Indeed, not all decarbonization assets will be financed as standalone projects in public capital markets. To the contrary, many decarbonization assets will be built in reliance upon the strength of a large corporate balance sheet, being evaluated in the internal capital markets of corporate capital allocation committees. However, project finance is still a valid litmus test. If a large corporation internally finances numerous projects that individually are too speculative to be financed externally, it will ultimately pay a severe price in terms of debt rating downgrades and poor stock price performance.

The horizontal, single-industry studies will focus on the commercial and pre-commercial technologies that can accelerate the trajectory toward major decarbonization by 2030 and onward to 2050 (*see* **Box 3** *for an example, page 31*). These solutions could include those that are technologically mature and ready to be deployed at scale (e.g., scaling renewables to hundreds of gigawatts in the U.S., broad electrification of transportation, etc.), as well as advanced technologies that are less mature but have the breakthrough potential to enable achievement of net-zero targets by midcentury (e.g., gigaton-scale technology-based carbon dioxide (CO_2) removal solutions, CCS, advanced small modular nuclear reactors, hydrogen, etc.)

Essential to these horizontal analyses will be the explicit consideration of three deployment thresholds that connote increasing levels of system maturity on the road to full commercialization. These are:

1. **First-of-a-kind (FOAK):** Includes technology licensing, completion of detailed engineering design, construction, and operation of a given design. FOAK is otherwise understood as "Serial Number 001" for a given design or industry application.

2. **Next-of-a-kind (NXOAK):** Includes the several projects (of a given design or industry application) that follow the FOAK (likely another two to four projects, for a total first generation of up to five projects) that are sufficient to:
    - Eliminate investor concerns regarding technological failure
    - Allow engineering, procurement, and construction (EPC) entities to offer reasonable, bankable commercial terms on lump-sum-turnkey construction contracts
    - Enable component/assembly suppliers to formulate manufacturing facility plans and designs for future scaled-up deployment

3. **Nth-of-a-kind (NOAK):** Includes projects that are fully commercialized because of the experience gained through the FOAK and NXOAK stages, with costs beginning to approach long-run trajectories given learning effects, supply chain establishment, and the availability and use of dedicated manufacturing capabilities.

It is crucial that government policies and support mechanisms are formulated and implemented to demonstrate coordinated support that will propel a technology sequentially through the FOAK, NXOAK and NOAK stages of technology deployment. This consideration is required to build a durable trajectory and sufficient investor confidence to see a technology through to cost-effective implementation at scale.

The Six Investment Risk Perspective Explained

Commercialization risk: Is there a commercial deployment track record?
Commercialization risks encompass the challenges of creating a proven track record of commercial deployment due to a variety of reasons. These include the technology and engineering risks from subsystems, the integration of subsystems, and the demonstration of manufacturing or operation at sufficient scale and duration. Overcoming these risks involves developing a track record sufficient to obtain bankable EPC contracts and/or neutralize financier concerns about asset reliability risks.

Indispensable to developing such a track record is understanding the kind, depth, variety, and source of performance and other information required to reach a level of commercial comfort for investors. Proven commercial deployment requires the construction and operation of enough full-sized units that contractors no longer feel compelled to include price premiums to address construction uncertainties, typically in the 20 percent to 30 percent range. Also, proven commercial deployment means that lenders and investors are willing to accept normal industrial capital project interest rates and equity rates of return. Given these conditions, a wide portfolio of policy measures may be required for a technology to reach the commercialization stage (i.e., so that at-scale manufacturing is consistently achieved or capital facilities transition from FOAK to NOAK installations.)

Revenue risk: Are there sufficient/stable revenues?
Revenue risks are defined by the challenges of securing stable and sufficient revenues to cover debt serving and return capital and margin to equity investors. Even if an industry reaches successful first-generation commercial deployment, it still may not generate sufficient revenue to attract private investments for a variety of reasons. These include the lack of long-term sales contracts, regulatory and ownership models, and challenging federal incentive structures.

