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Risky Business? Entrepreneurship in the New Independent-Power Sector

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Abstract
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Keywords
institutions, technology, electricity, founding, independent-power sector

Disciplines
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Building on sociological research on institutions and organizations and psychological research on risk and decision making, we propose that the development of institutions that reduce the risks of entering new sectors has a stronger effect on the founding rates of firms using novel technologies than on firms using established technologies. In an analysis of the independent-power sector of the electricity industry from 1980 to 1992, we found that the development of regulative and cognitive institutions legitimated the entire sector and provided incentives for all sector entrants; thus, foundings of all kinds of firms multiplied rapidly but had a stronger impact on those using risky novel technologies. In contrast, the central normative institutions that developed in this sector, state-level trade associations, provided greater support for particular forms (those using established technologies) and thus increased foundings of those favored forms more than foundings of less favored forms (those using novel technologies). Our study demonstrates how institutional forces can alter the mix of organizations entering a new industry and thus contribute to diversity, as well as similarity, among organizations.●

Entrepreneurship is inherently risky. The U.S. Small Business Administration showed that 71 percent of new ventures failed within four years and 85 percent failed within five years (U.S. Small Business Administration, 1983). A more recent study, which included only employing firms, estimated failure rates to be 34 percent, 50 percent, and 60 percent after two, four, and six years, respectively (Headd, 2001). Two factors exacerbate the risks associated with entrepreneurship: entering a new industry (or an emerging sector in an old industry) and using a new technology. As Aldrich and Fiol (1994) argued, the difficulties that all new ventures face are magnified in new industries and sectors by lack of familiarity and skepticism about the industry's viability on the part of resource providers and the general public. Founding firms that use new production or distribution technologies are especially risky because many of those needed to launch any new venture—employees, financial backers, suppliers, customers, and the general public—are unfamiliar with new technologies and thus are likely to be skeptical of or even hostile toward them.

Many scholars have noted the paucity of research on new kinds of organizations in emerging areas of activity (Aldrich and Fiol, 1994; Carroll and Hannan, 2000; Scott, 2001). Although we know that changes in the institutional environment can provide legitimacy for new organizational forms, we don't have a theory of how the development of cognitive, regulative, and normative institutions affects the legitimacy of new sectors or how this, in turn, affects the founding rates of organizations with forms that are considered to be higher risk. In general, we lack a theory that explains how institutional development affects the overall heterogeneity of firms entering new industries. Our focus in developing such a theory is on the conditions that encourage entrepreneurs to take risks on founding firms using novel, unproven technologies in new industries and the conditions that inhibit such risk taking, in particular, the economic, political, and cultural barriers

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to entry, and the institutions that raise or lower those entry barriers. We test this theory in a study of firms entering the new independent-power sector of the U.S. electricity industry in the 1980s and 1990s.

Starting in 1935 and for over 40 years thereafter, the U.S. electricity industry was heavily regulated, and regional monopolies held by established utilities precluded entrepreneurial activity. But in 1978, reacting to rising electricity costs, Congress passed a law requiring utilities to purchase and distribute power from independent power plants. Passage of this law created opportunities for these kinds of producers that had been foreclosed during the previous four decades, in effect, opening a new sector. Thousands of organizations using diverse technologies emerged to fill the independent-power sector (Russo, 2001). Our description of the independent-power sector below illustrates the challenges that await entrepreneurs who seek to enter new sectors, especially those who use new technologies, and grounds our development of hypotheses about the kinds of organizations and entrepreneurs that entered this sector. The theory we develop builds on psychological research on decision making under risk and institutional and ecological models of organizations.

ENTREPRENEURSHIP IN THE INDEPEPENDENT-POWER SECTOR

In the early 1970s, electric utilities were regional monopolies, the sole suppliers of electric power within their regions. They provided electric service on demand, and the prices private utilities charged for electricity equaled generating costs plus a reasonable profit. Utilities both generated and distributed power. Thus, utilities were regional monopsonies: non-utility generators could not sell directly to consumers, and utilities had no incentive to give non-utility generators access to their distribution networks. With the exception of large hydroelectric plants, utilities relied almost exclusively on production technologies that burned fossil fuels. Although innovators explored alternative electricity-generating technologies, utilities' monopsonistic position allowed them to lock would-be innovators out of the market for electric power (Hirsh, 1999: 81–83). Prior to the late 1970s, virtually no independent power plant sold wholesale power to utilities using either conventional non-renewable or novel renewable (see the Appendix) energy sources (Joskow and Schmalensee, 1983).

In October 1973, the situation began to change dramatically. An embargo by the Oil Producing and Exporting Countries caused major oil shortages (U.S. Department of Energy, 2001); these shortages were exacerbated by the Iranian Revolution of 1978. Between 1973 and 1979, oil and gas prices quadrupled. Utilities tried to reduce their reliance on oil and gas by converting to solid-fuel plants, but the costs of conversion and of solid fuel were high and were exacerbated by high interest rates; hence, electricity prices remained high.

This dramatic shift in energy economics provided a splendid opportunity for outsiders to promote new agendas (Sine and David, 2003). Environmental activists, who had been increasingly vocal since the publication in 1962 of Rachel Carson's alarm call, *Silent Spring,* joined forces with those who proposed to conserve energy through industrial cogeneration, involving the capture and use of excess energy (heat or steam) from existing industrial processes, and with advocates of various renewable energy-producing technologies. Activists and technologists banded together to found several grass-roots organizations, such as the American Wind Energy Association in 1974 and the Solar Lobby in 1978, which shaped public opinion by promoting environmentally friendly strategies for generating power. Some activists explicitly eschewed "brown" (non-renewable fossil and nuclear) fuels and advocated the use of only "green" (renewable) energy sources. Others encouraged more efficient use of brown fuels. Though the use of cogeneration technology and renewable energy sources to generate power for resale was extremely rare in the United States before 1980, it was common elsewhere (e.g., geothermal plants in Iceland, New Zealand , and the Soviet Union). New legislation sponsored by the Carter administration, however, changed all this.

In 1978, Congress passed the National Energy Act, which included the Public Utility Regulatory Policies Act (PURPA). PURPA's goal was to decrease reliance on imported oil by making it easier for entrepreneurs to found two types of independent power generators, cogenerators and small power plants (Fox-Penner, 1990; Russo, 2001). Cogeneration encompasses both plants using non-renewable fuels (coal, oil, natural gas, and nuclear fuel) and those using renewable energy sources (biomass, wind, geothermal, solar, hydro power). Small power plants were defined under PURPA as generators using biomass, waste, or renewable resources as a primary energy source and generating less than 70 megawatts per year. Our study only includes those cogeneration facilities that applied for qualifying status under PURPA in order to sell electricity to utilities.

PURPA allowed independent power producers ("qualifying facilities") to depreciate capital investments over five years instead of the usual fifteen, to burn natural gas in turbines, and to be exempted from some gas price increases and from expensive existing utility regulation policies. Finally, PURPA required utilities to buy or exchange power with qualifying facilities at utilities' avoided generation costs—the costs they avoided by not generating the power themselves. Although PURPA's intention was clear, the potency of its impact was largely unforeseen (Hirsh, 1999). As John B. Wing, general manager of General Electric's new cogeneration department declared, "PURPA created a whole new market, and a whole new opportunity for us" (Diamond, 1984: 2).`

Green versus Brown Technologies

The Appendix describes the major green and brown technologies used in the independent-power sector, organized by fuel source. The aim of PURPA was to encourage a variety of electric-power technologies, and all the technologies used by facilities founded after PURPA were to some degree unconventional. But there were critical differences between technologies that used "brown" or non-renewable fuels and those that used "green" or renewable energy sources. Most qualifying facilities using green power sources were small power plants, and those using brown power were typically cogenerators. At the time of PURPA's passage, with the exception of large hydroelectric plants, little power was generated in the U.S. using renewable sources: in 1978, of the 2,206 billion kilowatt-hours of power generated by utilities, 87 percent came from coal, petroleum, natural gas, or nuclear plants; 13 percent came from large-scale hydro plants; and less than 0.001 percent came from other renewable sources (U.S. Department of Energy, 2001).

Because they were virtually unused in the U.S., green technologies were viewed with more skepticism than brown technologies, and entrepreneurs promoting green technologies found it especially difficult to gain the support of key constituents, starting with investors. As one developer of wind power interviewed for this study remarked, "New technology is unnerving to the financial community."[1] Our interviews indicate that venture capitalists and private investors demanded high rates of return from organizations using new technologies, which they described as "new" and "untested" and thus risky. In line with this, Wiser and Kahn (1996) found that the cost of capital for wind-power plants averaged 20 percent higher than for traditional coal or natural-gas-burning plants. Reminiscing about a geothermal pioneer who claimed he could solve the energy crisis by pumping hot, salt-laden, subterranean water to the surface and using this heat to generate electricity, one investor recalled, "I remember thinking, 'Do I want to put money into this guy?' A lot of people thought he was not playing with a full deck of cards."

Many communities were similarly doubtful about technologies that tapped green energy sources. An early geothermal-power entrepreneur remarked, "Locals were very skeptical about drilling on or under their land. They had never heard of underground aquifers nor, for that matter, geothermal power." One early biogas-plant founder commented:

> It took four years to get the permits to build. Many people and local government officials had misconceptions about what the plant was doing. Some thought it was dangerous because it dealt with methane; others were worried it would explode; others thought it would be too noisy or vibrate. We had to bus a number of people to the plant and give them tours. People were simply afraid of new technology.

Ironically, the proposed biogas technology was much less of a threat to the surrounding population, in terms of noise and potential accidents, than the existing landfill. Because the biogas plant actively captured escaping methane and so reduced the chance of an explosion, it made the waste facility safer, not more dangerous. And the biogas plant made little noise, far less than garbage trucks entering and leaving the landfill.

Equipment suppliers were also more skeptical about unfamiliar green technologies than more familiar brown-fuel systems. Berger (1997: 27) reported a solar-power pioneer as recalling, "No establishment company would have anything to do with you. They considered solar to be off the wall." The inability to form partnerships with suppliers meant,

1
This quotation and others below come from interviews with entrepreneurs, venture capitalists, and other industry participants. More information on these interviews is in the Method section below.

among other things, that entrepreneurs could not secure lines of credit, which strained their meager cash flows. Finally, key personnel were hard to find. As one wind-power executive said, "In the late 1970s and early 1980s, it was difficult to recruit employees. No one took non-utility power companies seriously. We lacked legitimacy in the eyes of the public."

