Secretary of Energy Advisory Board

Task Force Report to Support the Evaluation of New Funding Constructs for Energy R&D in the DOE

March 28, 2014

U.S. Department of Energy

Report of the Task Force to Support the Evaluation of New Funding Constructs for Energy R&D in the DOE

I. Introduction and Charge to the Task Force

a. Terms of Reference

The Terms of Reference (TOR) from the Secretary of Energy authorizing the creation of a Task Force to Support the Evaluation of New Funding Constructs for Energy Research and Development in the Department of Energy (the Hubs+ Task Force) and its charge was generated on September 24, 2013. The complete TOR is in Appendix 1.

The Hubs+ Task Force was charged with an evaluation of the new R&D management and funding constructs introduced by DOE over the past six years [Bioenergy Research Centers (BRCs), Energy Frontier Research Centers (EFRCs), Advanced Research Projects Agency – Energy (ARPA-E), and Energy Innovation Hubs (Hubs)] in order to maximize the nation's ability to achieve energy breakthroughs as quickly as possible.

The Task Force provides a brief summary of the new funding constructs in Section 3 of this report.

The Task Force addresses the Secretary's questions in the following order in Sections 4-6 of this report:

- ***Is this suite of management and funding mechanisms proving effective? Are they complementary?*** [Section 4]
- ***Are there gaps in the DOE approach to energy, science, technology innovation and impact on industry development and deployment?*** [Section 5]
- ***Is the DOE effectively drawing on the resources of the labs, academia and industry, including entrepreneurial startups?***
  [Sections 4 and 6]

b. Task Force Members

The Task Force was composed of internal SEAB members [Rafael Bras, Persis Drell *(ex-officio),* John Deutch *(ex-officio),* Shirley Ann Jackson *(ex-officio),* Deborah Jin, Cherry Murray (chair), Carmichael Roberts, Martha Schlicher and Ram Shenoy] and external advisors [Robert Karlicek, Mark Little, Chad Mirkin, Maxine Savitz, Chris Somerville, and John Wall.]

Mackenzie Huffman was appointed as the Deputy Designated Federal Officer for this Task Force. The members' short biographies are in Appendix 2.

c. Materials Reviewed

The Hubs+ Task Force reviewed extensive materials requested by the Task Force and provided by DOE and external parties, including external reviews of various funded constructs. The Task Force members had numerous presentations and discussions with federal officials and directors of all Hubs and BRCs, held teleconference calls on November 8, 2013, November 25, 2013, March 3, 2014, and March 11, 2014, and met face to face at LLNL on December 3-4, 2013, and again in Washington, DC on January 8-9, 2014. The materials reviewed, and the face to face meeting agendas are summarized in Appendix 3.

II. Executive Summary

As the Department of Energy invests significantly to explore, develop and advance technologies to improve energy efficiency and to broaden access to new energy sources, it is important to seek and support innovation broadly while at the same time making these investments as efficient and cost-effective as possible. This requires a combination of innovation, risk tolerance and disciplined project management to identify and support projects that are risky and exploratory and also to support projects focused on delivering innovative products into real applications.

The set of funding modalities under review by the Task Force currently implemented by the DOE addresses this full range -- from basic science to speculative innovation to system-level integration -- and balances the magnitude of funding appropriate to the risk of successful delivery. Fundamentally, the Task Force supports these constructs. However, we find that a clearer definition of the role of each modality across the Department and more disciplined management would be beneficial to the Department to ensure that each mode of investment has the greatest opportunity to deliver on its intended objective.

Specifically:

EFRCs and ARPA-E projects are appropriately scoped and funded for the more basic, innovative and uncertain exploratory work they respectively represent. The key here is continued disciplined project management, with defined scope, schedule, cost and milestones for tracking progress, focused not on absolutely proving the initial hypothesis but on the work required to answer key scientific and technical questions along the path of discovery to validate or invalidate the hypothesis. In general, these programs appear to be progressing as planned.

The progress of the larger constructs, the BRCs and especially the Hubs, is less clear. In their implementation by DOE there are currently good examples, including the BRCs and some of the Hubs, and weaker performance among the Hubs. The management and organization of the BRCs and Hubs must be individually tailored to the particular transformational technologies they are created to address. The magnitude of investment in these modalities demands clearer objectives, more disciplined management during the course of each funding cycle, and a thoughtfully managed "ramp up" and "ramp down" at the beginning and end of each program, given the significant magnitude of human resources and capital investment involved in a nominally $25 million per year enterprise. These programs are the bridge between basic research and demonstration of feasibility for practical application, and must not stray too far in either direction. The Task Force will elaborate specific findings and recommendations on these constructs, particularly the Hubs, in our report.