Since there is no nationwide or stable carbon tax, cap-and-trade regime, or carbon emissions compliance limits in the U.S., a stable revenue source must be found to pay for the additional costs of abating or emitting carbon. This source will entail identifying the drivers of revenue for each technology and the adequacy (or inadequacy) of these revenues to enable widespread financing of new assets once initial commercialization is achieved. Moreover, this revenue characterization must be coupled with a full understanding of credit standards sufficient to garner conventional lending and investment quality standards for full public equity markets access.

Energy/environmental regulatory risk: Changeable policies or daunting hurdles?

To scale and accelerate technology deployment, the issuance of relevant licenses and permits needs to be facilitated to ensure projects can be constructed and operated for, at a minimum, the life of the expected debt payment. This guarantee includes both scenarios where the technology solution is a new build (greenfield) as well as a retrofit or repurposing of existing infrastructure. While the former is important for most clean energy supply technologies, the latter is essential to decarbonized end uses, such as building energy efficiency retrofits, industrial process greenhouse gas (GHG) control technologies, and expansion of charging and refueling infrastructure within the greater built environment. Other regulatory risks include incomplete or future-contingent regulations that do not provide a stable signal for how actions may be rewarded or penalized, for example, specific Internal Revenue Service rules concerning the transferability of tax credits among various tax-paying and tax-exempt entities because of the IRA.

Infrastructure risk: Are there network or services limitations?

A lack of infrastructure, or development risk of building infrastructure, can increase technology deployment costs and pose other risks to project implementation. Since infrastructure investments are capital intensive, with a long tail of expected revenue to recover capital and generate return, public support plays a crucial role in their development. This support is especially vital if demand for the services that infrastructure may provide (e.g., CO_2 or H2 transportation via pipeline) has not been established at scale but could develop for said infrastructure—in short, solving the so-called chicken and egg problem.

Financial regulatory risk: Unfavorable tax or financial regulatory treatment?

Even if an industry has a favorable risk-to-reward profile, specific financial regulation risks can constrain investments made by large capital pools such as foreign sovereign wealth funds and public pension funds, domestic pension funds (public and private), charitable foundations, university endowments, and family offices. These asset owners combined account for $40 trillion (AUM)[38] and represent an investor class that would otherwise be interested in both higher risk-adjusted returns/earlier stage commercial solutions and lower risk-adjusted returns/fully commercialized technologies as part of a balanced portfolio. However, U.S. IRS rules pertaining to some tax-exempt entities, foreign entities, and passive investors, among others, limit the attractiveness of certain kinds of investments, or make deal structuring overly complex.

Reputational risk: Are there looming issues surrounding the social license to operate?

Sometimes, financing barriers may not originate from formal regulatory issues but may, instead, be from issues surrounding reputational concerns, public perceptions, or the social license to operate. Financial institutions may be discouraged from investing in mission-critical decarbonization assets that are controversial in the popular press, and/or among primary stakeholders or local community interests. For example, the treatment of social and environmental justice is important for characterizing investments. In the absence of clear, well-accepted, science-based standards for life cycle emissions, good technologies may be blocked because of reputational risks and concerns. Even with good data in hand, legitimate questions concerning process, stakeholder participation, community preferences, and inclusive benefits of decarbonized projects and activities can hold up or block technology scale-up. Developers (and by extension investors) and policymakers have a vested interest in fair and equitable clean energy construction, a range of retrofits and the decommissioning of obsolete infrastructure to advance the energy transition.

Box 3:

Technology-specific value chain analysis in action: Turning CCS projects in heavy industry and power into blue chip financial investments

As a pilot project, EF³ applied a technology-specific value chain analysis to carbon capture and storage (CCS). CCS—the capture of point source emissions and permanent storage in geologic formations—is an essential component within a portfolio of decarbonization solutions. CCS can materially reduce the overall cost of achieving U.S. decarbonization goals. It can be deployed across various power and industrial applications, helping multiple sectors support the overall decarbonization mission. All the basic elements of the CCS value chain—capture, transport, deep underground injection, and ongoing monitoring—have been deployed in various commercial applications in the U.S. for decades. Yet, despite existing capabilities, CCS progress to date as a decarbonization solution in the U.S. has been disappointing.

