Grand Scientific Challenges in Clean Energy Innovation

This paper presents one of many possible initiatives that Mission Innovation (MI) governments could undertake to help frame their clean energy research portfolios and collaborations.

Proposal for MI Implementation

The MI Ministerial Steering Group would decide on a number (3-5 each year) of R&D topics of interest proposed by those MI Members who would be willing to host an MI R&D Opportunities Workshop on each of these topics. Any one or more MI governments could propose to host an MI R&D Opportunities workshop. The U.S. would be willing to host the first of these workshops on Carbon Capture Utilization and Storage.

These R&D Opportunities Workshops would convene government-supported scientists and technology researchers to learn from technical experts in industry and other experts what they think are the top R&D challenges for the particular topic of interest. Government-funded researchers from all MI Members would be invited to each workshop to present their ideas and to brainstorm with the experts and each other on strategic opportunities and directions to speed the pace of innovation. These R&D opportunities could range from basic science challenges relevant to the topic to possible new directions and advances in applied technology R&D.

A workshop chair and an international scientific committee would be proposed by the host Member(s) to run the workshop and to write the summary technical report(s). It is important that the chair and scientific committee be accomplished leaders in R&D, and that the chair has experience in managing complex community scientific endeavors, such as a distinguished member of a country's National Academy of Sciences.

The primary purpose and outcome of these workshops would be to guide, inspire, and mobilize the research community and the private sector in each country to explore some of the toughest challenges to energy innovation and identify clean energy research needs that address such challenges.

The benefit to MI member countries of a series of these R&D Opportunities workshops would be capacity building in relevant science and technologies, dissemination of ideas for advancing innovation, opportunities for researchers from each country working on or interested in a particular topic to meet and get to know their international cohort, and in so doing provide enhanced opportunities for researchers to recognize synergies and, after the workshop, to connect to propose to their respective governments ideas for bilateral or multilateral collaborations. If MI members do not send their researchers to the workshop they can still learn from the technical workshop summaries that would be published on the MI website.

Drawing on the U.S. experience, key elements and process steps of the workshop might include the following:

- Summarize the current state of technology, impediments, and/or status of the field, and the associated clean energy innovation and technology challenges and R&D needs in a report, either before the R&D Opportunities Workshop or at the start of the Workshop. This summary of the state of the field can be used as a resource, not only by workshop participants, but also for the larger clean energy research community.
- Define a set of clean energy technology R&D Opportunities.
- Identify and establish a set of priority research directions that address the Opportunities, and steps to further R&D along those lines.
- Develop and publish a workshop report highlighting the R&D Opportunities and the priority research needs. This report could be separate from the state of the field report, or merged into a single comprehensive report. Such a report could be used by countries to inform, guide, and mobilize their private sector and research community, and identify areas for collaboration with MI governments in that topic area.
- As post-workshop indicator of progress, MI countries could voluntarily report the extent to which their respective MI investments support the R&D Opportunities across the various topic areas.

The initiative is not meant to be exclusive. Under MI, national programs may emphasize a range of investments, including applied R&D, technology demonstrations and technology-to-market activities. This approach may be complemented, as MI governments shall decide, by an array of other approaches to spur innovation, including international competitions or prizes, bilateral or multilateral joint research projects, and/or national programs.

Background

Since its launch in November 2015 by the leaders of 20 of the world's most forward-leaning clean energy R&D funding nations, Mission Innovation (MI) has established itself as a global rallying point for advancing clean energy research and innovation. Its goal is to accelerate significantly the pace of innovation, reduce costs, and make clean energy technologies widely affordable worldwide. In June 2016 all MI members, now including the European Union, declared a collective baseline of $15 billion per year in clean energy R&D investment and pledged to seek to double that annual investment over the next five years to a level of $30 billion/year by 2020-2021. From 2016 to 2021, it is estimated that this would make available an additional $25 to $35 billion in clean energy R&D, on top of a business-as-usual baseline investment of about $75 billion over 5 years.

A fundamental principle of MI is that, while MI is an international initiative and all MI members made a commitment to seek to double investment, each participating MI member will organize its investment portfolio independently to serve its own national needs and investment priorities. While there is a MI secretariat to facilitate information sharing across a range of activities, there is no expectation *a priori* of a coordinating platform directing global R&D investment. This does not mean, however, that MI members should not seek opportunities for cooperation in areas of common interest, or be inspired by a set of well-defined fundamental science and basic research needs. Further, enhanced opportunities for international collaboration are likely to arise in many other areas under the MI banner, based on mutual interests, including applied R&D.