The Department needs to adopt best practices in engaging the community in deciding in which subjects to place large investments such as the BRCs and the Hubs, as well as best practices in project management. The Department needs to establish appropriate retroactive metrics of success for the constructs that intend to support transformation in technologies and the industry, and to be disciplined across the department in using them. Validation of best practices is best done by periodic scientific and management reviews by an outside disinterested entity, such as by the National Research Council, as an important validation and level setting. These reviews would supplement the regular DOE office FACA advisory committee reviews and the internal scientific and management advisory committees of each construct project.

The new constructs reviewed in this report have been effective in engaging national laboratories, academia, established industry and start-ups for the stated challenges, and are complementary to the regular DOE programs. The flexibility inherent in the system has allowed these partnerships to be customized to the individual problems being addressed.

We encourage DOE to consider how the efficiencies and productivity of the funding modalities discussed in this report, particularly at the scale of the Hubs, could be an appropriate way to organize work at the National Laboratories to ensure focus on problems of national interest.

III. Brief Historical Description of Each Management and Funding Construct Under Review (BRC, EFRC, ARPA-E, and Hubs)

a. BRC – 2007

i. The Concept of the BRCs

The concept and rationale of the Bioenergy Research Centers (BRCs) is to accelerate the transformational scientific breakthroughs necessary for cost-effective production of biofuels and bioenergy, including cellulosic ethanol. These centers conduct comprehensive, multidisciplinary research programs on microbes and plants to develop innovative biotechnology solutions to energy production.

ii. Rationale and How the BRCs Were Developed

The BRCs emerged from the intersection of two independent simultaneous studies. One was a review of the DOE Genomes To Life (GTL) program by the US National Research Council (NRC) that was published in February 2006 (www.nap.edu/catalog/11581.html). In brief, the NRC committee severely criticized a proposal by GTL to sequentially develop four specialized DOE user facilities for protein production and characterization, characterizing and imaging biomolecular machines, proteomic analysis of microorganisms, and modeling of microbial community cellular systems. The NRC committee went on to recommend that the DOE should sponsor four vertically integrated research institutes with a focus on low-carbon energy-related topics that included advanced biofuels.

The other formative activity was a joint Office of Science - Energy Efficiency workshop in December 2005 that focused on understanding the challenges associated with production of lignocellulosic ethanol. The results of the workshop were published in a highly influential study called "Breaking the Barriers to Cellulosic Ethanol" that was subsequently used as a roadmap by most or all of the consortia that proposed to form the BRCs in response to a solicitation in August 2006. The three awardees were announced by Secretary Bodman in June 2007:

- Joint BioEnergy Institute (JBEI) lead institution Lawrence Berkeley National Laboratory
- Great Lakes Bioenergy Research Center (GLBRC) lead institution University of Wisconsin-Madison
- BioEnergy Science Center (BESC) lead institution Oak Ridge National Laboratory

iii. DOE Management of BRCs

A program officer in The Office of Biological and Environmental Research (BER) within the Office of Science (SC) manages the BRCs.

In September 2007, DOE made an initial award of $10 million to each center and committed $25 million per year to each of the subsequent five years. At the same time, DOE issued a management plan for the BRCs (updated in 2012) which states "*The most important measure of BRCs performance will be demonstrable scientific progress on these three key axes (Feedstocks, Deconstruction, and Fuel Synthesis), in the realm of basic science to a point that can easily transition to applied science.*" In addition to the technical criteria, BRCs are evaluated in an ongoing way on the basis of four major management criteria:

- Environment, safety and health
- Team Integration and Coherence of Research Direction
- Management of facilities, equipment and business systems
- Coordination with DOE Management

Importantly, the Management Plan states that the three BRCs are part of a single program with coherent overall goals. Thus, there is good communication between the BRCs from first collaborating post-award to refine their areas of focus to current sharing of best practices. To ensure that the mission and goals of the BRC Program can be successfully achieved, the DOE Management system includes the following characteristics:

- Well defined BRC Program mission, goals and management processes
- Clear roles, responsibilities, authorities and accountabilities of the participants
- Identified metrics to measure the progress and results of the three BRCs
- Sufficient information and ability to make well informed, timely and sound decisions
- Effective communication across the program participants and between the program participants and the program sponsor
- Ability to obtain required funding

iv. Process for Renewal/Sunset

Following a major review by an external review panel, after annual progress reviews by BERAC, the scientific advisory committee to BER, the BRCs were renewed at the same funding level of $25 million per year for five years in 2012. There is no formal and public plan in place regarding the possibility of an extension beyond the current five-year commitment which expires at the end of 2017.

v. Status of the BRCs

Because of their common adoption of the "Breaking the Barriers" workshop report as a roadmap, the three BRCs were originally focused on a very similar suite of goals. Additionally, all BRCs have activities related to technology development and technology transfer and commercialization. The three Centers retain similar interests today, though there has been some evolution of the portfolios away from ethanol and toward drop-in fuels and other bioproducts. The BRCS were similar in that all had multiple partners but also diverged significantly in organization: GLBRC uniquely lacks significant involvement of a National Lab; JBEI is uniquely consolidated into a single location; and BESC is highly distributed and included a company as one of the partner institutions.

