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THE EMERGENCE OF SUSTAINABLE INDUSTRIES: BUILDING ON NATURAL CAPITAL

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This paper focuses on the emergence and growth of sustainable industries, specifically analyzing the rise of the wind energy industry in California. Based on a favorable institutional environment and the presence of abundant natural capital, the wind energy industry took root and flourished in California during the last two decades. This paper analyzes this phenomenon by exploring the determinants of where and when wind energy projects would be established. Findings suggest that in locations where natural, social, and economic influences converged, greater wind energy activity followed. The paper advances a simple framework that uses natural capital, site specificity, and institutional environments to predict which sustainable industries will enjoy growth in coming decades. Copyright © 2002 John Wiley & Sons, Ltd.

A MISSING LEVEL OF ANALYSIS

While a comprehensive review of organization and environment literature is yet to be attempted and may still be premature, a number of popular themes have achieved currency. Several initial studies explored the role of the corporation in society from a macroscopic perspective (e.g., Egri and Pinfield, 1996; Gladwin, Kennelly, and Krause, 1995; Shrivastava, 1995a; Starik and Rands, 1995). Many studies have focused on the role of environmental issues in strategic management (e.g., Christmann, 2000; Hart, 1995, 1997; Maxwell *et al*., 1997; Roome, 1992; Sharma and Vredenburg, 1998; Shrivastava, 1995b). Others have addressed the particular issue of whether or not the returns to corporate environmental performance are positive (e.g., Hart and Ahuja, 1994; King and Lenox, 2001; Klassen and McLaughlin, 1996; Nehrt, 1996; Russo and Fouts, 1997).

This volume of research illustrates how scholars have invested considerable energy at the levels of society and the organization. Curiously, however, in prior environmentally oriented studies, the level of the industry has received scant attention. The omission is not absolute. Starik and Rands (1995) do discuss some industry-level variables in both categories, but their schema, which moves outward from the level of the individual to the ecological level, jumps from the organizational to the political-economic level. Self-regulation, which generally operates on an industry level, has been mentioned by Cairncross (1995), King and Lenox (2000), and Schmidheiny (1992), and has been the subject of several case studies, including a well-known teaching case on the chemical industry's Responsible Care program (Lodge and Rayport, 1991). But scholarly work is sparse. As a result of a research trajectory that has largely bypassed industry-level issues, we cannot answer essential questions, such as where and when sustainable industries will emerge. Since many new industries have first appeared or moved from the fringes of the competitive landscape during the last several decades, including organic foods,

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ecotourism, and renewable energy technologies, the issue is quite current. If indeed we are witnessing the eclipse of capitalism as currently practiced (Hawken, Lovins, and Lovins, 1999), it also is of paramount importance.

One reason that the study of the emergence of new industries is vital for those studying organizations and the natural environment is that there are strong social (Bansal and Roth, 2000; Samdahl and Robertson, 1989) and institutional (Delmas, 2002; Hoffman, 1999; Jennings and Zandbergen, 1995) elements to the push toward greening. Carroll has observed that most industries begin looking like social movements (Carroll, 1997). Given this historically consistent story and the rise of environmentalism as a social movement (Dowie, 1995; Shabecoff, 1993), analyzing new sustainable industries is critical to creating knowledge about societies, organizations, and the environment.

The combination of the natural and social domains offers a point of departure for my theory. I hope to show that natural capital and geographic concentration of activity display an identifiable relationship to the siting of wind energy projects. The relationships also depend on project economics, which tether these factors to the financial realities of the energy field. A rigorous approach to the topic demands that I begin with a key definition.

What is a sustainable industry?

What is a sustainable industry? This is a challenging question, if only because the term sustainability has acquired so many overlapping definitions. Definitions also seem to be growing in length. Like a family's collection of Christmas ornaments, successive definitions of sustainability frequently add new items and only infrequently remove them. Starik and Rand's (1995) definition is worth utilizing, because they sought to create a definition that applies not just to organizations, but also several other levels of analysis. So beginning with it avoids the need for yet another definition. For Starik and Rands (1995: 909),

> Ecological sustainability is the ability of one or more entities either individually or collectively, to exist and flourish (either unchanged or in evolved forms) for lengthy time-frames, in such a manner that the existing and flourishing of other collectivities of entities is permitted at related levels and in related systems.

The key here is that such activities operate in ways that do not further exacerbate the limits facing activities in related fields. Clearly, few if any sustainable organizations and industries now exist according to this definition. But, interpreted broadly and with the addition of new 'ornament,' this definition can be utilized to define sustainable industries for my purposes.

Focus for a moment on the parenthetical note that highlights 'evolved forms.' Using this qualification, we can view industries that are on the path toward sustainability in more positive terms. Such a qualification also does not generally allow for many currently unsustainable industries to evolve toward sustainability. It is difficult to envision how copper mining, for example, can ever become sustainable, since it is nonrenewable and its extraction and use create significant impacts on the ecosystem and will continue to do so given any reasonable trajectory for the industry. Similarly, even if the automobile industry produces a high-efficiency, low-emission vehicle, its need for more and more roads represents a large and growing impact on individual and collective entities (Hart, 1997). On the other hand, consider solar energy facilities. Solar radiation is currently renewable, but its conversion and use are not without impacts. Even so, solar energy generation represents a transformational form that in two critical ways is on the trajectory toward sustainability. First, its current ecological impacts are an improvement over most traditional energy sources. Second, it is consistently evolving toward a future form that may be more decentralized. The current trend to move to generation facilities closer to users will mitigate the impacts of long-distance transmission.

