

**R&D INCENTIVES AND CO-UTILIZATION:  
ELECTRICITY MARKET PERFORMANCE**

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## **ABSTRACT**

Co-utilization of domestic fuels (CDF) represents a promising portfolio of new production processes and inputs. However, new technologies are unlikely to be adopted unless prototype testing demonstrates the efficacy of creative approaches to blending fuels. Beyond the R&D stage, utilities transforming inputs into useable energy must be convinced that these technologies will benefit the bottom line. The technical skills and innovations of engineers are needed more than ever, but unless the regulatory system rewards the introduction of more environmentally sustainable fuels, the funds needed for new initiatives are unlikely to be forthcoming. Current uncertainties regarding regulatory policies and industry restructuring along with investor perceptions of industry risk raise the cost of capital and thus reduce the likelihood of new initiatives. If the economic foundations of co-utilization are not solid, CDF will wait in the wings while traditional production technologies continue to dominate the marketplace.

### **Key Words**

Renewables, Regulation, Innovation, Electricity Performance

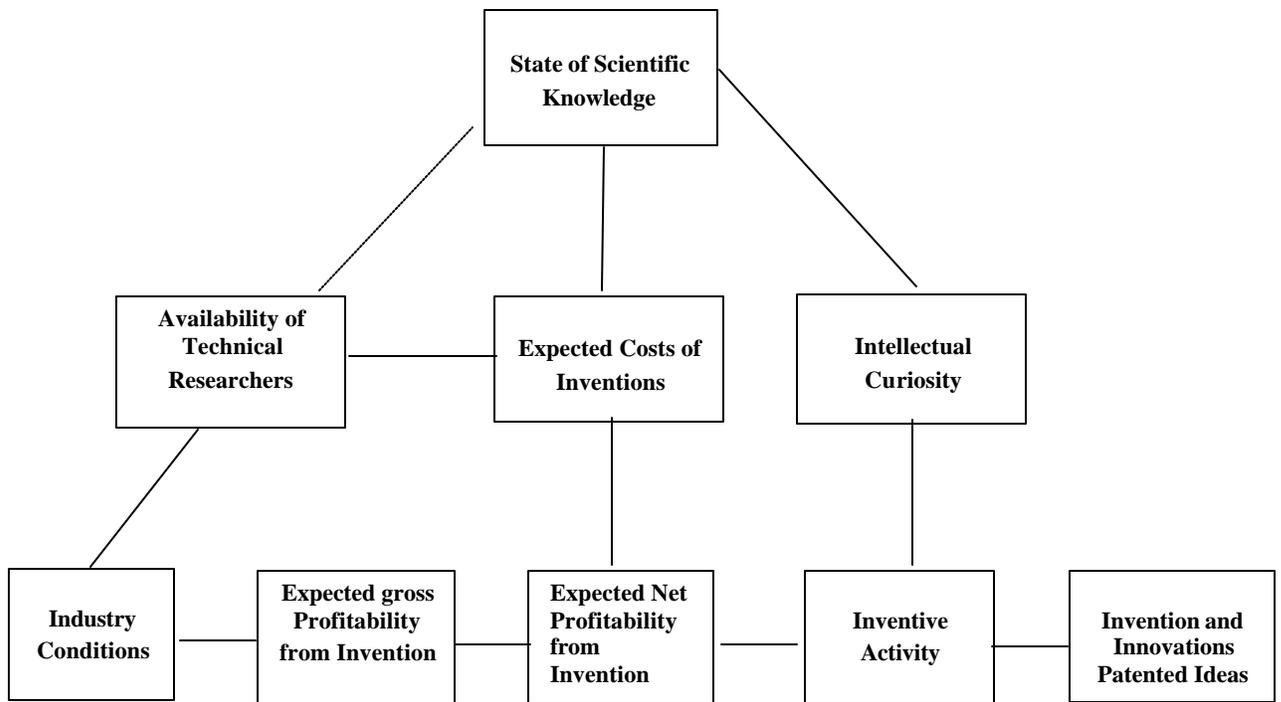
## **1. Introduction**

Interest is high in technologies that address energy, environmental, and economic problems simultaneously. However, scientific interest is not the same as economic interest, and the supply of good ideas will not lead to change unless there is also a demand for those ideas.