b. EFRC - 2009

i. The Concept of the EFRCs

The Energy Frontier Research Centers (EFRCs) are multi-investigator, multi-disciplinary centers funded by the Office of Basic Energy Science (BES) within the DOE Office of Science that tackle fundamental to use-inspired scientific challenges hampering advances in energy technologies.

ii. Rationale and How the EFRCs Were Developed

Before developing the EFRCs, the BES held 12 community workshops over five years, with 1,500 participants from universities, industry and DOE laboratories. Located across the United States, the EFRCs are led by universities, DOE national laboratories and private research institutions, and are conducting

fundamental research focusing on one or more of several "grand challenges" and use-inspired "basic research needs" identified in this major strategic planning effort by the scientific community. The purpose of the EFRCs is to integrate the talents and expertise of leading scientists in a setting designed to accelerate research that transforms the future of energy and the environment.

iii. DOE Management of EFRCs

The EFRCs are managed by program managers within BES.

The EFRC funding opportunity announcement, issued on April 4, 2008, resulted in the launch of 46 EFRCs on August 1, 2009, with each center funded for five years at a level ranging from $2 million to $4.5 million per year. These Centers involve universities, national laboratories, nonprofit organizations and for-profit firms, singly or in partnerships, selected by scientific peer review. The total funding level was $155 million per year, of which $100 million per year came from BES and $55 million per year came from the American Recovery and Reinvestment Act (ARRA) of 2009.

The defining characteristics of the EFRC's are to:

- Couple "grand challenge science" with research needs identified as needs in the community workshops;
- Assemble multiple investigators to enable significant scope and complexity; and
- Empower strong central management to shift resources among investigators as needed.

Scientific and management reviews of the EFRCs were conducted in 2012 and 2013 and concluded that:

- The EFRCs demonstrate scientific productivity and world leadership, and make progress in ways that would not have been likely through separate support of the individual scientists.

- The BES management processes for the EFRCs are very well implemented and effective. A number of well thought out mechanisms are in place and have been actively used to identify issues and resolve them.

- A number of the communication mechanisms between the EFRCs and the science community and the public are excellent, and, overall, the EFRCs have told an inspiring story to the general scientific community concerning the value of fundamental research that supports energy sustainability.

iv. Process for Renewal/Sunset

On September 30, 2013, a second EFRC Funding Opportunity Announcement was issued by BES for both renewals and new applications. The anticipated funding level is $100 million per year, with individual five-year awards at the level of $2 million to $4 million per year. While 46 EFRCs were launched in 2009 with a total funding level of $155 million per year, ($100 million per year from the BES and $55 million per year from the ARRA appropriation of 2009), the 2013 program funding level of $100 million means that the competition for renewals and new applications is fierce.

v. Status of the EFRCs

The 46 EFRC's that were launched in August 2009 are made up of:

- ~850 senior investigators
- ~2,000 students, postdoctoral fellows and technical staff
- ~115 institutions
- >260 scientific advisory board members from 13 countries and >40 companies

The planning and execution process for the EFRCs has engaged a significant fraction of the BES scientific community across the country.

c. ARPA-E—2009

i. The Concept of ARPA-E

The Advanced Research Projects Agency- Energy (ARPA-E) was established by the America COMPETES Act of 2007 following a recommendation in the National Academies report, "Rising above the Gathering Storm" (http://www.nap.edu/catalog.php?record_id=11463) in 2007. ARPA-E is modeled after the Defense Advanced Research Projects Agency (DARPA). The Gathering Storm report recommended that funding be $300 million the first year and increase to $1 billion per year over five to six years.

ii. Rationale and How ARPA-E was Developed

Initial funding for ARPA-E was provided in 2009 via the ARRA appropriation. It was stood up as a separate office within DOE reporting to the Secretary in 2009. In its short history, it has demonstrated that it can be an agile and effective technology program within DOE.

iii. DOE Management of ARPA-E

Since its inception in 2009, ARPA-E has developed and executed programs, recruited a talented and experienced technical team, and provided awardees with technical assistance and market awareness to help projects succeed. The team consists of program directors and technology-to-market advisors with three to four year limited terms. Focus programs are identified by the program directors to address a specific energy challenge. These are then developed through interaction with diverse science and technology communities, often with a workshop. They also engage with the appropriate DOE science and applied energy programs to prevent duplication and create synergies.

Program directors typically manage a roughly $30 million program, which consists of 10-15 projects. They have in-person meetings with awardees, prior to actual contract, to negotiate technical and tech-to-market milestones. The total time from FOA to negotiated contract is typically 8 months. The cost of this active program direction represents about 8% of the total budget.

