Practitioner Perspectives Matter: Public Policy and Private Investment in the U.S. Electric Power Sector

By

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Abstract

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This dissertation examines the influence of attitudes, beliefs, and preferences of energy industry practitioners on investment decision-making with regard to fuel choice for new electric power plants. The conclusions are based on in-depth interviews and an extensive online survey I conducted of 600-800 energy professionals in the U.S. power sector.

Chapter 1 analyzes the impact of policy uncertainty on investment decision-making in renewable energy, using the federal production tax credit (PTC) and wind energy investment as an example. It is generally understood that the pattern of repeated expiration and short-term renewal of the PTC causes a boom-bust cycle in wind power plant investment in the U.S. This on-off pattern is detrimental to the wind industry, since ramp-up and ramp-down costs are high, and players are deterred from making long-term investments.

The widely held belief that the severe downturn in investment during "off" years implies that wind power is unviable without the PTC turns out to be unsubstantiated: this chapter demonstrates that it is not the absence of the PTC that causes the investment downturn during "off" years, but rather the uncertainty over its return. Specifically, it is the dynamic of power purchase agreement negotiations in the face of PTC renewal uncertainty that drives investment volatility. This suggests that reducing regulatory uncertainty is a crucial component of effective renewable energy policy. The PTC as currently structured is not the only means, existing or potential, for encouraging wind power investment. Using data from my survey, various alternative policy incentives are considered and compared in terms of their perceived reliability for supporting long-term investment.

Chapter 2 introduces the concept of expected payment of carbon as a factor in investment decision-making. The notion of carbon risk (the financial risk associated with CO2 emissions under potential climate change policy) is usually incorporated into investment decision-making by including a cost of carbon in the budget analysis. Most existing literature uses the expected price of carbon as a proxy for this cost, where expected price is a weighted average of various scenarios, often comparing policy proposals and representing either the price of traded permits or level of carbon tax, depending on the type of policy. The literature focuses on the minimum price of carbon required to influence power plant investment decisions.

In contrast, this chapter introduces expected payment as a more accurate measure of carbon cost as it is perceived by industry practitioners. The expected payment of carbon is the expected price of carbon times the probability that this cost would actually be faced in the case of a particular investment. This concept helps explain both the 2005-2006 surge of activity in coal-fired power plant development and the subsequent decline in that interest.

The energy industry has been slow to move away from fossil fuels and towards renewable resources. In chapter 3 I find evidence for a cognitive bias that plays a role in this momentum. Energy executives' expectations of future energy prices are strongly correlated with their own preferences, which I document for the case of natural gas prices. This is an example of wishful expectations, a form of overconfidence in which people are excessively optimistic over uncontrollable future outcomes. This implies energy executives with strong exposure to fossil fuels are excessively optimistic on future prices and so continue to invest despite the presence of superior alternatives.

To little, brand new “Jonesie” Barradale, my daughter who was born May 13, 2010, ten days ahead of schedule. She is joyfully welcomed to this world by her whole extended family, even though she almost, but not quite, prevented me from filing my dissertation on the 14^{th}.

Merrill Jones Barradale
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Contents

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Introduction

This dissertation investigates investment decision-making in the electric power sector and, more specifically, the choice of fuel for new power plants. In other words, is the next megawatt going to be provided by coal, gas, wind, or some other fuel? This is an important decision, not just economically, but also from an environmental perspective. Because power plants are capital-intensive with a lot of upfront costs, but relatively low marginal costs, once they are built, emissions are essentially locked in for the next 20, 30 or 40 years, depending on the lifetime of the power plant.

Consider the global magnitude of this decision: 20 years from now, the world may be generating 11,000 billion kWh (= 11 PWh[1]) more electricity each year than it is today (EIA 2009). That will require building the equivalent of more than 5,000 large new power plants[2] between now and then. Let's compare the environmental impact in terms of CO2 emissions of these power plants, based on different fuel types. Fueled by coal, gas, or wind, annual CO2 emissions from these 5,000 plants would be, respectively, 3, 1.25, or zero GtC[3] per year.[4] For comparison, total global CO2 emissions from *all* energy-related sources, not just electricity, are currently 8.4 GtC annually.

Emissions from these 5,000 plants, if coal-fired, would in and of themselves equal more than a third of all current CO2 emissions. Assuming a 30-year lifetime for these power plants, we would be locking in over 90 GtC of CO2 emissions – nearly 11 times the level of current annual emissions (or 38 GtC and five times for natural gas). Obviously, not all of this new power generating capacity would be fueled by just one fuel source, nor does it make complete sense to compare current annual emissions with future lifetime emissions, but this gives a sense of the magnitude of impact that results from the sum total of each of these decisions. Note also that this is the capacity required only to meet *new* electricity demand over the next 20 years; it does not include new plants needed to replace existing plants whose lifetime will expire. This numeric example demonstrates the importance of the choice of fuel type for new power plants.

The angle I chose to take on understanding this investment decision is unusual in the investment decision-making literature: I did not do financial modeling in an effort to establish "answers" regarding investment scenarios, nor did I make any of the usual economic assumptions (e.g., rational choice theory) about decision makers' goals and behavior. Instead, I was interested in how people in the industry actually *think* about these issues.

The three chapters that constitute this dissertation are related both methodologically and thematically. I will address these two aspects in sequence.

[1] 11 Petawatthours (PWh) = 11 x 10^{15} kilowatthours = 11 x 10^{18} watthours (Peta means 10^{18})
[2] Assuming 500 MW per power plant and 50% capacity factor
[3] GtC = Gigatons of carbon
[4] Based on carbon intensity of 270 gC/kWh for coal and 110 gC/kWh for natural gas

0.1 Research Methodology

I started with what I call *informal participant observation*. This is distinct from the formal research method in social and cultural anthropology known as *participant observation*, which is the "study of people in their own time and place in their own everyday lives." Participant observation aims to get a close and intimate understanding of a group, mainly through extended observation of, and/or active engagement in, the group's regular activities.

From 1999-2003, I worked in banking and consulting in the electric power sector. This was not part of my formal dissertation research and thus did not constitute formal fieldwork. This is what I mean by "informal" participant observation: although I was engaged as a participant, and was naturally also observing, I was not engaged in this process "as a researcher" doing formal research. Still, this experience provided a wealth of background that informed my subsequent dissertation research.

The next stage began my formal data collection. First I conducted some 20-30 unstructured interviews with industry professionals (2005). Unstructured means not only open-ended questions, but the questions themselves are not set in stone and depend on how the interview unfolds – much like a conversation. These interviews lasted anywhere from 15 minutes to two hours, depending on time available, relevance and interest. Most of these interviews were conducted with people I met at industry conferences, such as the American Wind Energy Association (AWEA)'s annual WINDPOWER 2005 Conference and Exhibition in Denver, Colorado. Some of the interviews were conducted at conferences; others were conducted later, either over the phone or in person, with people I had met at conferences.

In general, I selected individuals who were involved in the business/financial/regulatory-policy side of the industry, as opposed to engineers and others involved in the technical side of the industry. I had two target groups within the power sector. One was focused on the wind industry, as I was interested in understanding the perspectives of people in a newer industry still in the process of establishing itself. I was also interested in the perspectives of those involved in more established areas of the electric power sector, such as coal and natural gas. An example of a conference I attended in this area is Infocast's Coal Power Project Development 2005.

In a few cases the interviews provided me with specific information or points of view that I reference. Mostly, however, the interviews served to shape the specific research questions I developed for my chapters and to give me lots of informed ideas about which areas and hypotheses would be interesting to pursue further. This led to the development of an extensive survey that constituted the third, and main, stage of my research.

The final data collection step was an extensive online survey with structured questions aimed at collecting input from hundreds of energy professionals in the electric power sector. Structured means the questions and their precise wording were fixed. Most of the data that I actually use in my subsequent analysis comes from this portion of my data collection process.

This methodology is intensive and time-consuming to do well.

I spent eight months developing and pilot testing the survey questions. During this time I worked with a core group of four people on an ongoing basis, plus another eight during the final stages. These included people from industry (my target group) as well as researchers who could provide a methodological perspective. Every question I wrote was torn apart dozens of times. Some of my favorite questions never made it into the final survey. It is actually a fairly humbling process. But it led to my motto for developing surveys: the respondent is always right.[5] Extensive testing and re-testing of questions is an absolutely critical component of good survey research.

My final survey was fairly extensive and in-depth, covering a number of topics (described below). I made extensive use of skip logic (taking the respondent to different questions, depending on their answers to previous questions) in order to

1. shorten the survey for respondents if certain sections were not relevant for that person;
2. follow up with more questions when a respondent's answers were particularly pertinent or they showed additional interest;
3. personalize certain questions according to situation and thus make them more user-friendly for the respondent, even when the content was not substantively different. An example of this personalization is to phrase a question in terms of "your current involvement" vs. "your past involvement" depending on the timing of a person's involvement with a particular project.

The ability to use extensive skip logic is a significant advantage of online surveys compared with paper/mail surveys, in which skip logic is not user-friendly and is known to be prone to user error, or even with interviewer-led surveys in which the interviewer can theoretically be instructed to skip certain questions and follow up on others but which are prone to interviewer error.

In all, my survey contained 117 different questions. The "minimum" path through the survey was 33 questions, and the "maximum" path was 93 questions. Number of questions, however, is not a very meaningful measure of survey length. Some simple questions, such as "are you male or female," take a few seconds to answer, whereas more thought-provoking questions, such as "how significant do you consider the following sources of project risk" are much more time-consuming. Ultimately what matters most to the respondent is time required. My survey took respondents 10-30 minutes to complete, depending both on the questions answered and on the level of thought the respondent decided to put into certain questions, with most respondents taking 15-20 minutes.

In addition to the time required to develop and test the survey, three months of work went into coming up with 10,000 email addresses in my target population. I used a combination of approaches. In some cases, industry associations, such as AWEA, worked with me to send the survey to thousands of people who had attended their annual conferences. In other cases, some of my contacts in the industry provided me with a list of some of their contacts in the industry. Or I

[5] Pilot testers representing the target group for the survey may not always have the best suggestion for the "right" changes to make, but if they spot a problem, then something needs to be changed.

looked online for membership lists of industry associations or used attendance lists from various industry conferences or workshops. Most of these efforts yielded a few dozen, or occasionally a couple hundred, email addresses at a time – hence it was a time-consuming process requiring much effort.

In general, I targeted conferences, associations, and organizations from which individuals were likely to meet the following criteria:

1. *Involvement with the U.S. electric power sector* (as opposed to other energy sectors, such as transportation or upstream oil and gas, i.e. drilling and refining);
2. *Involvement with the business/financial/regulatory-policy side of the sector* (as opposed to the technical side of the sector);
3. *Email addresses that ended in .com or .org or .gov* (as opposed to .edu) in order to focus on those people participating in the industry as opposed to observing the industry from an academic perspective.

My filtering of email addresses was not absolute and varied by case. If a particular conference was both industry-oriented (as opposed to academically oriented) and the topic was extremely pertinent to my research (e.g., "Finance and investment in wind energy in the U.S."), then I did not filter the attendance list, even if it included some academics and some people from outside the U.S. But if an association included half academics and half industry or significant international membership, then I tended to include only the U.S. members and only the industry people. When in doubt, I included people; the marginal cost of sending an additional email was very small. Further filtering was provided by people who felt the survey was not relevant to them and chose not to respond. Additionally I had the option post-survey of filtering out certain respondents because many questions asked the nature of people's involvement in the sector.

The email invitation that went out opened with an explanation of the area of my research (electric power sector) and the targeted perspective within that sector (business/financial):

> I am a PhD student at the University of California conducting independent, academic research on fuel choice and investment in the electric power sector. As part of my research, I am conducting a survey of industry professionals (particularly those with a business or financial perspective) to discover views on a number of topical issues.

I launched the survey in two waves. Wave 1 was conducted in May 2006 and focused on the wind industry. An email invitation was sent to approximately four thousand[6] individuals who had attended conferences on wind energy during the past year, including the American Wind Energy Association (AWEA)'s WINDPOWER 2005 conference in Denver. Of the 420 people who clicked on the survey link, 338 continued past the first question, and 272 reached the end of the survey. All questions were voluntary, with most questions soliciting about 300 responses,

[6] 4274 emails were sent, of which 475 were undeliverable, so 3799 emails "arrived" (at least were not returned).

representing an overall response rate of 8.9%.[7] Most questions were closed-ended (multiple choice).

Wave 2 was conducted June-August 2006 and went to the "general" electric power sector. I was very careful to filter my lists for overlap so that nobody who received Wave 1 was included in Wave 2. Over the course of three months, this email invitation was sent to approximately six thousand[8] individuals. Of the 619 people who clicked on the survey link, 509 continued past the first question, and 430 reached the end of the survey. Most questions solicited 400-500 responses, representing an overall response rate of 10.4%.

In total, I had 847 respondents, representing an overall response rate of 9.7%. 702 people completed the survey all the way to the end. (Since all questions in the survey were voluntary, the response rate to each question is different). Table 0.1 provides a profile of the respondents.

My survey sample cannot be considered representative of the electric power sector. Several sources of potential bias include:

1. *Intentional sources*.
    - Because I was targeting wind industry professionals in Wave 1, this group is over-represented in the full sample;
    - As mentioned previously, I focused on the business/financial/regulatory-policy side of the sector.
2. *Unintentional sources*.
    - People who attend industry conferences or are members of industry associations are not necessarily representative of everyone in the industry;
    - I cannot claim to have targeted either all, or a representative sample of, these industry conferences and associations;
    - Those who were willing to respond to my survey are not necessarily a representative cross-section of those who received my email invitation (respondent participation bias).[9]

Out of the practicality of real-world constraints, therefore, I did not set comprehensive reflection of the industry in my sample as a goal. Instead, I tried to reach as many people as possible who were members of my target group, and I strove to reach as broad a range as possible within that target audience – for example by making sure that I solicited people working with different fuel sources (coal, gas, wind, etc.) and in different roles within the industry (utilities, project developers, lenders, investors, etc.). While I cannot claim to have an impeccably representative sample, I can say (see Table 0.1) that I have a *broad* sample representing a wide variety of

[7] Since every question in the survey was voluntary, the response rate to every question is different. My "overall" response rate, for both waves, is calculated by dividing the number of respondents who went past the first question by the number of emails which "arrived."

[8] 5729 emails were sent, of which 828 were undeliverable, so 4901 emails "arrived" (at least were not returned).

[9] Another source of bias that is often of concern in online surveys, the exclusion of those parts of the population without internet access, is not a major concern in my case, because my target population, energy professionals in the U.S. electric power sector, does have internet access.

industry segments. And even if this sample is not a perfect reflection of the industry as a whole, it is surely more useful to get the perspectives of 700-800 people than of none at all.

Cognizance of this reality for my data set has influenced my approach to making claims based on it. For example, in chapter 2, I do not claim that because 84% of my respondents hold a particular view, the industry as a whole does so. Instead, I show that this view is predominant for all *types* of respondents in my sample, across a whole range of demographic characteristics and professional experience, such as educational background, involvement with regulated/deregulated markets, with different fuel sources, in different industry roles, etc. Because the point of view is common across all *segments* of the industry, I conclude that the perspective is prevalent in the industry as a whole.

Here are the topics I covered in my survey:

- Views on fuel sources
- Views on future natural gas prices
- Views on global warming and carbon policy
- Views on renewable energy incentives (Wave 1 only)
- Financial modeling methodology
- Motivations for wind project investment (Wave 1 only)
- Motivations for power project investment (Wave 2 only)
- Professional experience
- Demographics

The majority of survey questions were identical across the two waves, giving me one large sample for these questions. The section on renewable energy incentives was included only in Wave 1 because I was interested specifically in perspectives of the wind industry on these questions. Similarly, the section on motivations for wind project investment was relevant only to the wind industry and therefore went only to Wave 1. For this section, I substituted a similar section in Wave 2 on the motivations for power project investment generally, that is, without reference to a particular fuel source. For the questions in these areas, I obviously have smaller sample sizes. The Wave 2 survey was shorter by one section.