This paper outlines the factors affecting energy sector performance, focusing on those forces that might inhibit the introduction of new technologies in energy supply. Demand-pull and supply-push elements are both present. Two frameworks provide overviews of the main features of these two elements. The first (based on work by Schmookler [1]) outlines the factors that determine innovative activity in a sector, particularly the role of science as a supply-push factor. The second framework describes the institutional and regulatory features that determine the extent of demand-pull pressures. Economics is called the “dismal science” not because it predicts gloom and doom, but because it draws attention to scarce resources and our many competing needs. Science can reduce the constraints we face—by creating new knowledge that (when implemented in new production processes and products) generates more output with fewer resources. However, technological change depends on more than putting scientists and engineers to work.

## 2. Determinants of Inventive Activity and Technological Change

Fig. 1 outlines the demand-pull and supply-push factors behind inventive activity. Only three boxes in Fig. 1 represent demand-pull factors: availability of technical researchers, industry conditions, and expected gross profitability from invention—yet without commercial prospects, investors are unlikely to invest in R&D associated with the industry. All other boxes represent supply-push factors—though the image of pushing on a rope suggests that this force is weak. All factors are introduced and described briefly in this section. Industry conditions, including regulatory rules and incentives, are discussed more fully later.



**Figure 1. Factors influencing innovation**

We know that the level of inventive activity in a market is determined by the size and growth of that market. Small markets in decline will not attract a lot of R&D expenditures. Commercial prospects are also influenced by the extent of competition in an industry. Up to a point, some degree of rivalry puts pressure on firms to maintain their competitive edge. Of course, excessive rivalry (and the absence of patent protection) can dramatically reduce innovative efforts since the incremental cash flows required to justify projects are cut short when there is a rapid introduction of rival products. Traditionally, electric utilities have been vertically integrated monopolies, and regulatory incentives have been the primary determinants of industry conditions. We will consider this point at some length later.

The number of scientists and engineers trained to understand and improve on technologies is partly driven by historical developments: the state of the industry in the past. Students seek education and professionals shift careers on the basis of expected returns to their investment in human capital. The number trained also depends on government funding in various scientific fields, since support for graduate students and the size of programs depend on availability of university laboratories and research grants. Basically, input prices affect the cost of inventive activity, and the availability of technical researchers is a key factor in this equation. In addition, corporate cultures affect which types of projects receive funding. Executives with engineering backgrounds ask different types of questions than those with backgrounds in finance and management.

Industry size and demand growth determine expected operating cash flows, excluding the cost of the R&D and adaptations required in the associated system. The present value of these cash flows is a powerful component of project analysis.

Each year, scientists expand our fundamental knowledge of the way the world works. Chemistry, physics, and biology are just three of the fields that contribute to our understanding of energy and the environment. Some new ideas are difficult to patent, so universities have tended to be the organizations that conduct basic research. Profit-oriented firms are in a position to conduct the applied research and demonstration projects required to transform the possible into commercially viable processes and products.

Thus the state of scientific knowledge represents a fundamental constraint for technological innovation. The expected cost of developmental activity depends on the salaries of scientists and engineers trained in related fields and their understanding of key physical and chemical relationships.

The expected net profitability of inventive activity depends on both the revenues and R&D costs. It is the expected gross profit minus the expected cost of inventive activity. When there is substantial uncertainty, the discount rates for evaluating future cash flows must be higher. In a sense, inventive activity is not very different from an investment in physical capital that has a minimal salvage value. The R&D project enhances shareholder value only if the expected net present value is positive. Thus, a supply-push approach to promoting new technologies is flawed to the extent that industry conditions, including regulatory rules, must also be taken into account.

Intellectually exciting areas introduce a wild card into the equation. Researchers sometimes take on projects because of their intrinsic interest in an issue. Issues can present scientific puzzles that stimulate research and development activity. However, it is doubtful whether public policy can depend on intellectual curiosity to deliver the level and mix of inventive activity that is socially optimal.

