

Energy innovation in the private sector: A survey of US business establishments

Abstract for International Energy Workshop 2011

Charles A Jones and Laura Diaz Anadon

Energy Research, Development, Demonstration and Deployment Project
Belfer Center for Science and International Affairs
Harvard Kennedy School

A survey of business establishments in the United States was conducted to estimate private sector investment in, use of, and process of energy technology innovation (ETI). The *Survey of Energy Innovation* served both as data collection for initial estimates, and as a pilot for a future larger scale survey. This paper will discuss the lessons learned for survey design as well as present initial estimates of private sector ETI investments and process. The work we present will benefit those designing establishment surveys and provide data for models of firm strategy or innovation.

The study is motivated by the need for better management in the ETI effort (Anadon, Bunn, Jones, & Narayanamurti, 2010). Although all sectors—academic, governmental, non-profit, and private—have a role in energy technology innovation, the trajectory of a technological advance cannot be successful until a product or process is in use, which means production and sales by the private sector (FLC, 2007). Encouraging private sector innovation in energy and in general has been a goal of public policy (CCTP, 2006; DOE, 2006; EOP, 2009). Two problems hamper the ability to meet this goal: the amount and distribution of investment are poorly measured, and what indicators we do have suggest it is low compared to the need and potential for energy technology innovation (Nemet & Kammen, 2007).

Both the Business R&D and Innovation Survey (BRDIS) (NSF, 2010b) and its predecessor the Survey of Industrial Research and Development (SIRD) (NSF, 2009) ask a single question about energy R&D: “what percent [of R&D expenses] had energy applications” with little explanation of what that means (Census, 2009). SIRD was most recently completed in 2005 and asked about energy only to large companies (NSF, 2009). BRDIS asks all respondents about energy R&D, but data including this question is not scheduled for release until later in 2011 for 2008 data (Wolfe, 2010).

What existing data sources can reveal is that in 2008, \$398 billion worth of R&D was performed by all sectors, and \$268 billion of that (67%) was funded by the private sector. This amounts to approximately 2.8% of GDP, with 1.9% of GDP funded by private industry (NSF, 2010a). In 2005 – the most recent energy specific R&D survey available – the largest R&D providers reported \$2.9 billion in energy R&D (NSF, 2009); Bloomberg New Energy Finance recorded \$2.2 billion in energy-related venture capital (NEF, 2009); and the Department of Energy funded \$3.3 billion in energy sciences, energy R&D, and energy demonstration (Gallagher & Anadon, 2010). Even accepting that these are problematic proxies for overall energy innovation, their sum

is only 0.8% of the \$1.1 trillion of energy expenditures (EIA, 2010) and 40% of the funding is the Federal government.

To complement other data sources, we designed the Survey of Energy Innovation to be easy to complete, quick to turn around, and detailed across various energy and innovation segments. The instrument is split into two parts – screener and follow-up. Each question covers a specific area of activity to disaggregate types of energy innovation and reduce the need for respondent interpretation. The survey as a whole covers a broad range of activity across relevant aspects of energy use and innovation, from new types of energy equipment to techniques for reducing energy use. The instrument and sampling strategy are coordinated to uncover the many types of activity that are involved in using and generating energy technology innovation.

The questionnaire was tested for clarity and validity over several rounds of review. Our advisory board of experts from industry, government, non-profit, and academia provided critical reviews, as did one additional external researcher with experience in industry surveys. The instrument was also tested by five cognitive testers from different parts of energy-related businesses and engaged in different types of innovation activities. Testers participated in one-hour interviews after having a chance to review the draft instrument. We conducted the tests in a sequence of three cognitive interviews; revision and further expert and academic review; two more cognitive interviews; and finally revisions incorporating all feedback. The interviews revealed that testers had the same understanding of the questions as intended, and that their answers were robust to differences in wording. Most testers were able to complete the instrument in about 15 minutes per part; the most complex businesses took up to 45 minutes to complete the follow-up part.

The population of interest is all non-farm business establishments in the United States. The sample is, however, heavily stratified to concentrate on those industries where energy innovation is likely to be important. The sample frame is the Dunn and Bradstreet (D&B) business list, which has over 12 million establishments in our population of interest. The variables for stratification are the North American Industry Classification System (NAICS) code and the indicator for headquarters establishments. We sample a small number of establishments in trade, services, finance, etc. We sample a larger number of establishments from: specific manufacturing sectors; energy-related mining, construction, and utilities; R&D service providers and other technical services. We over-sample headquarters locations, and among those more manufacturing, mining, utilities, and construction than trade, finance and services.

The research services company Westat provided survey and statistical expertise during survey design, and conducted the survey. A large scale pilot was conducted August through November 2010. The sample included 1502 establishments in three groups: 32 establishments selected deliberately to test the procedures, 50 start-up firms in the clean energy business selected from the Bloomberg New Energy Finance database, and the main sample of 1420 drawn from the D&B business list. The instruments were mailed to the CEO or senior manager at each sampled establishment, with introductory and follow-up reminders to encourage participation. 197 were

returned as non-deliverable or were no longer in operation, leaving 1305 as the sample size. We received 192 responses for a response rate of 14.7%. An aggressive follow-up with a sample of 258 of the non-respondents yielded 82 additional data points for non-response bias testing. The non-response bias test served to determine whether non-respondents were on average as likely as respondents to engage in energy-related innovation.