Before moving on to the analytical framework that ties my three chapters together, I should cover one more important aspect of my survey methodology: respondent anonymity. In the case of face-to-face interviews, *anonymity* is not possible, since I, the interviewer, know whom I'm speaking with. Of course, the identity of respondents can be, and in my case is, kept *confidential*. Results from my interviews[10] are presented either in aggregate or in disguised form, so that no one reading my research would be able to identify the individuals with whom I've spoken.

In the case of an online survey (or any survey that is not conducted face-to-face), however, the researcher has the *option* of ensuring respondent anonymity. Many researchers – probably most –

[10] My interviews are distinct from cases in which I've quoted individuals by name who are making public statements in a public forum, such as a conference presentation addressing hundreds of people.

do not make this choice, but I did. From a research perspective, the advantage of anonymity is that if the identity of respondents is not linked to their answers they are likely to be both more willing to answer a given question and more honest in their answers to sensitive or confidential questions (and the researcher may not always know which those are). Researchers who do *not* ensure anonymity of their respondents must address this additional source of potential bias in their data. Furthermore, from a philosophical perspective of respect for privacy, I believe it is more respectful toward respondents to provide anonymity as the default, unless there is an explicit reason for not doing so. In my case, I asked myself whether I needed to know the identity of each respondent, and the answer was no.

That being said, there are some trade-offs involved with providing anonymity, some of which are more legitimate than others. These include:

1. *Researcher oversight*. It is easier not to worry about anonymity, especially in the case of online surveys, because many survey software programs are set up by default to link responses to email or IP addresses.
2. *Researcher reluctance*. Researchers tend to *want* to know who their respondents are, even when it is not strictly necessary, or at least not give up the option of ever knowing – for example, just in case they want to follow up with additional questions.
3. *Researcher convenience*. Researchers may want to provide an incentive to respondents to participate, and it’s necessary to know the identity of respondents in order to do this. Similarly, researchers may want to ensure that each respondent responds only once. This may be important in the case of collecting opinions that will directly impact an upcoming decision, particularly if the number of respondents is small, but the researcher should consider whether this is truly likely in a given situation (in my case, for example, I really did not think respondents would be motivated to take my energy survey more than once). Both of these goals (providing incentives and ensuring only one response per person) are most easily accomplished by simply linking identity with responses. It requires more effort to collect identities separately from responses.
4. *Less information*. This, in my opinion, is the only legitimate reason for not providing anonymity. To maintain respondent anonymity, the researcher must forgo collecting certain identifying information that might be nice to have for research purposes.

The decision to or not to provide respondent anonymity should depend on a conscious trade-off of the issues involved in a particular situation (alas, all too often it ends up as an unconscious decision). In my case, I decided that I was more interested in forthright, honest responses to questions that I really wanted to ask than in additional information that would be “nice to have” if I knew more about respondents’ identity.

I did two things to ensure anonymity:

1. From a technical perspective, I did not link responses with email addresses. This means I know the email addresses (but in most cases nothing more than the email addresses, since I wasn’t interested in names, etc.) of all the people who received my email invitation to participate in my research, but I do not know who clicked on the link to my survey and who did not. My downloaded data set consists of unidentified respondents to whom I have assigned numbers.

2. From a content perspective, I avoided asking questions or combinations of questions that could be used to identify either individuals or their companies, or could be so perceived. Here is some information I did not ask for:
    - *Geographic specificity within the U.S*. For some large companies, in combination with other information about types of markets served or type of company, this could provide identifying information.
    - *Respondent's current organizational type*. I did ask generally for positions held/types of organizations worked for over the course of the individual's career.
    - *Respondent's rank within current organization*. For people in top management, this would narrow the pool of candidates substantially.

Of course, this information would be nice to have. But I decided it was less important to me than giving respondents comfort in answering other questions as honestly and fully as possible. In addition, there is always the general trade-off between asking more questions and keeping the survey short enough to keep respondents from dropping out due to "fatigue". So I was always looking for questions to cut, if I did not think they were absolutely necessary.

0.2 Analytical Framework

Since my topic of interest is investment decision-making with regard to fuel choice for new power plants, an obvious question arises: did I in fact survey the actual decision makers in the industry, that is, are my respondents the utility CEOs, CFOs, and others within the industry who are actually making the investment decisions? The simple answer to this question is first, certainly not all of them, and second, I don't know which, or how many of them.[11] The reason was my conscious decision to not ask for people's rank within their current organization and thereby avoid asking for personally identifying information, as discussed above.

Instead, my approach was different. I sought not to ascertain the views of decision makers (i.e., top management in various organizations) in particular, but rather to understand how people in the *industry generally* think about various issues. My goal was to understand the culture of thinking within the industry, with the idea that the views of professionals in the energy industry as a whole will reflect those of the decision makers specifically. I assume that the decision makers, just like others in the industry, are influenced by the milieu in which they operate.

This does not mean that I assume just one mode of thinking across the electric power sector. A variety of perspectives certainly exists, based on any number of factors, likely including the choice to work with fossil fuels vs. renewable energy, training as an engineer vs. an MBA, or even personal values absorbed over a lifetime. What this assumption of the correlation between the opinions of the decision makers and those of people in the industry as a whole does mean is that I assume that rank *per se* within current organization is not one of the more important factors determining people's perspectives. Nonetheless, without threatening respondents' anonymity, I

[11] One respondent, in a question about types of organizations one has worked for, wrote "utility CEO" in the open-ended comment field at the end of the answer list provided, but most respondents did not volunteer this level of detailed information.

did ask about some individual characteristics which could likely relate to decision-making status within an organization: age, years of experience in the industry, type(s) of analysis used in daily work (e.g., financial vs. engineering).

Ultimately, I had to choose which factors about an individual would be most meaningful in terms of their possible contribution to that person's perspective. These choices were guided by my choice of analytical frame. I chose to focus on the individual as an energy professional rather than as a representative of his/her current organization. I chose this frame, because ultimately, firms don't make decisions; people do. That being said, I do believe an individual's organizational affiliation influences his/her perspectives, but only as one of many factors, including, for example, past organizational affiliation(s).

My analytical frame of individual as an energy professional is summed up in the explanation I gave respondents at the beginning of the survey:

> Throughout this survey... I am interested in **your opinions as an energy professional, based on your cumulative experience involving the electric power sector**, not just as a representative of your current organization or job.

As mentioned earlier, the goal of my research was to learn how people in the electric power industry think about investment decision-making. Two points about my survey questions on these perspectives need to be mentioned. First, I did not ask directly about investment decisions. Instead, I was interested in the aspects of people's thinking (beliefs, personal biases, etc.) that play a role in these decisions. Second, I did not use a "revealed preferences" approach to discovering information about people's preferences. This approach elicits information about people's behavior, either actual or hypothetical (as in: "what would you do under the following scenario?"), that would provide clues about their preferences. Instead, I asked directly about people's beliefs and opinions ("expressed preferences").

The overall approach I took to my data collection, encompassing both analytic frame of individual as energy professional and my interest in their expressed perspectives on a variety of issues can be summed up in the following question:

How do industry professionals in the electric power sector think about the various factors (regulatory policy, project risk, etc.) that go into investment decision-making and fuel choice for new power plants?

This question has guided my research approach and my inquiries, but it is too broad to qualify as a proper "research question." The specific research questions I examine in my chapters are:

Chapter 1 ("Impact of Policy Uncertainty on Renewable Energy Investment: Wind Power and the PTC"):

- Why does PTC[12] uncertainty cause a boom-bust cycle in wind plant investment?

- What does PTC uncertainty teach us about the effectiveness of policy incentives in promoting renewable energy investment?

Chapter 2 ("The Logic of Carbon Risk from the Investor's Perspective: The Expected Carbon Payment"):

- Why build new coal plants that are not CO2-capture friendly if carbon policy is possible, indeed (increasingly) probable, in the foreseeable future?

Chapter 3 ("Wishful Expectations in Natural Gas Markets"):

- Is there evidence of the "wishful expectations" bias in people's expectations for future natural gas prices?

I use my interview and survey data in a variety of ways throughout these three chapters, from single examples and anecdotal evidence to aggregate summary statistics to correlation and regression analysis.

The first two chapters discuss investment decision-making in the face of regulatory uncertainty. There is already literature in this area (e.g., Wiser and Pickle 1997; Meyer and Koefoed 2003; Bjornstad and McKee 2006). I contribute to this literature by adding the perspective of industry practitioners from my survey.

Chapter 1 examines the impact of uncertainty over the *continuation* of existing policy incentives to promote investment in wind energy. It uses a strategic negotiations model to understand the interaction of industry structure (in this case the prevalence of contract negotiations) and regulatory uncertainty on investment and then uses interview and survey data to support and augment the model's conclusions.

Chapter 2 looks at uncertainty over the *initiation* of new policy governing CO2 emissions. It examines industry beliefs about the nature of that future policy in order to understand interest in coal plant investment. It then proposes a conceptual framework to explain the survey data's results.

Chapter 3, on biases in people's prediction of future natural gas prices, addresses an underlying factor in investment decision-making. Projections about fuel prices critically influence the outcome of financial models and therefore investment decisions. For example, Bolinger et al. (2006), who compare forward prices with contemporaneous long-term price forecasts for natural gas in the U.S., find the forward prices that can be locked in through futures, swaps, and physical supply contracts to be significantly higher. They also find that it is the lower, long-term forecasts which are frequently used by utilities in long-term resource planning. They suggest this may

[12] Production Tax Credit

yield results that are biased in favor of gas-fired generation. In chapter 3, I find an association between people's preferences and their expectations for future natural gas prices – a bias that is consistent with Bolinger et al. (2006)'s results. This would suggest a possible need for public policy to support emerging industries, such as renewable energy, in situations where cognitive bias tends to support established technologies, such as fossil fuels.

Table 0.1. Profile of Survey Respondents

Question	Responses (% of Respondents[13])	Responded to Question
Experience in electric power[14]	15.5 years	676
Work focuses on U.S. [15] (exclusively or substantially)	670 (96%)	698
Work associated "very much" with...[16]		696
Private sector	528 (76%)	
Public sector	172 (25%)	
Non-profit sector	53 (8%)	
Experience by fuel source[17] (number responding "extensive")		835
Coal	232 (28%)	
Natural gas	312 (37%)	
Petroleum	133 (16%)	
Nuclear	110 (13%)	
Hydro	118 (14%)	
Wind	284 (34%)	
Solar	60 (7%)	
Geothermal	39 (5%)	
Biomass	65 (8%)	
Other	4 (0%)	
Professional positions held over course of career[18]		668
Developer	203 (30%)	
Finance/Investment	345 (52%)	
Utility/Load-Serving Entity	214 (32%)	
Equipment/Plant Services	199 (30%)	
Consulting	284 (43%)	
Government Agency	100 (15%)	
Research/Media/Advocacy	160 (24%)	
Other	90 (13%)	

[13] Percentages do not add to 100% because respondents are allowed to mark more than one answer. Percentages are of total respondents for the entire question.
[14] Exact question: *How many **years** of work experience do you have involving the **electric power sector**?*
[15] Exact question: *On which **regions** of the world has your work with the electric power sector focused?*
[16] Exact question: *To what extent is your experience with the electric power sector associated with the…*
[17] Exact question: *How much **professional experience** do you have with the following fuel sources?*
[18] Exact question: *Over the course of your professional experience involving the electric power sector, what "**hats**" have you worn?*

Chapter 1

Impact of Policy Uncertainty on Renewable Energy Investment: Wind Power and the PTC

1.1 Introduction

The observation that public policy uncertainty has a negative impact on private-sector investment is not new. Within the renewable energy industry, for example, Meyer and Koefoed (2003) look at the impact on investors of changing a decades-long, stable wind promotion policy in Denmark—in particular the impact of delayed implementation of the new policy—and find that it caused the wind industry to stall. The German wind power industry began to suffer similar investment downturns when a biennial review process was added to the Renewable Energy Act, causing significant uncertainty and opening the door for frequent changes in the feed-in tariff laws (Agnolucci, 2006). Similarly, the dramatic stop-and-go investment pattern in the U.S. wind energy sector has been attributed to ongoing uncertainty over the renewal of favorable tax incentives (e.g., Wiser et al., 2007a).

This paper investigates the dynamics of uncertainty over the renewal of the federal production tax credit (PTC) and why this discourages wind plant investment in the U.S. A strategic negotiations model is used to understand the impact of the contract negotiation process on players' investment decisions. The model incorporates the concept of bargaining power, willingness to wait vs. willingness to negotiate, the number of players on the buy and sell sides of power purchase agreements (PPA), and supply and demand for wind power. The model's results demonstrate that contract negotiation dynamics significantly amplify the effect of public policy uncertainty on corporate investment decisions. This happens because of the differing constraints the negotiating parties are under. During times of renewal uncertainty, IPPs, who are dependent on lenders, pessimistically assume no PTC renewal, whereas utilities, who are under regulatory obligation to secure least-cost power, optimistically assume PTC renewal. This asymmetry of assumption causes negotiations to stall in times of uncertainty.

This finding suggests that reducing regulatory uncertainty is especially important for industries in which contract negotiation is common. Since many industry observers agree that long-term contracts are necessary and useful for mitigating market risk and facilitating the financing of wind and other renewable energy plants (e.g., Johnston et al., 2008), effective renewable energy policy must focus on reducing uncertainty. In considering possible lower-uncertainty alternatives to a PTC, this paper presents data comparing investor attitudes on the stability of various types of policy incentives.

The source of this data is an online survey conducted in May 2006. An email invitation was sent to approximately four thousand[19] individuals who had attended conferences on wind energy during the past year, including the American Wind Energy Association (AWEA)'s WINDPOWER 2005 conference in Denver. Of the 420 people who clicked on the survey link, 338 continued past the first question, and 272 reached the end of the survey. All questions were voluntary, with most questions soliciting about 300 responses, representing an overall response rate of 8-9%. Most questions were closed-ended (multiple choice). Table 1.1 provides a profile of the respondents.

The rest of this paper is organized as follows. The second section, "PTC Volatility," describes the federal production tax credit, its history, and its connection to investment in the wind industry. The third section provides background on PPAs in the electric power sector in general and in wind power in particular. The fourth section, "PPA Negotiations," lays out the central argument linking negotiation dynamics with policy uncertainty and investment volatility. The fifth section, "Beyond the PTC," considers alternative policy incentives to the production tax credit for supporting renewable energy development. The final section summarizes the conclusions of this paper in light of recent developments in the energy sector and how these might impact the role of PTC uncertainty in the wind industry going forward.

1.2 PTC Volatility

The main form of policy support for the U.S. wind industry is the federal production tax credit (PTC), an income tax credit of 1.5 cents/kWh (1992$, adjusted annually for inflation) for the production of electricity from qualified wind plants and other renewable energy facilities. Plants receive the tax credit for the first 10 years of operation, provided they come online by the PTC expiration date. The current value of the PTC is 2.1 cents/kWh. The credit was created under the Energy Policy Act of 1992 and originally expired June 30, 1999. Since then, it has been renewed six times for one to two years at a time, currently expiring at the end of 2009 (AWEA, 2008).

Typically, the PTC has either been allowed to expire or has come within just a few months of expiring before being renewed. Hence, although retrospectively there has never been a gap in PTC coverage, there have been periods when renewal is uncertain. Furthermore, even after this uncertainty is resolved, ramp-up time is required before new capacity can be brought online, causing further investment delays. Periods of expiration and ramp-up ("off" years) result in drastic reduction in wind plant investment (see Figure 1.1).

This pattern of repeated expiration and short-term renewal of the PTC is broadly recognized within the industry to cause a boom-bust cycle in wind plant investment, with all the negative impacts of fluctuation, including reduced investment in "off" years. Based on interviews with industry participants, Wiser et al. (2007a) conclude that the volatility itself is the source of additional harmful impacts on the industry:

- Slowed wind development;

[19] 4274 emails were sent, of which 475 were undeliverable, resulting in 3799 emails which "arrived" (at least were not returned).

- Higher wind supply costs;
- Greater reliance on foreign manufacturing;
- Difficulty in rationally planning transmission expansion;
- Reduced private R&D expenditure.

Although it is widely agreed that volatility is detrimental, the precise source of this volatility is generally misunderstood. Industry participants commonly assume that it reflects wind power's dependence on the PTC and that the low level of investment during "off" years represents the level of wind energy investment that would be economically viable without the PTC.