Inventive activity ranges from procedural changes that result from “suggestion box” recommendations to large-scale formal R&D programs. The cumulative impact of shop floor discoveries shows up in learning curves that bring down costs over time. Projects associated with the other end of the spectrum can involve long time lags and significant investments. The

outcome of R&D is not guaranteed—there are high degrees of uncertainty surrounding the translation of engineering possibilities into production processes that are cost-effective. Ultimately, the level and type of inventive activity is reflected in patented products and new ways to meet consumer demands.

Innovations take technologies beyond the prototype testing stage to full commercialization. Adopting new utility production processes requires that managers be convinced that the systems will perform as predicted. Early users take risks that later adopters do not incur. Thus, industry conditions and regulatory incentives have a significant impact on the diffusion of new technologies. This is factored into the estimation of expected cash flows, which then drives inventive activity by external equipment suppliers and by the utilities themselves. We turn to those factors affecting utility sector performance to see how commercial opportunities are the result of a set of factors beyond the control of managers.

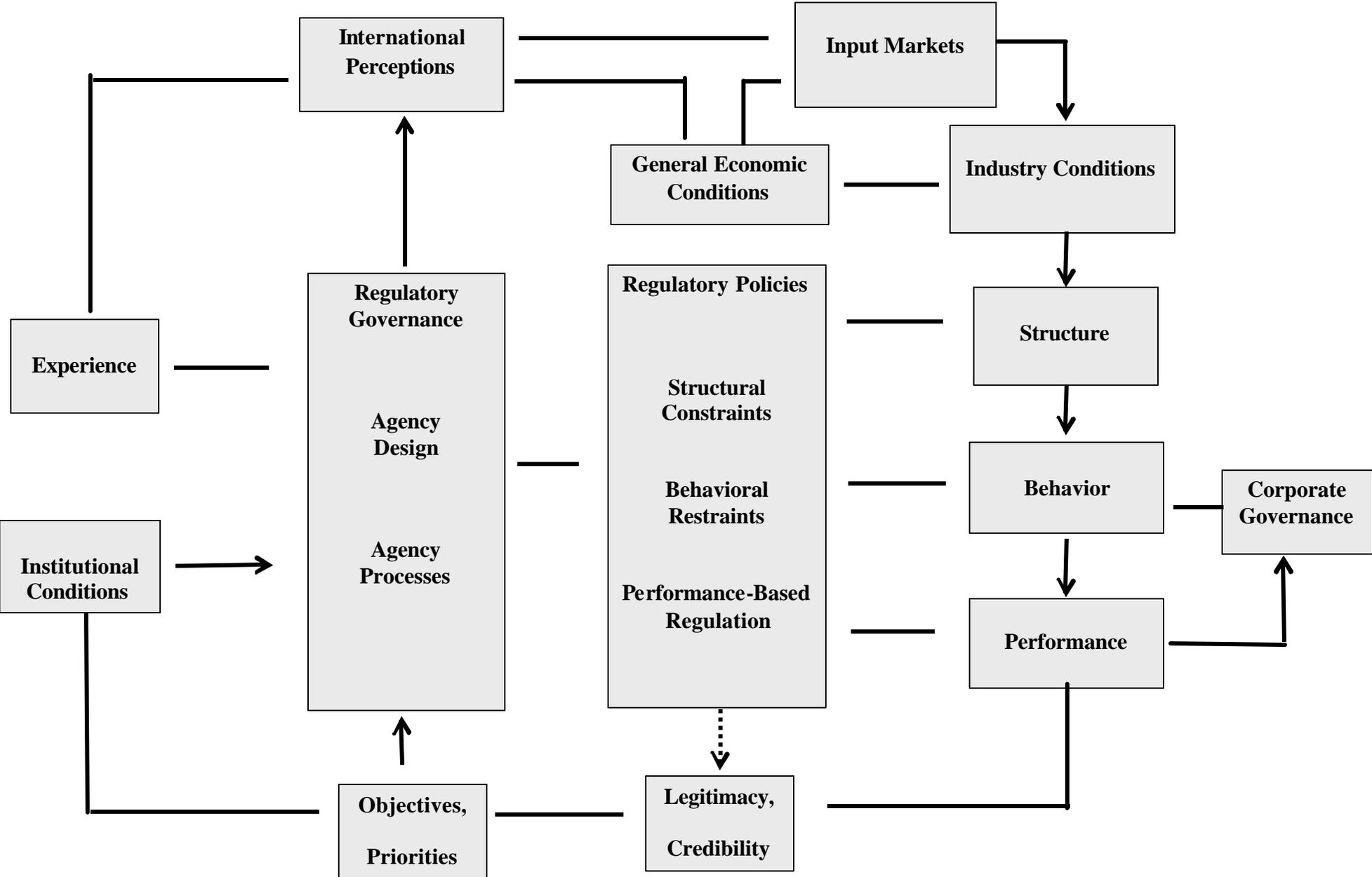
## **2. Factors Affecting Sector Performance**

