Research and Development by Public Utilities: Should More be Done?

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Three Takeaways

- Research and development (R&D) is critical for both economic growth and the survival and long-term prosperity of individual firms.
- A general concern exists over deficient R&D for both the country as a whole and individual industries, including energy public utilities.
- State utility commissions might want to revisit their polices and practices that affect utilities’ willingness and ability to invest in R&D.
The Importance of R&D

• Innovation (e.g., technological change) is a key element for economic growth and long-term prosperity
  ❖ It can spawn new products, improvement of existing products, or higher efficiency of production processes
  ❖ Economists have long held that technological change is critical for economic growth

• A precursor to innovation is investments in R&D

• Demand for R&D is therefore a derived demand for improved products/processes that are commercially profitable or achieve some public benefit more effectively or at a lower cost (e.g., knowledge for the sake of knowledge has no commercial value)

• Closer to home, R&D is also critical for advancing long-term policy objectives, like safety, reliability, cheaper energy, and a cleaner environment
The Innovation Process

“Innovation is the search for, and the discovery, development, improvement, adoption and commercialization of new processes, new products, and new organizational structures and procedures” (according to one definition)

Innovation consists of two basic steps: (1) create new ideas and (2) implement them

Innovation process normally involves three sequential actions:

- Scientific process of discovering new knowledge and determining the feasibility of new technologies (R&D)
- Demonstration stage where new ideas and technologies are implemented in prototype plants to evaluate performance and cost (required information, e.g., for assessing practical or commercial viability of a technology)
- Deployment involves commercialization of the new technology
National Trends in R&D

- Shift toward short-term R&D projects with quick payback
- Decline over time in the level of R&D funding (in constant $) by the federal government
- Total spending on R&D (public plus private) has been relatively stable over the past three decades at roughly 2.5% of GDP
- But the share of private R&D has increased while the share of public R&D has fallen
- After 1980, small firms rivaled and even surpassed large firms in terms of R&D intensity
- Because of the federal budget situation, we can expect lower R&D financial support from the federal government in the future

- There is concern over the downward trend in basic research affecting future innovation
- There is also concern over the low level of R&D in the energy industry
- R&D is vulnerable to budget cuts, by both the government and business sector, since its contributions are long term in nature and difficult to quantify
- During 1953-1987, the real annual growth rate in federal R&D spending was 4.9%, during 1987-2008 it grew at just 0.3%, and during 2008-2013 it declined by 1%
- The federal government funded most of R&D before the 1980s; share of business sector funded R&D rose relative to federal-funded R&D since the mid-1960s
Some Facts on R&D in General

- R&D in the U.S. totaled $456.1 billion in 2013
- Funding by the business sector accounted for $297.3 billion, or 65% of the national total
- The federal government funded $121.8 billion, or 27% of U.S. R&D
- Of the total R&D, basic research accounts for 18%, applied research for 20% and development for 62%
- Government is the most important source of financial support for basic research
- Over 50% of basic research is conducted by universities and colleges, 56% of applied research by the business sector, and almost 90% of development by the business sector (see slide 8)
- Five industries (that include chemicals, pharmaceuticals and medicines, electronic products) accounted for 87% of domestic business R&D in 2013
- There is a wide difference in R&D intensity across industries (see slide 9)
- For all industries in 2013, the R&D intensity was 3.3%; 3.8% for manufacturers and 2.7% for non-manufacturers
- The U.S. is the world’s largest R&D performer but its share has declined over time
- The U.S. spends less R&D as a percentage of GDP than many other developed countries
- Empirical evidence shows the social rates of return on R&D to be much greater than the private rates of returns
Some Facts on Energy R&D

- Utilities, which include power generation, transmission, and distribution, natural gas distribution, water supply and sewerage treatment, spent just 0.1% of revenues on R&D.
- Federal government energy R&D as a percentage of GDP has dropped since the 1970s, and private sector energy R&D has been flat.
- The federal commitment to energy R&D is less than 0.5% of the annual nationwide energy bill.
- While U.S. expenditures for energy R&D has risen in recent years, they are only about one-half the level in real dollars of R&D in late 1970s during the oil crisis.
- Federal R&D expenditures have shifted toward “clean air” programs, such as energy efficiency, renewable energy, and modernization of the electric grid.
- DOE receives about 7% of the total federal budget for R&D (Defense gets 50% with Health and Human Services receiving 25%)
- DOE has different R&D arrangements: contracts with industry, work at its labs, and grants to universities and industry consortia.
- As discussed later, we have seen R&D drastically curtailed in the natural gas sector.