In contrast, this paper shows that the volatility of investment associated with the PTC is unrelated to the underlying economics of wind; instead it is due to the dynamic of power purchase agreement (PPA) negotiations in the face of uncertainty. These negotiation dynamics, when coupled with PTC uncertainty, will lead to a volatile investment pattern *no matter how strong other motivations for investing in wind may be*. These motivations can include state and local policy incentives for wind investment, demand for wind power from green consumer programs, and exceptionally profitable project development opportunities. Since most wind is financed through PPAs (see Table 1.2), the dynamic of contract negotiations impacts the entire industry.

1.3 Background on PPAs

Historically, U.S. power plants were built, owned, and operated by utilities to serve their own load. The federal Public Utilities Regulatory Act (PURPA) of 1978 created a new class of non-utility generators that produced electricity from renewable resources. Utilities were required to purchase electricity from qualifying facilities under long-term contract at prices set by the state. The earliest grid-connected wind plants in the U.S. were built in the early 1980s under PURPA (Hyman et al., 2000).

Electricity deregulation in the 1990s created greater opportunity for independent power producers (IPPs) to get involved in the generation business—not just from renewables, but from all fuel sources. IPPs vary in size from single-plant generators to large electric companies operating power plants across the U.S. and include deregulated affiliates of regulated utilities. IPPs do not own transmission and distribution lines, nor do they serve customers directly.

IPPs sell the power from their plants either under long-term contract with a utility, known as a power purchase agreement (PPA), or on a short-term basis by bidding into spot markets operated by regional power pools. Power plants not under long-term contract are called merchant plants.

Until recently, utilities have generally not wanted to build and own wind plants, preferring to purchase wind power under contract—partly for financial reasons (Wiser, 1997) and partly because they didn't have as much experience with wind as some of the IPPs. As a result, most wind plants are developed and owned by IPPs. Individual plants are usually financed with a combination of debt (perhaps 70%) and equity (perhaps 30%) in a so-called "project finance" structure.

Wind plants are typically under PPA for two reasons. First, wind is a non-dispatchable resource (cannot be turned on and off at will) and therefore cannot be bid into spot markets as easily as can natural gas, the most common merchant plants. Second, in the early 2000s, at the time when wind power was beginning to expand, high natural gas prices were causing financial difficulties for many merchant gas plants, and lenders refused to finance new merchant plants of any kind. For both these reasons, lenders have not been willing to finance wind plants without a signed PPA guaranteeing a revenue stream (though some equity investors have been willing to take on merchant risk).

PPAs simplify the financial side of wind's intermittency and non-predictability[20] by setting a fixed price per kilowatt-hour, regardless of time of day or year generated.[21] PPAs normally cover all power generated by the wind plant, but occasionally include maximum or minimum delivery limits. Some PPAs are flat-rate over the contract term, and others have escalating rates, usually at approximately the expected rate of inflation. PPA terms are typically 20 years, with some earlier contracts up to 25-30 years and some more recent contracts as short as 10-15 years.

Most wind PPAs are for the purchase of electricity along with the associated renewable energy attributes, with the power purchaser acquiring the renewable energy certificate (REC). In a few cases, wind PPAs are for electricity only, leaving the owner of the wind plant free to sell RECs separately. RECs can be sold to utilities who are under state renewables obligations (compliance markets) or to meet customer demand for green power (voluntary markets) (Wiser and Bolinger, 2007).

Although industry structure has varied considerably over the last few years, PPAs are likely to remain its bedrock. 2005 saw the start of a shift, which accelerated in 2006, but has since reversed, away from the predominance of PPAs in wind plant development. Two factors contributed to this trend. First, IPPs became less dependent on PPAs for financing. As market rules enabling intermittent renewables (wind and solar) to participate in spot markets were adopted in more states, more projects were developed without a PPA. Additionally, lenders' distaste for merchant risk in general began to fade, and, as they gained experience with wind power and became comfortable with turbine technology and plant performance, they became more open to the idea of merchant wind power in particular. Although PPA financing remained the norm, merchant wind development jumped from a mere 42 MW in all previous years combined to 461 MW in 2005 and 794 MW in 2006.

The second factor contributing to the shift away from PPAs in 2005 and 2006 was greater interest on the part of utilities in owning wind plants, rather than just purchasing wind through PPAs. In 2006, for the first time, investor-owned utilities added more wind capacity through ownership than they did through PPAs, doubling their total wind capacity ownership. Reflecting

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[20] Technical aspects of intermittency must be addressed through an interconnection agreement with the local grid operator and through coordination with relevant system operators and short-term wind forecasts provided to load planners.

[21] Also called "take-or-pay" contracts, because offtakers are required to pay for all energy generated, whether they decide to take delivery or not.

this shift, Xcel Energy is seeking an additional 6,000 MW of wind capacity over the next years in order to meet its various state RPS obligations and would like to see "a balance of owned and purchased" wind capacity. Whereas to date, most of their wind has been purchased through PPAs, going forward they would like to participate in the wind industry as an equity investor, because their "capital return requirements are very appropriate" for wind (Bonavia, 2007).

In 2006, only 42% of new wind capacity was under PPA, with 24% under utility ownership and 32% merchant wind. However, this trend looks unlikely to continue. In 2007, both trends – toward merchant wind and utility ownership – slowed, with more than two-thirds of new wind capacity under PPA. Furthermore, the tightening of credit as a result of recent turmoil in the financial markets will almost certainly accelerate the return to PPA financing. In terms of industry structure, therefore, PPAs can be expected to dominate renewable energy financing for some time to come.

1.4 PPA Negotiations

In order to understand how the combination of PPA financing and PTC renewal uncertainty leads to investment volatility, it is necessary to consider the differing constraints the negotiating parties are under. IPPs are dependent on lenders, and lenders will not lend if there is significant downside potential, as there would be with a PPA that optimistically assumes PTC renewal which then fails to materialize. During times of renewal uncertainty, therefore, IPPs must assume no renewal when negotiating a PPA price. At the same time, utilities are constrained by their regulatory obligation to secure least-cost power for their customers. This means not overpaying for electricity that turns out to be cheaper later on. These constraints force the negotiating parties to make asymmetric assumptions during periods of uncertainty: utilities assume PTC renewal; IPPs assume no PTC renewal. These asymmetric assumptions leave no overlap in negotiating positions, precluding the possibility of meeting in the middle.

To illustrate, consider the following scenarios in which an IPP is negotiating a PPA price with a utility.[22] Assume a 2¢/kWh PTC and a 5¢/kWh cost of producing wind power (these are illustrative numbers only, not meant to represent exact costs).

Case 1: PTC available. The IPP can plan on receiving a 2¢/kWh revenue stream from the PTC, reducing its net cost to 3¢/kWh. The IPP is therefore willing to sign a PPA as low as 3¢/kWh. As long as the value of wind power to the utility is 3¢/kWh or greater, the utility is willing to sign a PPA for 3¢/kWh, knowing that represents the IPP's net cost and therefore the best price the IPP is able to offer. Utility and IPP sign a PPA for 3¢/kWh.

Case 2: No PTC. The IPP's net cost is now 5¢/kWh and certain to remain there, assuming there is no PTC and no prospect of its return. The IPP is willing to sign a PPA as low as 5¢/kWh. As long as the value of wind power to the utility is 5¢/kWh or greater, the utility is willing to sign a

[22] In the U.S., both counterparties are generally private-sector entities. For treatment of a different situation in the UK, in which the offtaker is government, see Johnston et al. (2008).

5¢ PPA, knowing that represents the IPP's net cost and therefore the best price the IPP is able to offer. Utility and IPP sign a PPA for 5¢/kWh.

Case 3: PTC uncertain. When PTC renewal is uncertain, the IPP cannot sign a PPA for less than 5¢ because lenders, upon whom the IPP is dependent for financing, conservatively assume the PTC will not be renewed. The utility will not sign a PPA for more than 3¢, because the IPP will receive the value if the PTC is subsequently renewed (as a windfall gain!), and the utility will have left substantial value on the table. To prevent the windfall gain from going to the IPP, it is in the interest of the utility to wait until uncertainty is resolved before signing a PPA, leading to a boom-bust cycle in construction.

These scenarios are summarized in Table 1.3.

Hence, *it is not the absence of the PTC that drives such drastic dips in investment during "off" years, but uncertainty over its return*. This happens because of the relative bargaining positions of utility and IPP. In a typical situation, a utility will issue a request for proposal (RFP) for wind power, and IPPs will respond by submitting a bid. There is often one buyer and several sellers in a market, creating a monopsony or near-monopsony situation.

It is not necessary for the utility to have full bargaining power: if even some of the value of the PTC flows through to the utility, that is sufficient for this negotiation dynamic to occur. In other words, if there is *any* difference between the PTC and no-PTC price of the PPA, then it is in the utility's interest to wait.

The only situation in which there would be *no* difference between the two prices is with a flat demand curve (see Figure 1.2). A flat demand curve represents the following situation:

1. There exist multiple buyers in the market (therefore no strategic behavior on the part of buyers); AND

2. All buyers have (an) alternative source(s) of power available to them at the same backstop price (e.g. coal at 5 cents)

Since this situation is not common for electricity markets, utilities do generally retain some bargaining power.

The evidence from actual PPA negotiations confirms that the utilities have bargaining power and are receiving the benefit of the PTC. In a request for proposal (RFP) for wind power issued in early 2005, at a time when PTC renewal was uncertain, the utility asked for two bids from each bidder, one assuming PTC renewal and the other assuming no renewal. According to a representative of the utility, the bids differed by exactly the value of the PTC.[23] This implies that the value of the PTC is passed through to the utility.

[23] Author interview with utility representative, July 2005

More recently, a leading industry player with considerable active involvement in structuring wind-financing contracts stated that “99% of the time, PPAs pass the value of the PTC to the utility” (Feo, 2007).

Respondents in the 2006 wind industry survey also said they consider utilities to be the major beneficiary of the PTC. Asked who would end up absorbing the cost difference between a PTC and a non-PTC world (see Table 1.4), 59% said the utility off-taker and 36% the developer. The fact that not all respondents said “utility off-taker” reflects the fact that not all plants are under PPA. In the case of merchant plants, utilities are no longer the sole beneficiaries of the PTC. As developers became less dependent on PPA financing in 2005 and 2006, they were able to make more money from wind projects (Armistead, 2006). In addition, some survey respondents predicted that some of the cost would be absorbed by turbine manufacturers (at the time, turbines were in short supply, and the price developers were facing had risen substantially). Still, the perception of industry participants is heavily weighted towards the off-takers.

In theory, a two-part PPA, in which the PPA price is agreed to be one price with the PTC and a different price without the PTC, would resolve this impasse. However, this does not occur in practice, for two reasons. First, utilities have not institutionally addressed the question of what they would do in a no-PTC world.[24] Second, utilities do not want to signal regulators or Congress what they would do in a no-PTC world.[25] Brasher et al. (2003) highlight that the motivations of utility and IPP are different: while the IPP is motivated by financial return, the utility is compelled to meet statutory requirements and is motivated to avoid the penalties of noncompliance. One of these is the obligation to secure least-cost power on behalf of its customers. Signing a two-part PPA risks sending a mixed signal about how much the utility could or should pay for wind power.

1.5 Beyond the PTC

The need for stable policy with a long-term horizon is broadly recognized as a priority within the wind industry. Not everyone agrees on the best strategy for achieving this goal, however. Some industry participants, including the American Wind Energy Association (AWEA), have been working to encourage Congress to pass a PTC lasting three to five years or longer. Indeed, Wiser et al. (2007a) finds that a longer-term PTC extension of five to 10 years would yield significant benefits for the industry, including: 1) encourage growth in domestic wind turbine manufacturing; and 2) reduce installed costs through greater efficiencies in capital and labor deployment, enhanced R&D, reduced exchange rate risk, and transportation savings.

Despite a history of bipartisan support for the wind PTC, however, Congress has repeatedly renewed the incentive for only one to two years at a time. Perhaps this is because of the way Congress calculates its budget: the cost of multi-year programs is reported when legislation is enacted, and legislators generally don’t like to be associated with big spending programs.

[24] Author interview with utility representative, March 2006
[25] Author interview with industry investor, September 2005

It is important to consider alternatives to the PTC not only because the short-term renewal cycle causes harmful volatility, but also because the PTC program is expected ultimately to end. Indeed, most survey respondents (58%) do not expect the PTC to last beyond 2011 (see Figure 1.3). Partly this may be due to the increasing cost of the tax credits to the federal government as the wind industry grows. Indeed, with tax revenues declining and spending needs rising as a result of the current economic downturn, expensive tax incentives may not represent a viable long-term policy, even for a new administration supportive of renewable energy. Hence, relying on the PTC as vehicle for getting to the industry's goal of 20% of U.S. electricity generation may not be realistic.

Not all industry participants think the PTC is a necessary, or even a good, way to support the wind industry. One prominent project developer and equity investor goes so far as to refer to the PTC as the "heroin" of the wind industry (Armistead, 2006). Other analysts have pointed to the adverse effects of tax policy in restricting ownership and financing structures (see for example Kahn, 1996).

How critical is the PTC to ongoing wind project development? Survey respondents were asked to imagine a world in which the PTC no longer exists and will never be reinstated. Less than 10% of respondents think this would kill the wind industry entirely; the vast majority expresses the view that at least some wind projects would still go forward. People estimate that across the U.S., a third (33.3%) as many projects would go through compared to with the PTC in place (see Table 1.5).

Optimism is greater among those whose organizations have already been involved in wind projects. Developers estimate that 42% of their own projects—and utility off-takers 48% of theirs—would still be developed without the PTC. The fact that off-takers suggest they would go forward with almost half of their projects even without the PTC is significant, because they drive the requisition process.

The discrepancy between people's estimates for the industry as a whole and for their own projects suggests two inferences: 1) the reality may not be as dire as people believe; and 2) those already involved in the industry may be less deterred by a no-PTC world than prospective new entrants.

Given the short-term nature of the PTC, it is useful to consider other types of policy incentives supporting renewable energy development that may (or may not) have a longer planning horizon. Some of the alternatives to production tax credits include:

- **Depreciation rules**. Accelerated depreciation for capacity investment can reduce a company's tax expense during early years.

- **Production subsidies**. These can be provided at the national or state and local levels.

- **Pricing or tariff mechanisms**. Guaranteed prices for renewable energy, for example as was the case under PURPA, address the risk that market prices are below cost. Favorable tariff mechanisms have been used to promote wind energy development in Germany and Denmark.

- **Renewable portfolio standards** (RPS). These require electricity suppliers to meet a certain percentage of their load from renewable energy sources. Suppliers can do this by 1) building plants themselves; 2) contracting with renewable energy plants to serve their load; or 3) purchasing renewable energy certificates (RECs) from producers of renewable energy who are selling the power elsewhere. 25 states in the U.S. have now passed mandatory RPS requirements. A federal-level RPS requirement has been debated but not yet enacted.

Many wind energy analysts have argued that renewable portfolio standards (RPS) policies ought to be more effective than the PTC in stimulating renewables development at a low cost to government. Initial experience with the RPS in Texas suggests that this is true (Langniss and Wiser, 2003). Since then, many more states have implemented RPS requirements, some using the successful Texas RPS as a model and others using their own. Some of the latter have so far failed to spur the growth of wind capacity, highlighting the importance of careful design and implementation in achieving policy goals (Wiser et al., 2007b; Wiser and Barbose, 2008).

The finding that RPS programs can provide a stable policy incentive is supported by survey responses. Respondents were asked to compare a variety of types of renewable energy incentives in terms of their perceived stability in providing a long-term planning horizon for investment. Respondents consider renewable portfolio standards to be most likely to stay in effect—above favorable depreciation rules, production tax credits, production subsidies, and favorable pricing mechanisms (see Figure 1.4). Interestingly, respondents consider state-level RPS programs to be somewhat more stable than a federal-level RPS (were it enacted). Despite this difference, however, there are good reasons for seeking a federal RPS, including lower transaction costs. Indeed, Xcel Energy, a utility operating in several states with an RPS and currently the largest purchaser of wind power in the U.S., supports a national RPS due to the lower transaction costs (Bonavia, 2007).