The framework presented in Fig. 2 (see [2]) focuses on the demand-pull side of innovative activity. It emphasizes the role of regulatory policies, public perceptions, and basic industry conditions as determinants of outcomes. If those outcomes match social priorities, the system is generally viewed as performing well, which gives political legitimacy to policymakers. If performance is perceived as sub-par, there are often calls for policy reform and greater public intervention in the industry. Addressing issues associated with energy and the environment has certainly been an important task in recent decades. To improve sector performance, research and development is often held out as having great potential. From this perspective, co-utilization of domestic fuels (CDF) represents a promising portfolio of new production processes and inputs. However, new technologies are unlikely to be adopted unless prototype testing demonstrates the efficacy of creative approaches to blending fuels. Utilities that are transforming inputs into useable energy must be convinced that these technologies will benefit the bottom line.

The framework presented in Figure 2 (see Berg, 2000) focuses on the demand-pull side of the innovation equation.

We begin with social objectives like efficiency, fairness, and environmental sustainability. Citizens have personal values, and these are transmitted to politicians via the voting process. Election outcomes please some and disappoint others, but federal and state policies and expenditures ultimately reflect a mix of citizen values and the power of special interest groups. Policymakers must make difficult choices between programs in health and education, national defense, and energy. Research and development represents one area where public policy could influence our energy future, so targeting co-utilization of domestic fuels represents an initiative that could potentially expand our nation's portfolio of production processes and inputs. However, universities and government laboratories have not had the resources to dramatically expand their basic and applied research programs. Lack of resources may be attributable to the unwillingness of elected officials to spend their political capital by drawing attention to energy issues. Alternatively, the public may perceive higher social payoffs to addressing other issues associated with health and education.

Figure 2. Factors Affecting Performance



If there is a consensus between the executive and legislative branches, initiatives are more likely to be sustained over time. The U.S. electorate has vacillated back and forth over the priority to be given to meeting environmental objectives. While there may be a shared political vision regarding the desirability of good environmental stewardship, the choice of specific policies to achieve good outcomes is certainly in dispute (for example, the lack of support for the Kyoto Protocols). Without strong institutional support for innovative initiatives in energy and the environment, actions are likely to be incremental rather than dramatic.

Communities, states, and nations learn from one another. New production processes do not have track records, and therefore will be viewed as riskier than the tried and true. In recognition of this tendency, governments often support research and prototype testing on promising but unproven technologies. Once approaches like CDF have demonstrated their cost-effectiveness, decision-makers are more likely to include them in project analyses.

Risk perceptions affect stakeholders' evaluations of industry opportunities. Currently, perceptions of utility misconduct in the aftermath of California's deregulation limit interest in new energy investments, especially those involving new technologies. So capital markets are unwilling to pour funds into new capacity. Similarly, public understanding of the risks associated with alternative production processes is often driven by fear of the unknown. Even siting plants with known environmental impacts is problematic: the NIMBY mentality ("not in my back yard") introduces costly delays in the process.