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### Funding and Performing Sector of Different Stages of Research

<table>
<thead>
<tr>
<th></th>
<th>Basic Research</th>
<th>Applied Research</th>
<th>Development</th>
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<tbody>
<tr>
<td><strong>Business Sector</strong></td>
<td>35.3% (24.2%)*</td>
<td>55.2% (56.3%)</td>
<td>80.9% (88.4%)</td>
</tr>
<tr>
<td><strong>Federal Government</strong></td>
<td>47.0 (11.8)</td>
<td>36.8 (16.6)</td>
<td>17.8 (8.9)</td>
</tr>
<tr>
<td><strong>Other Entities (e.g., universities, nonprofit groups)</strong></td>
<td>17.7 (64.0)</td>
<td>8.0 (27.1)</td>
<td>1.3 (2.7)</td>
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Source: National Science Foundation

* Performing sector
R&D Intensity for Different Industries (2013)

<table>
<thead>
<tr>
<th>Industry</th>
<th>R&amp;D Intensity</th>
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<tbody>
<tr>
<td>All industries</td>
<td>3.3%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>3.8</td>
</tr>
<tr>
<td>Chemicals</td>
<td>4.5</td>
</tr>
<tr>
<td>Pharmaceuticals and medicines</td>
<td>10.3</td>
</tr>
<tr>
<td>Automobiles, trailers and parts</td>
<td>2.4</td>
</tr>
<tr>
<td>Computer and electronic products</td>
<td>10.6</td>
</tr>
<tr>
<td>Electrical equipment</td>
<td>2.9</td>
</tr>
<tr>
<td>Non-manufacturing industries</td>
<td>2.7</td>
</tr>
<tr>
<td>Software publishers</td>
<td>9.0</td>
</tr>
<tr>
<td>Computer systems design</td>
<td>8.4</td>
</tr>
<tr>
<td>Finance and insurance</td>
<td>0.7</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.1</td>
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</tbody>
</table>

Source: National Science Foundation
The Economics of R&D: Challenges Abound

- Expensive
- Initiated by technology-push or demand-pull incentives
- Expenditures can incur several years before the firm reaps additional revenues or other benefits
- Inherently risky (“dry holes” are common) – costs and success are difficult to predict, and benefits are often distant
- In a dynamic world, R&D for one technology can quickly become obsolete with the introduction of newer, more promising technologies
- Benefits can be appropriated by others, competing firms in the industry or the public at large (“free riders”)
- The above comments imply that firms are unlikely to innovate unless the payoff from successful innovation is large, which is usually the case
- The market may also under-allocate resources to R&D, for example because of public benefits
- Innovation usually begins with R&D, but not always
R&D in the Private Non-Regulated Sector

- Driven by the profit motive
- Tradeoff of an early adopter between additional costs and potentially higher benefits
- For example, leaders can reap higher profits but often incur higher costs than later adopters because of learning by doing and scale economies
- For many non-regulated firms, survival depends on keeping a technological edge over competitors
- Firms shoulder all of the risk
- Benefit-sharing exists between firms and consumers (short-run v long run)
- The willingness of firms to undertake R&D depends on market structure (competition, monopoly, oligopoly)
Rationales for Public Funding of R&D