The study identifies six broad themes regarding the investment challenges for CCS that are consistently raised by project owners, developers, and investors. These themes are a mix of supply- and demand-side issues (commercialization, revenue, and financial regulatory risks); informational and industrial coordination barriers (energy/environmental regulatory and infrastructure risks); and environmental and economic justice concerns (reputational risks).

In response to the barriers identified, the study makes several policy recommendations to address these challenges and attract private capital. These include:

- Target Bipartisan Infrastructure Law (BIL) commercialization grant funds to the first three-to-five installations in core industries to supplement the current $85/metric ton tax credit, essentially providing low-cost equity to first movers (commercialization risk mitigation)
- Design 45Q direct pay and transferability provisions of IRA to help bring a broader range of new buyers into the market (revenue risk mitigation)
- Consider expanding the pool of eligible entities able to make use of all clean energy tax credits (financial regulatory risk mitigation)
- Create a per-state coordinating body to manage all state-level CCS regulatory interfaces including facility siting, eminent domain, pore space unitization, and long-term liability requirements (energy/environmental regulatory risk mitigation)
- Encourage congressional consideration of authorizing innovative public-private partnerships (including federal ownership stakes) in FOAK CCS pipeline and carbon storage infrastructure (infrastructure risk mitigation)
- Develop public direct funding for the capacity building of communities to lead the negotiation of community benefits agreements with CCS developers (reputational risk mitigation)

Perspective Two: Crosscutting and Industrywide Barriers

The second EF³ analytical approach examines crosscutting issues that impact investments across technology-specific value chains. Crosscutting issues may be wide in scope, such as perceptions about land use, or narrow in scope, such as the supply of copper needed in vastly increasing quantities by multiple clean energy value chains. Moreover, crosscutting issues exist within complex sociotechnical, political, and economic systems and may or may not originate or be contained within the energy sector. For example, the fiduciary requirements of domestic private pension funds, which cause restrictions in investment participation in early-stage clean energy projects, is an unintended consequence of ERISA.

For any barrier identified for a specific decarbonization project, there will be instances in which similar root-causes contribute to challenges across technologies and systems. One example of this scenario is found in the architecture of competitive wholesale markets, where current designs do not fully recognize the value of clean, firm baseload power, thereby reducing the demand signal for such solutions, examples of which include advanced nuclear, geothermal, and fossil-based generation coupled with CCS. At the same time, the implications of proposed solutions to crosscutting barriers may differentially result in a mix of intended and unintended outcomes for each technology-specific value chain. Returning to the competitive wholesale market example, how dispatchable clean power is valued will affect the investment case of any proposed generation project depending upon the combination of compensation levels, future mix of generation in a region, project operational capabilities, etc. Taken together, the breadth of crosscutting issues, and the effects of the solutions developed to address them, are of material consequence to the investment quality of current and proposed decarbonization projects.

Three additional and particularly prominent crosscutting issues include the consumption and structure of tax credits—especially given the passage of the IRA—infrastructure permitting, and carbon border adjustments.

- **Tax credit consumption and structure:** The passage of the IRA will lead to an expansion of the clean energy corporate income tax credit market from about $10 billion per year (2021 and 2022, measured in terms of cost to the Treasury in forgone tax revenue) to about $34 billion per year in 2031.[39] This $245 billion is incremental to the Office of Management and Budget's earlier estimate of approximately $572 billion of expected budgetary expense for pre-IRA programs that will occur over the same period.[ix] Attracting new participants to make use of transferred tax credits, thereby creating new sources of financial capital for U.S.-based clean energy projects, should be a priority for policymakers and regulators. In some instances, the current pool of tax credit consumers may have limited capacity to monetize additional credits, given a combination of relatively low corporate tax rates, coupled with longstanding federal limitations on a corporation's pre-credit federal tax liabilities that can be offset using corporate tax credits. In principle, there is more than enough remaining taxable corporate income across all sectors of the U.S. economy to fully take advantage of

ix Estimate extracted by summing corporate tax credit expense as shown in https://www.whitehouse.gov/omb/budget/analytical-perspectives/.

