Public Comments In Reply to the Department of Energy's Quadrennial Technology Review Framing Document
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[1] *The Information Technology and Innovation Foundation (ITIF) is a Washington, D.C.-based think tank at the cutting edge of designing innovation policies and exploring how advances in information technology will create new economic opportunities to improve the quality of life. Non-profit, and non-partisan, we offer pragmatic ideas that break free of economic philosophies born in eras long before the first punch card computer and well before the rise of modern China. ITIF, founded in 2006, is dedicated to conceiving and promoting the new ways of thinking about technology-driven productivity, competitiveness, and globalization that the 21st century demands.*

The Information Technology & Innovation Foundation (ITIF) respectfully submits the below comments regarding the Department of Energy's Quadrennial Technology Review Framing Document.

As a non-partisan think tank that seeks to advance policy in support of energy innovation, technological development, and productivity, ITIF is in full agreement with the President's Council of Advisors on Science & Technology on the importance of a Quadrennial Energy Review process, and fully supports the Department's efforts to develop such a review. Given inherent technology challenges and market failures in the energy space, and the public good impacts and externalities associated with energy use, government has a central role to play in filling gaps in the innovation ecosystem and accelerating technology development in close collaboration with the private sector. We're hopeful that a quadrennial review process will help lead to a coherent overall policy approach that works in sync across agencies and institutions to drive innovation.

We also hope that such a strategy will help keep the energy debate's focus on innovation, rather than simply attempting to find ways to prop up old, uncompetitive, or otherwise problematic energy technologies of yesterday – including both fossil fuels like oil and coal, as well as clean energy sources that can never hope to compete in the market in their current configuration.

Our responses to specific queries are found below. We have kept our responses fairly broad and focused on overall principles.

A) What do you think of the following mission statement for DOE energy research?
To facilitate the invention, refinement, and early deployment of meaningful technologies that enable options for scaling by the private sector toward national energy goals.

We generally believe the statement is appropriate and accurate. Given inherent innovation challenges in the energy space, the mission statement recognizes the Department's appropriate and necessary role in the development realm. "Meaningful" and "scale" imply a focus on technologies that will have an actual impact in the energy space, rather than focusing on far-fetched "blue-sky" breakthroughs, and also recognizes that technologies must be scalable and economically attractive to garner adequate private sector collaboration. Identifying the Department's role as a "facilitator" acknowledges the government's position as convener, able to connect the prime movers in the energy technology space – university researchers, venture capital firms, utilities, manufacturers, independent power producers, and others – who must all play leadership roles in advancing the next wave of clean technology, but must do so in concert.

Our lone suggestion would be to include "development" as one of the key goals along with "invention, refinement, and early deployment." "Invention" implies basic science research and the creation of fundamentally new technologies, while "refinement" implies incremental improvements to relatively mature technologies. Both of these are appropriate areas of work, but between them lay the very real gap in moving technologies from lab to market, through the "technological valley of death." This is often the make-or-break phase for radical technologies, where risks can keep away all but the least risk-averse private investors, and public intervention may in some cases be the determining factor in technical success or failure. Including more specific terminology that gets at the heart of this applied development function would more accurately capture the reality of the innovation cycle. This is not to imply that DOE can or should pick narrow firm-level winners and losers, as those choices are best left to the market, as the Framing Document acknowledges. But what DOE can do is broaden the menu of choices available to firms through collaborative development.

B) **Have we correctly identified and structured the six strategies to address our National energy goals?** The six strategies are:

1. Increase vehicle efficiency.
2. Promote progressive electrification of the vehicle fleet.
3. Develop alternative fuels.
4. Increase building and industrial efficiency.
5. Modernize the grid.
6. Drive adoption and deployment of a clean electricity supply.

ITIF generally agrees with DOE's six strategies, though we feel two points are important to make when outlining the strategy.

First, we feel there is room to add at least one more strategy that is cross-cutting and important. The additional strategy would be: develop advanced substitutes to, or eliminate the need for, critical materials. Many cleantech options require materials that are in limited supply and often found most abundantly in competing countries. This creates two significant issues: critical materials add to the trade deficit, and the United States' reliance on imports creates potential supply issues in the future as clean technologies grow in market adoption. Many of these materials, such as rare earth elements, are used in battery storage for electric vehicles, the smart grid, solar photovoltaics, wind turbines, and high efficiency light bulbs. The vast majority of these materials are supplied by China. Due to its own growing clean energy sector, China is expected to switch from being a net exporter of rare materials to a net importer of rare materials within the next few years. This complicates the development and deployment of next generation clean technologies and threatens to increase their costs.