- R&D has well-known free rider and public good characteristics (e.g., non-exclusivity)
- Distinctions between different stages (basic, applied and development) in risk and time span before expected benefits
- Firms view R&D from the perspective of profit expectations, thus focusing on the end stages of R&D
- Firms tend to conduct their R&D, for example, on “applied” projects where the payoff to them is more certain and immediate
- R&D is a public good that is likely to be suboptimal in scale without public support whether for the energy sector or other sectors of the economy
- Firms may consider the risk associated with R&D too high relative to the expected return (e.g., because of distant returns and uncertain outcomes)
- Market forces often fail to innovate or develop new technologies that provide the greatest benefit to the public (Why?); government should fill that gap
- Government spending on basic research has provided many of the ideas and breakthroughs enabling progress in society
- Government faces the challenge of allocating funds to projects with the highest potential social payoff (e.g., funding decisions based on an independent, peer-reviewed process)
- Overall, public sector R&D should address social needs warranting greater investment than what the private sector is willing to undertake
Four Distinct Actions on R&D

- Selection of projects as part of a R&D portfolio
- Funding levels
- Funding sources
- Project management
R&D by Public Utilities

- Energy-utility industry R&D spending has declined in absolute dollars since the mid-1990s
- One reason is that in responding to increased competition, utilities cut back on internal R&D in addition to reducing their support for collaborative research managed by EPRI and GRI
- As mentioned earlier, R&D intensity for utilities is much less than for U.S. industries as a whole
- Historically, utilities conducted much of their R&D through collaboration and outside vendors
- NARUC has passed two resolutions endorsing R&D in the energy utility sector

- Successful energy utility innovation consider technical performance, economic cost, commercial competitiveness, and environmental effects
- Utilities are both producers and consumers of innovation
- Industry-funded R&D may have to involve more basic research in the future, as the federal government is likely to spend less on R&D than in the past
- One economic argument is that more emphasis should fall on R&D and less on subsidies to promote new technologies that achieve specific policy objectives (e.g., clean air); the more efficient and effective approach would be to price pollutants and other externalities
The Case of Gas Utilities

- Government funding of gas distribution R&D is significantly less than for electric and potable water utilities
- Draconian cutbacks in government and industry-funded R&D over the past 15 years
- The elimination of DOE R&D funding earlier this decade reduced the federal government’s support for gas distribution infrastructure
- As gas markets became more competitive, some pipelines called for elimination of the mandatory mechanism to fund GRI

- Utilities in 29 states are funding GTI (but at a much lower level than utility funding for GRI in the 1980s and 1990s)
- Potential benefits of innovation include improved pipeline safety, reductions in methane emissions, greater energy efficiency, and more efficient and effective pipeline inspection and repair processes
- Any assessment of R&D adequacy is constrained by the absence of statistics on R&D funding for gas distribution and transmission
- **Legitimate policy question**: Are current levels of R&D funds for gas distribution adequate?

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The Case of Gas Utilities - continued

- GRI funding peaked at over $200 million in early and mid 1990s
- GRI was formed in 1976 in response to industry needs to develop new sources of supply
- FERC-required analyses showed that GRI R&D programs were highly cost-beneficial
- GTI provides R&D to meet industry needs in safety, reliability, a clean environment, and cost management (see next slide)
GTI’s Objectives

- “Expand the supply of affordable natural gas and renewable energy”
- “Ensure a safe and reliable energy delivery infrastructure”
- “Promote the clean and efficient use of energy resources”
- “Reduce carbon emissions to the environment”

These objectives advance the welfare of either gas consumers or society as a whole
Collaborative R&D Costs per Customer

Source: Concentric Energy Advisors, *Stimulating Innovation on Behalf of Canada’s Electricity and Natural Gas Consumers*, May 2015, modified by GTI
A Few Examples of Innovation in the Natural Gas Sector

- Fuel cells powered by natural gas
- 3-D and 4-D seismic mapping
- Hydraulic fracturing
- Gas turbines
- Application of GPS technology
- Methane detection and measurement
- Gas sensing and monitoring
- Natural gas vehicles
- Micro CHP for home use
The Effect of Utility Regulation

- Regulation affects: (1) the amount utilities spend to innovate, (2) the speed at which they innovate, (3) the nature of innovative activities, and (4) the management of R&D projects

