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DOE/ER62747-Final

FINAL REPORT
Technology Innovation for Global Change: The Role of Assessment, R&D, and Regulation
DOE Grant #: DE-FG02-99ER62747
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November 27, 2001

Through the research carried out under this grant, we have made considerable progress in addressing our fundamental research question: How and under what conditions can government stimulate radical technological innovation? More specifically, we have analyzed three pathways through which government may influence the decisions by firms to invest in radical technological innovation: technological opportunism (supply-push policies), regulatory responsiveness (demand-pull policies) and anticipatory action (assessments and information policy). We have produced several written documents, as well as made several presentations of our work. We are now working on a book based on this research, which we will have to a publisher in 2002. We are also pursuing other opportunities for dissemination of the results, including both presentations and articles in the academic and policy press.

Research Design

We addressed our research question by focusing on the role of government in the development of three technologies: gas turbines, wind turbines, and solar photovoltaics. A key component of this research was in depth interviews at leading firms in each of these industries. The firms that we included in the study are listed below. At each firm, we interviewed high level managerial and scientific personnel. The number of people we interviewed at each firm depended on firm size and organization. At the larger firms, we talked with 8 to12 people; at the smaller firms it varied, but was generally under 5. We have also completed extensive archival research on each of these firms and on the government programs that influenced the development and deployment of these technologies. The research also included interviews with Department of Energy, Environmental Protection Agency, and national laboratory personnel.

Gas Turbines

- General Electric
- Siemens-Westinghouse (interviews in Atlanta (formerly Westinghouse) and Munich (formerly Siemens)
- Enron

Wind Turbines

- Enron Wind (interviews at Enron Headquarters, Houston and Enron Wind, Tehachapi)
- The Wind Company

Solar Photovoltaics

- BP (interviews in Maryland (formerly Solarex) and in Britain with BP Solar and BP Headquarters)
- Siemens Solar (in Munich and in California)
- Evergreen Solar
- Astropower

Results

Analysis to date has focused on two of the three pathways - supply-push policies and demand-pull policies. We are in the process of analyzing the role of assessment as well as looking at the interaction of these three pathways. We are finding that assessment plays a less direct and generally weaker, but sometimes catalytic role in firms' strategic decisions to invest in technology innovation. We will be drawing lessons on the circumstances under which assessment activities can increase anticipatory action by firms. Below we summarize the some of our initial findings.

Our initial analysis of the first two pathways and their interaction (technological opportunism and regulatory responsiveness) has shed light on the role of government policy in closing the "gap" between invention and commercialization. This gap has recently been called "the valley of death," to describe the fact that many technologies perish after invention but prior to commercialization. Our research suggests that for clean energy technologies, this valley consists of funding, technical and market gaps. We expect these gaps to be wider for clean energy technologies than many other commercial technologies for several reasons: public benefits are not reflected in market prices; there are limited niche markets for many new energy technologies; there is a long time horizon between basic R&D and proof of principal; and there is often a need for complementary institutional and infrastructure development for new energy technologies to succeed in the marketplace.

Our research found that government policies and programs played a fundamental role in closing all three aspects of this gap. In terms of R&D funding, government support was critical for moving technologies from concept to proof of principal. For the firms in our sample, from one-third to almost 100 percent of the research budget came from public support. The private funding that firms received was often contingent on winning government contracts. Furthermore, government funding helped firms reach milestones necessary to receive additional funding from private sources. We also found that even for large firms with deep pockets, government support for R&D was critical for radical innovation. This is for several reasons: financial strength does not necessary translate into innovation for the public good; radical component innovation for mature technologies may be too risky for the private sector; the financial strength of a parent company does not translate into investment in radical innovation; and finally, even for an established technology, a slowdown in the market can reduce the ability to generate internal R&D funding. In terms of the technology gap, we found that government laboratories provided important complementary assets to private sector efforts in technology innovation, including testing facilities, design review, and in some cases technological knowledge. In terms of the market gap, we found that government support for markets had a

positive feedback to private sector investments in technology innovation. This is despite the fact that private funders often expressed cautiousness about investing in technology innovation for government created markets, due to the uncertainty in level and timeframe. In sum, our research suggests that there is the possibility of creating a virtuous cycle in which government programs and policies that simultaneously support both R&D and markets can stimulate private sector investments that move radical innovations through the learning process that is necessary for them to become commercially competitive.

Our initial analysis of the "technological opportunism" pathway has also focused on evaluating the evolving paradigm for government sponsored R&D, which emphasizes collaboration and partnership, and includes: cost-sharing, transfer of intellectual property rights to the private sector, funding closer to commercialization, and an increased focus on manufacturing. Within our cases we have looked in depth at three DOE sponsored R&D collaborations: the Advanced Turbine Systems (ATS) program, the Photovoltaic Manufacturing Technology (PVMaT) project, and the Thin-Film PV Partnership project. We conclude that through collaborative goal setting and implementation, these partnerships moved industry at a faster pace than it would have otherwise gone in the development and commercialization of radical technological innovation. For both gas turbines and PV, this resulted in having better products available for the current rapidly expanding market. In order to achieve these results, the government needed to provide significant cost-sharing, and industry had to believe that the goals were reachable and that the resulting technology would be competitive in the market. In this sense, these programs operated in tandem with energy and environmental regulation that was creating markets for these technologies, both at home and abroad. These programs were focused on near- and medium-term technological goals. In considering the application of R&D collaborations for radical innovation that is further from market, two additional issues must be addressed: balancing near-term and long-term technological goals and integrating evolving environmental science and regulation into project goals. We expect to take up this last point in more depth as we analyze the interaction of our third pathway – anticipating action.

Ongoing Analysis

The outline for our book is presented below. We have begun discussions with MIT Press on publication of this book.

Working Title: Technology Innovation for Global Change

Chapter 1: Introduction.
Chapter 2: Stimulating Technological Innovation: The Role of Assessment, R&D, and Regulation
Chapter 3: Public Policy in the Development of Photovoltaics
Chapter 4: Public Policy in the Development of Wind Turbines
Chapter 5: Public Policy in the Development of Gas Turbines
Chapter 6: Bringing Technology through Commercialization: Public Policy and Learning
Chapter 7: Conclusions: Policy Lessons

Presentations

In addition to several presentations by Robert Margolis and Vicki Norberg-Bohm in our weekly Science, Technology and Public Policy seminar at the Belfer Center for Science in International Affairs at Harvard University, over the last year, Vicki Norberg-Bohm has presented our work in progress in the following venues:

- Organization for Economic Development, Directorate for Science, Technology and Industry, Workshop on the Environment and Innovation, June 2000
- Energy and Resources Group seminar, University of California, Berkeley, September 2000
- Association for Public Policy Analysis and Management Annual Research Conference, Nov. 2000, in a panel titled, *Voluntary, Collaborative and Information Based Environment Policy: A Viable Path to Improve Environmental Performance.*
- American Association for the Advancement of Science Annual Meeting, February of 2001, in a symposium titled *The Government's Role in the Commercialization of Environmentally Enhancing Technologies.*

Vicki Norberg-Bohm is currently organizing a conference for the Department of Energy on *The Government's Role in Technology Innovation*, to be held in February 2002. She will be presenting results from this research, as well as inviting 5 other experts to present work on this topic.

Publications

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