The widespread lack of support for green power, relative to brown power, had a big impact on the choices of entrepreneurs. One financier described his decision to invest in brown-fuel cogeneration systems this way: "Green power is just not economically feasible." Another said, "The technology was not there. There really was no great alternative [to brown fuels]. Wind is ugly, geothermal is limited, and solar is not cost-effective." Entrepreneurs who sought to tap green energy sources also reported tremendous technical uncertainty. An engineer in a geothermal plant said, "We did not fully understand what we were getting into. Early on nothing worked." Given the difficulties that entrepreneurs attempting to found firms using green technologies faced, one might wonder why any entrepreneur would choose to found a firm using anything except an off-the-shelf, established technology, but many did.

Entrepreneurs' Choices and Types of Independent Power Firms Founded

Variations in entrepreneurs' choices of technology in founding new electric-power plants reflected several influences. First, in general, entrepreneurs' goals are heterogeneous. Some are motivated by money, others by technical or aesthetic challenges, and still others by a desire to improve society. Such heterogeneity was clearly evident among independent-power entrepreneurs. For example, cogeneration pioneer Michael Dingman, the chief executive officer of Wheelabrator-Frye, sought substantial returns on his investment, while Roger Sant and Dennis Bakke, the founders of Applied Energy Systems, were initially motivated by social concerns (Berger, 1997). Heterogeneous motivations are not peculiar to the electric-power industry. Among California winery owners, for example, only 22 percent of those surveyed were motivated by money, while 78 percent were motivated by "love," meaning pride in what they produced (Scott-Morton and Podolny, 2002).

Second, different entrepreneurs have access to different sets of resources, which also affects their technology choices. Education, prior work experience, and social networks affect access to knowledge, capital, and suppliers, as well as the ability to recruit technically proficient workers. Entrepreneurs' experience also affects their cognitive skills; specifically, it shapes their ability to recognize that new technologies can be used to build new kinds of organizations (Shane, 2000). In support of this argument, Boeker's (1988) analysis of the semiconductor industry showed that people with backgrounds in research and development founded first-mover firms using cutting-edge technologies, those from manufacturing founded low-cost firms using highly reliable mass-production technologies, and those from marketing and sales founded niche firms using flexible production technologies. A similar level of heterogeneity in terms of background and knowledge is apparent among independent power entrepreneurs. For example, wind-power pioneer Henry Clews was an aerodynamic engineer who had become a farmer (Righter, 1996: 161–171), while geothermal entrepreneur B. C. McCabe had strong ties to the oil industry and learned from oil exploration crews about hot subterranean lakes in the California desert (Berger, 1997; interview with Bill Cole and Paul Nakamoto, 1999).

Third, production technologies vary greatly in their level of development, which influences both entrepreneurs' choices and their ability to obtain external support. The level of technological development reflects two issues. Most basically, there is technical feasibility: Will something that works in small-scale laboratory demonstrations work in the field? Even after technical feasibility has been demonstrated, the issue of economic feasibility remains: Will something that works in the field be cheap and reliable enough to compete with established technologies? Because the costs and benefits of newer technologies are harder to assess than those of older, better-developed technologies, newer technologies are usually perceived as riskier bases for new ventures. This was apparent in independent power after PURPA was passed. Solar power was about ten times as expensive as traditional utility power in 1978 (Mead and Denning, 1991). While some experts were hopeful about its promise, others argued that it would never be economically viable (Velocci, 1980). Some entrepreneurs interviewed for this study predicted large increases in the efficiency of wind turbines, while others predicted that wind power would never be economically feasible. There was great uncertainty about the potential of biomass as a fuel source because the required infrastructure—systems for collecting, transporting, and processing biomass—simply did not exist (Hahn, 1980; Engalichev and Mathur, 1981). Likewise, geothermal power was viewed as an expensive and unproven technology, albeit one that held a great deal of promise (Berger, 1997). And although cogenerator technologies that burned oil and natural gas were fairly well developed, they were by no means mature. Thus, although brown technologies were generally better developed than green technologies, no technology appeared to be a clear winner.

Given variation in entrepreneurs' goals and background and variation in technological development, two choices made by potential entrepreneurs—whether to found a firm and what kind of firm to found—are difficult to separate logically or empirically. Some entrepreneurs first choose to launch and then choose what kind (the standard economic model), while others first choose what to launch and then choose whether and when to launch. In the independent-power sector, entrepreneurs who advocated the use of green fuels were most likely to follow the second path. Green entrepreneurs generally started by becoming interested in a particular technology and followed through only when prices paid by utilities, combined with tax credits, were high enough to support their technology of choice (Righter, 1996; Hirsh, 1999). Consequently, the willingness and the ability of entrepreneurs with differing preferences and resources to achieve their goals were affected by the development of institutions in the industry.

Institutional Influences on Foundings in New Sectors

As sectorwide institutions develop, they influence entrepreneurial activity by altering the costs, benefits, and risks associated with such activity, thus determining the likelihood that entrepreneurs will act on their diverse technology preferences. In this way, institutions determine the kinds of technologies that are eventually implemented in new ventures. Our ideas, laid out below, are based on general institutional and ecological arguments and on psychological research on decision making; we use evidence gleaned from interviews and industry histories to show that our arguments are germane to the independent-power sector.[2]

In analyzing how institutional forces affect the kinds of firms that are founded in new sectors, the well-established trichotomy of regulative, cognitive, and normative forces (Scott, 2001: 51–58) is useful in distinguishing between different institutional effects. In new sectors, regulative institutions—the laws and administrative guidelines that constitute the basic rules governing market transactions and so provide sociopolitical legitimacy for organized action—are usually undeveloped, limited in scope, or subject to contestation (Weiss, 1988; Lindberg and Campbell, 1991). Cognitive institutions—shared perceptions of the boundaries and viability of new kinds of social activity—are also largely absent from new sectors (Berger and Luckmann, 1966). And normative institutions—"expert" sources of information about the nature of new sectors, values (what is important and good), and norms (how things should be done)—take time to develop (DiMaggio and Powell, 1983). Because new sectors typically lack institutional support, the chances of success for all entrants are initially low; thus, few potential entrepreneurs are able to surmount entry barriers and actually found new ventures (Aldrich and Fiol, 1994; Suchman, 1995). The development of regulative, cognitive, and normative institutions legitimates new sectors and makes resources easier to acquire; in turn, these changes reduce perceived risks and increase entry rates.

Entrepreneurs who seek to enter new sectors using novel, rather than established technologies must shoulder a double burden: they incur both sectorwide and technology-specific risks. These combined risks strongly limit entrepreneurs' willingness and ability to act, in part because they limit other people's willingness to supply key resources to new ventures. When institutions reduce sectorwide risk, either directly by providing incentives or indirectly by increasing the sector's legitimacy, they have less impact on entrepreneurs who seek to use established technologies than on those who seek to use new technologies because, for the former, the probability of acting is already relatively high; in other words, a ceiling effect operates (Thaler et al., 1997).

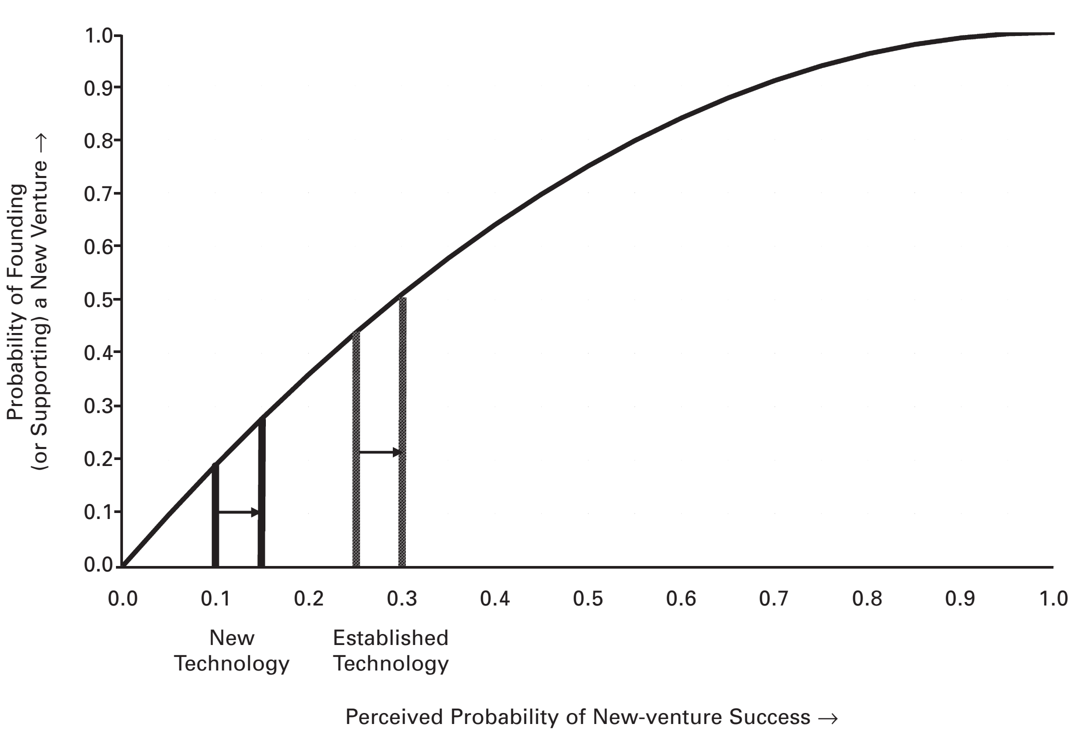
This ceiling effect occurs because people are risk averse: their estimates of the value derived from any action increase,

2
We do not apply the resource-partitioning model because it does not explain what kinds of organizations enter new industries or new sectors of old industries. This model assumes strong economies of scale in production or distribution, which is unlikely to be true of new industries or new sectors, where technology is in flux.

but at a decreasing rate, with the likelihood of realizing a desired outcome from that action. Moreover, people's perceptions of outcomes are highly dependent on their initial reference point: people respond to expected changes in outcomes—gains or losses—rather than to outcomes themselves (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992; Thaler et al., 1997). On top of this, the propensity to take any action is more sensitive to expected gains or losses when initial outcomes are small than when they are large (Weber, Shafir, and Blais, 2004), because perceptions of change in outcomes are proportional to the relative size of the change, not the absolute size (Weber, 1978). For example, the difference between a .10 and .15 probability of success (an increase of .05, or 50 percent over the initial probability) looms larger than the difference between a .25 and .30 probability of success (an increase of .05, or 20 percent over the initial probability). Such percentage framing (Thaler, 1980) guides many economic decisions.

