The Science of Science Policy: A Federal Research Roadmap

Report on The Science of Science Policy To The
Subcommittee on Social, Behavioral and Economic Sciences
Committee on Science National Science and Technology Council
Office of Science and Technology Policy

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The National Imperative

It is imperative to advance the scientific basis of science policy so that limited Federal resources are invested wisely.

- Rigorous Tools, Methods, Data For Analysis Must be Developed
  - Given the importance of federal science investments, it is imperative that science policy decision makers have at their disposal the most rigorous tools, methods and data that will enable them to develop sound investment strategies.
- Federal Government's Investment Strategy Must be Effective and Meet National Needs

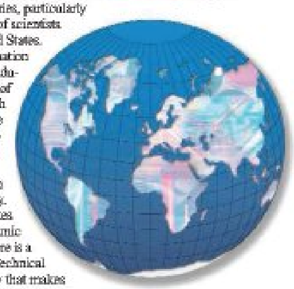
EDITORIAL

Wanted: Better Benchmarks

How much should a nation spend on science? What kind of science? How much from private versus public sectors? Does demand for funding by potential science performers imply a shortage of funding or a surfeit of performers? These and related science policy questions tend to be asked and answered today in a highly visible advocacy context that makes assumptions that are deserving of closer scrutiny. A new "science of science policy" is emerging, and it may offer more compelling guidance for policy decisions and for more credible advocacy.

All developed and many developing nations today have accepted the need to support technical education and research as keys to future economic strength. Studies from the 1990s show that U.S. investment in R&D development led to greater economic productivity, and that information technology, in particular, has been a major factor in sustaining U.S. productivity growth. The question is not whether R&D investments are important, but what investment strategies are most effective in the rapidly changing global environment for science. Here, ideas diverge.

Take the issue of the technical workforce. Sharply differing opinions exist regarding the production of U.S. scientists to meet possible impending shortages.* The differences turn on the interpretation of "benchmark" data regarding the numbers of degree holders produced in the United States and other countries, particularly China and India. In the latter countries, the rates of growth in the numbers of scientists are high, although actual numbers are small relative to those in the United States. Advocates for increased production of U.S. scientists point to our low graduation rates, whereas critics emphasize limited short-term job opportunities for graduates and postdocs. Resolution of this issue requires a broader understanding of socioeconomic factors in a number of nations that would allow us to attach probabilities to different future scenarios. Optimal strategies for large mature economies such as that of the United States will doubtless differ from those for smaller or developing economies. Here, as elsewhere in policy debates, the benchmarks do not speak for themselves.



The data we choose to collect do say something about the framework in which we understand the relations among science, government, and society. Our customary reliance on historical trends in national data, however, creates an inertia that causes data categories to lag far behind changes in the dynamic socioeconomic framework, now evolving internationally. We know that there is a complex linkage between workforce issues and other economic variables. Technical workforces in different countries are increasingly interdependent in a way that makes single-country data unreliable for workforce forecasts.

Globalization and changing modes of science that have blurred disciplinary distinctions have undermined the value of traditional science and engineering data and their conventional interpretations. The old budget categories of basic and applied R&D, still tracked by the U.S. Office of Management and Budget, do not come close to capturing information about the highly interdisciplinary activities thought to fuel innovation. A 1995 U.S. National Research Council (NRC) committee chaired by Frank Press took a step toward data reform when it introduced the combined category of "federal science and technology," declaring that "the linear sequential view of innovation is simplistic and misleading." More attention, however, is needed to definitions and models that suit current needs of policy. A recent report from the NRC Committee on National Statistics found that "the structure of . . . data collection is tied to models of R&D performance that are increasingly unrepresentative of the whole of the R&D enterprise." Further, "It would be desirable to devise, test and, if possible, implement survey tools that more directly measure the economic output of R&D in terms of short-term and long-term innovation."†

Relating R&D to innovation in any but a general way is a tall order, but not a hopeless one. We need econometric models that encompass enough variables in a sufficient number of countries to produce reasonable simulations of the effect of specific policy choices. This need won't be satisfied by a few grants or workshops, but demands the attention of a specialist scholarly community. As more economists and social scientists turn to these issues, the effectiveness of science policy will grow, and of science advocacy too.