The mandate to accelerate the pace of clean energy innovation, coupled with the significance of the additional MI Investment, calls for thoughtful and creative exploration of ideas on how and where to invest. The more applied R&D activities, that is, those that are near commercialization, often entail lower risk and promise higher near-term impact. Given sensitivities about international competitiveness, publicly-supported activities in this area are often left to the domestic strategies of each MI member and its self-selected partners. International activities are typically carefully governed to protect IP.

Areas, perhaps, better suited for multilateral cooperation under MI are those focused on earlier stages of technical exploration, supporting science, and "use-inspired" basic energy research. These activities can present unique opportunities to address fundamental barriers that impede long-term progress in specific technological areas ("uses") in clean energy innovation. Use-inspired basic energy research can create new knowledge, explore novel approaches, open new avenues of technological progress, and feed the innovation pipeline for more applied public and private R&D investment. This is the kind of investment that can lead to breakthroughs in scientific understanding and problem solving.

U.S. Experience

Numerous benefits have resulted from this genre of investment. As an example, such a series of workshops was sponsored by the U.S. Department of Energy's Office of Basic Energy Sciences (BES). Over a period of 15 years, more than 18 workshops were held, with participation from academia,

national labs, private industry, and federal agencies. Leading experts from foreign countries participated (Figure 1). A list of the workshops and links to their respective reports is provided in Appendix A. Similar reports were produced for the life sciences by DOE's Office Biological and Environmental Research.

Today, many of these reports need updating, due to evolving context and science and technological advances. Others are still current. More are in the pipeline. Additional topics need to be identified. There is an abundance of important work that could be usefully applied in this area.

The workshop reports are now internationally recognized as impactful, both as resources for guiding basic energy research and for giving rise to accelerated innovation and technology commercialization (see below). The series is viewed as a model for inspiring and attracting the scientific community to engage in publicly supported problem-solving associated with the challenges of clean energy innovation.

They formed the basis for broad area funding opportunity announcements soliciting peer-reviewed grant proposals. The workshop reports served as the basis for organizing and awarding 60 (mostly university-based) Energy Frontier Research Centers (EFRCs). Today, newly awarded EFRCs each receive $2 – $4 million per year for four years and may compete for renewal of their awards. While their focus is on basic research, EFRCs specialize in particular areas of technology innovation. They have led to at least 10 spin-off entities and start-ups. More than 90 companies have benefitted from the research knowledge and outcomes. Related outputs include: 7,700 scientific publications; 640 patent applications; and 100 licenses of intellectual property.

The workshop and reports also influenced the establishment of the Innovation Hubs. These are integrated research centers that combine basic and applied research with engineering to accelerate innovation in critical areas (e.g., the Joint Center for Energy Storage Research, Argonne National Laboratory).[1] The reports have also guided research calls from the Advanced Research Projects Agency – Energy (ARPA-E).

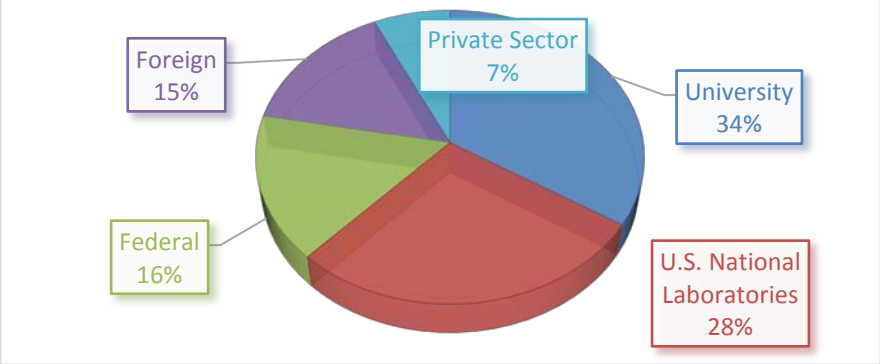

Figure 1: Demographics of the ~200 participants of the Solar Utilization Workshop (2005)

[1] For more information on EFRCs, see http://science.energy.gov/bes/efrc/. For more information on Innovation Hubs, see http://energy.gov/science-innovation/innovation/hubs.