In addition to focused programs, there have been two open solicitations, one in 2009 and the second in 2012. In 2009, ARPA-E received over 3700 concept papers and selected 36 projects with $176 million of funding available. In 2012, they received over 4000 concept papers and selected 67 projects at a funding level of $130 million.

iv. Process for Renewal/Sunset

Projects are fully funded at the time of award and are typically for a three to four-year period of performance. They range from $1 – 10 million with the average cooperative agreement being about $3 million over three years. ARPA-E recently started to award proof of concept awards, which are $250 thousand to $1 million and are 12 months in duration. They do not renew programs or projects, but additional funding can be added to an existing project under specific competitive guidelines to further the project development.

Several projects have already had "hand-offs". These include 24 projects which have generated spin-off companies, and 22 ARPA-E projects that received about $95 million in funding and obtained at least $625

million of publicly-announced private follow-on funding. More than 16 projects have been handed off to the DOE applied energy programs as well as DOD.

ARPA-E has cancelled approximately 15 projects that were not achieving milestones or the goals of the program. While these projects were cancelled for not achieving milestones negotiated at the time of selection, ARPA-E does not view cancelled projects as failures because the projects provided new insights and lessons learned for the overall program.

v. Status of ARPA-E

As of February, 2014, ARPA-E had funded 362 projects across 18 focused programs and two open solicitations. These projects were funded in 33 states with over $900 million in funding. In 2013, approximately 38% of the funding for projects was awarded to small business, 35% to universities, 19% to large businesses, 6% to national laboratories and 3% to non-profits. The funding level set by the 2014 Omnibus Appropriations Bill is $280 million, far short of the original Gathering Storm target.

As of July 2013, of 285 awards, 34 patents have been applied for and 16 have been awarded. There have been 48 papers published in technical journals. The success of ARPA-E projects will ultimately be measured by impact in the market place.

There has been no external review of ARPA-E to date. ARPA-E is required by law to have a review performed by the National Research Council in 2015. The evaluation is to include: whether ARPA-E should be continued or terminated and a description of lessons learned from the operation of ARPA-E and how those might be applied to other programs in DOE.

d. Hubs - 2010

i. The Concept of the Hubs

In contrast to the EFRCs and BRCs described previously, the Energy Innovation Hubs (Hubs) were an initiative of former Secretary of Energy Steven Chu. The Hubs were meant to advance highly promising areas of energy science and technology from their early stages of research to the point that the risk level will be low enough for industry to commercialize the technologies.

ii. Rationale and How the Hubs Were Developed

The President's proposed DOE budget for FY2010 included $280 million to fund eight multi-disciplinary Energy Innovation Hubs, each of which was to be focused on a particular energy challenge that had been resistant to solution by conventional R&D management structures.
The defining characteristics of the Hubs were to be:

- A lead institution with strong scientific leadership;
- A central location;
- If geographically distributed, state-of-the-art tele-presence technology to enable long distance collaboration; and
- A strong organization and management plan to effect goals.

Three Hubs were funded in the FY2010 budget addressing the challenges of:

- Fuels from Sunlight (JCAP), lead institutions California Institute of Technology and Lawrence Berkeley National Laboratory,

- Energy Efficient Building Systems Design (EEB Hub), lead institution Pennsylvania State University, and
- Modeling and Simulation for Nuclear Reactors (CASL), lead institution Oak Ridge National Laboratory.

Funding was awarded to the initial Hubs on the basis of external peer review of proposals responding to the FOA. While each Hub spanned several offices within DOE, each had an identified sponsor office within the Department with responsibility for oversight of the management of the Hub. JCAP was funded out of the Office of Basic Energy Sciences in the Office of Science. The EEB Hub was funded out of the Office of Energy Efficiency and Renewable Energy, and CASL was funded out of the Office of Nuclear Energy.

Subsequently two more Hubs were funded in the FY2012 budget, addressing the challenges of:

- Batteries and Energy Storage (JCESR), lead institution Argonne National Laboratory, funded out of the Office of Basic Energy Sciences in the Office of Science, and
- Critical Materials, lead institution Ames Iowa Laboratory, funded out of the Office of Energy Efficiency and Renewable Energy.

Four other Hubs (Carbon Capture and Storage, Electricity Systems, Extreme Materials for Nuclear Energy Systems, and Solar Electricity) have been proposed but have not been funded by Congress.

The initial suite of five Hubs is quite diverse. The scientific/technical challenge of each Hub and the unique traits of the scientific/technical communities that are responding to that challenge, along with the different mission emphases of the offices managing the Hubs, has meant that each Hub is unique. As noted in Figure 1, the breadth of mission of each Hub from basic research to implementation is quite different, making generalizations challenging.

iii. DOE Management of the Hubs

Management of the Energy Innovation Hubs program is closely coordinated across DOE program offices through a working group of senior technical program managers that has met regularly since the first Hubs were funded. Issues are addressed in the context of the Department's conventional line management. Recently the Department created a "Hubs Leadership Council" to provide a regular forum for discussion of Hubs issues at the senior program leadership level.

iv. Process for Renewal/Sunset

The funding level for the Hubs was set to be $25 million per year for five years ($125 million) with the possibility of renewal for a second five year period. The three inaugural Hubs are approaching their renewal with differing track records of success. In particular, challenges with the management of the EEB Hub had been noted in Congressional language in FY13 and the FY14 budget appropriations bill.