Extending these ideas to decisions by entrepreneurs to launch new ventures and decisions by resource providers to support new ventures, a decline in the overall level of risk associated with a new sector should have a bigger impact on the founding of firms using uncertain new technologies than those using more-certain established technologies. Figure 1 illustrates this effect. The horizontal axis represents the probability that a new venture based on a particular technology will be successful, while the vertical axis represents the probability that a new venture will be founded. In this graph, the relationship between the probability of success and the probability of acting (the value associated with the probability of

Figure 1. New venture-risk and founding probability: Ventures using new vs. established technologies.



founding a new venture) increases at a decreasing rate. The two vertical lines to the left show probabilities of a hypothetical new venture being founded using a risky novel technology, while the two vertical lines to the right show probabilities of a hypothetical new venture being founded using a less-risky established technology. The exact locations of these lines along the X axis do not matter. What matters is that the lines for a venture using a new technology are to the left of the lines for a venture using an established technology, reflecting the former's greater risk and lower chance of success. For each type of venture, the vertical line on the left shows the probability of founding when sectorwide institutions are less developed and thus sectorwide risk is very high, while the vertical line on the right shows the probability of founding when sectorwide institutions are better developed and thus sectorwide risk is lower.

When the development of institutions decreases sectorwide risk, the probability of success for any venture rises, regardless of whether it uses an established or novel technology. If we assume, as in figure 1, that the probability of success for any venture rises by .05, the probability of founding a firm using a novel technology rises from .19 to .28, an increase of .09 (47 percent), while the probability of founding a firm using an established technology rises from .44 to .51, an increase of .07 (16 percent). Thus the development of institutions that reduce sectorwide risk increases founding rates for all types of firms by making both entrepreneurs and resource providers more likely to act. But institutional development increases absolute founding rates more for firms using risky novel technologies than for firms using less-risky established technologies. Given the relative rarity of foundings of firms using novel technologies, these changes are much larger, in percentage terms, for firms using novel technologies than for firms using established technologies. These changes in founding probabilities, in turn, have the aggregate effect of increasing founding variety: foundings include a lot more of what had been relatively rare types of enterprise (those built around new technologies) and a little more of what had been relatively common types of enterprise (those built around established technologies).

The development of particular kinds of regulative, cognitive, and normative institutions will affect the risks entrepreneurs face and thus alter founding rates for different kinds of firms and change the mix of firms founded.

Regulative effects on foundings. Changes in government regulations can raise or lower sectorwide economic entry barriers by altering financial incentives for all players in the affected sector: making organizations subject to or exempt from costs associated with regulatory oversight; creating or eliminating price supports; and providing or eliminating tax relief, loans, or subsidies. When regulations lower economic entry barriers for an entire sector by increasing state financial support, foundings in the sector increase (Hannan and Freeman, 1977; Wholey and Sanchez, 1991). Increased state support for a new sector has the biggest impact on organizations that use new technologies, ones that face especially high levels of risk. Consequently, foundings of these formerly rare kinds of organizations should increase at a relatively high rate, which yields greater founding heterogeneity. Our interviews with advocates of green technologies accord with this general logic. PURPA was perceived by these advocates as creating opportunities to found electricity generators only when prices paid by utilities, combined with tax credits, were high enough to support their technology of choice. This conclusion is reiterated in interviews of small power-plant operators reported by Righter (1996) and Hirsh (1999). Thus, we hypothesize:

H1a: Increases in state financial support for the new independent-power sector will have a larger positive effect on the founding rate of firms using novel technologies than those using established technologies.

H1b: The greater the state financial support for the new independent-power sector, the greater the technological heterogeneity of foundings in that sector.

In addition to altering economic entry barriers, regulatory changes may affect political entry barriers (Aldrich and Fiol, 1994; Suchman, 1995; Strang and Sine, 2001). Laws that create a new sector are often challenged by organizations whose positions are threatened by the new sector. Although court verdicts upholding such laws do not necessarily end legal challenges to a new sector, by setting precedent they increase regulative legitimacy and reduce legal uncertainty. In short, favorable court rulings are interpreted as endorsements of a new sector and thus lower the risks of entering that sector. Again, because decreasing risk is especially important for organizations using higher-risk novel technologies, the effects of such rulings on the founding rates of organizations using novel technologies will be greater than on the founding rates of organizations using established technologies. As one entrepreneur we interviewed put it, "The greater the legal uncertainty, the more lawyers we hire, and the less chances we take." This differential effect on founding rates, in turn, generates increases in founding diversity.

Uncertainty over the legal status of PURPA was an important obstacle to entrepreneurs considering entering the independent-power sector. Early court battles between qualifying facilities and utilities created uncertainty and increased the difficulty of obtaining important resources, especially financing (Betts, 1983). On May 16, 1983, the Supreme Court upheld PURPA's mandatory-interconnection and avoided-cost provisions. Although this verdict did not keep some utilities from contesting the law on other grounds, it did provide a strong endorsement of the sector. In the words of several analysts, the Supreme Court decision removed the "legal clouds casting a shadow over the development of small power plants and cogeneration" (Nowak, 1983: 12) and was "the strongest possible endorsement for FERC's [the Federal Regulatory Commission's] avoided costs and interconnection rules" (Betts, 1983: 1). We therefore hypothesize:

H2a: Court rulings that uphold laws favoring the new independent-power sector will have a larger positive effect on the founding rate of firms using novel technologies than those using established technologies.

H2b: Court rulings that uphold laws favoring the new independent-power sector will increase the technological heterogeneity of foundings in that sector.

Cognitive effects on foundings. Cultural entry barriers are especially high in new sectors (Aldrich and Fiol, 1994; Zucker, Darby, and Brewer, 1998) because little is known about the determinants or even the probabilities of success, making both investors and entrepreneurs wary; hence, overall founding rates are low. The emergence of shared definitions of a sector as economically viable is shaped in part by the number (density) of organizations operating in it. Increases in the sector's density enhance its cognitive legitimacy, partly through diffusion processes: the more actors in a sector, the more knowledge of the sector is likely to spread, the more likely the public is to accept it as a viable sphere of economic activity, and the more likely potential entrepreneurs are to believe they could succeed (Hannan and Freeman, 1989; Hannan and Carroll, 1992). Moreover, increasing density fosters the development of social infrastructures that smooth the path for future entrepreneurs, such as standard operating procedures and contracts and specialized training programs for workers. Increasing density thus reduces sectorwide risk and enhances entrepreneurs' ability and willingness to launch new firms, especially those using higher-risk new technologies. Based on the logic above, increasing density will also lead to increases in founding heterogeneity.[3]

H3a: Increases in the density of organizations in the new independent-power sector will have a larger positive effect on the founding rate of firms using novel technologies than those using established technologies.

H3b: As the density of organizations in the new independent-power sector increases, the technological heterogeneity of foundings in that sector will increase.

Our interviews reveal that potential independent power entrepreneurs were initially very pessimistic that utilities would honor contracts with qualifying facilities; instead, many thought utilities would dip into their deep pockets to fight protracted court battles. As more qualifying facilities contracted with utilities, generated electricity, and sold electricity to utilities, their very existence eased the concerns of all potential entrepreneurs, those who preferred green and brown technologies alike.

The press also plays an important role in building a sector's cognitive legitimacy by disseminating information about a sector and by endorsing its practices, in short, by facilitating the sharing of experience and knowledge (Gamson et al., 1992; Pollock and Rindova, 2003). Media are "a site on which various social groups, institutions, and ideologies struggle over the definition and construction of social reality" (Gurevich and Levy, 1985: 19). Media discourse reflects as well as creates public opinion about particular sectors (Gamson and Modigliani, 1989); thus, media mentions also indicate the extent to which a sector is considered legitimate. Positive

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The effect of sector density on founding rates could be monotonic (positive) or non-monotonic (inverted-U-shaped), depending on whether sector density approaches the carrying capacity. As any new sector matures and the carrying capacity of its resource base is reached, further increases in density will trigger competition strong enough to overwhelm the beneficial legitimating effects (Hannan and Freeman, 1989; Hannan and Carroll, 1992). When that happens, foundings of organizations using risky novel technologies and founding variation should both decline. Because we studied the independent sector in its early stages—the first thirteen years of its history—we did not expect competitive effects, which would generate the inverted U. Nonetheless, in the analyses presented below, we investigated this possibility.

media attention to a sector both increases its status as a credible site for business and reflects the development of knowledge about the sector. Even neutral accounts—mere recordings of a sector's existence—can increase its acceptance by increasing public perception of it as a standard cultural category. Like increasing density, then, increasing media attention is associated with a reduction of the perceived risks of entry into a sector and an increase in foundings. Again, we expect the impact to be greater among firms using higher-risk new technologies than among firms using lower-risk established technologies, and therefore founding diversity will also increase.

In the independent-power sector, the initial lack of sector legitimacy was a significant obstacle for founders. Early on, entrepreneurs and potential investors were skeptical of the sector, particularly when utilities refused to interconnect with and purchase electricity from qualifying facilities (Righter, 1996; Hirsh, 1999). As the press documented successful outcomes of qualifying facilities' efforts to interconnect with utilities, entrepreneurs and investors gained assurance that the rules governing the new sector would be adhered to and that independent power generators could succeed. We therefore expect media coverage to have an effect on foundings and the heterogeneity of firms founded:

H4a: Increases in media coverage (neutral and positive accounts) of the new independent-power sector will have a larger positive effect on the founding rate of firms using novel technologies than those using established technologies.

H4b: As media coverage (neutral and positive accounts) of the new independent-power sector increases, the technological heterogeneity of foundings in that sector will increase.