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*D. Kennedy, J. Austin, K. Urquhart, C. Taylor, *Science* 303, 1106 (2004). †*Measuring Research and Development Expenditures in the U.S. Economy*, L. D. Brown, T. J. Plewes, M. A. Gerstein, Eds. (National Academies Press, Washington, DC, 2005).

10.1126/science.1114801

Helsinki

History of the Interagency Task Group (ITG)

The ITG Completed 4 Tasks:

- Literature Review & Synthesis
- Questionnaire to Federal S&T Agencies
- Review of Data Issues
- Roadmap

National Science and Technology Council
Committee on Science
Committee on Homeland and National Security
Subcommittee on Social, Behavioral and Economic Sciences
Interagency Task Group on Science of Science Policy

Charter

A. Preamble

The Interagency Task Group on Science of Science Policy (hereafter referred to as the "Task Group") is hereby established by the Subcommittee on Social, Behavioral and Economic Sciences (SBE). The Task Group serves as part of the internal deliberative process of the Subcommittee, which provides guidance and direction.

B. Purpose and Scope

Currently, science policy discussions are dominated by advocates for particular scientific fields or missions and policy decisions are frequently based upon past practice or data trends that may be out of date or have limited relevance to the current situation. We know that past investments in basic scientific research have had an enormous impact on innovation, economic growth and societal well-being, but we do not have the capacity to predict how best to make and manage future investments so as to exploit the most promising and important opportunities.

While some fields benefit from the availability of real-time data and computational models which allow for predictive analyses, science policy does not benefit from a similar set of tools and modeling capabilities. It is imperative to advance the scientific basis of science policy, through the development of data collection, analyses and modeling tools, so that we can make future policy decisions based on sound science and informed judgment. We must also develop both quantitative and qualitative tools to enable the collection of real-time data and to facilitate better retrospective analysis of the impact of federal investments on scientific discovery and innovation, the economy and society. In this way, we can learn from past investments and refine the accuracy of our predictive models.

In order to advance the academic discipline of the science of science policy, the SBE subcommittee is establishing a Task Group that will develop a roadmap for federal efforts directed toward the long-term development of a science of science policy.

C. Objectives

In formulating the roadmap, the Task Group will pursue the following objectives:

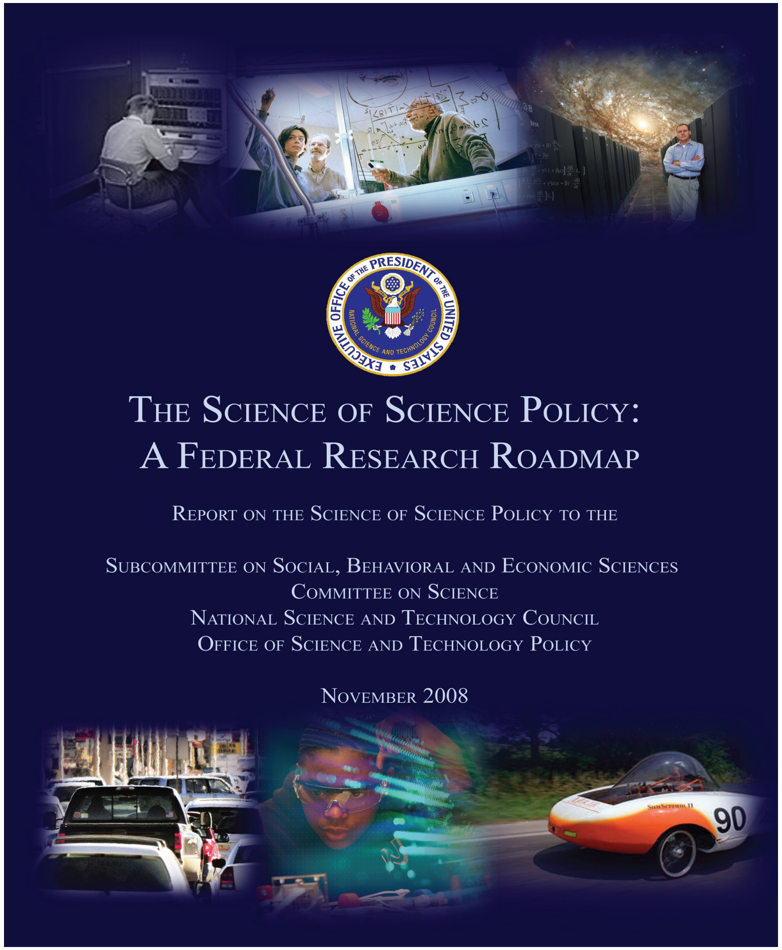
- Assess and inventory the current status of Federal and international efforts in the science of science policy and determine where gaps exist.
- Determine the sources of data and identify tools for modeling and analysis that have the potential to contribute to improved indicators and metrics for national and international research and development (R&D) investments.