A *core question* relates to the regulatory incentives for innovative activities by utilities

- Economists have criticized traditional rate-of-return (ROR) regulation for providing utilities with less-than-robust incentives
- But history has shown that, depending on the operation of ROR regulation and specific conditions, a utility could be either over-motivated or under-motivated to innovate
  - Electric utilities have often been adopters of new technologies under favorable conditions
  - For example, periods of regulatory lag under decreasing costs, high sales growth and no retrospective reviews
Major Policy Matters

- Incentives for utilities to innovate (i.e., utility demand for innovation)
- The effect of a new business model on creating new demand for innovation by utilities, customers and third-parties
- Role of R&D in innovation (link between R&D and innovation)
- Parties carrying out innovation (utilities, third-parties, e.g., Google): Why should utilities get involved with the development of new technologies; can’t other entities better serve this role?
- Groupings of innovations (supply-side, demand-side, private benefits, public benefits)
- Utility-customer demand for innovation
- Regulatory objectives for R&D
- The benefits of collaborative research
- Role of regulators in accommodating and supporting innovation that is in the public interest
- Regulatory guidelines or principles on utility R&D
Specific Questions for Regulators

- Who are the beneficiaries of innovation?
- How can utility customers benefit from innovation?
- How do customers express or signal their demand for innovation?
- How are innovations filter through to customers?
- Who are the potential creators/suppliers/users of innovation?
- What would motivate utilities to innovate?
- What are current artificial barriers to R&D?
- Who should initiate action? Do utilities always identify promising new technologies and other innovations to their regulators, or do regulators sometimes have to take the initiative?
- Does the current portfolio of ratepayer-funded R&D investments represent a good balance?
- How can we know that utilities are adequately innovating?
- Why would utilities ever want to stifle innovation?
- Why would utilities be apathetic toward innovation?
- How does R&D translate into innovation or products/processes that are commercially viable?
- What can regulators do to ensure that utilities adopt innovations in the public interest?
- How do regulators determine that a particular innovation is in the public interest?
- How do regulators know that utility customers are receiving full value for their R&D dollars?
Different Regulatory Postures on R&D/New Technologies

- Support utility proposals
- Keep abreast of emerging technologies
- Require utilities to evaluate emerging technologies as to their feasibility and economics
- Mandate utilities to adopt certain new technologies and other innovations (micromanagement?)
Why Utilities May Underinvest in R&D/Innovation

- The payoff to utilities may simply be too low relative to the risks
- Utilities (as well as other for-profit companies) discount or ignore completely public benefits
- Traditional utility regulation (1) restricts the threat of competitive entry and (2) tightly controls a utility’s prices and profits
- For example, prices are based on a utility’s actual costs
- Innovation might lead to the erosion of a utility's monopoly status

- Book depreciation can cause “stranded costs” of old assets
- The conventional wisdom is that regulation causes utilities to be slow to innovate, since the costs and benefits of innovation tend to be uncertain
- As one industry observer has noted, utilities operate within a “culture of caution”
## Features of Utility Regulation Affecting Innovation