A range of options is being considered for action at the close of the initial five-year award term from full renewal to partial renewal to phased termination.

v. Status of the Hubs

Of the three inaugural Hubs, CASL, EEB and JCAP come up for renewal in 2015. Funding for EEB has been scaled back in 2014 as a result of language in the 2014 Omnibus Appropriations Bill. In the bill, EEB is no longer referred to as a 'Hub'. DOE and Pennsylvania State University have negotiated a continuation of the EEB as the $10 million Penn State Consortium for Buildings Innovation until the end of the original five year contract for the Hub in 2016. The Hub has been de-scoped and moved into the standard EERE applied energy programs. The Hub Leadership Council has expressed a consensus view that at the time of

renewal, re-competition of the full scope of the EEB Hub is not a desirable option (in contrast to, for example, the renewal and re-competition process for the smaller EFRCs). They have also expressed a view that the bar for renewal for any Hub should be set extremely high due to the significant funding level and high visibility.

JCESR and the Critical Materials Hub, started in 2012, are still in the phase of aggressive ramp up.

IV. Findings, Comments and Recommendations

a. Overall Benefits and Challenges to having the New Management and Funding Constructs at DOE

Is this suite of management and funding mechanisms proving effective? Are they complementary?

i. Benefits

Finding: The Task Force agrees with the urgent need for accelerated energy RD&D in the US, and supports DOE providing the leadership management and funding constructs to focus the scientific community and the industrial sector on transformative R&D, especially in concert with a strategic energy policy informed by future Quadrennial Energy Reviews. Transformative energy R&D brings new science into novel technology development that changes industrial and market norm. By its nature, this spans offices within DOE and the academic, national lab and industry sectors. The urgency of the challenge invites a different form of management and funding than the normal modalities of the relevant DOE offices. These new funding constructs are complementary to DOE's other efforts in energy-related R&D. For example, individual investigator funding in the Office of Science, the construction and operation of science user facilities and DOE's applied energy programs are also essential components of DOE's overall efforts to accelerate advances in energy. DOE needs to carefully set a balance between the funding of these new constructs and the 'normal' programs.

Finding: All of the funding modalities being discussed have been effective in engaging national laboratories, academia, established industry and start-ups for the stated challenges. The flexibility inherent in the system has allowed these partnerships to be customized to the individual problems being addressed. We note that there are other constructs within DOE that also encourage such cross-institutional collaboration, but the high visibility of these new constructs has been a benefit.

Finding: The Task Force strongly supports the basic DOE concept of the four management and funding constructs summarized in Section 3 above. If effectively managed, and with some modifications, these constructs can enable new energy technology developments and systems that neither the science community, venture capital nor the industrial sector would be able to accomplish independently. They focus on important energy challenges and cover a spectrum from use-inspired basic research to applied research and technology development. They can create alignment among non-coherent research in different areas, provide essential feedback from the market into science breakthroughs, and accelerate the progress of scientific and technological breakthroughs in energy into useful products.

The EFRCs have been very successful in bringing the academic community together with the national labs to enable high quality collaborative science with relevance to energy science and/or industry.

The BRCs and Hubs provide an excellent construct for resolving major technological and science roadblocks in order to deliver advances at the system level. Hubs are large cross-disciplinary consortia of universities, national labs and industry, with the objective to integrate concepts from basic science through concept prototyping or technology transfer, and to incorporate feedback from technological need and practical application to basic science.

ARPA-E plays an important role by funding more applied high-risk technology development that has the potential for transformational impact on energy. The current ARPA-E budget is less than 2% of the total DOE R&D budget. This is not an unreasonable percentage of the budget to spend on high risk R&D. Arguments could be made for innovative 'risk-investment' of a more significant magnitude.

ii. Challenges

Findings: A number of challenges and opportunities for improvement revolve around risk management. The magnitude of investment in each of these constructs should be matched to the riskiness of the endeavor. The more speculative/risky initial proposals should be funded at a lower level in the initial phases with appropriate review points along the way to encourage further investigation while at the same time justifying further investment. This is an important and delicate balance. And the much larger investment in Hubs should be accompanied by strong project management and a "stage gate" review process to ensure that the programs are making progress toward the stated goal.

Troubles have also arisen in these constructs when the construct is not well matched to the problem being tackled, or if the rationale for the problem FOA or the metrics of success are not sufficiently well defined by DOE in conjunction with the community.