Broad macroeconomic conditions (inflation, unemployment, and exchange rates) are beyond the control of decision-makers in the energy sector. The stage of the business cycle influences expected payoffs from investments. If the expected returns are not commensurate with the commercial and technological risks, projects will not be initiated.

Capital, natural resources, skilled labor, and entrepreneurial talent are four inputs that affect the cost of production. Some inputs, like air, are not priced but require government intervention to ensure that pollution does not destroy our quality of life. Environmental regulations attempt to correct this market failure to price the value of natural resources. New types of production capacity often experience cost increases caused by interventions in response to perceptions of risk (or lost environmental amenities) by affected parties.

Four elements can be associated with basic industry conditions: technology, demand, information, and ownership arrangements (public vs. private). These, in turn, determine the optimal structure of an industry like electricity. Established technologies are less risky than new ones, which raises the bar associated with innovative projects such as CDF. If demand is growing, then new capacity will generally be built, but if input prices for particular technologies are falling (as was the case with natural gas until recent years), the demand for innovative solutions is reduced.

The distribution of firms according to feasible number and size depends on scale economies and entry conditions. Public policy has influenced both in the past. Transmission and distribution have natural monopoly characteristics, and generation has traditionally been

included in the utility, so vertical integration is widespread. Internationally, unbundling has occurred in many countries, with mixed results in the United States. Perhaps more importantly, entry barriers are higher for projects that look “different” from others. Because local communities can engage in “paralysis by analysis,” being a first-mover in the adoption of new technologies is problematic.

Prices, investments, siting, and production processes for electricity have been regulated to various degrees. Similarly, state commissions in the United States also establish incentives for R&D activity. Regulated electric utilities are not charities, and they cannot tax customers to experiment with new technologies. So adoption of innovative production technologies depends significantly on regulatory incentives. This point warrants being underscored. The science can be “done”, but if the risks are perceived as higher than the tried and true, regulatory commissions are in a position to play “heads I win, tails you lose”. If a project underperforms, the costs could be disallowed. Utilities will be reluctant to experiment if managers perceive regulation asymmetries. The demand-pull side of innovative activity is heavily dependent on the regulatory climate.

We arrive at the bottom line: how well the industry delivers the goods. There are many dimensions to performance: production efficiency, prices that reflect costs, fairness in the allocation of costs, minimal environmental impacts, and technological progress. The focus of this paper is on the last two, but electric utility regulators tend to focus on the first three. Broad public policy can alter these priorities, but legitimacy depends on there being a consensus, generally reflected in new legislation, regarding such changes.

One item that influences behavior is corporate governance. Firms have boards of directors that establish policy and managers that implement policy. Internal reward systems are designed to encourage cost-containment and innovation, with performance monitored over time. Regulators also use the information in evaluating performance. While most executives would prefer to be good stewards of the environment, they will take their cues from the law and the priorities expressed by political leaders.

The last three factors are perhaps the key drivers of industry conditions. We debate policy in public forums, as state and national regulatory commissions establish incentives for taking initiatives or playing it safe. Outcomes are judged according to how well sector performance conforms to stated objectives.

Agencies that monitor industry performance must collect information and allow participation of stakeholder groups in the regulatory process. Both transparency and accountability require clarity in regulatory objectives. The regulatory process yields policies that influence industry structure and the behavior of firms. Thus, cooperation (between state public service commissions and state environmental regulators) and legislative mandates will determine the role of CDF in the future.

Individuals and organizations respond to incentives. Historically, U.S. electric utilities have been under rate of return on rate base regulation, although some form of performance-based regulation is present in most jurisdictions. The introduction of new production processes has

generally required that the investment minimize the net present value of consumer expenditures. The impact on current price is given great weight in evaluating company initiatives. So again, the industry conditions outlined in the first section are shaped by state and national policies.

Citizens evaluate the legitimacy of sector outcomes in terms of how realized performance matches up against stated objectives. Investors evaluate the credibility of regulatory regimes in terms of their predictability and consistency. Few would argue that citizens are unconcerned about energy and the environment. Yet some would contend that decision-makers are missing opportunities in the energy sector. We turn to this issue next.