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<th>Feature of Regulation</th>
<th>Effect on Innovation</th>
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<td><strong>Entry restrictions for new firms</strong></td>
<td>- Reduces competitive pressure on utility to innovate</td>
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<td>- Natural monopoly structure favors large-scale technologies</td>
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<td><strong>Regulatory lag</strong></td>
<td>- As to costs, deters innovation because it takes longer for utility to recover its costs</td>
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<td></td>
<td>- As to benefits, encourages innovation because utility can retain benefits longer</td>
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<tr>
<td><strong>Cost-of-service rates</strong></td>
<td>- Diminishes utility’s benefits from innovation</td>
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<tr>
<td><strong>Benefits allocated largely to customers</strong></td>
<td>- Diminishes utility incentive to innovate</td>
</tr>
<tr>
<td><strong>Risk allocated largely to customers</strong></td>
<td>- Increases utility willingness to innovate</td>
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<td>- Unfair to customers if utility captures most of the benefits</td>
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<td>- Creates a “moral hazard” situation</td>
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<td><strong>Ratemaking treats cost savings from conventional and new technologies the same</strong></td>
<td>- Utility finds conventional technologies are relatively more attractive</td>
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<tr>
<td><strong>Book depreciation</strong></td>
<td>- Can diminish utility incentive to innovate</td>
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<td>- Can jeopardize utility’s ability to recover fully the costs of existing assets</td>
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<td><strong>Prudence and “used and useful” tests</strong></td>
<td>- Can deter utility from investing in high-risk innovations</td>
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<td>- Protects customer against subpar utility management performance or unexpected outcomes</td>
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<tr>
<td><strong>Emphasis on reliability and safety</strong></td>
<td>- Shifts interest away from cost-saving innovations</td>
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<td><strong>Favoritism toward certain innovations</strong></td>
<td>- “Jump starts” potentially socially desirable innovations</td>
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<td>- Risks choosing the wrong technology</td>
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Illustrative Regulatory Principles for R&D

- Sustained and stable funding
- Adequate funding levels for achieving regulatory/policy goals
- Consistent with a long-term and strategic perspective
- Portfolio approach for selecting projects within broad programs (challenging because of uncertainty and multiple policy/company objectives)
- Allowing utilities to assume reasonable risks, and encouraging innovation by willing to pass at least some (or all) costs of failure to customers
- *Articulated FERC criteria:* “R&D projects should be well-defined, clearly explained and with consumer benefits, targets and justification”

- Selection of ratepayer-funded projects based on the public interest
- Picking winners can easily lead to unfavorable technology lock-in
- Basic research best funded by government
- Consideration of new R&D funding mechanisms
- Well-managed R&D projects
- Measurable outcomes
- Retrospective and prospective analyses

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Fundamental Provisions in Regulatory Guidelines

- Funders of R&D
- Criteria for commission acceptability
- Third-party innovations
- Purpose of pilot programs
- Statement of R&D objectives
- Utility role
- Ex ante/ex post evaluations
- Cost allocation/recovery mechanism
Regulatory Tools to Bolster R&D/Innovation

- Modified ROR regulation (e.g., economic depreciation)
- Price caps
- Focused incentives
- Profit or benefit sharing
- Regulatory lag
- Benchmarking
- Planning (prospective) process
- Regulatory commitment
- Explicit rules
- Policy guidance (e.g., guidelines on pilot programs)
Concluding Comments

- Assessing the adequacy of R&D in the natural gas sector requires that one knows both (1) the optimal level and nature of research activities that promote the public good and (2) the current status of R&D activities in the sector; both factors are either unknown or highly speculative.
- The evidence suggests, however, support for speedier actions and higher levels of R&D funding in the natural gas sector.
- Like for other sectors, much of the R&D in the energy natural gas has a public-good nature that is likely to be suboptimal in scale without public support.
- The dramatic drop in collaborative R&D by the natural gas utilities over the past 20 years presents a real concern.
- Collaborative research has several benefits that regulators should recognize (see next slide); such research is more likely when companies are unconcerned about keeping a new technology or new information proprietary.
- Utilities would tend to underinvest in innovations that have public benefits or erode their monopoly status.
- There is a need for evaluating the effectiveness of R&D funded by utility customers:
  - To ensure that customers are getting bang for their buck.
  - To improve future performance.
  - To learn from failures.
- A poor R&D program is (1) short-term in nature and (2) thinly spread among countless uncoordinated projects that lack useful performance measures and are disconnected from outcomes.
The Benefits of Collaborative Research

- Avoids duplicative efforts and inefficiencies
- Avoids the “free rider” problem
- Exploits economies from pooling company resources to undertake R&D
- Results in a more diversified portfolio of research projects
- Allows companies that lack funds to participate in R&D activities that otherwise they would not have
- Spreads the costs of high-risk projects
- Helps participants stay on top of the latest technology developments
- Overall, enhances the industry’s capability to leverage R&D investments for addressing common needs