For example, some R&D challenges may not be large enough to require a Hub, or, in other cases, it may not be possible to aggregate resources into a large, centralized Hub. A Hub would not be the right construct for funding fundamental science with a very long time horizon or for funding pure deployment**.** Some confusion can arise in other DOE offices, the Office of Management and Budget, and Congress if the actual FOAs and metrics of success within a construct are not sufficiently uniform across DOE.

Other issues have arisen in the definition of appropriate problems for the larger multidisciplinary cross-sector teams, with stretch goals, but realistic for the time frame and funding level. Each of the constructs, but especially the larger ones, need sufficient critical mass and stable funding, excellent on-site leadership and good project management with clear and reasonable stretch goals with clear metrics to renew.

There have also been issues from DOE non-uniformly enforcing the best principles of project management from the outset for the larger constructs such as the Hubs, and difficulty with cultures have arisen especially when academic institutions have taken on a leadership role in big projects.

b. General Recommendations and Comments Across all the Constructs

The Task Force has a few important high level recommendations across all the new constructs, on crafting the FOA, requiring a project management culture with strong on-site leadership, to retroactive evaluation of the return on investment to the sharing of best management practices across all DOE offices.

i. Crafting the FOA

Recommendation: The best players must be able and encouraged to compete either to manage or perform in each construct. Universities, national labs and industry should be equally allowed to take the leadership role where relevant in each competition and FOA.

Comment: Uniform management practices are needed across DOE Offices in the contracts with and funding of academic entities. It is important to have the highest level of academic leadership closely involved from the outset with large projects such as BRCs and Hubs led by an academic institution, and this high level of leadership fully cognizant and responsible for meeting the requirements that it takes to implement this contract, both in the type of on-site scientific leadership and project management, as well as the close involvement of the PIs at the institution. Of particular note, ARPA-E has established a rapid contract and funding mechanism, and the Office of Science has a well-established academic engagement model.

Recommendation: The use of both top down grand challenges and bottoms up community input on the scientific and technology innovations needed is a best practice and should be followed for every construct FOA to carefully define the rationale, goals and metrics for success of the construct, its investment scale and timeframe.

Comment: BES in defining the FOA for the EFRCs and BER in defining the FOA for the BRCs both successfully used a combination of a large number of effectively managed scientific workshops to obtain bottoms-up community input; and a compilation of top-down grand challenges, either from Advisory Committee reports or National Research Council Studies, or both. In addition, ARPA-E has effectively used its annual Energy Innovation Conference to find the pulse of the community about possible technology innovations.

In the future DOE offices can augment these existing mechanisms with input from the Quadrennial Energy Review coupled with US energy policy in defining the top-down grand challenges that require transformative programs.

Comment: It is important to create goals for a program that are stretch goals, but reasonable within the size and timescale of the program. Before making a decision to invest a large amount of money to quickly advance from science to technology in a construct such as a Hub on a certain topical area it is important that there is considerable scientific and industrial community expectation that a transformative breakthrough could happen in a reasonable timeframe – such as 5-10 years. Developing a Hub FOA in the area through a series of top down and bottoms up scientific community workshops would give DOE a better appreciation of what the appropriate investment scale and timeframe should be and allow a better definition of some stretch and realistic goals for the particular area.

Recommendation: The larger constructs such as Hubs should include defined ramp-up and ramp-down phases at the beginning and sunset of each project with appropriate stage gate milestones to determine continuation of the project. It is wasteful to require the spending of a fixed sum of money per year with a fast turn-on. The process for review and sunset should be clearly defined in the FOA.

Comment: Given the importance of the endeavor, the importance and length of time it takes to build a multi-disciplinary and multi-sector world-class team to the effort, and the risk associated with these transformative projects, it is reasonable to create projects that propose a ramp up of funding, and set a 10-year horizon for success with very clear 5 year midterm reviews with teeth: clear sunset clauses at the outset for not satisfying the midterm review, and the appropriate funding level for a critical mass of effort.

ii. Requiring a strong project management culture driven by an effective on-site leader

Recommendation: The larger and more applications focused a construct is, it is imperative to have an effective senior on-site leader, respected by the scientific community, to support the research and lead a serious project management culture for the project, including a formal work breakdown structure and

change management process. An effective leader who leads both the science and the project management culture should be required from the outset, at proposal stage.

Comment: For the larger constructs such as Hubs and BRCs, performance milestones should be established and subject to an annual review with a re-baselining procedure in close consultation between DOE and construct senior management where appropriate. Best practices followed by ARPA-E program directors include site visits before work is started to jointly develop project milestones, followed up by regular site visits. How to effectively set more realistic targets for work breakdown of the more exploratory science projects within a construct should be shared as best practice within the Hubs Leadership Council and generally across all constructs. The BRCs appear to be good example of successfully executing science within a project management structure.

iii. Retroactive evaluation of the return on investment

Recommendation: A retroactive evaluation system needs to be established to measure transformational impact of all of the constructs, but especially the Hubs, BRCs and ARPA-E.