This trajectory toward sustainability is a key defining characteristic of a sustainable industry. But an important behavioral dimension should be added, which represents a second defining characteristic. It is that organizations within sustainable industries are mission-driven. As used here, the term mission-driven means that the organization includes not only economic sustainability within its charter, but also environmentally and socially oriented goals. For example, Gladwin *et al.* (1995), contrasting paradigms, associate 'technocentrism' with a goal of allocative efficiency, and 'sustaincentrism' with a broader goal: quality of life. So, organizations in sustainable industries evaluate success on multiple dimensions, at least one of which depends on ecological criteria. The industry under study here, wind energy, is moving toward sustainability under this definition. Compared to traditional electricity sources such as fossil-fueled power plants, using wind produces far fewer ecological impacts according to available surveys on the issue (e.g., Gibbons, Blair, and Gwin, 1989; Harper, 1996). Evidence of the mission-driven nature of the industry is available in several places. The American Wind Energy Association's website advocates 'the development of wind energy as a reliable, environmentally superior energy alternative in the United States and around the world' (AWEA, 2002).

In addition to environmental stewardship, several individual wind energy companies are very forthcoming about their commitment to social goals, including Baywinds Wind Energy Corporation, which reproduces a portion of Pope John Paul II's 1990 World Day of Peace message on its home page (Baywinds, 2002). In general, analyses of larger companies suggest that organizations rated highly for environmental performance are also rated highly for social performance. For example, in the data used by Berman *et al.* (1999), third-party scores on the natural environment had significant, positive correlations with employee relations, workplace diversity, product safety and quality, and community concerns.

Thus, the Starik and Rands (1995) definition can be amended to apply to sustainable industries in this way:

> An ecologically sustainable industry is a collection of organizations, with a commitment to economic and environmental goals, whose members can exist and flourish (either unchanged or in evolved forms) for lengthy time-frames, in such a manner that the existing and flourishing of other collectivities of entities is permitted at related levels and in related systems.

Sustainable industries often appear as a response to market opportunities, a connection that can be appreciated by reviewing the recent history of the alternative energy industry in California.

ALTERNATIVE ENERGY IN CALIFORNIA, 1979–92

The empirical setting for this study is the state of California. To understand the modern roots of the alternative energy industry, one must recognize that, until recently, severe institutional constraints on its development were in place (Joskow, 1997). This was due to the monopolistic nature of the electricity industry, and the legally permitted refusal by electric companies to purchase the output of alternative energy projects or transmit their electricity directly to end uses. Because such projects depend on their sites for energy production, few could be located near industrial customers or other possible direct users of the electricity. Hence, utility opposition effectively blocked entry into the industry.

The genesis of the modern alternative energy industry can be traced to a comprehensive set of energy-related bills that was passed by Congress in 1978. Included in a mammoth omnibus law, whose main focus was natural gas deregulation, was the Public Utility Regulatory Policies Act (*Public Utilities Fortnightly*, 1977). An obscure section within PURPA, as the Act became known, would eventually lead to a drastic overhaul of the institutional structure of the alternative energy field. This institutional shift began with mandates that electric utilities receive and purchase electricity from alternative energy providers, and that the price paid for that electricity be based on the utility's full 'avoided cost.' The avoided cost was theoretically equal to the marginal (and therefore highest) cost of electricity to the utility. To receive avoided cost pricing by gaining qualifying facility, or 'QF,' status, projects needed to be independent of utility ownership and be smaller than 80,000 kw. PURPA was intended to cover small applications of cogeneration technologies by industrial customers, wherein steam was produced first to turn electricity-producing turbines, and second for industrial purposes on-site. But the law also permitted the large-scale establishment of electricity-generating alternative technology projects utilizing wind, solar, and other energy sources. Although this trend was not envisioned by legislators (Persons, 1995), it soon became apparent that many alternative energy projects would be sited as a result of the law's combination of mandated purchases and high prices.

In California, several driving forces converged to create a great opportunity for alternative energy development. The state's utilities were heavily dependent on fossil fuels. This meant that their marginal costs—and hence the prices paid to projects organized under PURPA—would be among the nation's highest. Second, California enjoys an abundance of natural resources. For example, it has vast geographic expanses that receive strong, daily sunlight, and a large number of areas that experience very high wind speeds (California Energy Commission, 1981). Perhaps most importantly, in the early years following PURPA, California Governor Jerry Brown saw to it that the state's institutions held alternative generation in high esteem, providing tax credits and erecting a regulatory apparatus that protected and nurtured the alternative energy industry (California Energy Commission, 1981).

Thus, this empirical setting offers an exceptional opportunity to study the birth of a new, sustainable industry. The theory that is now constructed blends together a number of theoretical perspectives to explore the issue of where and when wind energy projects would be founded in California in the years following the passage of PURPA.

THEORY

Natural capital

A theory about the rise of industries that depend on natural capital must begin with a sense of how this resource is conceptualized. Defined as 'the stock that yields the flow of natural resources' (Daly, 1996: 80), natural capital exhibits properties that distinguish it from traditional notions of productive capital. Although natural capital can be renewable (e.g., fish, trees) or exhaustible (e.g., oil, minerals), in the case of wind energy it is not depleted as it is used, so that it is somewhat distinct from many forms of renewable natural capital. What is the role of natural capital, specifically wind, on the establishment of a new industry, specifically the wind energy industry?