The Road to the Roadmap

- Literature Review, Questionnaire, Data Investigations, and NSF's SCISIP Effort Provided the Data and Analysis
- Presentations at AAAS, AEA, WREN and Elsewhere Provided Context and Critiques
- Roadmap is Based on Three Key Themes that Emerged Over and Over Again During ITG Discussions and Analysis:
  - Understanding Science and Innovation
  - Investing in the Innovation Process
  - Using the Science of Science Policy to Address National Priorities

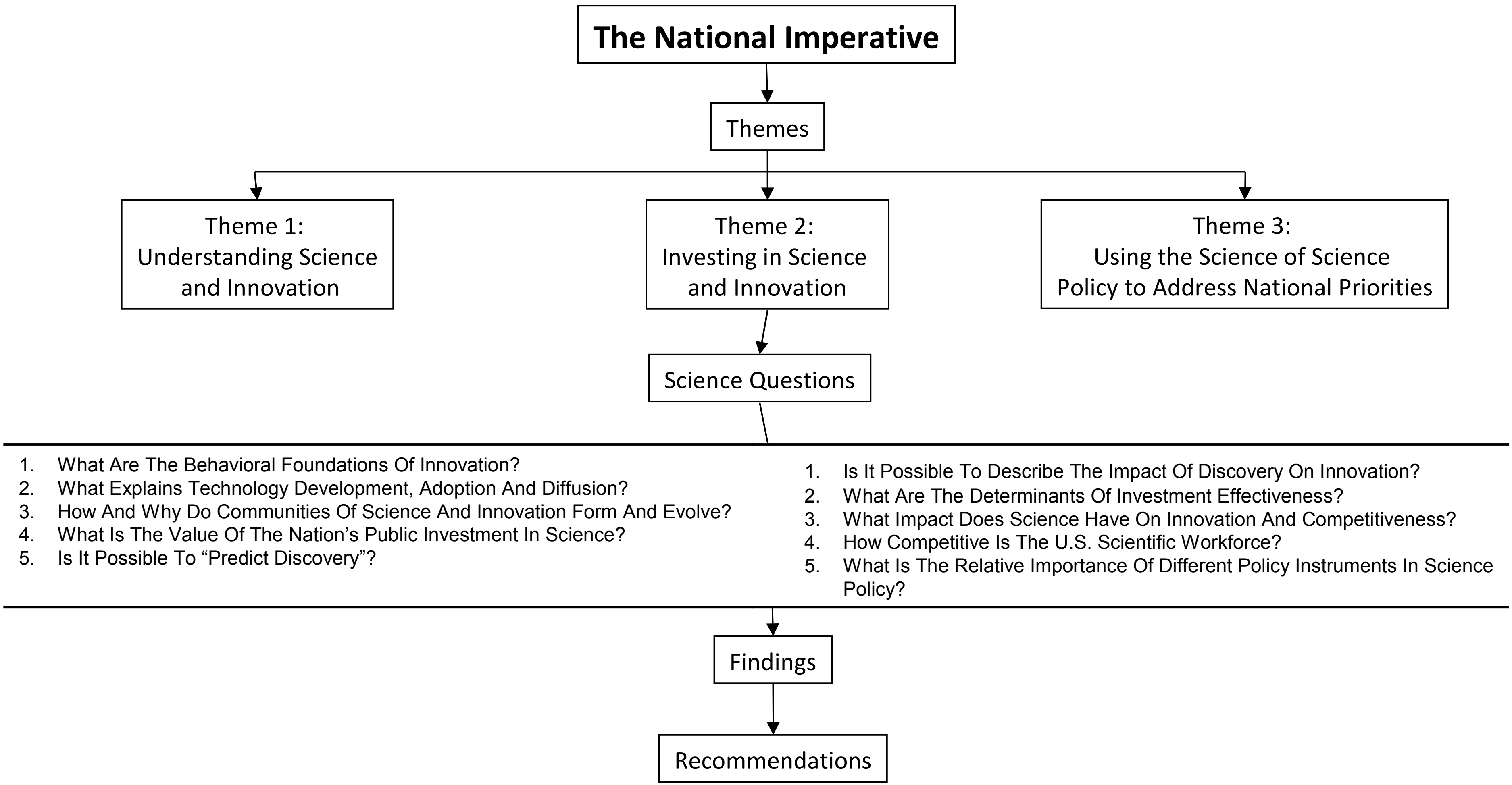
SoSP Roadmap

- Results
  - Two years of effort by 17 Federal Agencies
  - Has undergone an extensive interagency concurrence process
  - This Workshop is the first opportunity for the public to provide comments and advice



<u>Primary Conclusion:</u> "Expert judgment" remains the best available decision support tool for science policy makers, but a nascent community of practice is emerging in the science policy arena that holds enormous potential to provide rigorous and quantitative decision support tools in the near future. Support and development of this emerging community of practice can provide the Federal government with these much-needed decision tools.

Structure of The Roadmap



Theme 1:

Understanding Science and Innovation

- What are the behavioral micro-foundations of innovation?
- What explains technology adoption and diffusion?
- How and why do communities of innovation form and evolve?

Theme 1:
Key Findings

- Well developed body of social science knowledge: not applied to the study of science and innovation
- Study of technology adoption and diffusion largely confined to academia. Stronger links between academic and practitioner community needed
- Although each agency has its own community of practice, the collection and analysis of data about the scientists and the communities supported by those Federal agencies is heterogeneous and unsystematic. There is little analysis of the way in which the practice of science has become distributed across space, time, and disciplines as a result of computational advances. As a result, there is little understanding of how scientific communities respond to changes in funding within and across disciplines and countries, or to changes in program focus.