the new tax credit supply generated by IRA and other legislation. However, most of these firms are not familiar with federal clean energy tax credits and there will need to be a rapid capacity-building effort across the tax credit market to address this issue. Further, tax-exempt pension funds and charitable foundations are unable to directly participate in the tax credit market, thereby holding up large pools of capital from being deployed toward decarbonization assets. Tax-exempt pension fund and foundation fiduciaries have the financial sophistication to use tax-credits, but without the ability to access direct pay provisions and with no direct taxes owed to the federal government, they cannot easily use traditional noncash tax credits.

- **Infrastructure permitting:** Irrespective of the kind of clean energy or decarbonization facility proposed for development, there exists a thicket of federal, state, local, and tribal regulations that also holds up infrastructure buildout. One example is high-capacity, long-distance transmission lines where contention often relates to where such infrastructure can and should be built and how benefits will be allocated. For any proposed project, hold-ups can occur at local, state, and/or federal levels over concerns regarding environmental impact, aesthetics, property rights, etc. Limitations on the availability of connective infrastructure such as transmission lines pose a first-order risk to the economic viability (and thus investment quality) of projects like utility-scale solar and wind, whose anticipated operation date is delayed due to interconnection backlogs or whose generation may be curtailed during operation given insufficient line capacity to meet demand. Care is required to consider the needs and preferences of those affected by such projects, such as proximate communities, local and regional environmental concerns, and the requirements to rapidly expand such infrastructure to meet various decarbonization goals. The BIL and IRA have taken steps to address issues surrounding infrastructure permitting (including and beyond electricity transmission), in addition to proposed reforms by the Federal Energy Regulatory Commission, (e.g., to address the interconnection queue backlog.) Further legislative and regulatory actions are needed, however, to substantially allay the infrastructure risk tied in some respects to almost all decarbonization investments.

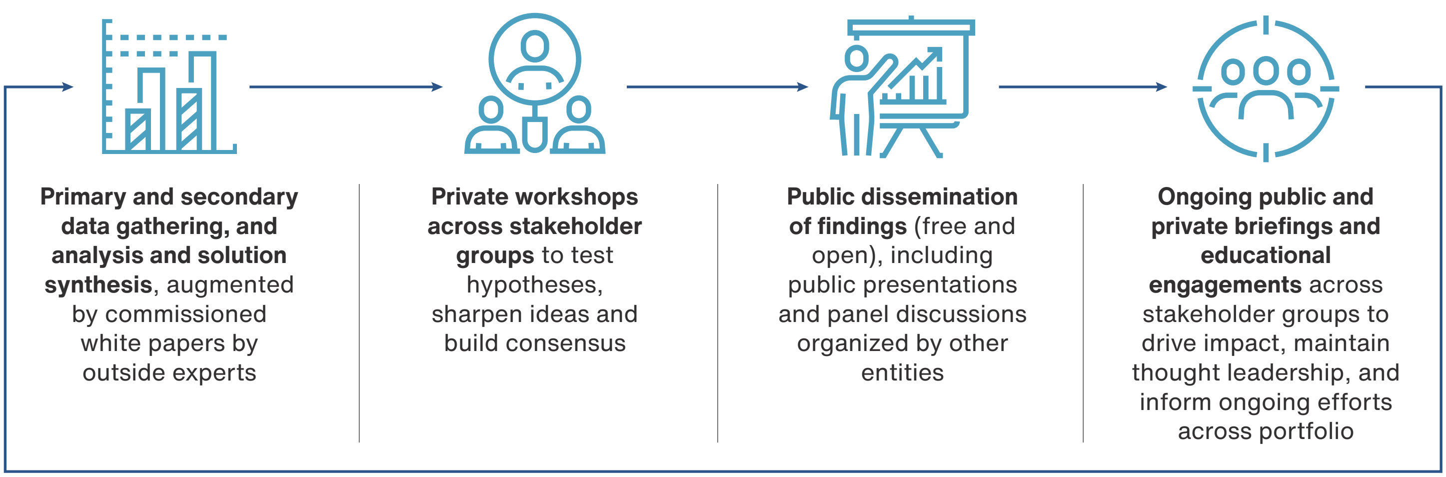
- **Carbon border adjustments:** Carbon border adjustment mechanism (CBAM) refers to a set of trade policy tools that aim to prevent carbon-intensive economic activity from moving out of jurisdictions with relatively stringent climate policies and into those with relatively less stringent policies.[40] Central to CBAM is the application of a fee on imported goods and commodities based on the estimated unmitigated GHG emissions generated during their production. Conversely, border adjustments could be applied to exports in the form of rebates or exemptions from domestic policies for producers that export their goods and achieve a threshold emissions intensity. In late 2022, the European Union reached a political agreement on the implementation of a CBAM on specific goods related to certain sectors within the economic bloc.[41] As other countries, including the U.S., examine the implications of the EU's CBAM, in parallel to considering their own border adjustments, the relative competitiveness of all decarbonization assets will change differentially across sectors and regions as carbon becomes a predominant parameter within international commerce and trade agreements.