Natural capital resembles the traditional economic concept of physical capital in that it produces a flow of valuable goods and services. Economic theories are quite straightforward in their analysis of natural capital, covering the optimal depletion of exhaustible resources and the optimal sustainable yield of renewable resources (Fisher, 1981). For most economists, the presence of natural capital represents a theoretical wrinkle but, essentially, decision-making still involves the comparison of long-term costs and benefits, with the alternative chosen having the lowest costs. But the story is not this simple, according to some economists (Costanza, 1991) and many business writers (Hawken *et al*., 1999). They believe that natural capital is systematically undervalued by short-term thinking, poor accounting systems, and skewed pricing.

An example taken from my empirical setting, the electric generation industry, will illustrate a simplified process of evaluation. In comparing two power plants, one that would use exhaustible resources and another that would use renewable resources, the calculus would look relatively standard. Both projects would incur capital and operation and maintenance costs. For the project using an exhaustible resource (e.g., coal), fuel costs would then be added. For the project using a renewable resource (e.g., wind), fuel costs (beyond securing property with high winds) would be zero. The total costs would then be compared, and the lower-cost alternative selected for development.

A familiar plot line in this story is the failure of market prices to reflect the full environmental cost of goods. This will occur when the procurement, production, and use of a product creates external costs that are not borne by those involved in these processes. It follows that if an ecologically destructive alternative has an artificially low cost for this reason, investment can be drawn away from ecologically preferred alternatives if those alternatives would be cost-competitive under a more complete accounting of costs. This tendency is well documented in the environmental economics discipline (Field, 1997).

But another plot line revolves around locational issues that distinguish the two energy sources. The key difference in the projects is that while grades of coal are relatively well understood and reflected in their price, the economics of the wind energy project are critically influenced by the site chosen for the project. The windier the site, the more electricity is produced, and hence the brighter the project economics, *ceteris paribus*. To put it another way, wind energy project economics exhibit *geographic site specificity* and differ by the location of the project. Unlike coal or oil, which is routinely moved over great distances, wind energy represents a type of natural capital that is immobile.

Geographic site specificity is an important element of the natural capital story. It is present when the viability and activities of an industry's participants are heavily influenced by the location in which those activities take place. Geographic site specificity is a common trait and a question of degree. Site-specific sustainable industries include wind energy facilities that are studied in this article, as well as ecotourism and other industries where location is critical. Nonsite-specific sustainable industries might include organic farming and fuel cell production that can succeed in a great many locations.[1]

Site specificity is a continuous variable. Solar energy displays site specificity, but to a lesser degree than wind energy. For solar energy, as one moves to locations with lower solar radiation, the possibilities for energy production are lower, but still potentially exploitable. Wind energy, on the other hand, is highly site-specific, because potential wind energy varies with the cube of the wind speed at a site. Thus, choice sites can generate far more energy than less windy sites.

But differences in the relative value of the natural capital associated with a site are not the sole determinant of whether or not development will occur. Returning to the comparison of coal plants and wind energy plants, the relevant comparison is not between coal plants and wind energy plants per se, because that is only clear when the location of the wind energy plant is known. Thus, a naive proposition might be that the greater the winds in a geographic area, the greater the wind energy development.

But prospective development must meet an economic test. As the cost of solar panels declines, areas with intense radiation are more likely to see photovoltaic projects built there. As the price being paid for wind-generated electricity rises, more wind energy projects will be built in windy areas. Put directly, the presence of significant natural capital may be a necessary—but not sufficient—condition for its conversion into human use. So the ability to economically convert wind energy into competitively priced electricity also was needed to activate development. In the California wind energy context, this implies:

> *Hypothesis 1: The interaction of the wind speeds in a county and project economics will be positively related to the founding of wind energy projects in that county.*

Geographic concentration and social capital

The remaining hypotheses recognize that the natural and economic conditions leading to development can be augmented by a powerful social factor, the formation of social capital. Geographic concentration promotes this formation.

Coleman (1988) argued that social capital materialized from changes in relationships between individuals that facilitate action. He describes several examples in which tight communities are able to use the network of relationships to promote positive outcomes for members that would not be possible under strictly economically motivated interactions. For example, Coleman traces out how casual markets in Egypt feature networks of merchants, all tied through personal and familial relationships. This social capital is valuable in promoting the aims of all by creating trust and facilitating exchange. In this same way, social capital can aid the establishment of a new industry.

One of the most important forms of social capital is the acquisition and dissemination of scarce information (Coleman, 1988; Nahapiet and Ghoshal, 1988). In new industries, information is in short supply (Pouder and St John, 1996). Organic farmers may not know the best outlets to display and sell their products. Ecotour operators rely on a limited track record on which overseas individuals are reliable and trustworthy enough to run tours that they organize. In the empirical context of wind energy development in California, information is limited on a number of critical dimensions.

Geographic concentration acts to overcome a number of hurdles through the development of social capital, especially when the condition of site specificity applies. Consider an individual who would like to build a wind energy facility in a given geographic area. Typical issues he or she will confront include finding landowners that might be willing to allow development of their land for energy production, determining what the going rate for compensation to landowners might be, learning county zoning procedures, and, perhaps most importantly, appreciating the peculiarities of the wind resource in a geographic subunit. Without information on these issues, considerable uncertainty persists, depressing development.