In addition to the policy incentives discussed above, global warming policy—at the regional, national or international level—could further encourage wind industry growth. Several states have already taken steps to reduce CO2 emissions as the primary contributor to global warming: 1) California passed legislation in August 2006 requiring state-wide CO2 emissions to be reduced to 1990 levels by 2020; 2) eight northeastern states, under the Regional Greenhouse Gas Initiative, have agreed to reduce CO2 emissions from power plants to 2005 levels by 2009 and by an additional 10% by 2019 through a cap-and-trade system. Federal policy is currently being debated, with a cap-and-trade program currently the most likely form of legislation. The main alternative would be a carbon tax. Under a cap-and-trade system, the regulator sets a total limit on CO2 emissions (the “cap”) and then divides this into individual permits, which are then allocated or sold to CO2 emitters such as power plants and industrial entities. These permits can be traded. Each emitter must either reduce CO2 emissions or purchase sufficient permits from other players to cover its emissions. As a zero-emissions resource, wind power becomes more valuable under either a cap-and-trade or a carbon-tax system, while conventional fossil fuels, such as coal and gas, become relatively more costly.

In a separate survey of the general electric power sector,[26] respondents indicated that they do expect to eventually see carbon legislation in the U.S., and that this legislation could begin to have economic impacts on the power sector within the next five to 10 years (see Table 1.6).

1.6 Conclusions

Over the past decade, the U.S. wind industry has followed a volatile boom-bust cycle of investment closely linked to the short-term renewal and expiration cycle of the federal production tax credit (PTC), currently the primary source of policy support for wind power generation. This paper demonstrates that this boom-bust cycle is caused not by the underlying economics of wind, as commonly assumed, but by the negotiation dynamics of power purchase agreements in the face of PTC uncertainty. These negotiation dynamics serve to exacerbate downturns in investment during periods of policy uncertainty, irrespective of any other factors motivating investment in wind projects.

Going forward, there are reasons to believe that PTC uncertainty could have a reduced impact on new wind development. First, the possibility of alternative policy support in the form of a federal RPS is likely to receive greater attention from the new administration and Congress. Second, the new administration and Congress will likely enact some form of climate change policy, for example a cap-and-trade program for carbon emissions in the electric power industry. Both of these policies would give wind energy a boost relative to conventional alternatives, reducing industry focus on the PTC as the only policy supporting wind development.

Among those who appear to believe that the risk of extreme industry volatility at the hands of PTC uncertainty has declined are turbine manufacturers, who have until recently refrained from setting up turbine manufacturing capacity in the U.S. due to the short-term nature of the industry. Clipper Wind and Gamesa became the first turbine manufacturers to set up manufacturing facilities in the U.S. As of September 2008, eight manufacturing sites are online, with 27 more expanding or announced (AWEA, 2008).

PTC uncertainty provides an important case study in how industry structure, and in particular the dynamic of contract negotiations, can amplify the impact of public policy uncertainty on corporate investment. Power purchase agreements are not the only significant contract negotiation in the wind industry. With wind turbines a significant portion of plant cost, the negotiation of turbine price between turbine manufacturer and wind plant owner can also fail in the face of regulatory uncertainty. Indeed, any significant contract negotiation is subject to the dynamics described in this paper.

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[26] Wave 2 of the survey was sent to ca. 6000 energy professionals in the electric power sector (members of various industry trade organizations and attendees of industry conferences) between June-September 2006. The results are based on 509 respondents, with ca. 400-500 responding to most questions, representing an overall response rate of about 10%.

Since contract negotiations are a key component of the renewable energy industry, this finding underscores the importance of reducing regulatory uncertainty if renewable energy policy is to prove effective. This in turn requires designing and implementing types of policy incentives that are perceived by industry players to provide greater stability in supporting long-term investment.

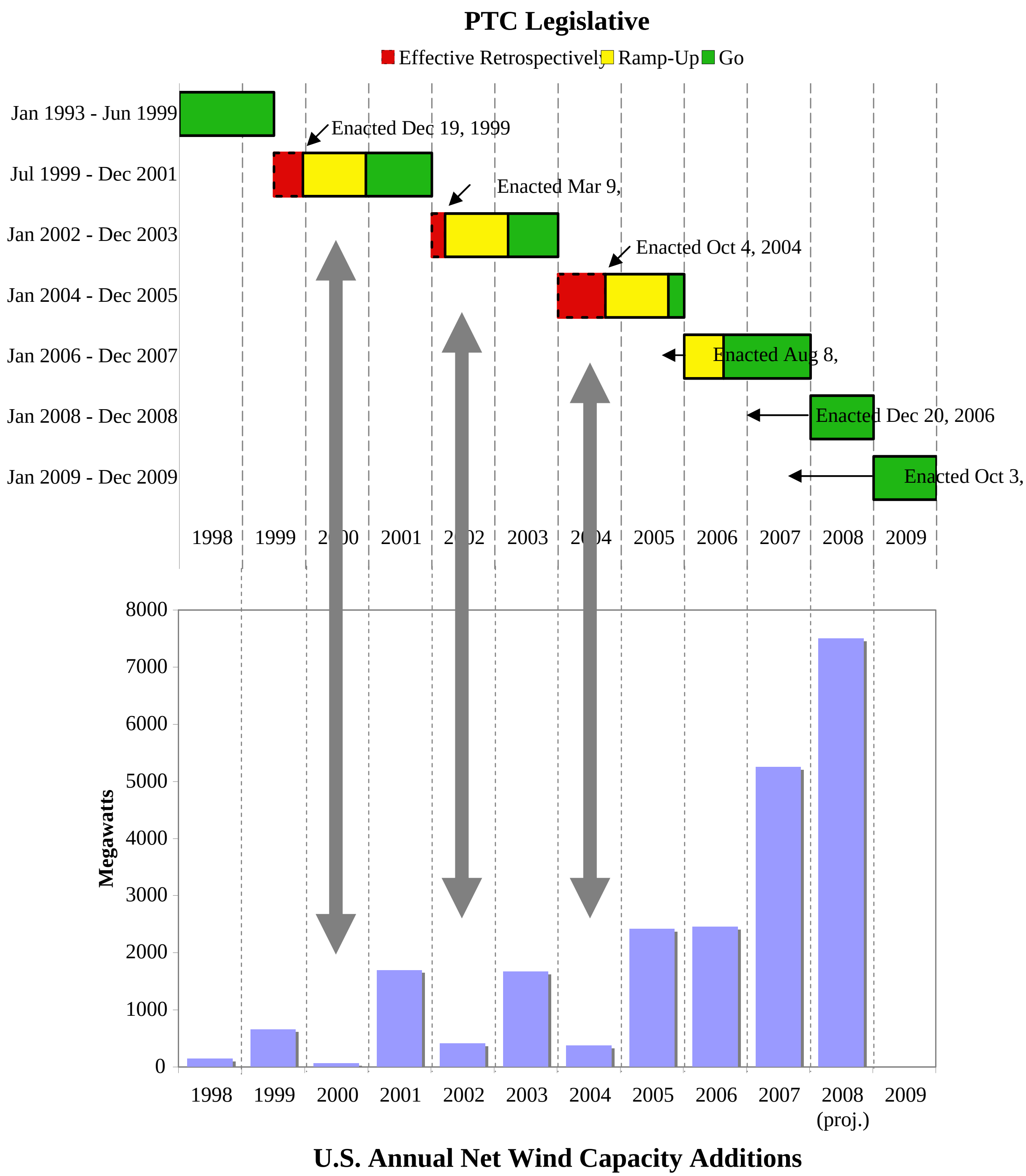

Figure 1.1. Even though PTC renewal has always been effective retrospectively (red), by the time it is renewed, ramp-up time (yellow) is required before new capacity can be brought online (green). Ramp-up period is assumed to be 12 months following renewal date; in reality ramp-up periods may be getting shorter as industry gains experience; this could explain significant capacity additions in 2005 and 2007 despite renewal dates as late as October 2004 and December 2006, respectively. However, capacity additions in both years were predominantly in the 4th quarter (56% 4th quarter vs. 2% 1st quarter in 2007), suggesting the continued presence of a boom-bust cycle. Source for PTC enactment dates: Wiser (2007). Source for wind capacity additions: AWEA (2008).

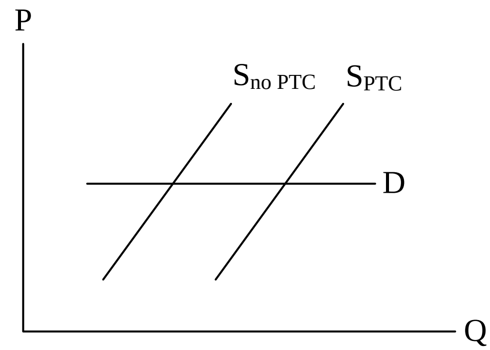

Figure 1.2. Wind Plant Supply Curves in a PTC- and no-PTC World. A flat demand curve is required for there to be no difference between the PTC- and no-PTC price of wind.

*How long **beyond 2007** do you think the U.S. government will continue **extending the PTC**?*

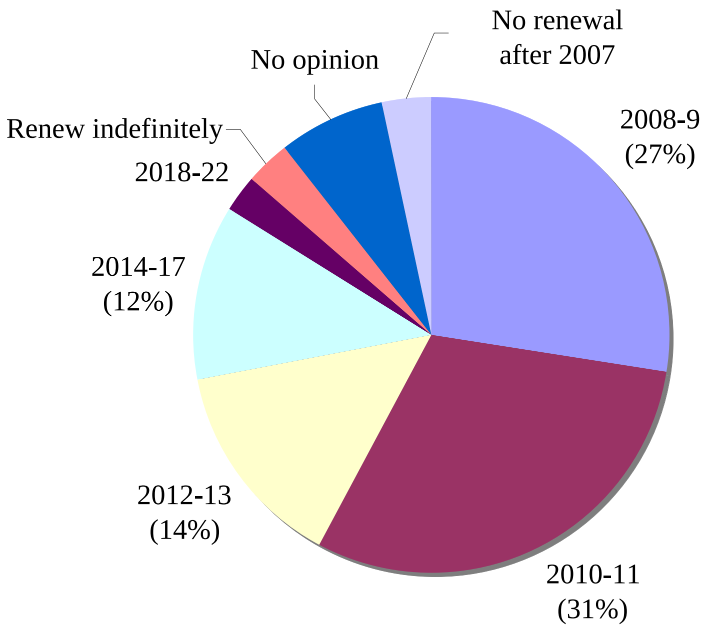

Figure 1.3. Respondents' Expectations for Final PTC Expiration (292 Respondents)

How likely would you consider the following types of renewable energy incentives, once enacted, ***to stay in effect*** *(i.e., law not likely to be reversed) long enough to influence long-term investment planning?*

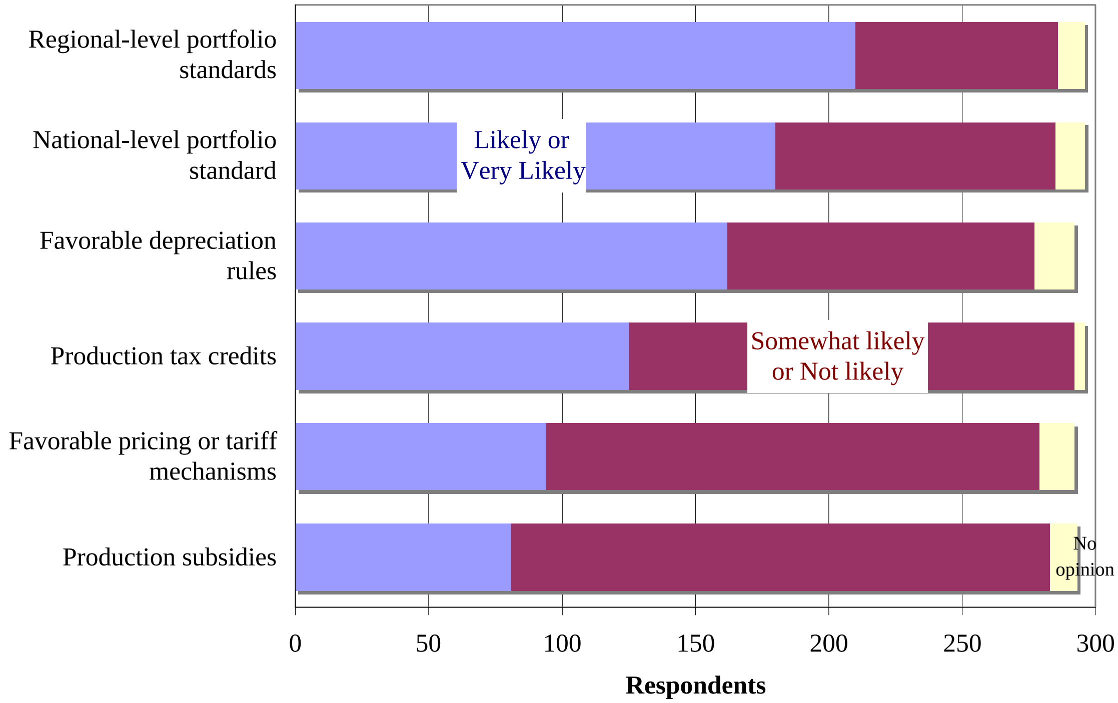

Figure 1.4. Respondents' Views on Stability of Various Policy Incentives

Table 1.1. Profile of Survey Respondents

Question	Responses (% of Respondents[27])	Responded to Question
Experience in electric power[28]	13.4 years	262
Experience in wind energy[29]	6.6 years	262
Work focuses on U.S. [30] (exclusively or substantially)	245 (94%)	262
Work associated "very much" with...[31]		261
Private sector	192 (74%)	
Public sector	61 (23%)	
Non-profit sector	20 (8%)	
Experience by fuel source[32] (number responding "extensive")		333
Coal	46 (14%)	
Natural gas	70 (21%)	
Petroleum	37 (11%)	
Nuclear	20 (6%)	
Hydro	32 (10%)	
Wind	216 (65%)	
Solar	29 (9%)	
Geothermal	12 (4%)	
Biomass	29 (9%)	
Other	5 (2%)	
Professional positions held over course of career[33]		249
Developer	117 (47%)	
Finance/Investment	105 (42%)	
Utility/Load-Serving Entity	47 (19%)	
Equipment/Plant Services	122 (49%)	
Consulting	116 (47%)	
Government Agency	27 (11%)	
Research/Media/Advocacy	59 (24%)	
Other	26 (10%)	

[27] Percentages do not add to 100% because respondents are allowed to mark more than one answer. Percentages are of total respondents for that question.
[28] Exact question: *How many **years** of work experience do you have involving the **electric power sector**?*
[29] Exact question: *How many **years** have you been involved in **wind energy**?*
[30] Exact question: *On which **regions** of the world has your work with the electric power sector focused?*
[31] Exact question: *To what extent is your experience with the electric power sector associated with the…*
[32] Exact question: *How much **professional experience** do you have with the following fuel sources?*
[33] Exact question: *Over the course of your professional experience involving the electric power sector, what "**hats**" have you worn?*

Table 1.2: Wind Capacity by Power Off-Take Arrangement (MW, per End 2007)

Off-Taker	PPA		Non-PPA		Total	
Investor-Owned Utility (IOU)	7,527		1,789		9,316	(55%)
Publicly Owned Utility (POU)	2,000		576		2,576	(15%)
Power Marketer[34]	2,891		0		2,891	(17%)
Merchant/Quasi-Merchant[35]	0		2,096		2,096	(12%)
On-Site[36]	0		25		25	(0.1%)
Total	**12,418**	(73%)	**4,486**	(27%)	**16,904**	

Source: Wiser and Bolinger (2007, 2008)

[34] Power marketers are defined as corporate intermediaries that purchase power under contract and then re-sell that power to others.
[35] Merchant power is sold on the spot market rather than under long-term contract. Even in these cases, hedging transactions are commonly used to mitigate price risk.
[36] Power used on-site by the plant owners (generally commercial entities) to offset their other electricity load.