We do understand that DOE is taking this issue seriously, most recently releasing a Department-wide Critical Materials Strategy Study that among other recommendations called for an integrated research agenda into developing alternative materials and studying methods of eliminating the need for rare materials. Clearly, DOE understands the importance and cross-cutting nature of the problem. Given this fact and the fundamental importance of the issue, we feel it should be a core strategy.

Second, the approach should make clear that not all strategies or technologies are necessarily equal. In fact some strategies, given the nature of U.S. energy challenges, are more important than others. In a report titled *10 Myths of Addressing Global Warming and the Green Economy*, we calculated that if the goal is a 50 percent reduction in greenhouse gas emissions by 2050, given the expected rate of growth in global population and per-capita income, the world would have to become 84 percent "cleaner." In other words, every unit of economic output would have to become 84 percent less polluting to reach a 50 percent goal (which is less than the goal set forth by President Obama).

Thus, we need to drastically transform our energy system. This means that some of the six strategies are higher impact than others. For instance, the United States simply cannot overly rely on energy efficiency (though vehicle and building energy efficiency are important) to solve our energy challenges. Instead, electrifying vehicles, developing alternative fuels, and developing and deploying radical new baseload energy supply seem more important and deserve greater emphasis than the other strategies, strictly because of the nature of the problem. Understanding the different emphasis placed on each strategy also recognizes that not all clean technologies are equally important. Some of the technologies are high impact, such as advanced battery storage, advanced materials, and the smart grid. Also, some technologies, such as solar, wind, biofuels, and vehicle electrification, are forecast to replace a greater percentage of fossil fuels than others. This is not to say that technologies like hydro, geothermal, and wave energy won't play a role, they are just not of the same significance as the others, as the Framing Document correctly points out. Recognizing this need for selective emphasis is important to address the strategies and ensure that DOE's overall approach is balanced towards developing the right technologies.

C) Clean Energy Leadership. How can DOE activities best support leadership in clean energy innovation? In clean energy manufacturing? In clean energy deployment? How do we balance international competitiveness against international cooperation?

E) What are the optimal roles for the private sector, government laboratories, citizens and academia in accelerating technology innovation?

> **a) How can DOE best coordinate activities between and among these types of organizations (including the wide variety of institutions within each class)? How should we gauge the effectiveness of this coordination? How can the basic-applied coupling be optimized? Are there examples in other sectors or other countries that can serve as models?**
>
> **b) What are the design principles for an effective 'technology user facility'?**
>
> **c) How can the Department best gather technology market information? How can information on private sector innovation be captured without compromising competitive advantage?**

Because questions C and E are closely related, we present a single commentary for both. Generally speaking, we believe the sensibilities of the framing document are very much where they need to be, and we commend DOE for this output. We also believe that many of the current programs are generally on the right track.

The central focus across all DOE activities has to be learning: in other words, to capture new scientific, technical, or market knowledge and apply it to new generations of technology. In the energy space, learning is often, but not always, best achieved through "distributed but connected" innovation systems with multiple actors bringing varied expertise to bear on diverse solutions, with some level of coordination, interaction, or exchange. Learning activities require sustained, steady investment, and can benefit from competitive pressures that drive improvements and yield better information through feedback from markets.

Distributed but connected learning paths can vary, but are extremely important, and can be more effective than more centralized top-down activities. For example, the decentralized learning system in the Denmark wind industry yielded gradual but meaningful innovation, which drew on limited but appropriate government interventions at the right time. These interventions included supply-side research and test-bed funding, support for standards and certification, and demand-side regulation, subsidy, and incentives. Conversely, early U.S. wind programs focused heavily on top-down, "shoot for the moon" approaches to radical new technologies in collaboration with aerospace firms, and lacked the same level of wide-ranging industry relationships as those found in the Denmark system. While the United States programs yielded some important technical and informational progress, there was little commercial success as a result. In Denmark, technology development activities were grounded in practice and more "market conforming" than "market contradicting."