However, as more projects are proposed and built, informal networks emerge. Individuals interact in ways that promote information dissemination, and create a variety of positive outcomes.

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[1] It is important to note that geographic site specificity is present in some sustainable industries and some nonsustainable industries. In the nonsustainable category, most extraction processes display site specificity, and numerous industries have little site specificity, such as many manufacturing industries.

Though speaking of much larger geographic units than studied here, Porter (1990, 1998) provides some reasons why concentration creates valuable benefits. First, tight geographic relations lead to a more efficient relay and exchange of information. For example, a member of an informal network would know which landowners would be unwilling to allow development of projects, removing them from the locus of possibilities. Sanctions are taken against individuals suspected of acting opportunistically. When individuals are known to shrink from verbal commitments, others in the network will withhold key information (Coleman, 1988). And by virtue of the existence of relationships, trust can be developed through repeated interactions. Such trust can reduce the transaction costs of interchange among its individuals (Chiles and McMackin, 1996). Second, better access to employees and suppliers may be possible, since local experience accumulates. The development of a new industry is certain to encounter numerous operational issues, and this local know-how can make or break new ventures.

Geographic concentration also has ramifications for those outsiders with whom individuals from the nascent industry interact. Long-standing networks of relationships exist among those with whom they will interact, which yield the same types of advantages (Aldrich and Fiol, 1994). Entrepreneurial organizations can join forces to act in the pursuit of their collective self-interest (Chiles and Meyer, 2001). In California, the network of landowners can be expected to display the same type of qualities as the network of project proponents. Again, the benefits of concentration are tangible.

The preceding discussion thus suggests the second hypothesis:

> *Hypothesis 2: The greater the number of recent wind energy projects founded within a county, the greater the number of projects founded in the current period.*

Given the theory developed so far, concentration within geographic subunits would have a consolidating effect. This is because the social networks that arise within the geographic subunit can have diminished value outside of this subunit. For example, a county's land use laws for unincorporated property can be completely different from those of an adjoining county, so that knowledge about practices (such as how to properly apply for a variance should a project be sited on agricultural property) is very county-specific. Once established, social networks help to spread such information, and over time a network's boundary will be influenced by that of the geographic subunit. In this way, the salutary effect of prior foundings on later foundings would be restricted to the geographic subunit in which they occur. Therefore, prior foundings should have no impact on the foundings in adjoining geographic subunits. For this context, the implication is:

> *Hypothesis 3: The number of recent wind energy projects founded in adjoining counties will have no effect on the number of projects founded in the current period.*

MEASURES

I focused on wind energy projects in California to capitalize on available statewide data that permitted a more complete and fine-grained statistical analysis. To track the founding of a wind energy project, the date on which the Federal Energy Regulatory Commission (FERC) received an application from the project's proponents was used. The certification that FERC granted after receiving its application was necessary to qualify for the benefits of PURPA, including avoided cost pricing. FERC provided information on the exact date of applications in the years 1979 through 1992 (FERC, 1992). The data were then scanned, in order to remove duplicate applications and subsequent applications for new projects by existing developers. In this way, each application could be treated as the founding of a new organization. Thus, the dependent variable is the number of projects sited in a county in a given quarter.

FERC data allowed the use of the county as a unit of analysis. This geographic subunit was large enough to encompass contiguous high-wind regions, and often counties are divided by natural features such as rivers and streams. But counties are small enough to permit cohesive communities of interest to take hold. As a political unit, the county is important, since it typically has jurisdiction for the type of unincorporated lands where wind energy projects are built. Thus, it deals with permits, zoning, and other contingencies where local knowledge is critical and may be of little value outside the county.

I began with California's 58 counties, removing first two counties that were outside of the service territories of the state's three major electric utilities. Also excluded were seven counties that were primarily on the east side of the Sierra Mountain range, because the major areas of high winds were in remote, inaccessible places. Thus, data for 49 counties were included in the study.

A quarterly time period was chosen because this offered greater precision in measurement, while allowing a long enough period of time for events to occur. Because no projects were sited in 1979, and because pricing information was available only from mid-1980, 51 possible quarterly time periods were available. One period was lost through the use of lagged data on independent variables, so data for a final number of 50 periods were available for analysis. Combined with 49 counties, this yielded 2450 observations for analysis.

To measure the extent of natural capital, detailed maps of wind speeds found in DeHarpporte (1984) were employed. In these maps, seven classes of wind speeds are identified, from Class 1 (below 9.8 mph average) to Class 7 (above 15.7 mph). Converting this data to county data involved projecting the wind speed map onto a map of California counties. This allowed the measurement of the percentage of the county's area that fell into each wind speed class. In conducting this assessment, state and federal parks and national forests territories were excluded, since these lands would be unlikely to be available for development. In conducting preliminary analyses (Russo, 1999), a clear break point occurred between Classes 1 through 5 and Classes 6 and 7.[2] The percent of a county's area that was in the latter two classes was clearly connected to wind energy development, while only a few weak effects were found in other classes. For this reason, and because interacting a number of wind speed variables with project economic variables would become cumbersome, the data were simplified. A variable termed High Wind Energy Potential was created by multiplying the percentage of a county's land that was in Class 6 by its energy potential in kilowatts/acre and adding this to the percentage of Class 7 land multiplied by its energy potential.