Because energy and innovation industries were sampled more heavily than others, a weight is applied to each respondent that reflects how much it represents the population as a whole. Those weights take into account both the probability of each establishment being selected and the response rate of similar establishments. Similarly, estimates of the standard errors take into account the variable response rate and complex sample design. We accomplish this using the multiple-factor jackknife (JKn) method (Brick, Morganstein, & Valliant, 2000) implemented using Westvar survey analysis software.

Of the 192 respondents to the screener questionnaire, 107 (56%) report some level of involvement with energy as we describe in 4.5.1; 88 (46%) report innovative activities or use of the results or innovation in other entities; and 54 (28%) report that their innovation activities and their energy activities are related. The establishments of greatest interest are those that report actual performance, funding, or direction of innovation – 61 or 32% of respondents do the innovation themselves, and 38 of these (20% of the total) do innovation in energy. The 82 establishments that did not answer the screening questionnaire but were interviewed thereafter were slightly less likely to engage in energy innovation, but the differences were not statistically discernable: 45% reported energy activities, 22% conduct innovation and 16% performed innovation related to energy.

Accounting for the design of the survey (the stratification) and the differing response rates allows us to make estimates of the energy innovation landscape in the United States. About a fifth of business establishments are involved in energy; about a fifth in innovation; 17% are involved in both with 16% specifically in energy innovation. About a tenth of establishments actually perform, fund, or direct energy innovation and another 5% consider energy innovation by others as important to their business. Table 1 presents the detailed estimates with standard margins of error. In calculating estimates and standard errors, only the establishments from the main sample (180 respondents from the D&B business list) are included because only they have statistically meaningful chance of being selected from which weight is calculated.

258 of the non-respondents were contacted in an attempt to measure response bias. 82 of these completed a telephone interview; 37 (45%) reported being involved in energy and 13 (16%) in energy-related innovation. Accounting for the sample design, an estimated 9.9% of the non-respondents are involved in energy and 4.3% in energy-related innovation—less than the estimate from those completing the survey proper, and evidence of response bias. Further evidence of response bias is that the weighted estimates of energy / energy-related innovation are 28.6% / 24.0% among those answering the first mailing, and only 8.3% / 2.6% from the second

mailing. Assuming the worst in response bias, i.e., that none of the non-respondents are involved in energy or innovation, still produces a floor of 3.4% of all establishments involved in energy, and 2.4% involved in energy-related innovation (with approximate error of 1.3%). Estimates are shown in Table 1.

Table 1: Prevalence estimates from the Survey of Energy Innovation

Activity	Estimate	Standard Error
Involved in Energy	21.0%	4.6%
- Services, goods, equipment	15.8%	10.7%
- Energy use	9.8%	7.1%
- Innovation providers	5.4%	4.6%
Involved in Innovation	19.1%	10.7%
- Perform, fund, direct	12.7%	10.2%
- Use of others	18.8%	10.7%
Both Energy & Innovation	17.3%	10.6%
Involved in Energy-related Innovation	16.0%	10.6%
Conducting Energy-related Innovation	11.1%	10.3%
Start-up Companies	0.64%	0.3%
- Involved in Energy	0.57%	0.3%
- In Energy-related Innovation	0.27%	0.2%
Floor estimate of establishments involved in Energy	3.4%	1.1%
Floor estimate of establishments in Energy-related Innovation	2.4%	1.3%

Of the 192 respondents, 33 described themselves as start-ups, and reported a total of \$394 million in capital raised to date. 20 of these were both start-up and ETI participants, representing most (\$330 million) of the capital raise to date. However 10 of these start-ups including the largest were in the seeded or New Energy Finance sample. Over the entire population, just over six tenths of a percent of all establishments are start-ups; and nearly half of those are engaged in energy technology innovation. The sample yields an estimate of 66 thousand (se=30thousand) start-ups in the D&B database, with \$55 billion (se=\$34 billion) in capital raised to date.

Establishments that reported innovation activities related to energy activities (n=57) were sent a follow-up survey instrument, including 3 that did not follow instructions correctly but seemed to have energy related innovation. 29 completed the follow-up instrument – 15 start-up and 14 not. There were only 20 eligible start-ups in the 57 sent follow-up instruments, displaying a much higher response rate. The 17 of these establishments that conduct energy innovation as a normal part of business report \$33 million (\pm \$21 million) in innovation expenses in 2009. Four establishments reported only using and not generating innovation, and 8 reported that innovation occurred only as the result of special projects. Their most recent special projects were reported as totaling \$5.4 million, and having been completed on average one year in the past. More start-ups do as normal business (12/15) than do established firms (5/14).