Table 1.3: PPA Agreements Under PTC Certainty and Uncertainty

PTC?	Net cost to IPP	Why?	PPA price	Conditions for agreement
Yes	3¢	2¢ PTC	3¢	As long as value to utility ≥ 3¢
No	5¢	No PTC	5¢	As long as value to utility ≥ 5¢
Maybe	5¢	PTC not bankable	No deal	No matter how valuable wind is to utility

Table 1.4. Respondents' Views of Cost Absorption in a No-PTC World

Question	Answer	% of Respondents[37] (Number)	Mean Share of Cost (Respondents)
Who would absorb cost difference?[38]	Developer/plant owner	13.1% (33)	
	Split between developer and off-taker	49.2% (124)	
What percent split?[39]	*Developer*		*47.0% (87)*
	Off-taker		*53.1% (87)*
	Utility off-taker	32.5% (82)[40]	
	Other[41]	5.2% (13)	
Total	Developer		36.2%
	Off-taker		58.7%
	Other		5.2%

[37] Percentages exclude 19 respondents who answered "No opinion."
[38] Exact question: *For those projects that you believe would go forward even without the PTC, who do you think would generally **absorb the cost difference** between a PTC and a no-PTC world?*
[39] The 124 respondents who answered "Split between developer and off-taker" to the previous question were asked: *Approximately what percentage split?*
[40] The 82 respondents who answered "Utility off-taker" were asked: *How much of that cost difference do you think would get passed on to the customer?* The mean response was 89.8% (68 responses).
[41] "Other (please specify)" included turbine manufacturers.

Table 1.5: Respondents' Views of Wind Development in a No-PTC World

Question	Answer	% of Respondents (Number)	Mean Share of Projects (Respondents)
Any new projects?[42]	No, none at all	8.7% (26)	
	Yes, at least some	91.3% (274)	
What percent of projects?[43]	*All projects in U.S.*		*33.3% (226)*
	Respondent's own projects		*37.0% (128)*

[42] Exact question: *Suppose the federal production tax credit* ***no longer existed*** *and you knew it would* ***never*** *come back. Do you think* ***any new wind projects*** *would be planned and developed in the U.S.?*

[43] The 274 respondents who answered "Yes, at least some" to the previous question were asked: *What percentage of* ***new*** *projects (i.e., not already under construction) do you think would go forward even* ***without*** *the PTC?*

- *Percent of* ***all*** *projects in U.S. (%, capacity basis)*
- *Percent of* ***your*** *projects in U.S. (%, capacity basis)*

Table 1.6: Respondents' Expectations for Carbon Policy

Question	Answer	% of Respondents[44]	(Number of Respondents)
Carbon policy?[45]	No	10.7%	(46)
	Yes	89.3%	(408)
When affect economics of generation?[46]	*Next 5 years*	*39.2%*	*(157)*
	Next 6-10 years	*44.4%*	*(178)*
	Next 11-20 years	*14.5%*	*(58)*
	More than 20 years	*1.5%*	*(6)*
	Never	*0.5%*	*(2)*

[44] Percentages exclude 14 respondents who answered "No opinion" on first question and 7 respondents who expressed no opinion on second question.

[45] Exact question: *Do you think that the U.S. will at some point enact a* ***carbon policy*** *to address the perceived/predicted threat of global warming?*

[46] The 408 respondents who answered "Yes" to the previous question were asked: *When do you think the* ***effects*** *of this U.S. carbon policy will be significant enough to affect the* ***economics of electricity generation****?*

Chapter 2

The Logic of Carbon Risk from the Investor's Perspective: The Expected Carbon Payment

2.1 Introduction

For investors in the energy sector, *carbon risk* refers to the financial risk associated with carbon policy (any climate change policy which imposes a cost on CO2 emissions). Although no carbon policy currently exists at the federal level in the U.S., there is at least some probability (many would argue near certainty) that some form of carbon policy will be adopted within the time horizon affecting current energy investments. Any new investment in fossil fuels, or in assets that burn fossil fuels and therefore emit CO2, is subject to carbon risk. Since coal is a very carbon-intensive fossil fuel (emitting twice as much CO2 as natural gas per kilowatthour generated), among investments in the electric power sector, coal-fired power plants are particularly sensitive to carbon risk.

My goal is to understand industry attitudes toward this basic and vital concept of carbon risk.

One common way to incorporate the notion of carbon risk into investment decision-making is to include a cost of carbon in the budget analysis. The usual proxy for cost in the investment decision-making literature is carbon *price*: either the price of traded permits or the level of a carbon tax, depending on the type of policy. The notion of uncertainty (hence risk) is incorporated by using *expected* price (probability-weighted average of various scenarios, often comparing policy proposals).

This research takes an approach different from that typically reflected in the literature – survey research instead of modeling – and results in a different proxy for the cost of carbon: expected *payment*, instead of price.

Despite the high vulnerability of coal-related investment to carbon risk, only in the last couple years has the energy industry taken this financial risk into serious consideration. From the 1950s until the 1990s, coal dominated power plant construction in the U.S. (except for a brief period during the late 1970s and early 1980s when nuclear power had its heyday). In the 1990s, natural gas overtook coal as the fuel of choice for new power plants, and by the early 2000s coal plant construction had ground to a near halt. Then natural gas prices, which had remained low for well over a decade, began to increase substantially, leading in 2004-2005 to a resurgence of interest in building coal-fired power plants.

Plans for most of these coal plants relied on pulverized coal technology, which is not well suited to carbon capture, thereby precluding low-cost options for retrofitting later. Significantly, enthusiasm for coal plant development continued unabated during 2006 and much of 2007, even as the debate over climate change heated up and legislation began to look more likely – apparently reflecting little concern over the notion of carbon risk.

Typical of this mindset was the enthusiasm demonstrated by developers, utility representatives, and bankers, who came together at an industry conference in June 2005 to discuss prospects for new coal plant development. Presentations did not address carbon policy, and the notion of carbon risk was never raised in discussions.

This led to my research question: Why build new coal plants that are not CO2-capture friendly if carbon policy is possible, indeed (increasingly) probable in the foreseeable future?

In order to explore the possible reasons, I interviewed several of the conference participants, asking what they thought about the prospect of carbon policy and how that might impact planned investments in coal plants. A few were climate change skeptics who apparently gave no further thought to carbon risk, but most had thought-out reasons for not considering it a significant issue: either they expected existing coal plants to be grandfathered (i.e. exemption for existing plants, with sufficient time remaining for current investments to be included under "existing"); or they assumed that any costs would be treated like most other "unforeseen" fees, taxes, and fuel price increases: as pass-throughs to the ratepayer. A common perspective was the "too big to fail" argument. Coal currently fuels half our electricity. "You can't just tax everybody – that would cause the entire economy to falter, and no government is going to do that."

This led to my hypothesis: Industry practitioners in 2005 and 2006 saw many possibilities for investors to avoid paying the cost of carbon associated with the new plants they were developing. To test my hypothesis more generally and see if these perspectives were more broadly typical, I designed a survey.

The rest of this paper is organized as follows. The second section describes my survey methods, and the third section describes the survey results. The fourth section, "Interpretation: Carbon Payment, not Carbon Price," uses the survey results to introduce a new proxy for carbon cost (and hence carbon risk): expected carbon payment. This is the expected carbon price times the expected probability of payment. The section goes on to discuss how expected payment is different from expected price, the usual benchmark found in the carbon risk literature. The final section summarizes the conclusions of this paper in terms of their contribution to both the investment decision-making literature and policy design.

2.2 Survey Methods

This survey was conducted online from May to August 2006. An email invitation was sent to approximately ten thousand[47] individuals who had attended various power sector conferences during the previous year or who were members of various industry associations. Of the 1,039

[47] 10,003 emails were sent, of which 1,303 were undeliverable, resulting in 8,700 emails which "arrived" (at least were not returned as undeliverable).

people who clicked on the survey link, 847 continued past the first question, and 702 reached the end of the survey. All questions were voluntary, with most questions soliciting about 700-800 responses, representing an overall response rate of 8-9%. Most questions were closed-ended (multiple choice). Table 0.1 provides a profile of the respondents.

In one section of the extensive survey, respondents were asked a series of questions on their beliefs about prospective carbon policy in the U.S. electricity sector, including: 1) whether and when they think carbon policy will eventually be adopted; 2) whether they expect some form of grandfathering (i.e. exemption for existing plants); 3) which plants they expect to qualify for grandfathering; and 4) whom they expect ultimately to bear the cost of carbon policy compliance. Table 2.1 gives the exact questions.

2.3 Survey Results

In 2006 most respondents believed that current plant investments would not be impacted by policy. Although most respondents expected the U.S. to eventually adopt carbon policy (85%), and relatively soon (70%), they also expected grandfathering (64%) and compliance cost pass-throughs. Most respondents expected that investors would not ultimately have to pay the cost of carbon policy compliance; instead, costs would be passed on to ratepayers or to the general taxpayer (e.g., 80% for utility-owned plants; 51% for plants under power purchase agreement).

To better describe respondents' beliefs about carbon policy, I grouped respondents not just by their answers to individual questions, but by the *series* of answers they gave to all five questions. I constructed a "belief tree," where each branch represents a particular answer and each path through the tree represents a different storyline, or set of beliefs, about carbon policy. The first node categorizes respondents by their beliefs about the *timing* of future policy. The second set of nodes further divides the respondents by their beliefs about grandfathering. The final set of nodes groups respondents by their beliefs about *who* will foot the bill for carbon policy. The numbers represent the number of respondents at each node.

A full tree would have more than 100 branches. For illustrative purposes, I have created a simplified tree with grouped answers (Figure 1). This tree depicts beliefs for utility-owned plants; the third set of branches ("who pays?") would be different for PPA and merchant plants. The branches are organized such that stricter policy beliefs are at the top of the tree and lax beliefs towards the bottom. For example, the top branch represents those respondents who believe carbon policy will happen within the next five years, that there will be either no grandfathering or grandfathering only for plants already in operation, and that investors, not ratepayers, will foot the bill for compliance. In contrast, the bottom branch represents those respondents who think the U.S. will never have carbon policy.

The significant thing about this tree is how few paths represent "what you'd have to believe to be concerned about carbon policy" from the perspective of an investor. Laxness on any single front – policy a long time from now, generous grandfathering, or the ability of shareholders to pass costs on to others – would seem to justify not taking future carbon policy seriously in considering current fossil plant investments.

The tree has two paths that are definitely sufficient to warrant concern about carbon policy. These respondents are considered to have *"strict"* carbon policy beliefs. Five of the paths are possibly sufficient to warrant concern about carbon policy. These respondents believe carbon policy will be *"somewhat strict."* The remaining paths represent *"lax"* policy beliefs.

The actual method used to divide respondents into the strict, somewhat strict, and lax subgroups is akin to a full tree with all response combinations. Beliefs about "who pays" are scored separately for each type of power plant (utility-owned; plants under power purchase agreement (PPA); merchant plants), resulting in three separate belief trees. The scoring method can also deal with respondents whose answers are not sufficiently complete to assign them to a specific tree branch yet are sufficient to assign them to a subgroup. The scoring method is described in detail in Appendix A.

The resulting division into subgroups is shown in Table 2.2. The most relevant results are for utility-owned plants, since very little new coal plant development has followed the PPA or merchant model. Nonetheless, the overwhelming result for all types of plants is a belief by the majority of respondents in lax carbon policy.

In order to gauge the significance of this result we need to know who is in the strict subgroup and who is in the lax subgroup. Is it possible that the strict subgroup, though small, contains all the "experts", and the lax subgroup, though large, is comprised of inexperienced, insignificant, or misinformed individuals?

My next step therefore was to compare these three subgroups in terms of their demographics and professional experience. The details are described in Appendix B. The result of this analysis indicates that the subgroups are not significantly different from each other in terms of these characteristics.

Thus the fact that 84% of survey respondents held lax policy beliefs in 2006 is indeed meaningful and suggests that these beliefs were prevalent in the electric power sector at the time.

2.4 Interpretation: Carbon Payment, not Carbon Price

This result affirms my hypothesis: Industry practitioners did indeed see many possibilities for investors to avoid the cost of carbon associated with the new plants they were developing. Significantly, these views are independent of how high the carbon price itself may be. They reflect instead a belief about *whether* the carbon price will be paid by those who are choosing to build new coal plants.

Consider for a moment the everyday experience of automobile drivers deciding how vigilant to be about paying parking meters. Their behavior depends not only on the size of the parking fine, but also on the level of local enforcement. Similarly, in the case of CO_2, it is not just the carbon price which influences decision making, but the probability of having to make payment in particular situations. We therefore need a measure for carbon risk that integrates both price and payment probability. I suggest a new concept that combines these factors: *expected carbon payment*, where

$$\begin{matrix} \textit{Expected} \\ \textit{Carbon Payment} \end{matrix} = \begin{matrix} \textit{Expected} \\ \textit{Carbon Price} \end{matrix} \times \begin{matrix} \textit{Expected} \\ \textit{Probability of Payment} \end{matrix}$$

Since 2006 an assortment of relevant studies (see Table 2.3) shows a range of expected carbon prices, but no obvious trend from lower prices for earlier estimates (not price year) to higher prices for later estimates. Indeed price expectations from my survey are among some of the higher estimates, despite being earlier. Lately, however, the enthusiasm for coal plants has turned around, with significant cancellations of announced projects (see Table 2.4). Discussions with industry representatives also indicate a shift in beliefs since 2006 toward greater concern over the impact of carbon policy on current plant investments (author interviews, June 2007, November 2007, November 2008, May 2009).

What, then, explains the shift in attitude towards carbon risk, if expected price of carbon has not changed dramatically? I argue that what has changed the most over the last few years is people's beliefs about the expected *probability* of payment. The relationship among payment probability, carbon price, and expected carbon payment is shown graphically in Figure 2.

The investment decision-making literature to date (e.g., Sekar et al., 2007; Bergerson and Lave, 2007; Patiño-Echeverri, 2007 and 2009; Reinelt and Keith, 2007) has focused on the vertical axis of this graph: the expected carbon price. This literature models the coal plant investment decision as essentially a choice between two competing technologies. Pulverized coal (PC) is currently the favored technology for new coal plant development in the U.S. An alternative, integrated gasification combined cycle (IGCC), is more expensive, but would be less expensive to retrofit for carbon capture. Thus, the decision to build PC vs. IGCC can be framed as a real options problem in which the incremental cost of IGCC represents insurance (or an option) against the cost of future carbon regulation.

Sekar et al. (2007) address this decision for new plant investment, using discounted cash flow models to calculate an indifference curve between the two technologies, where the choice depends on both initial level and growth rate of carbon prices. Bergerson and Lave (2007) include the cost of other pollutants (SOx, NOx, mercury) in the investment decision. Both Sekar et al. (2007) and Bergerson and Lave (2007) find that the indifference point between the two technologies is around \$30/ton CO2. Patiño-Echeverri (2007) approaches the investment decision from the perspective of an existing coal plant and whether it should be retrofitted or replaced. Reinelt and Keith (2007) include natural gas plants as one of the investment choices. In all these cases the focus is on the "price of carbon" (assumed to be the cost of traded permits or other policy) and how high that price would have to be in order to change investment behavior.

Uncertainty of carbon price is incorporated in this model-based literature by using *expected* price: the cost of permits/tax in a given scenario times the probability of that policy scenario (or a weighted average of multiple scenarios). For example, to derive the expected price of \$11/per ton of CO2 in 2015, Reinelt and Keith (2007) assume a 13% probability that the price will be

$55, a 27% probability that the price will be $14, and a 60% probability that the price will be $0. The vertical axis of the graph in Figure 2 (expected price) incorporates this uncertainty in carbon price.

The horizontal axis (probability of payment), however, represents a different type of uncertainty: the probability that the prevailing carbon price will have to be paid in the case of a particular investment. While carbon price is generic (i.e., the cost of permits/tax is the same for everyone), payment probability is specific to individual plants. It will depend on such factors as whether the plant is utility-owned, merchant, or under PPA (and perhaps the specific terms of the PPA). It may also depend on whether the plant is already operating, under construction, or in early development. The appropriate choice of expected payment for a particular budget analysis will therefore vary from case to case.