Energy Futures Finance Forum: Analysis and Engagement Approach

EF³ is organized as an initiative within the EFI Foundation.[x] It is permanently staffed with an interdisciplinary and experienced team and will also draw on the considerable expertise and credibility of EFI. EF³ will seek strategic guidance through the formation of an advisory board, which will advise on strategic direction, research frameworks, and work plans. Final decisions on areas of analytical focus, methodologies, and recommendations rest with EF³ leadership.

EF³'s general approach cycle is outlined in *Figure 6*. The cycle will start with analysis and solution synthesis for an identified decarbonization pathway or a crosscutting issue, leading to sharpening and consensus building on the findings through private workshops with a range of stakeholder groups. The findings will be published and disseminated through public presentations or panel discussions, as well as through ongoing public and private briefings and educational engagements across stakeholder groups. Prior to the cycle starting, the subject of research, a pivotal decarbonization pathway or crosscutting issue, will be selected through a landscape analysis that considers technological readiness, projected overall need for a decarbonized economy, stakeholder interest, and robust discussion with advisors and outside expertise. EF³ will initiate several cycles per year on various technology-specific and crosscutting topics to create an ongoing portfolio of work and engagement.

Figure 6: **PROJECT LIFECYCLE: DEEP RESEARCH & SOLUTION CONSENSUS BUILDING COUPLED WITH ONGOING ENGAGEMENT**



x EFI Foundation was established by EFI in February 2022 building on EFI's accomplishments in clean energy transition. EF³ is the first initiative within the EFI Foundation, launched in April 2022.

The general approach for each cycle contains the following:

Primary and secondary data gathering, and analysis and solution synthesis, augmented by commissioned white papers by outside experts. This will address the specific barriers identified and increase the overall investment quality of examined issues, while also addressing higher-order concerns such as energy security and job creation, where appropriate. Policy recommendations will be developed through the commissioning of individual topical white papers, co-developed through the formation of a taskforce, or developed through a combination of these kinds of activities.

Private workshops across stakeholder groups to test hypotheses, sharpen ideas and build consensus. Stakeholders may include finance and industry leaders, policymakers, regulators, and subject matter experts. EF^3 will share in-progress work with core advisors and outside expertise to gain valuable feedback, pressure test ideas, and build interest.

Public dissemination of findings (free and open), including public presentations and panel discussions organized by other entities. Results will be presented at purposeful convenings, refined, and distributed publicly as a set of roadmaps for policymakers and financial actors.

Ongoing public and private briefings and educational engagements across stakeholder groups to drive impact, maintain thought leadership, and inform ongoing efforts across portfolio. Engagement strategies may include policy blueprints, op-eds, briefings to policymakers and their staffs, and partnerships. Importantly, active engagement with policymakers on a bipartisan basis, financial leaders, primary associations, and research organizations will be held to provide ongoing opportunities to inform decisions, receive feedback, and offer thought leadership/education.