Theme 2:
Investing in Science and Innovation

- What is the value of publicly funded knowledge?
- Is it possible to predict discovery?
- Is it possible to describe the impact of discovery?
- What are the determinants of investment effectiveness?

Theme 2:
Key Findings

- Although determining the value of publicly funded knowledge is the critical outcome measure for Federal scientific agencies, the analysis is largely agency specific
- Agencies are using very different approaches and tools designed to develop scenarios that anticipate the effects of discovery and innovation
- Agencies are using a wide variety of approaches to describe the impact of discovery.
- Approaches that are used by Federal agencies to determine program effectiveness span the spectrum from mature to those in the pilot stage, but there are many open research questions.

Theme 3:

Using the Science of Science Policy to Address National Priorities

- What impact does science have on innovation and competitiveness?
- How competitive is the US scientific workforce?
- What is the relative importance of policy instruments in science policy?

Theme 3:

Key Findings

- The ITG finds that there is a real opportunity to develop new tools and data sets that could be used to quantify the impact that the scientific enterprise has had on innovation and competitiveness.
- Many critical questions about the quality and global nature of the STEM workforce cannot be answered due to a lack of data. While the models and tools exist to study flows of workers within and across disciplines and nations, lack of data means that the science policy community cannot answer important questions about the scientific enterprise.
- There has been very little investment in the U.S. and in other countries in understanding the relative importance of policy instruments. While the models and tools exist to examine the effectiveness of different approaches, there are gaps in the analytical structure, the data infrastructure, and a way of conveying information to policymakers