Comment: Definition of success cannot rely solely on great science being done - the number of papers or patent applications submitted. For these transformative programs some measures of evidence of industry transformation need to be gathered over time. This means measures of impact on technology, and eventually the market, need to be followed for many years, even after the particular program has ended. It may take years or even decades to generate an impact. These measures could include new startup companies being formed, technologies getting into the market, students getting hired into energy companies, surveys of industry leaders' views of the values of the technologies, buyouts, market share, adoption, etc. ARPA-E, BRCs and the Hubs especially need to establish a consistent framework now to track programs for 5 – 10 years after completion of funding to determine if it led to technologies, solutions for energy demand and supply that had impact. The Office of Energy Policy and Systems Analysis would be a relevant office to establish the methodology for retroactive evaluation across DOE applied programs, including the applications focused constructs, making use of outside expert advice to validate the methodology. A possible framework for retroactive evaluation was used in the National Research Council study "Energy Research at DOE: was it worth it?" (http://www.nap.edu/catalog.php?record_id=10165)

iv. Sharing of best management practices across the DOE Offices

Recommendation: The Hubs Leadership Council should be expanded to include the BRCs. The Council should continue to compile and continuously share "light-touch, but with teeth when needed" program management lessons learned across all offices. In particular, sharing of best practices and experiences across the BRCs and Hubs would be especially useful.

c. Comments Specific for Each Funding Modality

i. Specific comments for BRCs

***Process for Renewal/Sunset*:** BER has not made a formal public commitment regarding the possibility of an extension beyond the second five-year commitment, which expires at the end of 2017. DOE or the National Research Council should undertake an updated evaluation of the state of the field and the role of the BRCs in contributing to further development of the field. It would also be legitimate to ask whether having three BRCs is still appropriate, whether the mandate and goals of the BRCs is still compelling relative to other opportunities, and whether the BRCs are sized right and appropriately organized relative

to forward-looking goals. The program manager of the BRCs is planning a forward-looking workshop in summer 2014, which might address some of these questions.

Industry Voice in Assessment: The field of advanced biofuels has progressed significantly since the BRCs were first envisioned. There are several commercial-scale lignocellulosic biorefineries in operation and several more are apparently slated to startup in 2014. Thus, industry should have a voice in assessing future needs for the BRCs. Whatever the case, the future of the BRCs should be decided before mid-2015 in order to ensure an orderly transition to the next phase for the BRCs.

Evaluation of the BRCs: Although the BRCs are considered by DOE to be part of a single program, they were reviewed separately until year three. It is desirable to periodically have a single committee review all three centers to facilitate a comparison of effectiveness of the three centers.

Importance of Team Research*:* The key opportunity of the BRCs is the potential to have multidisciplinary teams of researchers working coherently to solve a larger problem than typically feasible for an individual research group. The degree to which such team efforts have been implemented should be added as a criterion for evaluation of success. Certainly a lesson learned in starting the BRCs was the lack of academic experience in managing large multi-institution efforts as high performance teams. Management training should be considered as a part of any further similar funding concepts.

ii. Specific comments for EFRCs

Extend beyond BES: Currently EFRCs only exist in the Office of Science, Basic Energy Sciences. DOE may want to consider expanding this successful funding modality for use-inspired research relevant to energy or environment to other parts of the Office of Science.

Proposal Review: EFRCs are best judged by peer review, where the review process includes diversity of thought. There needs to be turnover among the EFRCs, and they should have only competitive renewals as is being planned. In addition, given the five-year funding cycle, we support the current EFRC management practice to have an intermediate review with 'teeth'. Finally, we note that the current situation with all EFRC proposals (new and renewals) being reviewed at the same time, presents a significant challenge for the review process. The advantage of being able to have a comparative review across the entire program is offset by the challenge of reviewing so many proposals involving a large fraction of the community at the same time. DOE should consider a plan to avoid this congestion in the future.

iii. Specific comments for ARPA-E

Validation of Success: ARPA-E appears to be doing well: it has had strong leadership, it has used workshops to gather community input, it funds a good mix of topics, it provides close monitoring of projects, and it has implemented a quicker than usual funding process. However, at this stage, it is challenging to validate the success of the program. For example, since ARPA-E intentionally funds high-risk projects, one expects a relatively low fraction of success, as measured by throughput to industry and/or follow-on non-government funding. In addition, the program has not undergone an external review. ARPA-E is required by law to have a review done by the National Research Council by 2015, and DOE should be planning now for this review. The Director of ARPA-E is the appropriate Office to contract with the National Academies to sponsor the review.

Caliber of Program Managers: The Task Force notes that the caliber of the program managers, who should have demonstrated leadership and expertise in energy-related science and technology, is essential to the success of the ARPA-E endeavor. The caliber of the program managers over the entire length of the program should be one of the criteria for measuring success in an external review.

iv. Specific comments for Hubs

Consensus Building on Topics: Selecting topics for any of the modalities requires due diligence, and should include community input and consensus building in defining priority challenges for energy. This is particularly important for the Hubs, which represent a large effort. For new Hubs, DOE should engage with the scientific and industry community to define priority challenges as well as to decide if a Hub is the best approach for a particular challenge.