Appendix

Estimates of Investment Needed to Achieve a Net-Zero Economy in the United States and Estimates of U.S. Gross and Net Fixed Investment

Projections of the incremental annual investment needed to achieve a net-zero economy in the United States indicate a substantial increase of expected capital spending. However, the results vary depending on assumptions and methodologies. The projections of Larson, et al. (2020) and National Academies of Sciences, Engineering, and Medicine (2021) are consistent with the IEA Net-Zero Emissions by 2050 (2021), and IEA (2019)'s projection is consistent with net-zero emissions by 2070.

Table A1: **LARSON, ET AL. (2020) PROJECTIONS OF CAPITAL INVESTMENTS, ANNUAL AVERAGE OF 2021 TO 2030, USD BILLION**[42]

		E+ Scenario*	Reference Scenario	Incremental Investment
Supply-Side Capital Investment (2021 to 2030)	Power generation	126	183	83
	Transmission	61		
	Distribution	45		
	Fuels conversion	10		
	CO_2 transport and storage	14		
	Industry	10		
	Total	266		
Demand-Side Capital Investment (2021 to 2030)		1,220	1,129	91
Total Capital Investment (2021 to 2030)		1,487	1,312	174

* E+ Scenario requires net-zero emissions by 2050, aggressive end-use electrification and unconstrained energy supply options.

Table A2: **NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE (2021) PROJECTIONS OF CAPITAL INVESTMENTS, ANNUAL AVERAGE OF 2021 TO 2030, USD BILLION**[43]

		Net-Zero Scenario (by 2050)	Reference Scenario	Incremental Investment
Total Supply-Side Capital Committed (2021 to 2030)	Electricity	90	28	63
	Networks	81	56	26
	Industry	4	1	3
	Total	175	84	91
Total Demand-Side	Buildings	NA	NA	95
	Vehicles	NA	NA	25
	Total	NA	NA	120
Total (rounded)		NA	NA	211

Table A3: **INTERNATIONAL ENERGY AGENCY (2019) PROJECTIONS OF CAPITAL INVESTMENTS UNDER SUSTAINABLE DEVELOPMENT SCENARIO, ANNUAL AVERAGE OF 2021 TO 2040, USD BILLION**[44,45]

	Annual Average, 2014 to 2020	Annual Average, 2021 to 2040*	Incremental Investment
Renewables	42	79	37
Nuclear	4	8	3
Electricity Networks and Battery Storage	65	52	-13
Energy Efficiency	42	165	123
Renewables for End Use; Other End Use Including EV	2	137	135
Liquid Biofuels and Biogases	1	13	12
Total	157	454	297

* The trajectory for emissions in the sustainable development scenario is consistent with reaching global net-zero carbon dioxide (CO_2) emissions in 2070.

Tables A4 and A5 provide U.S. gross and net fixed investment by actor and type, respectively, as derived from Board of Governors of the Federal Reserve System, Z.1. Financial Accounts of the United States.

Table A4: **U.S. GROSS AND NET FIXED INVESTMENT BY ACTOR, 2021, USD BILLION**[46]

Actor	Gross Fixed Investment	Consumption of Fixed Capital	Net Fixed Investment
Household and Nonprofit	1118	706	411
Nonfinancial Corporate Business	**2219**	**1811**	**408**
Nonfinancial Noncorporate Business	484	395	90
Federal Government	360	320	40
State Government	442	325	117
Financial Sector	319	290	29
Total	4942	3848	1094

Table A5: **U.S. GROSS AND NET FIXED INVESTMENT BY TYPE, 2021, USD BILLION**[47]

Type of Fixed Capital	Gross Fixed Investment	Consumption of Fixed Capital	Net Fixed Investment
Structures	2016	1379	637
Equipment	**1424**	**1246**	**178**
Software	1457	1222	235
Adjustments	45	0	45
Total	4942	3848	1094

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