Recommendations

- Create an interagency research program to address the 10 scientific challenges
  - Invest in research data infrastructure
  - Invest in models, tools and metrics using ITG Evaluation Template
- Develop a National Innovation Framework
  - Explain benefits and effectiveness of S&T investments
  - Provide scenarios and options
- Create interagency entity to develop and sustain science policy analysis efforts
  - Synthesize and provide guide to current policy analysis practice
  - Nurture the nascent community of practice consisting of researchers and practitioners

Tools, Methods, and Data

The ITG also examined tools, methods and data that are either in use or could be used to do rigorous analysis.

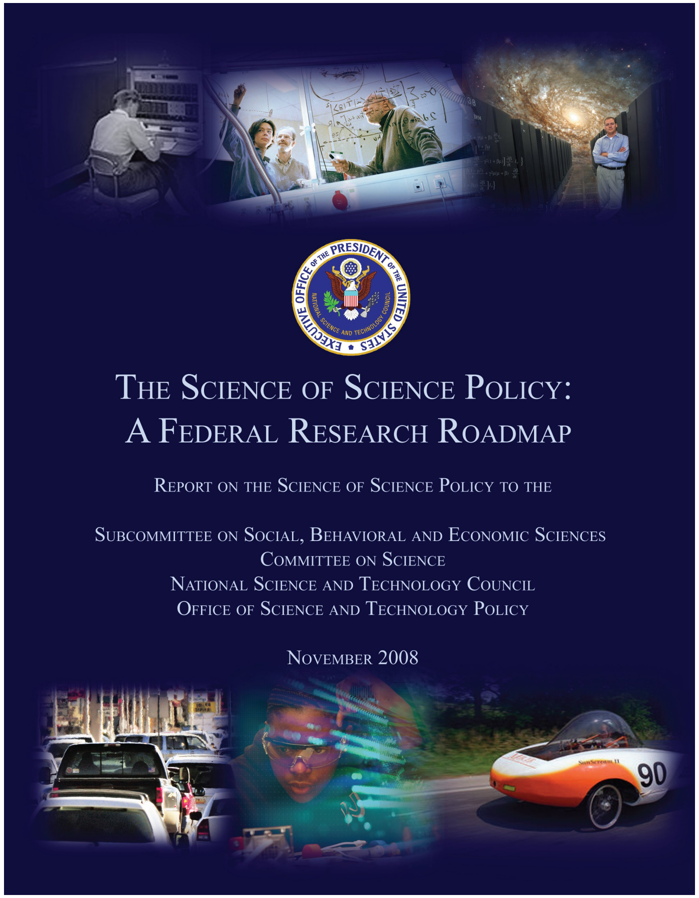
They were analyzed using two criteria:

- Potential Value
  - Relevance to Vision
  - Breadth of Use
  - Scientific Rigor
- Potential Cost
  - Maturity
  - Resource Intensity
  - Availability of Inputs

MODELS/TOOLS		Theme	Potential Value Value of Investment			Potential Cost		Main Missing Element
			Relevance to Vision	Breadth of Use	Scientific Rigor	Maturity	Access to Inputs	
Quantitative Analysis	Deterministic Models							
	- Econometric	1,2,3	Green	Red	Green	Yellow	Yellow	Data, Community
	- Risk Modeling	2,3	Green	Red	Yellow	Yellow	Yellow	Community
	- Options Modeling	2,3	Green	Red	Yellow	Yellow	Red	Community
	- Cost Benefit	2	Green	Green	Yellow	Yellow	Red	Community
	- Cost Effectiveness	2	Green	Green	Yellow	Yellow	Red	Community
	Stochastic Models							
	- Agent Based	2	Green	Red	Green	Red	Red	Data, Community
	- System Dynamics	2	Green	Yellow	Green	Yellow	Green	Community
Qualitative Analysis	- Case Studies	1, 2	Green	Green	Green	Green	Green	Community
	- Peer/Expert Review	2	Green	Green	Green	Green	Green	Community
	- Delphi	2	Green	Yellow	Red	Green	Yellow	Community
	- Strategic/Logic	2	Yellow	Green	Red	Green	Yellow	Community
Visualization Tools	- Network Analysis	2,3	Green	Red	Green	Red	Red	Data, Community
	- Visual Analytics	2, 3	Green	Red	Green	Yellow	Red	Community
	- Science Mapping	2,3	Green	Red	Red	Red	Red	Data, Community
	- Scientometrics	2, 3	Green	Green	Red	Yellow	Red	Data, Community
Data Collection Tools Tools	- Survey	1,2,3	Green	Green	Green	Green	Yellow	Data, Community
	- Web Scraping	1, 2,3	Green	Red	Red	Green	Yellow	Data, Community
	- Administrative Data	1, 2,3	Green	Red	Green	Green	Yellow	Community
	- Data Mining	1,2,3	Green	Red	Yellow	Red	Red	Data, Community