Although the workshops are focused on fundamental problems, steeped in science, and define basic research needs, they are inherently "use-inspired". That is, they are motivated to find solutions that can overcome barriers to advancing specific energy technology and applications. The report titles in Appendix A display their purposes, namely, *Basic Research Needs for the Hydrogen Economy*, *Basic Research Needs for Energy Storage*, *Basic Research Needs for Solid State Lighting*, B*asic Research Needs for Carbon Capture*, and so on.

Next Steps and Potential Deliverables

In the planning horizon of the next several months, a number of steps could be undertaken to evidence meaningful progress under Mission Innovation by organizing an international effort on Grand Scientific Challenges in Clean Energy Innovation. Next steps and potential deliverables could include:

- At the London Workshop, present this as one possible initiative for adoption by MI members.
- Identify, in conjunction with Workshop discussions of "missions" by the IAR MI Sub-Group, high-priority topics for "R&D Opportunities Workshops in Clean Energy Innovation".
- Announce a call for proposals to the MI Members to host an R&D Opportunities Workshop.
- At the end of the open call, the MI Steering Committee selects a series of proposals for 2017.
- Announce the 2017 MI R&D Opportunities series of workshops and reports, with schedules and hosting MI governments.
- At COP22 or other scheduled MI ministerial gathering or event, have MI governments publicly signal their willingness to entertain grant applications and research proposals focused on the R&D Opportunities Workshop reports, and include their related funding plans/priorities.
- MI governments voluntarily highlight their domestic MI investments in areas that address the R&D Opportunities.
- The MI Secretariat collate and showcase the results periodically at various international events focused on energy, research and innovation, and around the MI events, such as subsequent anniversary dates of the launch of Mission Innovation (November 30) and a 2nd or 3rd Ministerial, perhaps co-located with the Clean Energy Ministerials, the next of which will be hosted by China and tentatively planned for May or June 2017 in Beijing.

Appendix A: List of "Basic Research Needs" Reports

Workshop/Report	Date	URL
Basic Research Needs for Innovation and Discovery of Transformative Experimental Tools	2016	Report in preparation
Basic Research Needs for Synthesis Science for Energy Relevant Technology	2016	Report in preparation
Basic Research Needs for Quantum Materials for Energy Relevant Technology	2016	Report in preparation
Basic Research Needs for Environmental Management	Feb-16	http://science.energy.gov/~/media/bes/pdf/reports/2016/BRNEM_rpt.pdf
Science for Energy Technology: Strengthening the Link between Basic Research and Industry	Aug-10	http://science.energy.gov/~/media/bes/pdf/reports/files/Science_for_Energy_Technology_rpt.pdf
Basic Research Needs for Carbon Capture: Beyond 2020	Mar-10	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Carbon_Capture_rpt.pdf
New Science for a Secure and Sustainable Energy Future	Dec-08	http://science.energy.gov/~/media/bes/pdf/reports/files/New_Science_for_a_Secure_and_Sustainable_Energy_Future_rpt.pdf
Basic Research Needs: Catalysis for Energy	Aug-07	http://science.energy.gov/~/media/bes/pdf/reports/files/cat_rpt.pdf
Basic Research Needs for Materials under Extreme Environments	Jun-07	http://science.energy.gov/~/media/bes/pdf/reports/files/Materials_under_Extreme_Environments_rpt.pdf
Basic Research Needs for Electrical Energy Storage	Apr-07	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Electrical_Energy_Storage_rpt.pdf
Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems	Feb-07	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Geosciences_rpt.pdf
Basic Research Needs for Clean and Efficient Combustion of 21st Century Transportation Fuels	Oct-06	http://science.energy.gov/~/media/bes/pdf/reports/files/Clean_and_Efficient_Combustion_of_21st_Century_Transportation_Fuels_rpt.pdf
Basic Research Needs for Advanced Nuclear Energy Systems	Jul-06	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Advanced_Nuclear_Energy_Systems_rpt.pdf
Basic Research Needs for Superconductivity	May-06	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Superconductivity_rpt.pdf
Basic Research Needs for Solid-State Lighting	May-06	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Solid-State_Lighting_rpt.pdf
Basic Research Needs for Solar Energy Utilization	Apr-05	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_Solar_Energy_Utilization_rpt.pdf
Basic Research Needs for the Hydrogen Economy	May-03	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_for_the_Hydrogen_Economy_rpt.pdf
Basic Research Needs to Assure a Secure Energy Future	Oct-02	http://science.energy.gov/~/media/bes/pdf/reports/files/Basic_Research_Needs_to_Assure_a_Secure_Energy_Future_rpt.pdf