To create a proxy for project economics, I considered two components. The first was a measure of the value of the wind resource to utility grids. Avoided cost information was obtained from the California Public Utilities Commission (CPUC, undated), and covered the period from mid-1980 through 1992. Avoided costs were thus on hand for each of California's major public utilities: Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas and Electric Company. These figures changed periodically, and were converted to quarterly averages for each utility. Because information on which counties were served by each utility was on hand, an estimated price that would be paid to prospective energy projects for each kilowatt-hour they produced could be established. In a few cases, the boundaries of two utilities' service territories lay inside counties. In those cases, the avoided costs for the two utilities were averaged. As these costs moved relatively in unison (reflecting national fossil fuel markets), this is a safe approximation.

The second component picks up the tax credits available to wind energy projects in California. A federal tax credit of 15 percent and a supplemental California tax credit of 25 percent of construction costs were in effect through 1985; in the year 1986, the California tax credit was reduced to 15 percent and no federal credit was offered. In 1987 and thereafter, no credits from either source were available. Because these two factors intertwine, I created a summary variable for project economics as follows:

$$\text{Project Economics Index} = \frac{\text{Avoided Cost}}{(1 - \text{Tax Credit})}$$

where Tax Credit is expressed as a decimal number. Thus, as avoided costs rise or tax credits rise, the Project Economics Index also rises.[3]

In practice, the simple interaction of High Wind Energy Potential and Project Economics Index was highly correlated with the former, and could have produced unstable regression estimates. So, to

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[2] This approach also is strengthened by two facts. First, wind energy potential varies with the cube of the wind speed, meaning that Class 1–5 areas have much less potential than Class 6–7 areas. Also, there may be threshold effects for the economics of wind energy, which suggests that below a certain wind speed projects will not be economically feasible.

[3] Clearly, project economics are more complicated than this index suggests. The capital costs associated with construction are implicitly assumed constant across the study period, and no operations and maintenance costs are included. But the index does pick up how project economics vary with avoided costs and tax credits, so it suits the purpose of the measure.

reduce the correlation, a procedure recommended by Aiken and West (1991) was used to address the problem. It involves 'centering' the direct terms by subtracting the overall mean of each variable from the values for each observation. Coefficient estimates for equations without the interaction term are not changed and the interaction term created by the multiplication of the two demeaned direct variables displays little correlation with those direct terms when used in regressions. Doing this reduces the correlation between the interaction and its constituent terms to no more than 0.02.

To test Hypothesis 2, a variable for recent wind energy activity in the country was computed to see if the location of prior projects led to current project development. To create this variable, the sum of wind energy projects in a county during the 12 months previous to the start of a given quarter was computed and used as a variable. In order to test Hypothesis 3, which concerns developments in neighboring geographic areas, the number of wind energy projects sited in counties that adjoined the focal county was tallied. Here also, the 12 months prior to the start of a given quarter were used.

I also entered three control variables. The first was population density within the counties, included to pick up the negative effect of urbanization on foundings. Data on county populations for 1980 and 1990 were available (United States Department of Commerce, 1994); straight-line interpolations were used for other years. The second was the prevailing interest rate, for which the average industrial cost of capital for the year was used. The final variable, following Russo (2001), is a dummy variable for whether or not an industry association for qualifying facilities existed. Since the formation of the California industry association took place in 1982, this dummy was coded 1 for the years 1983 and thereafter.[4]

ANALYSIS

This is a panel study, wherein events within counties are analyzed across time. I used an event count model to analyze organizational foundings in the California wind energy industry, adopting a log-linear relationship between foundings (i.e., events) and independent variables, following Hannan and Freeman (1989) and others.

A negative binomial model was specified for the data, which is appropriate for tracking discrete events across time. The negative binomial model has the desirable facility of handling so-called overdispersion of data (Barron, 1992). Overdispersion refers to the property wherein the variance of the estimated count of events exceeds its mean. The negative binomial model addresses this problem by including an error term that varies, so as to capture overdispersion effects. In parameterizing this error term, a common approach (e.g., Swaminathan, 1995; Baum and Singh, 1994; Carroll and Wade, 1991) has been to assume a Gamma distribution. This distribution can accommodate a variety of shapes and is flexible from a computational perspective. My specification assumes that the number of foundings in year t, y_t, conforms to a 'true' distribution, represented by the random variable Y_t, in this way:

$$Pr(Y_t = y_t) = \exp(-\lambda_t)\lambda_t^{y}t/y_t!$$

In this equation, the founding rate parameter, λ_t, is related to the vector of covariates, $\mathbf{X}_t$, in the following log-linear fashion:

$$\ln \lambda_t = \alpha + \beta \mathbf{X}_t + \varepsilon_t$$

with ε_t following the Gamma distribution. At this point, one must estimate how the variance of the expected value is related to the expected value. Here, the following form is used:

$$\mathrm{Var}(Y_t) = f(E(Y_t), \theta)$$

where θ is the overdispersion parameter. Regressions were performed using the subroutine HILBENB, which operates within the SAS statistical package (Hilbe, 1994). The analytical routines employ maximum likelihood techniques to obtain regression coefficients for the variables in the models.

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[4] Russo (2001), in a multistate study of independent power production, also found that wind energy development was linked to the state's commission having formally defined avoided cost and to the state's regulatory climate. But since the CPUC created this definition in the first year of the study period, there was no variation on this variable, and it could not be used in the analysis. Similarly, for the study period, there was no variation in the measure of regulatory climate within the state of California.