Normative effects on foundings. Collective actors, such as professional and trade associations, are major sources of normative institutions (DiMaggio and Powell, 1983). Such collective actors are generally absent from new sectors, but over time, recognition of common interests—securing passage of supportive state regulation, sharing information about common problems, and promoting the sector to investors and the general public—often leads sector participants to band together formally (Aldrich and Fiol, 1994; Romanelli, 1989). Organizations representing collective interests can contribute to the legitimacy of a new sector in several ways (David, Sine, and Haveman, 2005). First, they often help foster the creation of regulative institutions (e.g., favorable tax policies) that reduce economic and political entry barriers and lower sectorwide risk. Second, by serving as a source of public information, collective actors contribute to the spread of knowledge about the sector; thus they contribute to the development of sectorwide cognitive institutions as well, which lower cultural entry barriers and sectorwide risk.

In addition to increasing the legitimacy of the sector as a whole, these kinds of collective actors may differentially affect the legitimacy of different forms of organization. By selecting particular conference speakers, emphasizing certain topics in association publications, and disseminating information in other ways, such organizations often, intentionally or unintentionally, promote particular practices and forms of organization as "best," thereby creating form-specific normative support. By providing normative support for some kinds of organization, such as those that use particular production technologies, collective actors decrease investors' and entrepreneurs' perceptions of the risks associated with founding the favored kind of organization. By the same token, the lack of support for other kinds of organizations may increase their perceived risks. Because active participation in collective organizations is often costly, in terms of personal time and money, such organizations are often dominated by elites—wealthier, relatively conservative members (Selznick, 1949; Lipset, 1950; Heinz and Laumann, 1982). Consequently, collective organizations' policies and sanctioned practices often reflect the interests of these risk-avoiding elites and so tend to favor less-risky established technologies over riskier new technologies.

In New York and California, the most powerful collective representatives in the independent-power sector were two trade associations, the Independent Energy Producers Association of California (IEPA, founded May 15, 1982) and the Independent Power Producers of New York (IPPNY, founded June 17, 1986). The IEPA lobbied the state government on such issues as interconnection with utilities, tax credits, the formula used to define avoided costs, and the creation of standard contracts. The IPPNY also promoted legislative changes that benefited its members. Both associations collected, codified, and distributed information about the independent-power sector. For example, the IEPA held annual conferences at which experienced entrepreneurs and technologists were invited to discuss the costs and benefits of particular power-generating technologies. At these conferences, entrepreneurs met and shared stories with owners and managers of other generating facilities and thus learned what really worked—so-called "best practices." The IPPNY collected data on qualifying facility location, size, technology, and plant efficiency. These data were summarized in reports and distributed to association members; entrepreneurs often consulted these reports before establishing new generating plants. Finally, both organizations promoted the industry to the media by issuing numerous press releases. In these ways, state-level trade associations distilled, codified, and diffused norms across the independent-power sector and so influenced entrepreneurs' technology choices.

Although created to represent the general interests of firms in the new sector, the IEPA and IPPNY were, like many other collective organizations, dominated by a particular segment of the membership, one identified with more established technologies. The IEPA was originally founded to lobby California legislators on behalf of cogenerators. Although the IEPA recruited all types of independent power plants and sought to represent the entire sector, active involvement in IEPA governance required substantial resources, which representatives of firms using cogeneration technologies could contribute more easily than representatives of other types of organizations. Thus, in 1987, over half of the members on the IEPA's board of directors were from firms using cogeneration technology. Several people interviewed for this study suggested that a subtle emphasis on cogeneration pervaded the organization and its activities. Because over 99 percent of cogenerators used brown fuels (mostly natural gas or coal), the emphasis in these associations on cogeneration also meant an emphasis on less-risky fossil-fuel technologies.

The sectorwide effects of these collective institutions is to increase foundings using novel technologies more than foundings using established technologies and therefore to increase founding heterogeneity. These effects are largely indirect, however, operating through the associations' effects on regulative institutions (e.g., increased state support for a sector) and cognitive institutions (e.g., increased media coverage of a sector). In contrast, the form-specific effects of collective institutions, which narrow the spectrum of organizations founded by favoring certain types of organizations over others, operate directly. Therefore, we propose that after the effects of mediating regulative and cognitive institutions have been taken into consideration, only the narrowing direct effects of normative institutions on new independent power firms will be observed:

H5a: The establishment of trade associations in the new independent-power sector will have a smaller positive effect on the founding rate of firms using novel technologies than those using established technologies.

H5b: The establishment of trade associations in the new independent-power sector will decrease the technological heterogeneity of foundings in that sector.

METHOD

Sample

We studied independent power producers founded between 1980 and 1992, inclusive. These start and end dates conform to important events in the history of the electric power industry. Although PURPA was passed in 1978, the first qualifying-facility filings were not submitted until 1980. The passage of the Energy Policy Act in October 1992, which allowed non-utility generators to circumvent the restrictions of the Public Utilities Holding Company Act of 1935 (PUHCA), changed the regulatory environment dramatically once again. This law created a new category of electricity producers, exempt wholesale generators (e.g., Enron). Some exempt wholesale generators did not meet qualifying-facility guidelines, while others did, making qualifying facilities founded in 1993 and onward very different than those founded before.

We limited our analysis to two large states, New York and California, because high-quality data are available from each. Most other states (e.g., Idaho, Washington, and Utah) kept incomplete records, while a few states (e.g., Arizona) did not dictate any specific formula for calculating avoided costs, leaving it up to the utilities and qualifying facilities to negotiate. This often resulted in a complex bargaining process in which utilities had the upper hand (Arenchild, 1996; Russo, 2001). Because our data are derived from only two states, it may be appropriate to view the analysis as a comparative case study. But because these two states were leading sites for independent power, our sample of 2,067 qualifying facilities represents almost half of the facilities founded in the U.S. during our 13-year observation period. Of these, 2,027 involved new generators, 33 involved generators that existed prior to PURPA but had not sold power to utilities, and 7 involved both existing and new components. Limiting our analysis to new generators did not change our results; accordingly, the results we show below include data on both new and existing generators.

Data Sources

The U.S. Federal Energy Regulatory Commission (FERC) required all owners, operators, or developers of electricity-generating plants that sought recognition as qualifying facilities to file basic facts about their plants. If a proposed facility met PURPA's ownership and technical requirements, it was accorded the status of a qualifying facility. FERC published a database of all filings (U.S. FERC, 1993) from which we derived the core data for our analysis: applicant name, address, filing and certification dates, generator type (new, existing, or both), facility type (cogenerator or small power plant), and energy source (biomass/biogas, geothermal, hydro, solar, wind, fuel oil, natural gas, coal, waste natural gas, nuclear, other waste, or "other," which includes anthracite culm, blast furnace gas, coke oven gas, digester gas, and petroleum coke).

We supplemented the archival data with 52 interviews of qualifying-facility founders, managers, and technical employees conducted by the first author. We randomly selected two facilities founded in New York and two founded in California each year from 1980 to 1992 and interviewed representatives from these facilities. In addition, the first author interviewed 20 other industry participants and observers, including venture capitalists, energy consultants, state regulatory board members, trade association representatives, and FERC and Department of Energy employees. These interview data grounded our thinking about this sector; in particular, they guided our choice of measures and strengthened our understanding of hypothesized structural relationships.

Dependent Variables

We examined two outcomes: (1) founding rates of firms using novel (green) and established (brown) technologies between 1980 and 1992, inclusive, and (2) heterogeneity among firms founded between 1980 and 1992, inclusive. Both dependent variables rest on a classification of organizational forms derived from categories used by government and private-sector analysts. This classification reflects two key dimensions of production technology: fuel (biogas, natural gas, hydro, etc.) and facility type (cogenerator or small power plant). Table 1 lists the organizational forms in order of founding frequency and notes their average sizes.

These technology-based organizational-form categories capture important differences. First, a MANOVA analysis revealed that within-form variation on size is significantly less

Table 1

Forms of Independent Power Producers in California and New York, 1980–1992

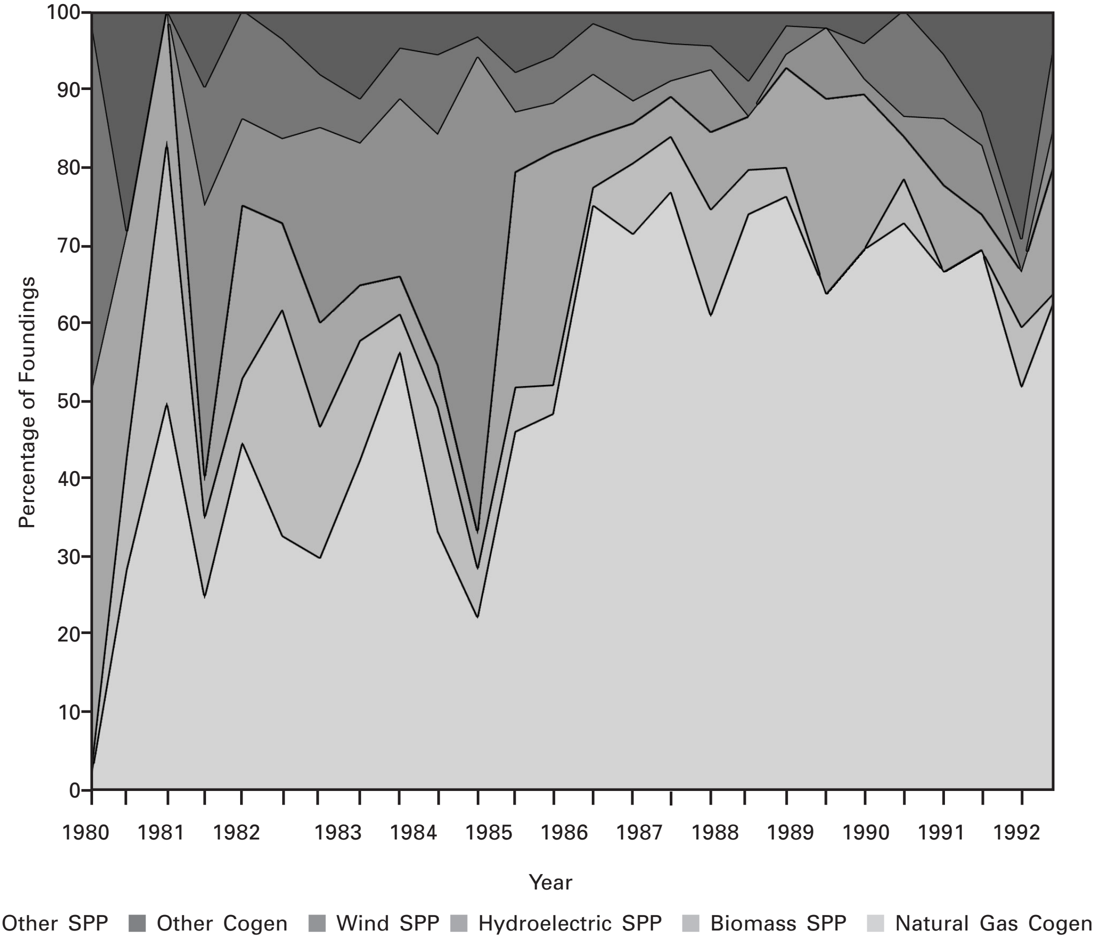
Generator form*	Frequency (percent of the population)	Average size (kilowatt)
Natural gas cogenerator	39.37	9,904
Hydro small power plant	16.25	3,584
Wind small power plant	12.97	2,624
Biogas/biomass small power plant	11.72	8,471
Coal cogenerator	4.56	39,194
Other waste small power plant	3.67	7,594
Biogas/biomass cogenerator	3.18	14,553
Geothermal small power plant	2.01	16,971
Fuel oil cogenerator	1.48	7,390
Other waste cogenerator	1.25	23,301
Solar small power plant	1.01	5,803
Other cogenerator	0.88	15,250
Other small power plant	0.78	1,663
Waste natural gas small power plant	0.45	2,255
Natural gas small power plant	0.18	615
Solar cogenerator	0.08	213
Nuclear cogenerator	0.04	9,762
Waste natural gas cogenerator	0.04	707
Fuel oil small power plant	0.02	25
Geothermal cogenerator	0.02	5,000
Hydro cogenerator	0.02	180
Wind cogenerator	0.02	4,000