Purpose of the Workshop

- Comments on the Roadmap
- Begin Implementation of the Roadmap
- Promote the Nascent Community of Practice



Purpose of Pre-Assessment Activities

- Understand the Contents of the Roadmap
- Begin Thinking About Implementation Issues, Particularly in Relationship to Your Current Role in the Science of Science Policy Community
- Identify Members of the Science of Science Policy Community

Structure and Purpose of Breakout Groups

The Breakout Groups have been designed to promote critical thinking and discussion:

- Development of Electronic Decision Support Tools
- Assignments to the Breakout Groups
- Paper Copies

- Facilitators and Dialog
- Results of the Breakout Sessions
  - Posting Next Day

Theme 1

Tool Question 1: High Level input on Questions, Findings and Recommendations

This tool is intended to get your input on the relative importance of the science questions identified by the ITG as well as invite alternative suggestions. We have allocated 10 minutes to collect your input on this topic, to be followed by 10 minutes of group discussion.

Please record your view on the importance of the following questions for understanding science and innovation. Then also rank the priority from 1 to 3.

Importance				Priority Rank (1-3, 1 being highest)		
High	Med	Low		1	2	3
			Question 1: What are the behavioral micro-foundations of innovation?			
			Question 2: What explains technology adoption and diffusion?			
			Question 3: How and why do communities of			

Do you have alternative suggestions for scientific questions?

Save & Proceed

Save & keep me in this screen

Theme 4

Workshop Decision Tool: Theme 4:
Identifying Data Needs for Implementing SoSP

We have developed five sets of exercises within this tool to get input from workshop participants. These results will be used to help guide the next steps and recommendations of the SOSP Interagency Group (ITG). Of course, your input will be kept confidential – only summary statistics will be produced. You will have an opportunity to fill the tool out now as well as to log on to update your responses online later.

The five sets of exercises cover the following topics the ITG has identified as being necessary to establish an empirical platform for implementing the science of science policy.

- Tool Question 1: Measuring and tracking federal funding of science
- Tool Question 2: Measuring and tracking the scientific workforce
- Tool Question 3: Measuring and tracking scientific outcomes
- Tool Question 4; Measuring competitiveness
- Tool Question 5: Analytical Access by researchers and federal government agencies

Each section begins by identifying broad research questions, then possible ways in which the data infrastructure should be established (e.g. surveys, administrative records or web-scraping). Each section concludes by identifying possible data elements that could be collected and then asks for your open-ended input.

Conclusion: Where We Are Headed

- WIKI will be Promoted
  - Support A Community of Practice
- Workshop Results Implemented
  - Roadmap Modification
  - Development of Roadmap Implementation
  - Plan for the ITG
- Search For Low Hanging Fruit
  - Tools, methods and data that could support the National Imperative
- Create Tools, Methods and Data to Support Emerging National Imperatives

"Invest $150 billion over the next ten years to enable American engineers, scientists and entrepreneurs to advance the next generation of biofuels and fuel infrastructure, accelerate the commercialization of plug-in hybrids, promote development of commercial-scale renewable energy, and begin the transition to a new digital electricity grid. This investment will transform the economy and create 5 million new jobs."

http://change.gov/agenda/technology_agenda/