Figure 2 allows us – for a given carbon price – to see expected payment as a function of probability. My purpose is not to establish *an* appropriate value for payment probability, but rather, to demonstrate the importance of the concept and to suggest that overall across the industry, there has been a shift from 2006 to 2009.

How do we choose probability if the appropriate value varies from plant to plant? The results from my survey can be used to calculate an *illustrative* probability of payment that represents an average of industry beliefs. For utility-owned plants, I've assigned the following payment probabilities to each subgroup:

- 0% for the 88 respondents who said there would "never" be carbon policy in the U.S.;
- 10% for the rest of the "lax" subgroup;
- 50% for the "somewhat strict" subgroup;
- 100% for the "strict" subgroup.

This results in an industry average of 18%. Applying this payment probability to carbon price (see Figure 3) results in very low values for expected carbon payment – only $2 to $5 – for a range of prices as high as $30. Even if the *price* levels expected in 2005-2006 were not sufficient to induce definite changes in investment behavior, they were within range of mattering. To make a long-term investment assuming they would not matter was to take a calculated risk. If we incorporate payment probability and look at the resulting expected *payment* of carbon, however, we see numbers that are not even within an order of magnitude of mattering. From the perspective of expected payment, the investment risk appeared negligible. No wonder enthusiasm for coal plant development was unaffected by the carbon policy debate a few years ago!

Although it is impossible to calculate a precise probability of carbon payment to reflect current beliefs, recent discussions with industry participants suggest that answers to these same survey questions would be quite different now. The change comes largely in two parts of the tree. First, people are less confident that there will be grandfathering (for example, permits may be auctioned instead of distributed). Related to this, the window between now and the time that policy may go into effect is shortening, so that even with grandfathering, there may no longer be time to get a plant permitted or under construction, much less online, by the cutoff. Second, people are no longer so sure that costs will simply be passed through to someone else (with ratepayers or taxpayers, rather than shareholders, paying the bill).

If we were to assume a payment probability of 75% as plausibly reflective of current beliefs, this would translate into a $15 carbon payment for an expected price of $20 or $22.50 for an expected price of $30 (see Figure 3). These numbers are more substantial.

Evidence of industry attitudes toward carbon risk can also be found in utility Integrated Resource Plans (IRPs). Barbose et al. (2008a and 2008b) summarize current utility practices for addressing the regulatory risk of future carbon policy based on recent IRPs put out by utilities in the Western U.S. The authors find that utility carbon cost estimates in scenarios in these publications are significantly lower than the prices in recent legislative proposals (see Table 2.5). One explanation for these lower estimates may be that utilities implicitly incorporate their expectations for payment probability along with their expectations for the prices set by policy. This data also shows that the average carbon costs in IRPs published in 2007 are significantly higher than the average found in IRPs published in 2006, suggesting a shift in utilities' attitudes toward carbon risk toward greater concern over time.

2.5 Conclusions

Survey respondents in 2006 saw many possibilities for investors to avoid paying the cost of carbon. This result leads to some important conclusions for the investment decision-making literature:

- Expected carbon payment, a new concept which incorporates both price and payment probability, is introduced. Specifically:

$$\begin{matrix}\textit{Expected} \\ \textit{Carbon Payment}\end{matrix} = \begin{matrix}\textit{Expected} \\ \textit{Carbon Price}\end{matrix} \times \begin{matrix}\textit{Expected} \\ \textit{Probability of Payment}\end{matrix}$$

- The big change in industry views over the past few years is not so much in the expected carbon price as it is in the expected payment probability.

- Expected carbon payment is a better proxy for carbon cost and carbon risk, as perceived by industry participants, than is expected carbon price.

This research is also relevant for policy design. Recalling the aforementioned example of parking fine enforcement, the difference between probability of enforcement and probability of payment is that enforcement is external to policy, whereas payment is internal to policy (non-enforcement of illegal behavior vs. legal loopholes within the policy). Probability of payment is not just a matter of enforcement; it is central to policy design itself. This research offers some useful lessons in this area:

- Policy incentives must directly impact those who are making investment decisions. If people in the industry see many possibilities for investors to avoid paying the cost of carbon, as my survey suggests, then one clear conclusion is the need for policy to be designed to avoid such “loopholes”. Presumably, if people’s beliefs have changed since 2006, it reflects lower confidence that these loopholes will remain. This means it is important for policy makers to be aware of the potential pitfalls in designing policy so that they do in fact avoid them.

- Policy intentions are not the same as policy results. The idea of giving away permits may be motivated by a desire to make the transition to a low-carbon economy easier for utilities, but may in fact create the perverse incentive of encouraging rather than discouraging carbon-intensive investment.

- The negative impacts of regulatory uncertainty are exacerbated when future expectations are for lax policy. One possible solution to help bridge the period of uncertainty until legislation is enacted would be for Congress to pass a law stipulating that as of immediately, any new power plants will be subject to future carbon legislation, whatever form that takes (Morgan, 2006).

All these conclusions point to the importance of understanding the perspectives of those we hope to influence with policy. Survey research is a helpful tool in this endeavor. If climate change policy is to succeed, it must impact all aspects of investment decisions – what developers propose, what lenders finance, and what utilities build.

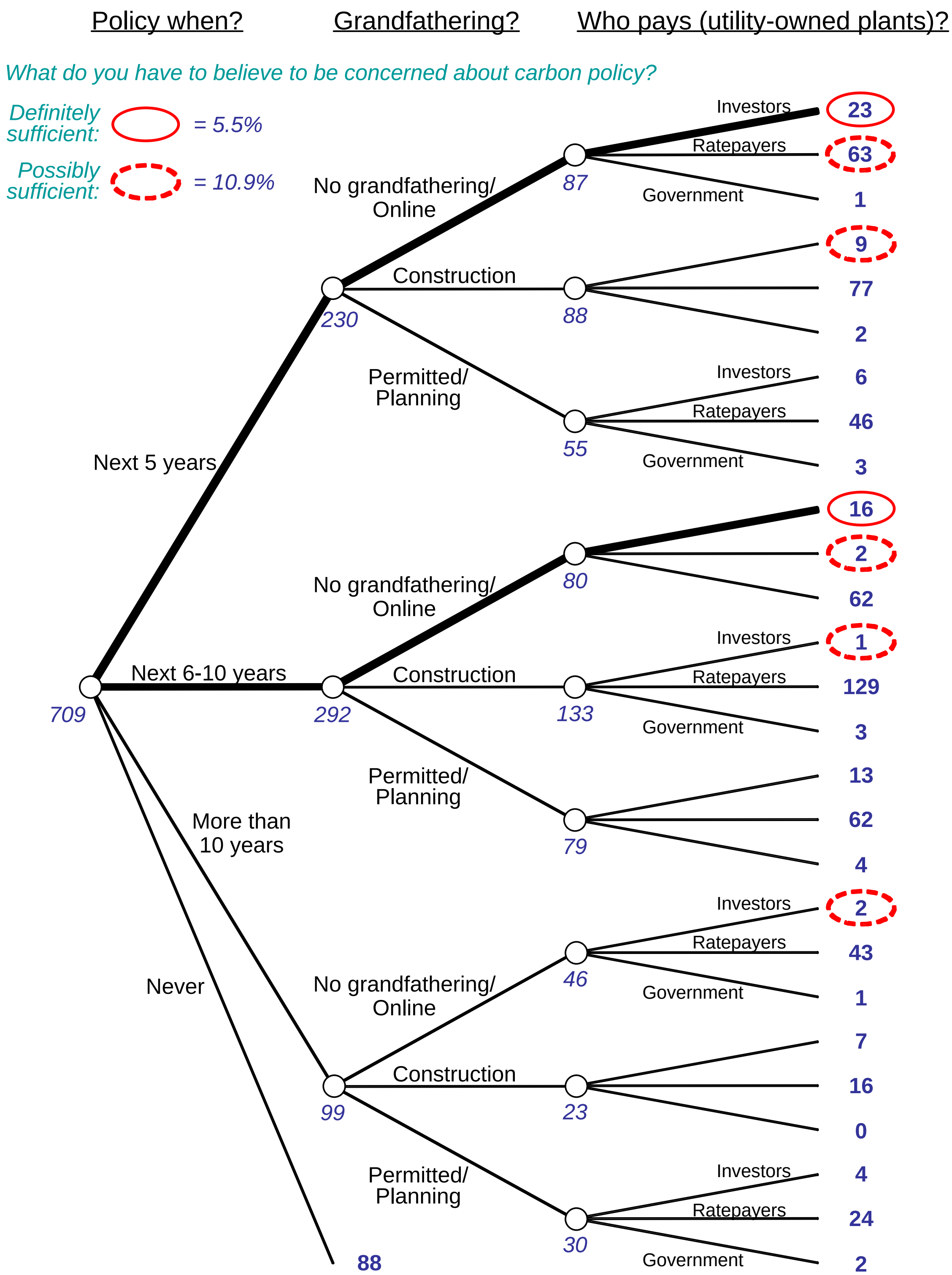

Figure 2.1. Illustrative Belief Tree for Survey Respondents

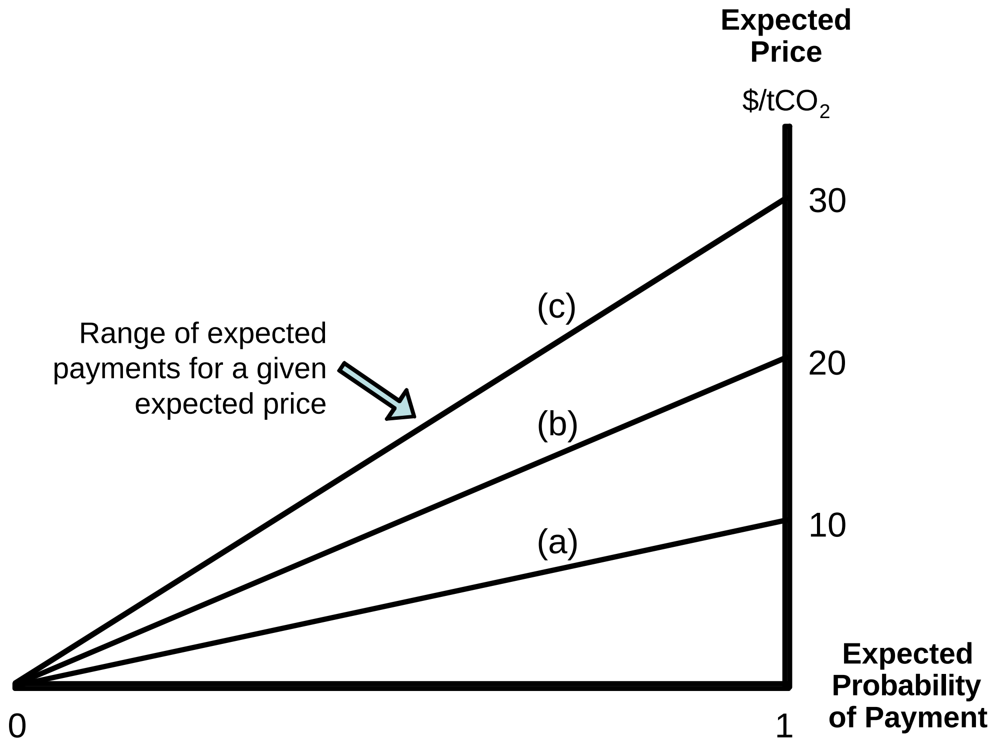

Figure 2.2. Expected payment as a function of expected probability for an expected price of (a) $10; (b) $20; and (c) $30.

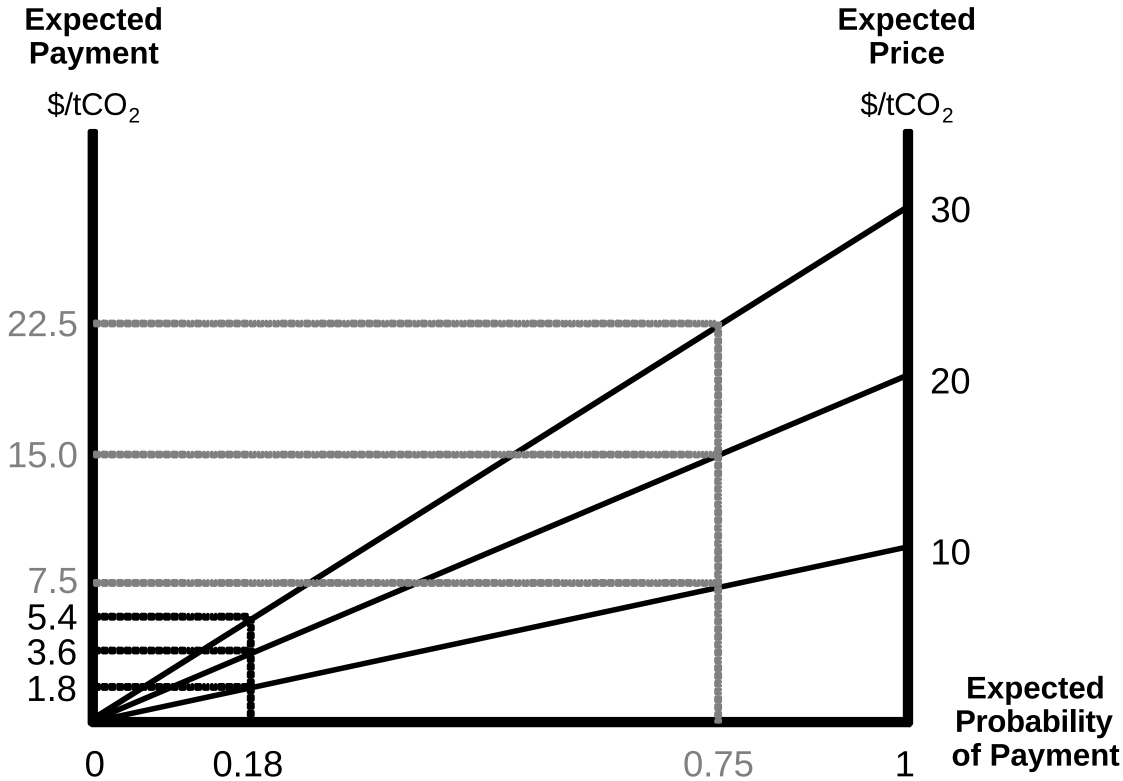

Figure 2.3. Expected carbon payments for a payment probability of (a) 18% (2006) and (b) 75% (hypothetical 2009) range from $1.80 to $5.40 and from $7.50 to $22.50, respectively, for an expected price range of $10-$30.

Table 2.1. Survey Questions on Carbon Policy

CP 1. Do you think that the U.S. will at some point enact a **carbon policy** to address the perceived/predicted threat of global warming?

___ Yes
___ No *[--> skip rest of section]*
___ No opinion

CP 2. When do you think the **effects** of this U.S. carbon policy will be significant enough to affect the **economics of electricity generation**?

___ Next 5 years
___ Next 6-10 years
___ Next 11-20 years
___ More than 20 years
___ Never *[--> skip rest of section]*
___ No opinion

CP 3. Do you believe this future carbon policy would apply to **all plants equally** or to **new plants differentially**?

___ All plants equally (e.g., **no grandfathering**)
___ New plants differentially (e.g., existing plants would be grandfathered)
___ No opinion

If new plants differentially:

CP 4. What is the **earliest stage** of development that you think would **qualify** for grandfathering?

___ Plants in early **development/planning**
___ Plants already **permitted**
___ Plants under **construction**
___ Plants already **online**
___ No opinion

CP 5. **Who** do you think would ultimately bear the economic **cost of carbon policy compliance** for fossil fuel plants in the U.S.? *(Mark all that apply)*

	Plant owner	Offtaker / Load serving entity	Pass-through to rate payers	Govern-ment/ General taxpayer	Other *(please specify below)*	*No opinion*
For **plants owned by utilities**						
For **plants under PPA** (long-term contract)						
For **merchant plants** (selling into spot market)						

Table 2.2. Respondent Subgroups by Carbon Policy Belief

	Respondents (%)			
Beliefs for:	Strict	Somewhat Strict	Lax	Total[48]
Utility-owned Plants	39 (5.5%)	77 (11%)	593 (84%)	709 (100%)
Plants under PPA	76 (11%)	107 (16%)	499 (73%)	682 (100%)
Merchant Plants	86 (13%)	45 (7%)	515 (80%)	646 (100%)

[48] Totals vary because not all respondents answered for every type of plant.