***** The category “other waste” includes liquid acetonitrile waste, tall oil, waste alcohol, medical waste, paper pellets, sludge waste, solid byproducts, tires, agricultural byproducts, closed loop biomass, fish oil, and straw. The category “other” includes batteries, chemicals, hydrogen, pitch, sulfur, and purchased steam.

than between-form variation ($F = 9.64$; d.f. = 2,066; $p < .001$), indicating that the scale of operations is strongly related to the technological form. Second, technological choices influence alliance patterns. For example, cogeneration plants using natural gas require the cooperation of industrial facilities, while wind farms often rely on alliances with farmers and ranchers. Third, plants that tap into different fuels have very different production processes; for example, biogas plants siphon and burn methane from garbage dumps and sewage facilities, geothermal plants drill deep wells and transfer heat from scalding subterranean lakes, and wind farms capture winds to move giant blades that spin turbines (for details, see the Appendix). Figure 2 charts foundings of the four most common forms over time. Although natural gas cogenerators dominated after 1985, many firms with other forms were also founded.

Founding rates of firms using established vs. novel technologies. We captured the distinction between novel and established technologies by classifying facilities into those that used green fuels and those that used brown fuels. Because brown technologies were better-understood technically, had lower development costs, and were more culturally established than green technologies, they were generally less risky bases for new ventures than green technologies. Following the U.S. Department of Energy and industry analysts, we categorized these fuel types as green: biomass/biogas, geothermal, small hydro, solar, and wind. We categorized the remain-

Figure 2. Technology diversity among newly founded independent power producers.



ing fuel types as brown: fuel oil, natural gas, coal, waste natural gas, nuclear, other waste, and "other." There were cogenerators and small power producers in both categories, although most cogenerators used brown fuels and most small power producers used green fuels.

Heterogeneity of foundings. After classifying new qualifying facilities using the categories listed in table 1, we calculated the heterogeneity of foundings in California and New York every six months between January 1, 1980, and December 31, 1992, as follows:

$$\text{heterogeneity}_t = 1\sum_{i=1}^{n} P_{it}^2,$$

where P_{it} is the proportion of all foundings in a focal state during the six-month period t with form i (Blau, 1977). This index measures the probability that randomly sampled pairs of firms being founded in any given period will have different forms (Lieberson, 1969). The minimum value of this index, which occurs when all foundings in a period are of a single form, is zero. As foundings include a larger number of forms, the index approaches one. The maximum value equals 1 – 1/n, where n is the number of forms among the organizations founded in the focal six-month period. We aggregated data on founding heterogeneity into six-month spells because we reasoned that for a new sector, one-year intervals would not be fine-grained enough to capture important changes. We decided against using three-month spells because many would see only one, two, or three kinds of qualifying facilities founded, and so the range on the dependent variable would be restricted.

Model Specification and Estimation

Firm founding rates. Founding can be understood as an arrival process, wherein each newly founded independent power plant is an addition to the unit of analysis—here, the state. We have exact founding dates for all independent power plants, so we could calculate the exact time between arrivals in each state and estimate event-history models, rather than aggregated event-count models. This approach maximizes the use of available information. We modeled founding as a semi-Markov process, which assumes that the founding rate does not depend on history (i.e., the time path of prior arrivals) but, rather, depends on characteristics of the population and its environment and time since the last founding event (e.g., Hannan and Freeman, 1989; Carroll and Hannan, 2000).

We used the Cox proportional-hazards model introduced by Kalbfleisch and Prentice (1980), which is quite flexible with respect to time dependence. We estimated this model using the stcox procedure in the Stata statistical package (Stata, 2001), which controls for right censoring. We estimated separate models of green- and brown-technology founding rates.[4] To do so, we created one observation for every founding event of the focal type, meaning green- or brown-technology founding. The start date of each event was the day on which the previous founding event occurred of the same technology type; the end date was the day on which the focal founding event occurred. We created two dependent variables. Each was coded as one whenever the focal type of firm (using green or brown technology) was founded, and zero otherwise. We analyzed 2,067 foundings of two organizational forms in two states over 13 years; thus on average, 39.8 foundings of each organizational form occurred in each state each year, or one founding of each organizational form in each state every 9.2 days.

Our data contained many "tied" observations, meaning many days that saw two or more foundings, but ties did not cluster by day of week, week, day of month, or month. To deal with tied observations, we estimated all models using the exact-marginal calculation, which calculates the conditional probability of the tied events. This method is more accurate and more reliable than other methods (Kalbfleisch and Prentice, 1980; DeLong, Guirguis, and So, 1994). We used a Stata utility, the link test, to verify adequate parameterization of our models (Cleves, Gould, and Gutierrez, 2002). We used the Wald test to determine whether the difference between the pair of coefficients on each independent variable (green- vs. brown-technology founding rate) was statistically significant (Cleves, Gould, and Gutierrez, 2002). Finally, we reestimated

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We could also have estimated these two founding rates together, using a competing-risks model. Both approaches, estimating the two founding rates together and estimating them separately, yield identical results (Cox and Oakes, 1984: 142–146; Allison, 1995: 186–188).

all models using the robust option in Stata, which generates robust standard errors based on the Huber-White estimator; we also estimated all models using the cluster option for state. These results did not differ materially from the baseline results, so we do not present them here.

Heterogeneity of foundings. Because founding heterogeneity is a continuous variable, we analyzed it using linear regression methods. Our data set for this analysis consists of 52 observations: 26 six-month periods for each of the two states. Because we observed each state multiple times, our observations were not independent. Consequently, we faced three possible forms of bias: serial autocorrelation, cross-sectional autocorrelation, and heteroskedasticity. To deal with these biases, we used a feasible generalized least-squares estimator, the xtgls command in Stata (2001). We also conducted a tobit analysis, because the dependent variable is truncated (its range runs from zero to almost one). The tobit analysis generated results similar to linear regression. Because the linear regression results are easier to interpret, we report them below.

Explanatory Variables

Regulative effects. We employed three variables to index regulatory institutions. The first, *avoided costs,* taps the effects of regulations concerning the price utilities paid independent generators for power. PURPA defined avoided costs rather loosely as the costs utilities would incur for generating the same amount of electricity as they purchased from a qualifying facility. Interpretation and enforcement of avoided costs was left to individual states. In California, regulators generally calculated avoided costs for each utility as a function of fuel prices and construction costs for new plants; the precise formula for avoided costs depended on each utility's past investments and fuel mix. California also offered long-term contracts that specified avoided costs at particular rates over a certain number of years. In New York, in contrast, regulators set avoided costs at the same level for all utilities in the state. We gathered data on avoided costs from the California Public Utility Commission and the New York State Energy Research and Development Authority. For each state, we calculated the average avoided costs paid by utilities during each six-month period. We lagged this variable six months to allow time for entrepreneurs to react to changes in this institutional support; that is, we measured avoided costs six months before the start of each observation on foundings (for analyses of green- vs. brown-technology foundings), or six months before the start of each six-month period (for analyses of founding heterogeneity).

A second measure, *tax credit,* gauges the impact of tax relief to independent power generators. From 1978 to 1985, the federal government offered a 10-percent investment tax credit for all qualifying facilities. The variable we created to assess the impact of this tax credit on foundings was coded one when the sectorwide tax credit was offered, and zero otherwise. A third measure, *Supreme Court decision,* assesses the Supreme Court decision of May 16, 1983, which upheld PURPA's mandatory-interconnection and avoided-cost provisions. This variable was set to one after the Supreme Court decision and zero before. Again, we lagged these measures of regulative institutions six months.

Cognitive effects. We captured cognitive institutional effects with two measures: the density of independent power producers and the total number of positive and neutral articles about this sector in major U.S. newspapers and magazines. Unfortunately, we could not procure a central registry of qualifying facilities, so we had to find other sources for these data. All power sold on the wholesale market by independent power producers was purchased by traditional utilities, who kept records of all firms with which they had contracts and the start and end date of each contract. We gathered these data from each utility in California and from the New York Public Service Commission. We then created a database of all facilities that sold power to traditional utilities and measured sector density as the number of facilities that had contracts with utilities in a focal state. We also created a squared term for sector density to capture possible competitive effects of density.