### **3. Missed Opportunities or Rational Decisions?**

There are many claims on public resources, including claims by those who desire increased investments in energy conservation and other technologies. A case can be made that CDF represents an untapped field because it was a neglected alternative in the past: basic industry conditions were such that firms focused on different inputs (coal, natural gas, biomass, agricultural wastes, and biosolids) and viewed other energy sources as competitor fuels rather than as potential complements in the production process. Was this a “market failure”—an opportunity that has gone untapped because of narrow visions, lack of information, or petty industry feuds? Or was this outcome merely part of the natural evolution of production processes, where significant gains in one or another technology (e.g., combined-cycle gas turbines) and changes in relative input prices led to investment choices that left CDF on the shelf? No one is likely to have a definitive answer to that question.

Have utilities deliberately ignored promising technologies? There is no evidence that decision-makers have made bad decisions with respect to the mix of generating capacity. However, if environmental externalities are not taken into account, the resulting impacts on air and water will be negative. The issue then becomes one of whether state and national policies adequately protect the environment. There are both benefits and costs to expanded protections, and both can be difficult to quantify. The health benefits of reduced SO<sub>2</sub> or the long-term climate impacts of CO<sub>2</sub> are subject to some scientific debate. Similarly, the costs of compliance with new emission standards can be difficult to estimate in advance, especially since the learning curve is likely to lead to reduced compliance costs over time. Even so, the rate of decline can be in dispute, and the burden of proof rests on those who would argue that past investments in achieving environmental objectives have been inadequate or misdirected.

If we believe that past energy sector performance has been sub-par, we need to be careful about placing blame on particular groups. Politicians respond to polls and elections. They will generally place public funds into programs that people support. Similarly, executives are interested in environmentally sustainable production processes because these are less costly in the long term and less difficult to justify. We all prefer stable institutions and ecological amenities that promote sustainable economic growth. Yet, ultimately, the bottom line drives current utility investment and operating decisions. The net present value of expected cash flows determines whether the blending of domestic fuels makes economic sense.

Scientists and engineers ignore these political and economic realities at their peril. Good ideas must have a track record behind them. Deep insights and prophetic visions cannot substitute for the careful studies and prototype tests required to demonstrate not just feasibility, but cost-effectiveness. Reconfiguration of power systems, demand-side management, and experimentation with innovative approaches to mitigating environmental impacts are tasks engineers take on with pleasure. At the same time, the utility business continues to change. Competitive pressures have led to spin-offs, downsizing, and R&D reductions by incumbent firms immune to such pressure in the past. Electricity market reform also creates new opportunities for firms, including incentives to use funds for new initiatives. However, the post-Enron environment has not been conducive to risk-taking by electric utilities.

#### **4. Evaluating the Impacts of Policies**

Market outcomes can be described in terms of performance criteria (profitability, efficiency, innovation, and meeting other social objectives, including environmental sustainability). A key feedback in this process involves R&D since it can lead to innovations that affect the production technologies, environmental impacts, and entry conditions. Although many analysts view energy as a high priority sector from the standpoint of reform, the outcomes of specific policy reforms and R&D initiatives are difficult to predict for three reasons: inadequate models, complex institutional feedbacks, and exogenous shocks to the regulatory system. In a sense, all three reflect the fact that our knowledge base is limited. First, we do not fully understand the linkages within the economy: we lack experience in translating principles into practice and are in a continual state of learning. As an example of the learning process, consider the evolution of environmental policies in the United States. Greater emphasis is given to tradable emissions markets today, and there is less reliance on technology mandates. The economic side effects of new policies are beginning to be more fully appreciated by technical analysts and politicians.

A second reason predictions are difficult is that changes in any system are likely to have unexpected (often unintended) impacts on stakeholders. These can affect the planning process, system reliability, the environment, local governments, and/or particular customer groups. Furthermore, there are likely to be political and institutional reactions to adverse economic outcomes. For example, re-regulation in California is a result of many factors, including some that could have been predicted and others that would have been difficult to anticipate.