Multiple Hubs on a Single Topic: In some cases, funding multiple, complementary Hubs aimed at a single broad problem may be appropriate.

System Feasibility and Market Relevance vs Prototypes: While product prototypes are a desirable goal of the Hub process, a deliverable prototype should not be required of every Hub. In some cases, demonstrating system feasibility and market relevance, with deliverables consistent with market feasibility, is more important than delivering a prototype.

Funding Level: DOE should consider a range of funding levels for Hubs, for example between $15 and $30 million per year.

Hubs Leadership Council: Oversight and involvement by DOE is essential. To this end, the DOE Hubs leadership council plays an important role in helping avoid basic management failures and in communicating best practices. Key characteristics for success of a Hub are a focus on a high-level energy goal, a coherent research plan that incorporates community input, clear objectives with measurable milestones/outcomes and tracking of progress to the plan, a strong leader, and excellent program management.

Mid-Term Reviews with Teeth: Within the contract for five years plus a possible five year extension, DOE should conduct a mid-term review in the first five years that includes termination or funding level modification within the first award period as possible outcomes, and a another mid-term review in the second five years that addresses reevaluation of the need for the Hub and plans for the transition of the Hub enterprise after DOE funding is completed. The recent modification of the EEB Hub funding during the first award period is an example of how such midterm evaluations can be used.

Renewal Options. The Department has not yet faced the decision that comes at the conclusion of the initial five-year award term. The first Hubs are up for renewal in 2015. However the Hub Leadership Council has expressed a consensus view on some aspects of the renewal decision.

Due to the substantial human capital and infrastructure investment and long lead-time in establishing and growing a functioning Hub project team, re-competition of the full scope of a Hub is not considered a desirable option. However, the bar for renewal should be set extremely high due to the significant funding level and high visibility. A range of options is being considered for action at the close of the initial five-year award term.

- Full renewal at ~ $20-25 million per year for an additional five years term.
- Partial renewal with a subset of the research tasks with lower funding level and/or shorter term; may include a guided refocusing of the management structure and/or project plan.
- Phased termination.
- Continuation of some of the program elements as part of the regular DOE office programs.

The Task Force endorses these as good options for the Hubs going forward:

1. ***Extended Funding beyond 10 Years:*** DOE should not extend funding beyond 10 years without a reevaluation of the need for the Hub that includes input of the external community, industry, and the DOE Hub Leadership Council.
2. ***Hubs Acting as Hubs:*** Hubs should make effective use of the output of EFRCs and ARPA-E projects as well as regular DOE programs that are funded in their particular area of focus by including the PIs in their regular meetings and communications.

V. Gap Analysis

Figure 1 shows in schematic form how the management and funding constructs discussed in this report span the program offices within the department and also the spectrum of various stages of basic and use-inspired research, applied research, to prototypes, scale up and deployment to industry. The wide disparity in the breadth of mission of each of the current Hubs from basic research to implementation is quite different as is illustrated in the figure.

The Hubs and BRCs along with ARPA-E for the most part do a good job at spanning the broad energy research and development to deployment space.

While Hub-like constructs (including the BRCs) span a broad range of the scientific fields described in the horizontal axis of the plot, the very successful EFRC construct has only been used in material and chemical sciences. We encourage the Office of Science to consider extending the funding construct of $2-5 million per year for multidisciplinary fundamental-to-use-inspired science into other areas in the Office of Science. The computing (ASCR) 'co-design' program is similar in scale to the EFRCs and has been very successful.

VI. Discussion of How National Labs Could Benefit from Similar Funding Constructs

The Task Force agrees with the urgent need for accelerated energy RD&D in the US. The new constructs reviewed in this report have been effective in engaging national laboratories, academia, established industry and start-ups for the stated challenges. The flexibility inherent in the system has allowed these partnerships to be customized to the individual problems being addressed.

The National Laboratory system is inherently structured to attack problems of scale with coordinated multidisciplinary teams that range from basic to applied science and draw from industry and academia as well as the National Laboratories. In addition, a project management culture is natural and accepted in a national laboratory. We encourage DOE to consider how the efficiencies and productivity of the funding modalities discussed in this report, particularly at the scale of the Hubs, could be an appropriate way to organize work at the National Laboratories to ensure focus on problems of national interest.

Figure 1. New Management and Funding Modalities at DOE

Notional depiction of the span of the new management and funding constructs across the disciplines in the offices within the Office of Science and the Applied Energy Programs (horizontal axis) as well as the spectrum of basic research to industry deployment (vertical axis).

Appendix 1. Terms of Reference

Appendix 2. Short Biographies of Task Force Members

Appendix 3. Task Force Meeting Agendas and Materials Reviewed