We assessed media coverage by counting the number of positive and neutral articles on the independent-power sector reported in three major newspapers (the *Wall Street Journal, New York Times,* and *Washington Post)* and three business-oriented journals (the *Economist*, *Business Week,* and *Newsweek).* These outlets have national readership, cover national business trends, and have electronic archives.[5] We searched on-line databases for each source using several key words: independent power, qualifying facility, QF, PURPA, cogeneration, cogenerator, solar, wind, biomass, biogas, and Public Utility Regulatory Policies Act. Positive articles focused on the positive attributes of the sector and spent relatively little time reviewing its weaknesses, while neutral articles pointed to both the pros and cons of the energy policy or simply reported on events within the sector. Purely negative articles were rare (43 out of 2,739 articles), so we excluded them from our analysis. We lagged this variable six months.

Normative effects. The most powerful sources of normative influence in this sector were the two trade associations mentioned above, the Independent Energy Producers Association of California (IEPA, founded May 15, 1982) and the Independent Power Producers of New York (IPPNY, founded June 17, 1986). Interviews with association founders and employees revealed that once an association was founded, it took approximately a year to gather information, arrange conferences, and distribute information to association members and the media. Thus we created dummy variables set equal to one a year after association founding and zero before that date.

Control Variables

Because we pooled data from two states, our analyses included a binary indicator variable (CA = 0, NY = 1) to control for state-level differences not captured by the independent or control variables. Human population and the economy affect entrepreneurs' perceptions of the viability of new enterprises, so we controlled for *state population* (in millions), *gross*

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Forbes and the *Los Angeles Times* have no electronic archives for the period 1978 to 1985; therefore, they were not included in our sample of news media.

state product (in hundreds of millions of 1996 dollars), and the *prime interest rate.* The *price of natural gas* affected production costs, so we controlled for this factor (in 1996 dollars per thousand cubic feet). *Sector age* signals durability and reliability to potential entrepreneurs and resource providers, so we included as a control the number of months since the passage of PURPA. In analyses of founding heterogeneity, we also controlled for the *number of foundings* in the focal state in a given period because periods when few firms were founded tended to have low heterogeneity.

In addition to the tax credits that supported the entire sector, which is one of our independent variables, there were also tax credits that promoted green energy specifically. From 1980 to 1985, the federal government offered a 15-percent credit for investment in renewable energy (Klepper, 1978; Glanternik and Lipton, 1979; Wells, 1986). In 1985, this tax credit was reduced to 10 percent (U.S. Department of Energy, 1996, 2001). In addition, from 1980 to 1992, California offered tax credits for qualifying facilities that used renewable technologies (Fox-Penner, 1990; Arenchild, 1996; personal communication, California Public Utilities Commission, 2000). We measured *green tax credits* separately from the sectorwide tax credits. For each state in each year, we added the applicable federal and state tax credits together into a single measure and divided it by 10, so its scale would match that of the sectorwide tax credit. For example, in 1980, California offered a 25-percent tax credit for qualifying facilities using any green technology, and the federal government offered 15 percent; thus the measure of green tax credits in 1980 equalled 4.0 and 2.5 for California and New York, respectively.

RESULTS

Tables 2a, 2b, and 2c report descriptive statistics for variables used in the analyses of founding rates and founding heterogeneity, respectively. Several variables in our analysis are highly correlated. Such multicollinearity makes regression coefficients unstable and inflates standard errors. Several authors have suggested dealing with multicollinearity by orthogonalizing highly correlated variables using a modified Gram-Schmidt procedure (Cohen and Cohen, 1983; Saville and Wood, 1991). This technique partials out the common variance, creating transformed variables that are uncorrelated with one another. We used the orthog command in Stata to generate orthogonalized measures. We then tested for multicollinearity and found that all variance-inflation factors were substantially less than 30, and most were less than 2, indicating an acceptable level of multicollinearity.

Founding Rates of Organizations Using Green vs. Brown Technology

Table 3 shows Cox proportional-hazard models of the founding rates of firms using green and brown technologies. For each kind of venture, model 1 is a baseline model containing only control variables, while model 2 is a fully specified model containing all variables.

Regulative effects. All three regulative variables had positive effects on the founding rates of green- and brown-technology firms. The effects on the green-technology founding rate were always larger than the effects on the brown-technology founding rate, and the differences between all three pairs of coefficients were statistically significant. Holding all other variables at their means, when avoided costs increased by $.01/kilowatt-hour, the founding rates of firms using green and brown technologies rose by 27.3 percent and 10.7 percent, respectively. On average, the sectorwide tax credit increased green-technology foundings by 18.3 percent, but it had a non-significant effect on brown-technology foundings. Taken together, these two results support hypothesis 1a. Following the Supreme Court ruling, the founding rates of

Table 2a

Descriptive Statistics for the Analysis of the Founding Rates of Brown-Technology Independent Power Producers*

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. State (CA = 1)	.77	.42														
2. State population/10^6	25.2	4.13	.96													
3. Gross state product/10^8	.57	.12	.57	.77												
4. Prime interest rate/10	9.53	1.97	.02	−.12	−.41											
5. Natural gas price	2.63	.53	.07	−.12	−.54	.57										
6. Sector age/10	8.81	2.91	−.23	.02	.64	−.53	−.69									
7. Green tax credit/10	3.19	1.02	.82	.67	.15	.15	.46	−.52								
8. Avoided costs/10	4.55	1.43	−.53	−.71	−.84	.46	.62	−.43	−.04							
9. Sector tax credit	.20	.40	.09	−.10	−.51	.70	.76	−.69	.22	.47						
10. Supreme Court decision	.29	.24	.11	−.03	−.39	.15	.66	−.58	.36	.34	.54					
11. Brown density/100	5.65	3.74	.80	.89	.80	−.42	−.36	.19	.51	−.82	−.42	−.11				
12. Brown density^2/100	4778	3514	.72	.83	.80	−.46	−.47	.25	.38	−.87	−.50	−.21	.98			
13. Green density/100	3.02	1.7	.63	.81	.97	−.41	−.54	.53	.21	−.89	−.53	−.36	.89	.90		
14. Media coverage/100	.60	.39	.11	−.02	−.34	.14	.59	−.51	.28	.19	.41	.59	−.12	−.18	−.31	
15. Trade association dummy	.68	.47	.77	.85	.76	−.37	−.25	.17	.55	−.68	−.36	−.07	.95	.90	.81	−.13

* These statistics cover 2,067 observations on foundings of independent power producers in California and New York between 1980 and 1992. The univariate statistics reflect the untransformed variables. For all correlations greater than .06, $p < .05$.

Table 2b

Descriptive Statistics for the Analysis of the Founding Rates of Green-Technology Independent Power Producers*

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. State (CA = 1)	.76	.43														
2. State population/10^6	24.50	3.92	.96													
3. Gross state product/10^8	.51	.11	.52	.73												
4. Prime interest rate/10	1.40	2.22	.17	−.01	−.46											
5. Natural gas price	2.98	.57	.33	.15	−.37	.45										
6. Sector age/10	73.3	29.5	−.24	.01	.68	−.70	−.67									
7. Green tax credit/10	3.41	1.13	.88	.77	.25	.20	.57	−.40								
8. Avoided costs/10	5.26	1.31	−.19	−.37	−.59	.20	.50	−.38	.12							
9. Sector tax credit	.49	.50	.31	.11	−.42	.66	.73	−.72	.30	.36						
10. Supreme Court decision	.40	.29	.21	.13	−.13	−.03	.57	−.30	.32	.32	.43					
11. Green density/100	2.16	1.54	.52	.73	.97	−.45	−.39	.61	.26	−.69	−.47	−.17				
12. Green density^2/100	704	885	.38	.61	.91	−.34	−.49	.61	.07	−.76	−.49	−.30	.95			
13. Brown density/100	4.57	3.35	.71	.85	.85	−.37	−.10	.32	.55	−.52	−.26	.08	.89	.75		
14. Media coverage/100	.67	.41	.13	.03	−.22	.12	.48	−.35	.27	.21	.19	.33	−.21	−.25	−.11	
15. Trade association dummy	.82	.38	.18	.31	.59	−.58	−.26	.56	.11	−.15	−.36	.34	.51	.35	.54	−.14

* These statistics cover 2,067 observations on foundings of independent power producers in California and New York between 1980 and 1992. The univariate statistics reflect the untransformed variables. For all correlations greater than .06, $p < .05$.

Table 2c

Descriptive Statistics for the Analysis of Founding Heterogeneity among Independent Power Producers*

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Heterogeneity	.51	.22															
2. State (CA = 1)	.50	.50	.13														
3. State population/10^6	22.5	4.98	.08	.95													
4. Gross state product/10^8	49.4	17	.08	.57	.78												
5. Prime interest rate/10	11	3.44	−.32	.00	−.19	−.62											
6. Natural gas price	2.69	.54	.44	.00	−.13	−.43	.32										
7. No. of foundings/100	.04	.05	.14	.47	.43	.26	−.29	.14									
8. Sector age/10	93	45.4	.11	.00	.24	.79	−.80	−.51	.03								
9. Avoided costs/10	.45	.21	.74	−.16	−.23	−.07	−.33	.33	.13	.20							
10. Sector tax credit	.42	.50	.02	.00	−.21	−.69	.75	.68	−.18	−.86	−.10						
11. Green tax credit/10	4.32	7.07	.31	.51	.27	−.20	.31	.45	.42	−.48	.27	.39					
12. Supreme Court decision	.04	.19	.23	.00	−.04	−.13	−.01	.29	−.02	−.15	.12	.23	.09				
13. Sector density/100	5.22	5.16	−.09	.60	.80	.92	−.52	−.46	.32	.62	−.30	−.62	−.24	−.13			
14. Sector density^2/100	533	802	−.14	.59	.79	.87	−.40	−.42	.22	.53	−.37	−.53	−.27	−.12	.97		
15. Media coverage/100	.10	0.37	−.23	.00	−.14	−.46	.74	.13	−.41	−.56	−.31	.60	.23	−.05	−.42	−.32	
16. Trade association dummy	.56	0.5	.00	.35	.50	.78	−.59	−.38	.40	.76	.05	−.65	−.14	−.02	.68	.56	−.49

* These statistics cover 26 six-month spells for California and New York each. The univariate statistics reflect the untransformed variables. For all correlations greater than .28, $p < .05$.