One additional concern was the presence of autocorrelation in the data (Barron and Hannan, 1991). In order to mitigate autocorrelation, I analyzed the data using a fixed effects model. This was attempted first by inserting a string of dummy variables, one for each of the counties in the analysis. Each variable was coded 1 if the county of the observation matched the county of the dummy variable, and 0 otherwise. This approach produced convergence problems, so a computationally equivalent process, wherein variables are de-meaned (Hsiao, 1986), was used. In this process, the average value for a particular variable across all observations for a given county is calculated, and the actual value for the variable is then reduced by this figure. Variables that are constant for a given county (e.g., wind speed zones) are not de-meaned, nor are variables that are constant across all counties during a given time period (e.g., interest rates). In both cases, de-meaning would have no impact on regressions.

Variables that changed with time were lagged one period, except for the Project Economics Index. This was because it depends on tax credits that were only available for projects sited in the period in which the credits were in effect.

RESULTS

Correlations among the variables are shown in Table 1. Correlations are relatively low, except for several cases. Interest rates were highly correlated with both the QF association variable and the project economics index. Regressions run without the interest rate variable provided similar results to those that appear in Table 2, so the interest rate variable was kept in the analysis. The only other correlation among independent variables was between the QF association variable and project economics. As with the interest rate variable, omitting the QF association variable led to similar regression results.

Table 2 provides the results of regression analyses. Model (A) contains the model with only the control variables and direct effects for wind potential and project economics. Of the controls, only the QF association variable is significant: the presence of an association is positively connected to project foundings. Of the direct effects, wind energy potential is positively related to foundings, but project economics is not. This may indicate that, of the two, wind potential is the most crucial to projects. It may also indicate that project economics exceeded some threshold level necessary for development for the duration of the study period.

Model (B) tests Hypothesis 1 by adding the interaction term to the variables included in Model (A). Its coefficient is significant, and model fit is significantly improved ($\chi^2 = 18.28$, $p < 0.001$). Thus, having both natural capital and enhanced project economics together predicated wind energy foundings in this sample. Model (C) tests Hypotheses 2 by adding variables for foundings in the previous year. Hypothesis 2 is supported, as prior foundings are closely associated with current foundings. Again, the model fit rises significantly ($\chi^2 = 12.62$, $p < 0.001$). Model (D) tests Hypothesis 3 by adding

Table 1. Correlation coefficients[a]

	Mean	S.D.	1	2	3	4	5	6	7
1. Wind Energy Projects Founded	0.04	0.26							
2. County Population Density	651.7	2249.0	0.01						
3. Interest Rate	10.89	1.94	0.06	−0.02					
4. QF Association in Existence	0.80	0.40	0.02	0.01	−0.77				
5. High Wind Energy Potential	0.24	0.80	0.20	0.06	0.00	0.00			
6. Project Economics Index	6.26	3.59	0.09	−0.01	0.89	−0.58	−0.01		
7. Wind Energy Projects Founded in Prior 12 Months	0.15	0.77	0.51	0.02	0.03	0.05	0.27	0.08	
8. Wind Energy Projects Founded in Adjacent Counties in Prior 12 Months	0.87	1.80	0.02	0.20	0.05	0.16	0.10	0.14	0.03

[a] Correlations at or above |04| significant at 0.05 level.

Table 2. Regression results[a]
Dependent variable: Number of wind energy projects founded countywide in current quarter

	Model (A)	Model (B)	Model (C)	Model (D)
Intercept	−8.084*	−8.711**	−8.179**	−8.682*
	(3.176)	(3.098)	(2.917)	(3.766)
County Population Density	−0.350	−0.852	−0.703	−0.893
	(1.133)	(0.793)	(0.728)	(1.219)
Interest Rate	0.218	0.245	0.243	0.244
	(0.251)	(0.244)	(0.230)	(0.296)
QF Association in Existence	2.173***	2.615***	2.006**	2.436**
	(0.652)	(0.683)	(0.633)	(0.905)
High Wind Energy Potential	0.665***	0.407**	0.335*	0.449*
	(0.113)	(0.148)	(0.154)	(0.184)
Project Economics Index	0.132	0.074	0.045	0.024
	(0.104)	(0.099)	(0.096)	(0.127)
High Wind Energy Potential × Project Economics Index		13.294***	11.030**	12.839**
		(3.679)	(3.783)	(4.658)
Wind Energy Projects Founded in Prior 12 Months			0.422***	0.388**
			(0.115)	(0.153)
Wind Energy Projects Founded in Adjacent Counties in Prior 12 Months				0.102
				(0.095)
Log-likelihood	−328.59	−319.45	−313.14	−322.48
θ	9.38	5.10	3.39	16.00

[a] Standard errors in parentheses. Significance levels, based on two-tailed tests: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

the variable for foundings in adjacent counties. Its coefficient is not significant.[5] The findings for Hypotheses 2 and 3, then, provide support for the idea that geographic concentration was an important factor in the rise of the California wind energy industry. In summary, the results are consistent with the hypotheses developed above.

DISCUSSION

Earlier sections of this paper argued that there was much scholarly opportunity in research that analyzed industries rather than organizations or societies. This study has demonstrated that a convergence of economic and social factors can act in concert with the natural environment to incubate whole industries.