In hindsight, the decentralized, practical Danish system had it right for wind, and this is an important lesson for any future large-scale technology development activities, even in more capital-intensive technology areas. If DOE is to thoroughly establish leadership in the energy innovation space, investment in radical innovation in the basic research phase is critical, but just as important are efforts to build and foster knowledge networks within industry and universities (as DOE has been doing in many respects). This thinking suggests the role for a program to facilitate cross-disciplinary, multi-sectoral clean energy research consortia to leverage university, governmental, and private sector research communities, manufacturers, venture capital, and other participants. It also suggests a greater focus on a clusters approach to promote collaboration between actors in similar geographic regions, thereby augmenting the productivity of individual firms, researchers, or agencies.

Following the learning theme, driving technical change and productivity needs to be an explicit focus of all activities where appropriate, including those focusing on commercialization of new technology. In other words, it's not simply about producing *more* solar power or *more* manufacturing facilities, but *better, more productive* facilities. Some might argue that simply scaling up technologies is the key to unleashing innovative potential, and thus policy should drive deployment, but policy can be made more effective where technology and productivity improvements are explicit primary goals tied directly to deployment. This suggests dynamic incentives tied to year-on-year performance improvements, to drive steady energy productivity gains. This contrasts with many existing static programs that simply offer unchanging quantity-based incentives, which effectively prioritize quantity over quality. Making technological productivity explicit in all incentive program areas wherever feasible, including in manufacturing and technology deployment initiatives, would provide better signals to the market and more directly drive innovation.

There are two other points worth making. Interagency collaboration can also be important, such as through the establishment of a Federal Energy Innovation Council to address cross-cutting issues (while the full mid-decade QER would serve this purpose, formalizing the process in an interagency working group does not need to wait). A Federal Clean Energy Innovation Council ideally would be composed of high-level representatives of DOE, DOC, NSF, DOD, OSTP, the business community, and representatives of regional industry clusters. The Council would develop criteria that ensure that existing federal programs are leveraged effectively through integration with industry clusters, academia, and international collaborators, as well as interagency collaboration. Two particular focus areas for interagency collaboration could include educational programs in conjunction with the Department of Education to ensure adequate levels of human capital available to the emerging cleantech industry; and further coordination of testing and procurement policy with the Department of Defense, which is an important early market and demanding buyer for new technologies. While this type of inter-department organization is outside the purview of the DOE-specific QTR, DOE could nevertheless take a leadership position by creating an intra-DOE Innovation Council that includes key program mangers, Secretaries, and lead researchers. Such a council would provide information on clean technology development from "the trenches" as well as provide sound, detailed advice on methods of advancing DOE's mission. This intra-agency council could also inform efforts and practices to create a larger interagency council.

Lastly, on the question of international collaboration versus competition, it's worth remembering that one of the main goals of energy innovation activities is to address climate change, a global problem. On the one hand, we shouldn't ultimately discriminate as to where game-changing knowledge or technologies may come from; but on the other hand, we should also be aggressively building up the nation's domestic competitiveness relative to the rest of the world to ensure at least a share of global cleantech leadership. Domestic competitiveness is best served by ensuring the right mix of productivity-based programs and incentives to optimize the innovation system and ensure domestic firms remain on the cutting edge. The function of international collaboration should be to expand the knowledge base available for domestic firms; so long as this knowledge base is steadily expanded, and all participants abide by the rules of the game with regard to IP and other relevant areas of trade policy, collaboration should not be a threat to competitiveness, but in fact a boost, by allowing domestic firms to learn from work occurring in other parts of the world.

But there is also a flipside to this coin: as ITIF argued in *The Good, The Bad, the Ugly (and the Self-Destructive) of Innovation Policy*, some countries don't play by the rules of the game, and instead seek unfair advantages for their domestic firms through lax IP enforcement, domestic content or ownership requirements, trade restrictions, and other mercantilist measures. Just as it should be DOE policy to seek mutually beneficial international collaboration through reciprocal agreements, it should also be DOE policy to avoid working with those states that do not play by the rules of the game and resort to mercantilism.

D) What principles should the Department follow for allocating resources among technologies of disparate maturity and potential time to impact? How many technology options should the Department provide for the private sector and how should the value of that diversity be weighed against timeliness, scale, and cost effectiveness? What should the threshold be for entry of a technology into the DOE portfolio? Does every technology deserve a program? When should we declare "mission accomplished" for a government RD&D effort or cease efforts on a program whose costs may outweigh its benefits?