Table 3

Event-History Analysis of the Founding Rates of Brown- and Green-Technology Independent Power Producers (N = 2,067)*

Variable	Brown model B1	Brown model B2	Green model G1	Green model G2	Significant difference between brown and green coefficients?
State	−.053••	−.063••	.028	.002	
	(.025)	(.029)	(.029)	(.034)	
State population/10^6	−.135•••	−.208•••	.147•••	.174•••	
	(.026)	(.029)	(.027)	(.034)	
Gross state product/10^8	−.033	−.046	−.109•••	−.090•••	
	(.028)	(.029)	(.029)	(.034)	
Prime interest rate/10	−.098•••	−.081•••	−.017	−.023	
	(.023)	(.028)	(.027)	(.033)	
Natural gas price	−.076•••	−.109•••	−.100•••	−.049	
	(.029)	(.030)	(.032)	(.036)	
Sector age/10	−.210•••	−.359•••	−.01	−.028	
	(.026)	(.030)	(.029)	(.034)	
Green tax credit/10	.085•••	.045	.087•••	.153•••	
	(.029)	(.029)	(.031)	(.034)	
Avoided costs/10		.102•••		.241•••	Yes
		(.030)		(.037)	
Sector tax credit		−.041		.169••	Yes
		(.030)		(.036)	
Supreme Court decision		.235•••		.334•••	Yes
		(.030)		(.036)	
Density of focal form/100		.251•••		.220•••	No
		(0.030)		(0.040)	
Density of focal form^2/100		.013		.106•••	Yes
		(.029)		(.036)	
Density of other form/100		.105•••		.434••	Yes
		(.030)		(.037)	
Media coverage/100		.046•		.234•••	Yes
		(.025)		(.034)	
Trade association dummy		.638•••		.195•••	Yes
		(.035)		(.036)	
χ^2	96.25	595.37	55.27	385.88	

• $p < .10$; •• $p < .05$; ••• $p < .01$; two-tailed test.
* Standard errors are in parentheses below parameter estimates. All independent variables have been orthogonalized.

green- and brown-technology firms increased by 39.6 percent and 26.5 percent, respectively, which supports hypothesis 2a.

Cognitive effects. Our first measure of cognitive institutions is sector density. To analyze founding rates of green- vs. brown-technology firms, we distinguished between focal-form and other-form density.[6] For brown-technology foundings, focal-form density had a linear effect: the coefficients on the linear and squared terms were both positive, but only the coefficient on the linear term was statistically significant. For green-technology foundings, focal-form density had an exponentially increasing effect: the coefficients on both the linear and squared terms were positive and statistically significant. Thus, for both green- and brown-technology foundings, we see only legitimating effects of focal-form density, not competitive effects. This seems reasonable, given the sector's youth. On average, focal-form density increased the founding rates of firms using green and brown technologies by 36.4 percent and 28.5 percent, respectively. The difference between these effects was statistically significant. In addition, other-form density had positive effects on both kinds of foundings. The effect of other-form density on the green-technology foundings was larger than the effect of other-form density on brown-technology foundings, and the difference between the coefficients was statistically significant. Together, these results support hypothesis 3a.

Our second measure of cognitive institutions, media coverage, also had positive effects on both founding rates. The effect on brown-technology foundings was only marginally significant ($p < .06$), while the effect on green-technology foundings was significant. The coefficient on green-technology foundings was larger than the coefficient on brown-technology foundings, and the difference between the coefficients was statistically significant. On average, media coverage of the sector increased green- and brown-technology founding rates by 26.4 percent and 4.7 percent, respectively. This pattern of results supports hypothesis 4a.

Normative effects. Finally, the presence of trade associations significantly increased both green- and brown-technology foundings, but in line with hypothesis 5a, the creation of these associations had a stronger impact on the brown- than on the green-technology foundings. After trade associations were founded, the founding rate of firms using brown technologies increased by 89 percent, while the founding rate of firms using green technologies increased by only 22 percent. The difference between coefficients was statistically significant.

Founding Heterogeneity

Table 4 reports results for the analysis of overall founding heterogeneity. Model 1 is a baseline model that includes all controls. Models 2 and 3 add independent variables; model 3 includes the squared term for density, to explore possible non-monotonic effects. Given the small number of observations, the parameter estimates show reasonable stability.

6
We also estimated the effects of overall sector density and found results similar to those discussed here, specifically, stronger positive effects on green-technology foundings than on brown-technology foundings.

Table 4

Generalized Least Squares Regression Analysis of Heterogeneity among Newly Founded Independent Power Producers (N = 52)*

Variable	Model 1	Model 2	Model 3
Intercept	.118	–.834••	–.819••
	(.180)	(.354)	(.356)
State†	–.016	.044•	.045•
	(.034)	(.025)	(.025)
State population/10^6†	.016	.022	.025
	(.034)	(.022)	(.022)
Gross state product/10^8†	–.162	–.008	–.004
	(.289)	(.172)	(.168)
Prime interest rate/10†	–.045•	–.038•••	–.033••
	(.025)	(.012)	(.014)
Natural gas price†	.027	.061••	.063••
	(.037)	(.028)	(.028)
No. of foundings/100	.624	.605	.529
	(.577)	(.410)	(.409)
Sector age/10	.084••	.173•	.163•
	(.041)	(.095)	(.095)
Green tax credit/10	–.016	–.032	–.05
	(.034)	(.081)	(.085)
Avoided costs/10		.897•••	.943•••
		(.182)	(.187)
Sector tax credit		.227•••	.230•••
		(.063)	(.067)
Supreme Court decision		.116•	.116•
		(.070)	(.071)
Sector density/100†		.098•••	.118•••
		(.036)	(.041)
Sector density^2/100†			–.018
			(.020)
Media coverage/100		.129••	.140••
		(.058)	(.059)
Trade association dummy		–.156••	–.0177•••
		(.061)	(.065)
χ^2	11.79	206.12	208.28

• $p < .10$; •• $p < .05$; ••• $p < .01$; two-tailed test.
* Standard errors are in parentheses below parameter estimates.
† Variable has been orthogonalized.

Regulative effects. Founding heterogeneity increased as avoided costs rose, as predicted by hypothesis 1b. When avoided costs increased $.01/kilowatt-hour, founding heterogeneity rose by 18 percent. Having a sectorwide tax credit increased founding heterogeneity by 45 percent, further supporting hypothesis 1b. The Supreme Court decision had a positive effect on founding heterogeneity; however, this coefficient was only marginally significant ($p < .10$). This result provides only weak support for hypothesis 2b. Notwithstanding its marginal statistical significance, the substantive significance of the Supreme Court ruling was considerable: founding heterogeneity was 22 percent higher after the Supreme Court ruling than before.

Cognitive effects. Sector density had a positive impact on founding heterogeneity, in line with hypothesis 3b. An increase of 100 in the number of qualifying facilities with contracts increased founding heterogeneity by 23 percent. As shown in model 3, the squared term for density had a nonsignificant effect, indicating a linear (purely legitimating) rather than curvilinear (legitimating, then competitive) relationship. Media coverage, as indexed by the number of articles about the independent-power sector, also increased heterogeneity, which supports hypothesis 4b. Publication of 100 more articles increased founding heterogeneity by 27 percent.

Normative effects. Hypothesis 5b predicted that the formation of state-level trade associations would decrease founding heterogeneity, net of the influence of regulatory and cognitive institutions (which the associations may have helped create). Our results support this hypothesis. The coefficient on the trade association dummy is negative, as predicted, and statistically significant. Holding all else constant, the existence of an industry association decreased founding heterogeneity by 34 percent.

DISCUSSION AND CONCLUSION

Much previous research has suggested that organizational diversity is greatest when societal sectors are new and that diversity declines as political, technical, and cultural institutions develop and stabilize social interactions (e.g., DiMaggio and Powell, 1983). In particular, research on technology and organizations suggests that at the beginning of technology life cycles, firms experiment with diverse technologies and that diversity declines after a dominant design emerges (Tushman and Anderson, 1986). Our study, which focused on the pre-dominant-design phase of technological and organizational evolution, revealed a more complex pattern.

We found that the development of regulative institutions and cognitive institutions, which we argued served to increase the legitimacy of the new independent-power sector as a whole, increased the founding rates of all kinds of organizations. The impact of such institutional developments was most pronounced, however, on entrepreneurs founding firms using risky new technologies. This is consistent with general psychological arguments that reductions in risk, and therefore increases in the probability of success, have bigger impacts on behavior when initial probabilities of success are relatively low (Thaler, 1980; Weber, Shafir, and Blais, 2004). As the overall risk level declined, foundings of what had been rare types of entrants increased more than foundings of what had been common types of entrants, and founding heterogeneity increased.

In sharp contrast, the emergence of normative institutions, created through the activities of trade associations, served to reduce the overall heterogeneity of foundings. As is the case for many collective organizations, these trade associations were dominated by organizations with “deep pockets” that typically used brown-fuel cogeneration technologies. As a consequence, the trade associations tended to promote established technologies over new ones. Such selective support increased the founding rates of organizations using established technologies more than the founding rates of organizations using new technologies. The aggregate effect was to reduce the variety of newly founded firms—to spur a lot more of what were already common events (foundings of firms using established technologies) and only a little more of what had been rare events (foundings of firms using new technologies).

This paper contributes to three lines of research on organizations: ecological analysis, institutional approaches, and studies of technology and entrepreneurship. For all three lines of research, we depart from most prior studies by analyzing causal links between micro-level phenomena (perceptions of risk by potential entrepreneurs and resource providers) and macro-level outcomes (founding rates and founding heterogeneity). Doing so suggests non-obvious predictions about entrepreneurial behavior in risky settings such as new sectors.

We contribute to ecological analysis by examining the external forces that affect the overall level of organizational diversity. Although many previous ecological studies have shown how environments come to favor some forms over others (for a review, see Carroll and Hannan, 2000), we have little knowledge of the forces that drive overall levels of organizational diversity, especially in new sectors. Organizational diversity plays a critical role in organizational evolution: the types of organizations selected by the environment depend on which types of organizations exist. Therefore, organizational diversity facilitates societal adaptation by increasing the probability that solutions well suited to changing environmental demands will exist (Hannan and Freeman, 1989). Our study demonstrates that institutional forces can play two different roles, either enhancing conditions for all kinds of organizations or supporting particular forms of organization. In particular, our analysis extends previous ecological studies by showing that the density of organizations in a new sector affects not only rates of founding but also the variety of organizations founded.