Table 2.3. A Sampling of Expected Carbon Prices from the Literature

Source	Year of Estimate	Expected Price in Various Years ($/tCO2[49])			
		2010	2015	2020	2025
Simbeck (2002)[50]	2002	$11	$11	$11	$11
McCain-Lieberman 2003 (S. 139)[51]	2003	$24	$35	$53	$66
Simbeck (2005)[2]	2005	$10	$10	$10	$10
Barradale (2006)	2006	$20	$24	$27	$35
McCain-Lieberman 2007 (S. 280)	*2007*		*$15*	*$22*	*$33*
Bingaman-Specter 2007 (S. 1766)	*2007*		*$12*	*$15*	*$20*
Lieberman-Warner 2007 (S. 2191)	*2007*		*$21*	*$29*	*$42*
Stark-McDermott 2007 (H.R. 2069)	*2007*	*$7*	*$16*	*$24*	*$30*
Larson 2007 (H.R. 3416)	*2007*	*$16*	*$26*	*$41*	*$67*
Average of 2007 legislative proposals	2007	$11	$18	$26	$38
Reinelt & Keith (2007)	2007	$5	$10	$15	$20
Yang et al. (2008)[2]	2008	$22	$22	$22	$22
Moody's (2008)[2]	2008	$11	$11	$11	$11

Sources for legislative proposals. S. 139: EIA (Jun 2003), pp. 10-11; S. 280: EIA (Jul 2007), p. x, core case; S. 1766: EIA (Jan 2008), p. v; S. 2191: EIA (Apr 2008), p. 16, core case; H.R. 2069 and H.R. 3416: Metcalf et al. (2008), p. 8.

[49] All prices converted to 2005 dollars using the Producer Price Index. Currency year assumed to be year of estimate unless otherwise stated. Future nominal prices converted using the average annual rate of inflation 1990-2008 of 2.2%.

[50] Price year not given in source.

[51] Another set of estimates for permit prices under S. 139 is given by MIT Joint Program on the Science and Policy of Global Change, Report No. 97. 2010: $20-46; 2015: $26-58; 2020: $33-74, with Scenario 9 representing the low end and Scenario 4 the high end of each range (converted to 2005 dollars). See Paltsev et al. (2003).

Table 2.4. Decline in Enthusiasm for Coal Plant Development

Utility	New Coal Generation Cancelled, Scaled Back, or Postponed
TXU	8 out of 11 coal plants cancelled for private equity deal
FPL	Glades County plant opposed by Governor, rejected by FPSC
Duke Energy	1 of 2 plants cancelled due to escalating and uncertain costs
Oklahoma Gas & Electric	Red Rock plant not supported by OCC/environmental concerns
Sunflower Electric Power	Holcomb plant air permit rejected over CO2 concerns, appealing
Idaho Power	New generation changed to gas from coal due to costs/CO2
Xcel Energy	No PPA to be executed with new Iron Range merchant coal plant
Avista	Has ruled out pursuing new coal plants
Associated Electric	Norborne plant indefinitely postponed due to costs/CO2

Source: Moody's (2008)

Table 2.5. Carbon Cost Estimates Used in Utility Integrated Resource Plans

Source	Year of Estimate	Expected Price in Various Years ($/tCO2[52])			
		2010	2015	2020	2025
Utility IRPs					
Idaho Power	*2006*		*$15*	*$15*	*$15*
Nevada Power	*2006*	*$6*	*$7*	*$8*	*$9*
PG&E	*2006*	*$5*	*$6*	*$6*	*$7*
SCE	*2006*	*$5*	*$6*	*$6*	*$7*
SDG&E	*2006*	*$5*	*$6*	*$6*	*$7*
Seattle City Light	*2006*	*$5*	*$5*	*$5*	*$5*
Average of 2006 IRPs	2006	$5	$7	$8	$9
Avista	*2007*		*$7*	*$7*	*$8*
NorthWestern	*2007*	*$9*	*$9*	*$9*	*$9*
PacifiCorp	*2007*	*$4*	*$8*	*$8*	*$8*
PGE	*2007*	*$7*	*$8*	*$9*	*$11*
PSCo	*2007*	*$19*	*$21*	*$24*	*$28*
PSE	*2007*		*$7*	*$8*	*$9*
Sierra Pacific	*2007*	*$6*	*$7*	*$7*	*$8*
Tri-State	*2007*	*$24*	*$24*	*$24*	*$24*
Average of 2007 IRPs	2007	$11	$11	$12	$13
Legislative Proposals (from Table 2.3)					
McCain-Lieberman 2003 (S. 139)	2003	$24	$35	$53	$66
Average of 2007 legislative proposals	2007	$11	$18	$26	$38

Source for IRPs: Barbose et al. (2008a), Tables 1 and 2.

[52] IRP figures given in short tons converted to metric tons. All prices converted to 2005 dollars using the Producer Price Index. Currency year assumed to be year of estimate unless otherwise stated. Future nominal prices converted using the average annual rate of inflation 1990-2008 of 2.2%.

Chapter 3

Wishful Expectations in Natural Gas Markets

3.1 Introduction

After a decade of stable and low natural gas prices during the 1990s, which made natural gas the fuel of choice for new electric power plants, the volatility of natural gas markets has increased in the past 10 years, with substantial increases in average prices. As natural gas prices became more volatile, the range of projections for future prices widened. Significant differences of opinion among energy professionals about the future of natural gas prices began to surface around 2001-2002 and have continued. Generally speaking, two schools of thought emerged: 1) the era of cheap natural gas had come to an end, and scarcity, coupled with high demand, would cause prices to stay high into the future; or 2) the current supply limits causing higher prices were temporary, and new sources would become available (e.g., liquid natural gas imports), bringing future prices down – perhaps not quite as low as the 1990s, but lower than at present. Each of these storylines had multiple variations, but these represent the general spread of beliefs.

Is this variation in projections from different analysts random, or is there a pattern in the variation? My research hypothesizes that there *is* a pattern and that it falls along the lines of "wishful expectations:" those whose interests would be furthered by lower gas prices will tend to predict lower prices, whereas those who would benefit from higher prices, such as renewable energy proponents, will tend to predict higher prices. The "wishful expectations" bias was first observed by Ito (1990), who found that among people in the import-export business, views on future yen-dollar exchange rates correlated with whether they were on the import or export side of business, with expectations matching hope/self-interest.

The wishful expectations (also called "wishful thinking") bias has been looked at extensively in psychology and behavioral experiments (e.g., Windschitl et al., 2010; Vosgerau, 2010; Seybert and Bloomfield, 2009; Sigall et al., 2001) as well as predictions of election outcomes (e.g., Krizan et al., 2010; Babad and Yacobos, 1993; Babad et al., 1992). In an example of real-world forecasting (as opposed to laboratory experimentation), Ashiya (2009) examines predictions made by professional macroeconomic forecasters over 26 years to look for evidence of a number of cognitive biases, including wishful expectations.

In the energy arena, very little research has been done on the role of either wishful expectations specifically or cognitive bias generally on the formation of expectations. One study does examine 10 years of Swedish survey data on the public's preferences and expectations regarding the future of nuclear power and finds a consistent influence of wishful expectations (Granberg and Holmberg, 2002). With regard to expectations for energy *prices,* however, no such research has been found.

Research on energy forecasting (whether oil, gas, or electricity) is dominated by modeling approaches, generally assuming rational expectations. In the area of natural gas, a lot of modeling and analysis has focused on the role of natural gas storage and supply (e.g., Geman and Ohana, 2009; Gay et al., 2009; Chaton et al., 2009; Chagnon et al, 2000). Others have used long-term historical price data to create models for predicting future prices (e.g., Shafiee and Topal, 2010; Pindyck, 1999), and Buchanan et al. (2001) develop a price prediction model based on traders' positions in natural gas futures markets. There is also empirical research documenting a discrepancy between forward prices and expected future spot prices (also known as the futures-spot bias or forward risk premium) in electricity markets (e.g., Furio and Meneu, 2010; Redl et al., 2009) and in natural gas markets (e.g., Wong-Parodi, 2006; Bolinger et al., 2006), but no work on cognitive bias as a possible explanation of such discrepancies has been done.

To test my hypothesis on the presence of a wishful expectations bias for natural gas prices, I conducted a survey in summer 2006 of about 700 energy professionals in the electric power sector. In one section of the extensive survey, I questioned respondents about their expectations (over four different time frames) for natural gas prices and then about their preferences for high or low prices.

The rest of this paper describes first my survey methods and then my survey results, in which I describe the two statistical methods of association that I performed on my data. I also experimented with variations in coding scales. This is followed by an examination of the interesting and philosophical question of causality (as opposed to correlation). The final section summarizes my conclusions: I find a clear association between preferences and expectations in the 5-, 10-, and beyond-10-year horizons. I discuss these results and note that more research could be done on the causality factor.

3.2 Methods

My survey was conducted online from May to August 2006. An email invitation was sent to approximately ten thousand[53] individuals who had attended various power sector conferences during the previous year or who were members of various industry associations. Of the 1,039 people who clicked on the survey link, 847 continued past the first question, and 702 reached the end of the survey. All questions were voluntary, with most questions soliciting about 700-800 responses, representing an overall response rate of 8-9%. Most questions were closed-ended (multiple choice). Table 0.1 provides a profile of the respondents.

In the natural gas section of the survey, I had 600-728[54] responses on price expectations (depending on the time frame) and 699[55] responses on preferences. Because the overlap of these groups is not complete, I have 559-671 individuals (depending on time frame) who responded to both questions and thus constitute the sample for my analysis.

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[53] 10,003 emails were sent, of which 1,303 were undeliverable, resulting in 8,700 emails which "arrived" (at least were not returned as undeliverable).
[54] This excludes 31-141 respondents who marked "No estimate."
[55] This excludes 13 respondents who marked "Indifferent."

Ito's data set consists of 44 individuals and 51 observations made twice per month for just over two years. Of these 44 individuals, 20 can be categorized as having a preference: 9 represent export-oriented companies, and 11 represent import-oriented companies.[56] Ito finds that the export industry's predictions reflect a significant yen *depreciation* bias (for all three time horizons), the trading companies predictions reflect a significant yen *appreciation* bias (for all three time horizons), and the import industry's predictions also reflect a significant yen appreciation bias (for the one-month horizon).

Ito's data has the advantage that it covers a two-year period, and he finds the wishful expectations bias to be consistent over time. My data set consists of a single observation at one point in time, but on the other hand, it contains some 650 respondents, compared with Ito's 20.

Further, Ito's data is for expectations only, and he assumes preferences on behalf of importers and exporters (not an unreasonable assumption). My respondents, however, were specifically asked about their preferences, in addition to their expectations.

It was important to ask respondents about their expectations *before* asking about their preferences, in order to avoid potentially biasing the expectations they reported in the survey.

I asked about expectations (see Table 3.1) for four time frames: a) 1 year from "now"; b) 5 years out; 10 years out; and d) beyond 10 years. For each time frame, respondents could choose among six bins, each representing a range of prices. The time frames and price bins were chosen in consultation with industry practitioners to ensure meaningful categories. To help give context for price figures, I provided information about historical prices from 1990 to the present (spot prices at Henry Hub are the most widely quoted "standard" in the U.S. natural gas industry).

To ascertain people's preferences (see Table 3.2) for "high" vs. "low" natural gas prices without establishing a dollar amount for these terms, I started by determining how they frame their thinking about natural gas prices (question NG 4), and then framed the expectations question (NG 5a, 5b, 5c) in relation to threshold prices defined by respondents. This is one advantage of online surveys compared with paper surveys: skip logic can be used to tailor questions according to previous answers. This is comparable to questions being read aloud by an interviewer (with instructions about when to ask which questions), but reduces the error rate of interviewers.

For preferences, I did not distinguish different time frames – thereby making the implicit assumption that preferences would not vary across time, a simplifying assumption[57] that obviously may not be entirely accurate. If I were conducting this survey again, it might be worth distinguishing between short- and long-term preferences, but I would not use more than two time frames.

[56] These 11 individuals represent 5 "import-oriented industries" and 6 "trading companies". Ito points out that the leading Japanese trading companies handle more imports than exports and so can be included on the import side of the industry.
[57] Note that Ito also makes this implicit assumption by assigning one preference to importers and the opposite preference to exporters.

I coded both expectations and preferences as ordinal variables, using a scale of 1 to 6 for expectations and 1 to 5 for preferences (see Tables 3.3 and 3.4). Treating these variables as ordinal (as opposed to nominal) variables means that the *order* of the categories is significant (for example, "Very high" is higher than "High" is higher than "Low" and so forth), but the relative distances between the categories is arbitrary.

3.3 Results

Two general trends are visible in the expectations data (Table 3.5): 1) rising prices over time (e.g., most respondents expect higher prices in 10 years than in one year); and 2) strong clustering around the middle of the scale early on shifting towards greater bifurcation in beliefs later on (more expectations at both ends of the scale and fewer in the middle). Table 3.5 also shows strong clustering around the middle of the scale for preferences (i.e., far more respondents prefer high, middle, or low prices than very high or very low prices).

In terms of the relationship between the two variables, overall I found a significant relationship between preferences and expectations at the 5, 10, and beyond-10-year horizons, but not at the one-year horizon.

The first measure of association I looked at was Pearson chi-squared, a standard measure of association for categorical variables. The resulting p-values (see Table 3.5) were 0.09 (significant at the 10% level, but not at the 5% level) for expectations in one year and less than 0.000 (significant at the 1% level) for expectations in 5, 10, and beyond 10 years. Because large samples (like this one) are more likely to show significant levels of association by the mere fact of their size, Cramér's V is a way of adjusting these results for sample size (for categorical data). In general, a relationship is considered weak when the Cramér's V test statistic is less than 0.2, moderate when it falls between 0.2 and 0.49, and strong when it is 0.5 and higher (Acock, 2008). This suggests that the relationship between preferences and expectations at the 5, 10, and beyond-10-year horizons is somewhat weak, though statistically very significant.

The Pearson chi-squared and Cramér's V test statistics are measures of association that can be applied to all categorical variables, both nominal (unordered) and ordinal (ordered). However, because they do not take account of the ordered nature of ordinal variables, they are less powerful than other measures of association which are applicable specifically to ordinal variables (Agresti, 2007).

Kendall's tau-b is a test that does take account of the ordered nature of the variables. As with Cramér's V, a relationship is considered weak when the tau-b test statistic is less than 0.2, moderate when it falls between 0.2 and 0.49, and strong when it is 0.5 and higher. In my data, although tau-b shows a somewhat weak relationship at the 5, 10, and beyond-10-year horizons, the relationship is stronger than with Cramér's V (in fact, almost moderate).

Significance for the tau-b test is calculated by dividing the tau-b test statistic by the asymptotic standard error (ASE) to get a standard normal z-test value. As with the Pearson chi-squared, the tau-b test is statistically significant at the 1% level for the 5, 10, and beyond-10-year horizons ($p < 0.000$).

I also considered some variations in the coding scales for preferences and expectations. With regard to preferences, I considered excluding those respondents who chose the middle category on question NG 5b, as these respondents don't have a clear preference for high or low prices. I also considered combining the two high categories ("high" plus "very high") and the two low categories ("low" plus "very low) with the idea that respondents' preferences may not be nuanced enough to provide a meaningful distinction between degrees of high and degrees of low, whereas they do hold a clear preference for high vs. low. Various combinations of these two simplifications result in three additional preference scales beyond the original 5-point scale used above (4-, 3-, and 2-point scales). In fact, the 2-point scale is closest to Ito's methodology, as he considers only those industry groups he assumes to hold preferences (importers and exporters) for the wishful expectations portion of his analysis. Furthermore, he categorizes these assumed preferences only as "high" or "low" and not in degrees of either.

My analysis (see Appendix, Table C-1) shows that condensing the preference scale progressively results in a stronger relationship (as measured by both Cramér's V and Kendall's tau-b) at the 5, 10, and beyond-10-year horizons, but collapsing the ends of the scale has a more significant impact than eliminating the middle category. With the 2-point preference scale that is akin to Ito's analysis, my results show a moderate relationship that is statistically significant between preferences and expectations at the 5, 10, and beyond-10-year horizons (but still not at the one-year horizon).