Within a broader context, these questions drive at the same issue: how should DOE manage its technology portfolio? Given limited funding and annual budget uncertainty, DOE must strategically "spread the risk" of its investments so as not put all of its eggs in one basket. Spreading the risk also provides a better probability that DOE investments in clean energy innovation will yield commercially viable technologies, which is important given the immediacy of U.S. energy challenges. With this in mind, we believe the following broad principles for project and technology selection address the questions posed above:

1. DOE should implement an investment strategy similar to that used by ARPA-E for choosing projects within each technology category. The ARPA-E model (and the DARPA model it is based on) allows an open culture of "letting the best ideas win." As not all technology proposals can be supported, ARPA-E balances its investment by risk and the technologies' stage of development (basic science through deployment). DOE does this to a certain degree for some technologies, most notably battery storage research across the three DOE offices charged with developing the technology. But DOE should strive to apply this approach for all technology categories and ensure that strategic and balanced investments are made department-wide. With that said, not every technology deserves a program, and instead broad technology categories that offer high impact results (i.e. effectiveness, accessibility, and efficiency) should be targeted.
2. DOE should take a more nuanced approach to choosing projects based on its estimated "time of impact." While balancing investment decisions across a range of technologies at different stages of development is sensible, weighting time of impact should be done cautiously. Projects should be chosen across a range of potential time horizons to recognize that U.S. energy challenges are immediate and the energy sector requires radical changes. In essence, the U.S. needs clean energy technologies now, but also needs breakthrough technologies that may take more time to develop. The key is developing a balance of near-term technologies and long-term projects. Further, care should be taken to prioritize funding projects that impact larger energy technology (ex. developing a new material to use in advanced wind turbines). These complementary investments may significantly reduce the time of development for clean technologies.
3. DOE should weight proposed projects that have the greatest potential for technological innovation and commercial deployment: in particular, projects that hold the potential to scale and become cost effective. While DOE should support a wide range of technology innovations across the risk spectrum, DOE should also be mindful in its selection philosophy that these technologies are expected to make clean energy cheap and widely accessible to consumers and businesses. If not, the technology should not be considered.

4. DOE should also weigh investment decisions as to whether the proposed innovation would likely lead to greater exports or reduced imports. Clean energy innovation investments should aim to help U.S. industrial competitiveness. This particularly includes enabling innovations like energy storage and critical materials that are fundamental to the efficacy of many clean technologies.
5. Flexibility should be a central tenet of DOE management of its technology portfolio. DOE should be flexible in both continuing a project through each phase of innovation as well as ending a project if the costs of the project far exceed the benefits to society. This factors into how DOE incorporates new technologies into the portfolio as well as how DOE pronounces whether a project is complete or canceled. DOE should implement a rigorous strategy for periodic reviews, similar to ARPA-E, so that progress and potential can be measured and a decision on the projects future can be made. Such a strategy would both help DOE decision-making as well as serve useful for Congressional oversight into projects that have reached the end of their usefulness, and avoid politically-driven continuation as a form of pork.

How can DOE be more effective at each stage of the innovation chain? Are technology targets useful markers?

ITIF believes that this particular question is of vital importance to the success or failure of the DOE technology portfolio. We believe that technology targets would be helpful in ensuring that progress and success are the driving goals of project managers, and should be tied to well-thought-out clean technology roadmaps. These roadmaps would lay out a future course for clean technology development by articulating what stage of development specific technologies currently reside in and what innovations are needed to move each forward. Detailed technology roadmapping is currently conducted by a number of organizations. In particular the International Energy Agency already produces biannual reports on key clean technologies, as well as an ongoing series of technology-specific roadmaps, of which DOE should use in its analyses of technologies across the board. But in addition to technology roadmapping, there are institutional changes that could greatly enhance DOE effectiveness in spurring innovation. In short, as we stated in our response to question one, DOE can be more effective at bridging technologies across the valley of death from the labs to testing/demonstration as well as from testing/demonstration to deployment. ITIF proposes two solutions.