Although the pilot phase results have large standard errors and display evidence of response bias, the picture that emerges is important for policy-making. A large part of the population has some involvement with energy-related innovation. Most of the follow-up respondents (11 of 17) report

less than \$200 thousand in ETI expenses, though the total value is dominated by 2 start-ups who report \$5-20 million. There may not be significantly more investment than the existing data suggest, but there is far broader participation and small-scale innovators are important. All stages of innovation and all technology areas were represented even in our small sample.

Respondents described the effect of policy and market forces on their ETI efforts. Respondents viewed energy prices and cost-cutting opportunities as the biggest drivers of energy innovation. Government R&D grants and support promote innovation more than the R&D tax credits; taken together, government policies that encourage demand were seen as more significant than grants and tax credits as a group. High commercialization cost was the single largest barrier to ETI, but the set of R&D process issues was mentioned just as often as the set of market issues. Both sets are more often seen as barriers than technological, policy, or other issues.

Institutional sources (such as universities and the national labs) are, along with energy prices, most significant sources of information for ETI decisions, but they are less significant than firms' own industries as an actual source of innovation itself. Cooperation with government and with universities are the most commonly mentioned beneficial trends. In evaluating investments in ETI, an expected payback time (mostly 2-3 years) is the most common method, but informal evaluations are nearly as common. The start-ups that completed the follow-up instrument report on average 75% of start-up capital was spend on ETI.

The principal problem identified in the study was the low response rate. The single mode, mail-out / mail-in method was chosen to preserve resources for the design, testing, and sampling efforts. In a larger-scale conduct of the survey, a more robust collection method will be needed to improve the return to resources expended, possibly collecting the screening data by telephone. Additionally, incentives will be available to qualifying respondents, such as early access to a report of the survey which could be of strategic value. There is some indication in the responses that many firms saw the survey as not applying to them. The survey opened with questions on energy and innovation, which appealed to our testers, but possibly at the expense of appeal to establishments in general. Starting with questions that apply to more firms may increase response rate and reduce response bias.

In contrast, other aspects of the test were successful. Only 5 instruments of the 221 instruments over two phases were completed contrary to instructions. Where it was possible to check, the answers provided were internally consistent. The instrument proved easy to answer and provide rich detail on the processes of energy innovation. An expanded scale study should provide good estimates of the investment in ETI by the private sector, while illuminating the process and measuring the distribution of that effort.

References

- Anadon, Laura Diaz, Bunn, Matthew, Jones, Charles A, & Narayanamurti, Venkatesh. (2010). *U.S. Public Energy Innovation Institutions and Mechanisms: Status & Deficiencies* (Policy Memo). Cambridge MA: Belfer Center for Science and International Affairs, Harvard Kennedy School. available at belfercenter.ksg.harvard.edu/publication/19877/.
- Brick, J Michael, Morganstein, David, & Valliant, Richard. (2000). *Analysis of Complex Sample Data Using Replication* (Technical Report): Westat.
- Climate Change Technology Program. (2006). U.S. Climate Change Technology Program Strategic Plan (DOE/PI-0005). Washington DC: DOE.
- US Census Bureau. (2009). Business R&D and Innovation Survey (Help Site). Washington DC. available at <http://bhs.econ.census.gov/BHS/BRDIS/index.html>.
- Department of Energy. (2006). U.S. Department of Energy Strategic Plan (DOE/CF-0010). Washington DC: DOE.
- Energy Information Administration. (2010). Annual Energy Review 2009 (DOE/EIA 0384(2009)). Washington DC: EIA. available at www.eia.gov/emeu/aer/contents.html.
- Executive Office of the President. (2009). A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs (white paper). Washington DC: NEC & OSTP.
- Federal Laboratory Consortium. (2007). Federal Laboratories & State and Local Governments: Partners for technology transfer success. Cherry Hill NJ: FLC.
- Gallagher, Kelly Sims, & Anadon, Laura Diaz. (2010). *DOE Budget Authority for Energy Research, Development, and Demonstration Database* (Energy Technology Innovation Policy Report). Cambridge MA: John F. Kennedy School of Government, Harvard University.
- New Energy Finance. (2009). NEF Desktop 3.0 (proprietary database). available at www.newenergymatters.com.
- Nemet, Gregory F, & Kammen, Daniel M. (2007). U.S. energy research and development: Declining investment, increasing need, and the feasibility of expansion. *Energy Policy*, 35(1), 746–755.
- National Science Foundation Division of Science Resource Statistics. (2009). Research and Development in Industry: 2005 (NSF 10-319). Arlington VA: NSF.
- National Science Foundation Division of Science Resource Statistics. (2010a). National patterns of R&D resources: 2008 data update (NSF 10-314). Arlington VA: NSF.
- National Science Foundation. (2010b). Science and Engineering Indicators 2010 (NSB 10-01). Arlington VA: National Science Foundation. available at www.nsf.gov/statistics/seind10/.
- Wolfe, Raymond M. (2010). *U.S. businesses report 2008 worldwide R&D expense of \$330 billion: Findings from new NSF survey* (Info brief No. 10-322). Arlington VA: National Science Foundation.