We contribute to institutional research by shifting the focus from mimetic isomorphic processes, which tend to increase organizational homogeneity (for a review, see Mizruchi and Fein, 1999), to a more balanced view of how institutional forces can promote both homogeneity and heterogeneity. In doing so, we extend the few institutional analyses that have focused on organizational heterogeneity (e.g., Clemens, 1997; Schneiberg, 2002) by investigating interactions between institutional processes and entrepreneurial action. We also answer Scott's (2001: 211) call to examine all three institutional pillars, their "interactions, conjoint effects, [and] conflicts." Our analysis shows that regulative, cognitive, and normative institutions can have divergent effects on organizational heterogeneity. Finally, whereas past institutional research has focused on the legitimacy of an organizational form or practice (Meyer and Rowan, 1977), we distinguished between the legitimacy of an entire sector and the legitimacy of a particular organizational form within that sector (see also Powell, 1991; Aldrich and Fiol, 1994; Deeds, Mang, and Frandsen, 2004).

We contribute to research on technology and entrepreneurship by revealing the link between technology entrepreneurship and the institutional environment, which has received little attention (Shane and Venkataraman, 2003). Our analysis showed that foundings in independent power became more varied as regulative and cognitive institutions lowered barriers to entry, in large part because lowering entry barriers reduced risks associated with the sector, thus enabling those who were committed to novel technologies to mobilize the resources they needed to found their ventures. For example, the density of firms in the sector that used established technologies increased founding rates of ventures using novel technologies. This suggests that the early entrance into a new sector by firms that use established technologies helps legitimate this new sector and that the benefits of density-dependent legitimation of a new sector spill over to help entrepreneurs using more radical technologies. And, unlike most economic research, in which entrepreneurs are seen as actors who seek to maximize profit by adopting the most efficient technology, our analysis indicates that the type of technology chosen by entrepreneurs is shaped by their goals and experience, as well as by access to material and social resources. Interviews with green-technology entrepreneurs who advocated wind power showed that they rarely built gas cogenerators if the price of natural gas declined. Instead, they waited until they were able to mobilize the necessary resources to use their preferred technology.

Our study also has relevance for public-policy scholars. Our findings clearly demonstrate that government policies can have a significant impact not just on overall founding rates (Russo, 2001) but on the types of organizations founded. Of particular interest in this respect are the effects of avoided-cost policies, which are contrary to the expectations of both economic analysts and many industry participants. Typical economic explanations predict that the market price of an undifferentiated product such as electric power will not influence the choice of technology used to make the product; instead, the most economical method of producing the commodity will be chosen, to maximize profit. Our research tells a different story. Increasing sectorwide subsidies, such as avoided-cost rates, greatly increased the probability that riskier new technologies would be used and so spurred the founding of a wider array of technological forms.

As Hirsh (1999) observed, the niche created by PURPA served as an incubator for a host of innovative technologies whose efficiencies increased dramatically during this period (see also U.S. Office of Technology Assessment, 1985; Berger, 1997). For example, the cost of wind power dropped from an estimated $.30/kilowatt-hour in 1980 to $.05/kilowatt-hour in 1990 (compared with an average electricity price of $.08/kilowatt-hour in 1978). After taking into account subsidies and societal costs like pollution, many analysts have argued that wind power is competitive with power generated by fossil fuels (Righter, 1996). Wind power has become a worldwide growth industry, with $9 billion of new investment in 2003 and an annual growth rate greater than 18 percent. Similar technical advances were witnessed in other electricity-production technologies. The current success of wind and other formerly novel technologies is a direct result of the entrepreneurial activity in the 1980s and early 1990s (Hirsh, 1999). By creating a space in which entrepreneurs could experiment with and develop new technologies, PURPA greatly increased the pace of technological innovation. The diverse technologies developed in the wake of PURPA have created options to manage future disruptions in fossil-fuel supplies and serious public-health issues such as air pollution. Ironically, these technologies are currently being adopted by the very utilities that resisted their development. But the entrepreneurs who overcame the challenges and risks of new technologies in this new sector were the ones who paved the way.

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APPENDIX: Technologies for Generating Electricity

The information in this section comes from the following sources: (1) the online edition of the *Encyclopœdia Britannica,* http://www.britannica.com; (2) Solstice, the Internet information service of the Renewable Energy Policy Project and the Center for Renewable Energy and Sustainable Technology (REPP-CREST), http://solstice.crest.org; (3) the Oregon Office of Energy Web site, http://www.energy.state.or.us/renew/costs.htm; (4) the U.S. Department of Energy Web site, http://www.energy.gov/; (5) the Energy Information Administration Web site, http://www.eia.doe.gov/; and (6) the University of Rochester's Department of Engineering Web site, http://www.energy.rochester.edu/cogen/.

Green Technologies (Renewable)

Biomass/biogas. The biomass category comprises all organic materials that are used to produce energy: wood (trees, timber waste, wood chips), bagasse (the residue remaining after a plant has been processed, for instance, after the juice has been removed from sugar cane), crop residues (corn and rice hulls, peanut shells), solid waste (grass clippings, leaves), animal wastes (manure), and waste from food processing and municipal sewage treatment plants. There are several ways to convert biomass to energy. In direct combustion, fuel is burned with direct heat. In pyrolysis, the biomass is thermally degraded by heat in the absence of oxygen. In this process, biomass feedstocks, such as wood or garbage, are heated to a temperature between 800 and 1400°F, but no oxygen is introduced to support combustion. Gasification converts biomass such as wastewater (sewage), manure, or food processing wastes (mixed with water and fed into a digester tank without air) to methane or hydrogen through heating or anaerobic digestion. Fuel alcohol can be produced by converting starch to sugar, then fermenting and distilling the sugar into alcohol. Finally, biogas can be generated by the decay (anaerobic digestion) of buried trash and garbage in landfills or sewage plants; when such organic waste decomposes, it generates gas that is approximately 50 percent methane. Biomass small-power plants include local sanitary landfills that produce biogas used as fuel in internal combustion units. Cogeneration biogas units typically burn wood waste to produce steam, this steam used primarily in manufacturing and secondarily to run steam turbines. The cost of electricity produced from biomass currently ranges from $.055/kilowatt-hour to $.065/kilowatt-hour.

Geothermal. Energy flows from the interior of the Earth to the surface in steam or hot water, most often in areas of active volcanoes. There are several methods for capturing this heat to generate electricity; typically, however, geothermal reservoirs with temperatures of 180°C or higher are used. Steam from wells drilled to depths of hundreds of meters drives turbine generators. Geothermal generators are usually very capital-intensive, with 30 to 40 percent of costs allocated to drilling and exploration. Geothermal technologies are sophisticated and involve a high level of risk. Although the concept of tapping the Earth's heat as an energy source has been around for decades, the technology to do this on a large scale is still fraught with uncertainty. U.S. geothermal electricity generation currently totals about 2,200 megawatts, about the same as four large nuclear power plants. The cost of developing geothermal sites varies, but current costs average $.052/kilowatt-hour to $.065/kilowatt-hour.

Micro hydro. Hydro-electric power stations capture the energy in flowing water to produce electricity. Small hydro-electric generating systems, which generally have capacities up to 2 megawatt and which account for about 30 percent of the world's hydroelectric potential, provide clean and cheap electricity for local applications. Micro hydro systems are less environmentally destructive than large dams. The technology involved is simple: hydraulic turbines change the energy of fast-flowing or falling water into mechanical energy that drives power generators, which in turn produce electricity. The costs of electricity produced from this source average between $.07/kilowatt-hour and $.11/kilowatt-hour.

Solar. Solar energy can be captured as heat in solar thermal applications or it can be converted directly into electricity using photovoltaic cells. Solar thermal technologies use the heat in sunlight to produce hot water, heat for buildings, or electric power; applications range from simple residential hot water systems to multi-megawatt electricity generating stations. Large generators typically use solar thermal technology. Currently, this is the cheapest solar energy, averaging $.08/kilowatt-hour. Photovoltaic cells convert solar radiation into electricity. Most are made of silicon, but other semiconducting materials can be used. A conventional solar cell consists of a wafer of silicon that is about .02 inches thick. Typical cells, 4 inches in diameter, produce about 1 watt of power; dozens of cells are grouped into modules; modules are further grouped into panels; finally, panels are grouped into arrays. Each array can produce several kilowatts of power. Although the cost of electricity produced by photovoltaic cells has decreased over the last two decades, it is still relatively high, about $.194/kilowatt-hour to $.236/kilowatt-hour.

Wind. Wind contains tremendous amounts of energy. Wind-power systems have four components. Wind turbines convert kinetic energy to electric power. Blades or rotors catch the wind by changing the horizontal movement of wind into a rotational force turning a shaft. A generator then converts the mechanical energy of the rotating shaft into electrical energy. A tower lifts the wind turbine (sometimes more than ten stories high) so that it can take advantage of the stronger, more consistent winds that blow above the ground. The capacity of wind farms varies substantially, from less than 1 megawatt to over 90 megawatts. The cost of wind power has declined substantially over the past two decades; it now averages $.045/kilowatt-hour to $.081/kilowatt-hour.

Brown Technologies (Non-renewable)

Fuel oil. Fuel oil has been used in electricity generation for decades; it currently is used primarily with cogeneration systems. The fuels in this category include fuel oil numbers 1, 2, 4, 5, and 6; crude oil; petroleum coke; kerosene; liquid butane and propane; methanol; liquid byproducts; oil waste; sludge oil; and tar oil.

Natural gas. Natural gas has been a source of electricity since the early 1900s. It is a relatively clean-burning fuel. In the context of PURPA, this fuel is used primarily in cogeneration systems.

Coal. Commonly used since the eighteenth century, coal still accounts for about one-third of all power produced in the U.S. Under PURPA, qualifying facilities were allowed to burn coal only in cogenerators, not in small power plants.

Waste natural gas. This is a low-grade fuel that, under PURPA, could be burned in both cogenerators and small power plants.

Nuclear. For the most part, nuclear cogenerators are government, military, and (occasionally) university facilities. There were only two nuclear cogenerators in our sample.

Other waste. This classification includes all fuels used in small power plants and cogenerators that are non-renewable: batteries, chemicals, hydrogen, sulfur, purchased steam, medical waste, tires, liquid acetonitrile waste, solid by-products of industrial processes, and pitch.

Other. This category includes diverse brown fuels, notably propane and oil mixtures, that are occasionally used in small power plants and cogenerators and that do not fit in any other category. In our sample, only 1.2 percent of generators (25) fell into this category.