This point leads to the third reason it is difficult to predict outcomes. Developments totally beyond the control of decision-makers affect performance outcomes. On the negative side (from the standpoint of consumers), electricity costs are affected by input price increases, so a “good” policy change in conjunction with an adverse exogenous development can be perceived as problematic. On the positive side, technological improvements can result in improved sector performance that exceed what would have occurred had alternative policies been pursued. Still, it is difficult to untangle the benefits of policy reform from developments that would have occurred without that change.

Clearly the linkages surveyed here are very complicated. The fact is that mistakes will be made whatever policies are adopted. However, policymakers can strengthen the institutional environment for reform by

- ? setting a tone that promotes realistic expectations among stakeholders,
- ? drawing on the lessons from initiatives in other jurisdictions,
- ? recognizing the role industry conditions play in determining the optimal configuration of productive capacity (and technologies),
- ? stimulating innovations that can promote environmental sustainability,
- ? incorporating concerns of all key stakeholders in the policy development process

These principles stem from an understanding that while the energy system is extremely complex, it is not necessarily fragile. The art of policymaking involves determining which policies have low downside risk with substantial upside potential. It also involves asking the right questions because no one has all the answers.

## 5. Concluding Observations

Decision-makers in government and business must understand the broad economic and technological forces affecting energy. The factors affecting effective regulatory policy are complicated. Fig. 1 and 2 suggest that policymakers must take a number of factors into account when establishing R&D investment programs. They also indicate that pioneers for innovation face a difficult set of hurdles if they wish to alter the status quo. Ultimately, it is important that we all recognize the importance of communicating information to opinion leaders, policymakers, and citizens.

I conclude with a story about the learning process. At the initial offering of the PURC/World Bank course<sup>1</sup> at the University of Florida, one attendee from a developing country was that nation's first energy regulator. He understood the pivotal role he would be playing in the years ahead, and the importance of a sound regulatory framework for capital attraction and for the sustainability of his new regulatory institution. He sat each morning in the front row, following the presentations carefully and asking intelligent questions of the speakers. Often he would comment on particular observations, sometimes supporting the generalization and sometimes qualifying the point by recognizing other trade-offs. His eloquence and insights were acknowledged by all.

Since I sat in the front with the other speakers, I noticed that he had two notebooks. Sometimes he would write a paragraph in one, then after hearing other ideas developed by the speaker, he would dig into his briefcase and write in another notebook. Near the end of the two weeks, my curiosity could not be contained. I asked him about the two notebooks. He responded: "This one is for *useful* ideas." I was pleased, but still puzzled. I enquired about the other notebook. "Ah, the other is for *interesting* ideas."

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<sup>1</sup> To date, nearly 1,100 regulators and infrastructure managers from 110 nations have attended the *PURC/World Bank International Training Program on Utility Regulation and Strategies*. In the thirteen deliveries of this two-week course, participants hear from international experts, work on cases in small groups and share experiences with one another. In one of the group exercises, participants are asked to identify their top three objectives from a set of ten (including low prices, reliability, revenue adequacy, economic efficiency, innovation, and infrastructure development). Of the one hundred teams to date, not one has identified innovation as a high priority! Apparently regulators from emerging markets view new technologies as a by-product of other forces.

As a professor who tries to translate principles into practice, I understood the distinction quite well. He wanted to return to his homeland with an agenda for his staff. He wanted to apply some ideas and principles immediately. However, he recognized that other ideas needed more time to germinate. The particular conceptual framework from a session might be interesting (and show promise), but it needed more time before it could be applied. Perhaps the idea provided a sound intellectual basis for some development (such as incentive regulation), but it could not be applied in the present institutional environment.

My hope is that the points raised here contribute to our understanding of the complex supply-push and demand-pull forces influencing technological change in the electric utility industry. The technical issues addressed by engineers cannot be separated from the managerial and regulatory context in which solutions will be implemented. There is much that is interesting and useful yet to be learned. As an academic involved in that learning process, I would urge that policymakers pay attention to debates going on at universities and other research organizations. Educational institutions can play an important role in providing forums for sharing experience, exploring new ideas, and clarifying important public policy issues.

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