Natural capital as a strategic resource

Natural capital is in many ways an unconventional resource. Often, it is highly site-specific, and can be moved only with cost. In the case of wilderness areas, this cost essentially is infinite; even in the case of wind energy, disruptive and costly transmission lines have been necessary to move its product more than a small distance. This site specificity suggests an interesting analogue to the idea of strategic fit.

For years, strategy theorists have argued that managers must fit the organization's strategy to its market environment (Hofer, 1975). My results provide an analogue to this rule by showing how organizations can exhibit a strategic fit with their *natural* environment. So organizations that recognize—and to the extent possible, inventory—their natural capital assets will have a competitive advantage in coming decades. Their mandate is to protect and enhance their supply of natural capital.

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[5] Adding this variable led to the log-likelihood statistic falling between Model (C) and Model (D), which should not occur. This is due to the regression routine, which converged on a suboptimum solution. A simple substitution of foundings in adjacent counties in the prior quarter (not year) returned very similar results to Model (D) in terms of the size and significance of coefficients, but with an insignificantly small improvement in model fit. When this substitution was done, the log-likelihood of the new Model (D) was −312.68, giving a χ^2 of 0.92 (n.s.) when compared to Model (C).

Geographic concentration in sustainable industries

The results presented here demonstrate that wind energy producers tended to concentrate in geographic areas. Greater development within counties increased subsequent founding rates, but the level of foundings in adjacent counties did not affect those rates. The results are consistent with the view that tight communities and attendant social capital are valuable to a new industry.

Aldrich and Fiol (1994) analyzed the context of industry creation, arguing that legitimacy is especially low for entrepreneurs in emerging industries. They outlined a number of methods for overcoming this lack of legitimacy, which operate on levels ranging from organizational to institutional. They do not discuss geography in the article, but if the creation of social capital is linked to later efforts to promote legitimacy through collective action or otherwise working with third parties, then geographic concentration can certainly help the cause. This point was made by Pouder and St. John (1996) in their study of 'hot spots,' and my results are consistent with this story. Legitimacy is crucial to sustainable industries, which have suffered from lingering notions that they represent unsettling social and economic changes to the status quo. In particular, they often face suspicious exchange partners. Utilities worry about the reliability of electricity they buy from alternative energy sources; supermarkets worry about pest infestations from produce they buy from organic farms.

A subject of some import is whether or not geographic concentration can be intentionally created by new industries. Scholars have been skeptical on this point, as the emergence of geographic clusters of development has been difficult to predict prior to their formation (Scott, 1992). However, an important ramification of this study is that when natural capital is site-specific, geographic concentration is not a random occurrence.

Generalizing and extending these results

An important question with practical implications is, 'How will sustainable industries evolve in the future?' Such an analysis would begin by considering how the industry's product performance and economics compare to those of its traditional counterpart. This initial analysis is not dissimilar to comparisons between two traditional industries. But when the comparison is between traditional and sustainable industries, it is important to consider three related questions:

- How does the placement of activities impact the costs and benefits of the industry's products?
- How rapidly will prices within the industry and traditional counterparts reflect true ecological costs?
- What is the level of threat to the traditional industry?

To work through these issues, consider two sustainable industries: organic farming and wind energy conversion to electricity.

The answer to the first question is critically linked to the level of site specificity of the industry. Organic farms embody little site specificity, and can sprout up in a wide variety of locations. By contrast, since the energy of the wind varies with the cube of its speed, the potential of natural capital is acutely site-specific. Although there are exceptions to this rule, site specificity typically covaries with remoteness. Therefore, the environmental costs associated with this distance from users rise with specificity. At one end of specificity, organic farms create some fuel and related driving impacts when they are taken to market, but utilize existing infrastructure. At the other, new wind energy developments can necessitate miles of transmission lines, new roads, and have extensive land use ramifications (Flavin, 1995: 62). The upshot is that site specificity may well prove a liability in the future, if and when these other costs become internalized. Thus, as a wider set of ecological costs are recognized and reflected in prices, the use of natural capital for human consumption will change. Natural capital that lies closer to users will see its relative value rise.

What does this mean for sustainable industries? First, *ceteris paribus*, investing to exploit natural capital may best be made in situations where site specificity is low and proximity to users is high. These are the situations that are least likely to be impacted by the increasing internalization of costs now improperly allocated to society at large and the environment. In the case of wind energy, to the extent that transmission feeder lines create a need for large-scale transmission lines to aggregate and deliver that power, community opposition can be strong. These complaints are symptomatic of costs that are now externalized but are created by wind energy development. By contrast, there do not appear to be analogous impacts associated with organic farming.

The second of the three questions is important because there will be more growth for sustainable industries whose traditional, nonsustainable counterparts generate the externalities that are most likely to be recognized and mitigated. It is important to note that when predicting which sustainable industries will be so benefited, the analysis recognizes that the most ecologically destructive industries are not necessarily the most likely to receive remedial action. Such action will also reflect political and institutional realities. On this score, wind energy looks better, since initiatives like a carbon tax have entered the national debate and possibly may be enacted sometime in the future. When carbon taxes are enacted, the fossil fuels-based energy sources with which wind energy competes will become more costly, boosting prospects for sustainable energy generation. On the other hand, though awareness of their impacts is clearly rising, except for outright bans in severe cases there is not yet a forceful effort to internalize the ecological costs of pesticides that are used in traditional farming, but not organic farming. Initiatives will never be politically popular if they can be portrayed—however unfairly—as taxing food.