First, DOE can become more effective moving technology through each stage of innovation by making information about each technology more transparent and easily accessible. This would make DOE more effective at ushering technologies through the different developmental stages as well as make more informed investment decisions at each stage of innovation. To this end, DOE should make knowledge of its projects at the technology level public. The DOE, both within federal labs and through external funding, conducts a considerable amount of research and collects a considerable amount of data. Too often this information is not publicly disseminated or hard to access not just by the public, but by researchers and staff within the agency as well. Federally funded research should be made publicly accessible and easy to obtain. To do so, DOE should create a clean technology knowledge bank (e.g. such as an online database), where all ideas generated from federally funded energy research as well as their progress would be publicly available to entrepreneurs, other department offices, and other researchers. Government contract managers making federal research fund awards and department managers crafting project proposals would know what intellectual property is being developed and what technology has potential.

Second, to better strengthen DOE's "valley of death" support, a process should be put in place to increase communication, collaboration, and coordination among all technology transfer institutions. Moving ideas, people, money, facilities and equipment seamlessly among the collaborators (government, university, industry, NGO, foundation, etc.) is essential in a global, knowledge-based economy. Creating these partnerships would go a long way towards facilitating commercialization through the development of a cluster of essential actors such as research and business partners as well as those with specific expertise in economic development, financing and regulation. Building these new networks would create a more complete innovation system and enhance DOE effectiveness.

F) What are best practices in performing large-scale demonstration projects? How close to commercial viability does a demonstration have to be? What are the optimal cost sharing arrangements? How might demonstrations be coordinated with DOE financing activities? How can demonstration projects better benefit all stakeholders beyond the immediate participants? How are lessons learned best captured and promoted, and how is intellectual property best handled? How should DOE determine the number of demonstrations needed to address technical and operation risks? How do we think about failure in the demonstration phase?

ITIF is pleased that DOE is assessing its technology demonstration strategy, for demonstration is a critical stage of technology development. Unfortunately, it also represents a critical gap, and is a stage of development that receives underinvestment from both the private sector and the public sector. Currently, DOE is undertaking a number of demonstration projects like FutureGen CCS, the Savannah River Small Modular Reactor, and a number of wind and solar sites. But there is no formal departmental strategy for setting demonstration as a goal of R&D projects or providing a framework for establishing a demonstration project. From afar, it seems ad hoc. For example, the FutureGen project is the sole CCS demonstration project, but the publically owned Tennessee Valley Authority operates 11 coal-fired power plants that could easily be used as additional demonstration sites for new coal technologies. So, to better transfer the wealth of R&D knowledge generated at DOE to the market, a clean energy testing and demonstration project strategy should be implemented. As part of this strategy, DOE should:

1. Establish a comprehensive catalogue of government-owned sites eligible for testing and constructing technology-specific demonstration projects in collaboration with DOE, the Bureau of Land Management, and the Department of Defense. These eligible sites should be zoned for future clean energy projects.
2. Formally make demonstration a goal of all R&D projects managed or funded by DOE. Project managers, even at the R&D stage of development, should have a clear goal to see

a new technology idea demonstrated in the field. It isn't enough to create new knowledge if that knowledge is never used.

3. Create a cost-sharing strategy when demonstrating technologies in partnership with private industry. For large scale demonstration projects, DOE should provide no more than 50% cost sharing for a project and, when able, should use its financing activities to leverage demonstration projects when necessary as part of any cost sharing agreement. DOE should also provide the basic infrastructure needs at demonstration sites such as buildings and energy access, if necessary.
4. Be flexible and allow failure in the demonstration phase to be acceptable. The goal of DOE at this phase of development is to accelerate the *rate* of deployment of clean technologies. Demonstration is just one phase of development and if a project is deemed unsatisfactory or the costs exceed its social benefits, then DOE must be flexible and cancel the project so resources can be reallocated to other demonstration projects. And information and reasons for its failure should be transparent and public, and easily accessible to Congressional decision makers as well.
5. DOE should continue to collaborate with DOD on demonstration projects within the MOU signed earlier this year.

Ultimately, new management, procurement, and funding mechanisms are needed to truly create a cohesive, networked demonstration and testing policy in DOE. To do so would take an act of Congress. But in lieu of such Congressionally mandated authority, the above steps would be a step in the right direction for instilling a new culture of developing technologies not just in the lab, but also in the field as well.