The third and final question, for which I thank a reviewer, is that the emergence of a sustainable industry may provoke resistance at points of contact with a traditional industry. And these points of contact are likely to multiply as the sustainable industry reaches adolescence. For example, as wind and other new energy sources become a more substantial element of generation, a world of 'distributed generation' becomes more feasible (United States Senate, 2001). This world, highly threatening to utilities, is likely to meet with vigorous opposition. Organic foods may face some problems in this category as well. In the past, dedicated organic outlets sold these foods. But as organic foods go 'mainstream' and move into supermarkets, their growers and distributors will find themselves requiring shelf space that traditional food sellers will defend with all their resources. In general, resistance to sustainable industries will be stronger the more homogeneous and unified are incumbents within the threatened industry. By contrast, when industries are fragmented, they offer more product and distribution niches for the entry and success of organizations in sustainable industries.

These three dimensions—site specificity, the speed with which traditional alternatives properly reflect ecological costs, and the level of threat posed by the sustainable industry to its corresponding traditional industry—will interact to yield different outcomes for different industries. In the case of both wind energy and organic farming, two of the three dimensions do not portend well for the industry. In order to make a final judgment on prospects for both, a metric that can place responses to the three questions on a common scale must be developed. The construction of such a scale requires expertise that spans disciplines running from biology to political science. This serves to underscore a pressing need in the field: *Research in sustainable enterprise must become an interdisciplinary endeavor*.

Institutions and new industries

As a final note, I reiterate the pivotal role played by institutions in industry-level processes. Prior to the passage of PURPA, in theory, the wind energy industry could have appeared, given the simple economics of the situation. Utilities were seeing costs rise, and alternative energy projects offered at least the possibility of lower-cost power. Yet none were built. This can be attributed to the very high transaction costs facing a potential wind energy project prior to PURPA. Because they are immobile and connected to a single buyer, once projects were built sales of electricity to utilities could be subject to any number of transactional hazards. PURPA reduced the risks in this contracting interface and, nationally, the rise of alternative energy projects within states is partly explained by how soon and how favorably their regulatory commissions implemented the statutes of PURPA (Russo, 2001). California's institutional environment was highly supportive of wind energy projects, offering powerful tax incentives to increase the likelihood of development. The presence of an industry association to vest the interests of wind energy developers within the policy-making framework there also enhanced wind energy project formations.

Evidence of the cruciality of the institutional environment for other sustainable industries is clear and compelling. The firestorm of protest over the proposed national organic food standards in 1998 (*E Magazine*, 1998) and ensuing revisions by the Department of Agriculture suggest that the organic food industry also recognizes the value of a supportive institutional environment. And the ability of African nations to attract tourists to view gorillas and natural wonders greatly depends on the success of those nations in implementing preservation programs (Convery, 1995). These observations and the results of my analysis suggest a certain irony for existing research. A number of studies (e.g., Hart, 1995; Russo and Fouts, 1997) have contended that the marketplace is driving corporate greening by producing market opportunities for existing firms. This may be true, but researchers should not lose sight of the value of a facilitative institutional environment in creating the potential for sustainable industries to first emerge. The alternative energy industry may well thrive as electricity marketplaces evolve. But without early institutional support, this outcome could not be predicted confidently.

Institutional backing in the form of public subsidies that augment private economic incentives also can stimulate new industries, as shown by the significant interaction term in my analysis. This demonstrates that natural capital and economic returns to its development, while potentially of value individually, have a profound effect when they rise in unison. It cannot be said that the presence of either represents a necessary but not sufficient condition for development, because in this study natural capital (high wind energy potential) elicited project foundings on its own. But when combined with a higher potential economic payoff, the presence of greater natural capital had a much greater impact on those foundings. Policymakers may choose to boost economic returns for the deployment of natural capital via tax credits, statutory guarantees on prices received for its use, or in some other fashion. Such programs can produce inefficiency and even malfeasance (Cox, Blumstein, and Gilbert, 1991), and may be a decidedly suboptimal approach. But this study does show that the provision of this support elicited new wind energy projects.

It is worth pausing at this point to consider a broader context. Although institutional support generated a burst of activity in the American independent power industry, resistance was stubborn. In every jurisdiction, but particularly at the national level, the utility industry still fought independent power vigorously. This opposition and the accelerated development of alternative technologies in less developed countries may be part of the same phenomenon. As a set of events, this history fits with Christensen's idea that disruptive technologies encounter resistance in mature markets, but flourish in emerging markets that traditional players cannot serve or have ignored (Christensen, 1997). This is precisely what is occurring with photovoltaics and several other sustainable technologies, which are enjoying significant growth in off-grid locations in less developed countries (Christensen, Craig, and Hart, 2001).

A number of critical questions that go well beyond this analysis await study. We are far from understanding the interplay of economic, social, and natural factors in sustainable industry creation. For example, if full Pigouvian pricing (Pigou, 1918) of elements of the natural environment was in effect, would the social element of industry creation become less important? How should the development of sustainable industries be balanced with other social imperatives? At the organization level, a great many other issues arise. How can groups of organizations overcome the free-riding problem (Olson, 1965) as they organize to pursue favorable institutional treatment? To what extent should organizations that owe their existence to green products be organized as social collectives as opposed to business enterprises? Perhaps most importantly, how should organizations in emerging sustainable industries change if and when their industry moves into the mainstream? These and other unanswered questions prove that the emergence and growth of sustainable industries is a research platform whose potential is largely untapped.

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