With regard to expectations, I considered collapsing the two lowest price bins, because so few respondents picked these, particularly the lowest one, resulting in a 5-point scale. Across all preference scales, this simplification had virtually no impact on the measures of association.

Overall, therefore, I conclude that there is a weak to moderate relationship between preferences and expectations for natural gas prices at the 5, 10, and beyond-10-year horizons, and that this relationship is statistically significant at the 1% level, but at the one-year horizon the relationship is very weak and not statistically significant.

Why the difference between the one-year horizon and the longer time horizons? Beyond a possible "wishful expectations" effect, there are other factors which influence people's beliefs. The "anchoring" effect[58], for example, causes people's future expectations to stay somewhat close to current price levels, especially for the relatively near future. This survey was conducted in summer 2006, less than a year after Hurricanes Katrina and Rita devastated New Orleans and the Louisiana coast, where Henry Hub, the major natural gas trading hub in the U.S., is located. Although natural gas prices had come down from their post-hurricane spikes, it is likely that

[58] I am using quotation marks around "anchoring" to mean "close to current levels" without specifying a cause for this effect. One explanation could be the natural, rational consequence of a random-walk process with little time for variation. Another explanation could be the cognitive bias known as anchoring, in which people tend to latch on to starting points. I suspect there may be a bit of both going on.

recent events still loomed large in people's minds. Indeed, expectations for the one-year horizon were almost entirely clustered in the middle two price categories (86% of respondents), with over half (56%) of respondents choosing the bin representing current prices. In other words, at the one-year horizon, the "anchoring" effect appears to dominate other effects. Expectations for more distant time horizons, on the other hand, were much more dispersed, and it is the longer horizons which are more important for investment decision-making.

3.4 Causality

Correlation, of course, is not causality. In general, to establish causality unequivocally, two conditions must hold:

1) The causal factor must precede the result temporally;
2) The presence of a third factor causing both results must be eliminated.

The idea behind the wishful expectations hypothesis is that the connection between preferences and expectations is due to preferences causing expectations, and not the other way around. Although it is possible that a third factor could be the source of both, the more compelling alternative hypothesis to "wishful expectations" is that causality runs in the opposite direction.

How does Ito go about arguing the direction of causality? In a footnote on p. 442, he acknowledges that theoretically there could be "self-selection among entrepreneurs and dealers: Those who are optimistic about the yen appreciation (depreciation) develop import (export, resp.) business." However, in practice, he argues, this is not what's happening:

> Those who are in charge of foreign exchange expectations and trades in those companies are usually in-house staff, who are subject to a lifetime employment practice. It is hardly the case in Japan that foreign exchange professionals hop companies according to their biases in expectations.

Thus, while Ito demonstrates *correlation* quantitatively, his argument for *causality* relies on a (simple) narrative approach.

Likewise, my survey data does not enable me to establish a definite time frame or sequence for development of preferences and expectations by respondents. However, for some respondents in the wind industry, I know how long they've been involved in the field. For these people, we could assume that their preferences have not changed since the start of their involvement with the wind industry.[59]

With regard to expectations, let us assume the contribution of multiple factors to belief formation, including: 1) current price levels ("anchoring"); 2) historical price levels; and 3) wishful expectations. The relative importance of these factors may vary depending on both the timing of the survey and how far into the future projections are made. For example, as discussed

[59] This assumption may not hold in all cases, since the exact nature of involvement with wind energy is not specified.

above, expectations for the one-year time horizon may be dominated by the “anchoring” effect, whereas wishful expectations may come into play more for longer-term expectations. In addition, during a period of price stability, historical trends may dominate expectations (for all time horizons), whereas times of greater volatility may see the increased influence of other factors.

The graph in Table 3.1 shows that natural gas prices were stable and low throughout the 1990s. During that period, most people had little reason to expect gas prices to rise substantially during the subsequent decade. It is unlikely, therefore, that people who joined the wind industry during the 1990s did so *because* they thought natural gas prices would rise substantially in future. The first significant spike in natural gas prices, caused in large part by Enron’s manipulation of the market during a particularly hot California summer, occurred in the second half of 2000/first half of 2001 and was generally considered circumstantial rather than systemic. Indeed, by late 2001/early 2002 prices had returned to pre-spike levels. However, as prices began to rise *again* during the first half of 2002, some people stopped taking a return to 1990s-level prices for granted.

Significant differences in opinion among energy professionals about the future of natural gas prices began to surface around 2002 and have continued – in other words, during a period of generally rising prices as well as one of significant price volatility. Throughout this period, since it was a prominent topic, most energy professionals were at least reconsidering their beliefs about future gas prices, even if they didn’t all change their beliefs.

It seems reasonable to assume, therefore, that most people’s expectations formed after 2002, and have probably been revisited multiple times since then. And for those people who were involved in the wind industry before 2002, we can assume that preferences were established prior to beliefs. So how does the relationship between these two variables look for this subgroup of respondents?

The raw data (see Table 3.6) shows that across all time horizons both expectations and preferences are high for the majority of respondents. The statistical measures of association tell a much less compelling story, however: the relationship is neither strong (and in a couple cases negative) nor statistically significant. Why not? One reason is that this subgroup, consisting of only 102-124 respondents, is too small for the number of degrees of freedom. The full-scale comparison of these two variables has 30 (6x5) cells. In general, it is considered necessary to have at least 5 respondents in each cell (or at least most cells) for these measures of association to be meaningful. In this case, most cells contain far fewer than 5 respondents, especially due to the high concentration towards the upper end of both scales. To alleviate this issue, I ran the comparisons again using condensed scales (5x3). Although this reduced the problem (see Appendix, Table C-2), there is still a predominance of sparsely populated cells on the low end of both scales and a concentration at the high end.

This leads to a second reason this type of correlation analysis does not work well for this subgroup: there is not enough variation in the expectations, and especially the preferences, for this sample. In fact, this is not surprising, since they are all people who have been involved in the wind industry and therefore can be expected to have similar preferences for (high) natural gas prices. Pearson chi-squared, Cramér's V, and Kendall's tau-b are most appropriate for measuring correlation in random samples with sufficient variation, which this sample is definitely not.

It is interesting to note that respondents associated with the wind industry generally prefer "high," as opposed to "very high," natural gas prices. This probably reflects dual attitudes toward natural gas. On the one hand, they would like prices to be high enough to make renewables (and particularly wind) competitive. On the other hand, natural gas is the cleanest fossil fuel (in terms of both carbon and other emissions), so they would not like it to be so expensive that it is out-competed by coal.

3.5 Conclusions

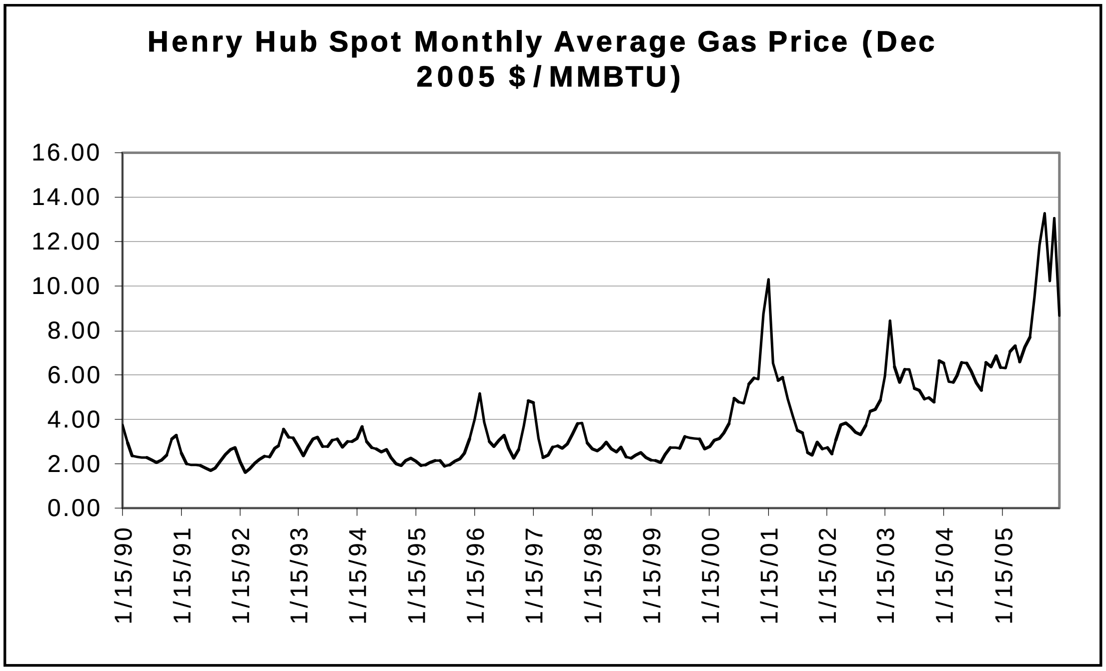
My data shows a clear association between preferences and expectations for future natural gas prices at the 5-, 10-, and beyond-10-year horizons – the timeframes most relevant to investment decision-making.

Demonstrating causality is more difficult, because for the majority of respondents I do not have information that would allow me to establish the order in which people's preferences and expectations were formed. The subgroup for which I am able to plausibly establish that preferences preceded expectations (those who have been involved with the wind industry since before 2002) does not have sufficient variation in the variables I am measuring in order to conduct meaningful correlation analysis, although it is clear from looking at the raw data that there is a predominance of high values for both preferences and expectations (which is what one would expect, given the bias of this subgroup).

Although I am not able to prove causality, using the same line of reasoning that Ito relied on, it is unlikely that energy professionals are hopping back and forth between different fuel types or between the buy and sell side of natural gas markets as frequently as they reevaluate their price expectations. Therefore, it is unlikely, at least on an ongoing basis, that beliefs are driving interests and preferences. It is of course possible that one-time shifts do occur in that direction. For example, some of the growing interest in wind over the last 5-10 years (reflected for example in the increasing numbers of people joining the industry) may be due to rising natural gas prices, which caused a change in people's beliefs about the future and therefore a "switching of sides" in the industry, which would then lead to a shift in preferences. Still, this would not be the case on an ongoing basis, which suggests that other factors are also playing a role in the association of preferences and expectations that my data shows – e.g., the wishful expectations bias demonstrated by Ito 20 years ago.

Table 3.1. Survey Question on Natural Gas Price Expectations

NG 2. Natural gas prices in the U.S. have risen significantly since the 1990s. The graph below shows **historical prices** from 1990 to the present in inflation-adjusted dollars per MMBtu*, measured at Henry Hub, Louisiana.



What do you think the **average future price of natural gas** in the U.S. might be? *(in 2005 dollars per MMBtu* at Henry Hub)*

	Below $4	$4-5.50	$5.50-7	$7-10	$10-15	Above $15	*No estimate*
1 year from now							
5 years from now							
10 years from now							
Beyond 10 years							

* MMBtu = million British thermal units = 1.055 GJ = 1.055 billion joules

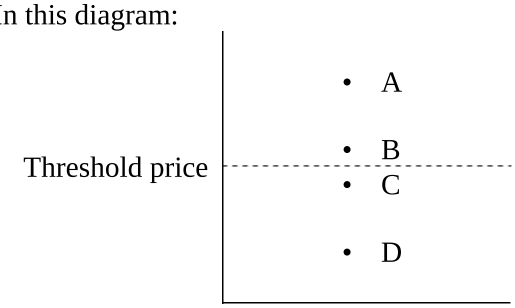
Table 3.2. Survey Questions on Natural Gas Price Preferences

NG 4. Is there some **threshold natural gas price** above which or below which you consider the economics of power generation to be significantly impacted?

___ Yes, there is a threshold **above** which power generation economics are significantly impacted
___ Yes, there is a threshold **below** which power generation economics are significantly impacted
___ Yes, both (two separate threshold prices)
___ No

If "yes, one", go on to 5a; if "yes, both", go on to 5b; if no, go on to 5c.

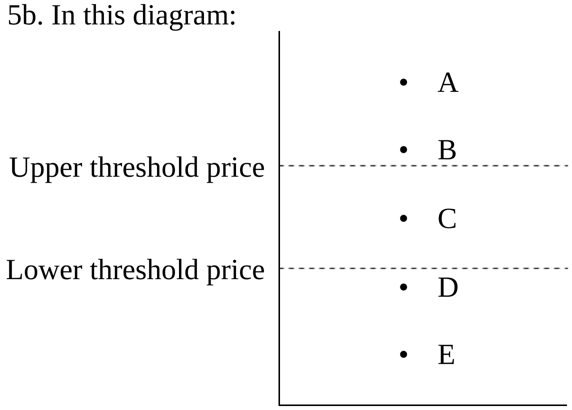
NG 5a. In this diagram:



Would you prefer to see the price of natural gas at:

___ A
___ B
___ C
___ D

NG 5b. In this diagram:



Would you prefer to see the price of natural gas at:

___ A
___ B
___ C
___ D
___ E

NG 5c. Would you generally **prefer** to see **high** or **low** natural gas prices?

___ High
___ Somewhat high
___ Somewhat low
___ Low
___ Indifferent

Table 3.3. Coding for Survey Question NG 2 (Natural Gas Price Expectations)

Code	Code Value Label	Response to Question NG 2
1	Very low	Below $4
2	Low	$4-5.50
3	Somewhat low	$5.50-7
4	Somewhat high	$7-10
5	High	$10-15
6	Very high	Above $15

Table 3.4. Coding for Survey Question NG 5 (Natural Gas Price Preferences)

Code	Code Value Label	Response to Question NG 5				
		NG 5a	*or*	NG 5b	*or*	NG 5c[60]
1	Very low	D		E		Low
2	Low	C		D		Somewhat low
3	Middle			C		
4	High	B		B		Somewhat high
5	Very high	A		A		High

[60] Response “Indifferent” is not categorized, as it does not represent either a high or a low preference (13 respondents).

Table 3.5. Natural Gas Price Expectations vs. Preferences, 2006 (ALL RESPONDENTS)

(a) Expectations 1 year out

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	0	2	0	1	1	**4** (1%)
Low	1	0	6	3	1	**11** (2%)
Somewhat low	30	47	51	52	25	**205** (31%)
Somewhat high	54	84	79	123	33	**373** (56%)
High	9	10	14	23	12	**68** (10%)
Very high	1	4	0	2	3	**10** (1%)
Total	**95** (14%)	**147** (22%)	**150** (22%)	**204** (30%)	**75** (11%)	**671**

P-value for Pearson X^2: **0.090** Cramér's V: **0.1038** Kendall's tau-b (z-stat): **0.0382** (**1.12**)

(b) Expectations 5 years out

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	0	1	1	0	1	**3** (0%)
Low	10	21	23	5	3	**62** (9%)
Somewhat low	29	47	39	45	14	**174** (26%)
Somewhat high	25	47	43	75	31	**221** (33%)
High	26	24	33	60	19	**162** (24%)
Very high	5	4	10	19	6	**44** (7%)
Total	**95** (14%)	**144** (22%)	**149** (22%)	**204** (31%)	**74** (11%)	**666**

P-value for Pearson X^2: **0.000** Cramér's V: **0.1354** z-stat for Kendall's tau-b: **0.1405** (**4.68**)

(c) Expectations 10 years out

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	2	2	2	0	0	**6** (1%)
Low	11	20	27	8	4	**70** (10%)
Somewhat low	21	34	25	26	9	**115** (17%)
Somewhat high	14	29	32	47	17	**139** (21%)
High	25	41	35	67	23	**191** (28%)
Very high	15	11	24	52	18	**120** (18%)
Total	**88** (14%)	**137** (21%)	**145** (23%)	**200** (31%)	**71** (11%)	**641**

P-value for Pearson X^2: **0.000** Cramér's V: **0.1467** z-stat for Kendall's tau-b: **0.1688** (**5.45**)

(d) Expectations beyond 10 years

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	2	3	6	0	0	**11** (2%)
Low	9	14	11	9	3	**46** (7%)
Somewhat low	15	28	33	18	6	**100** (15%)
Somewhat high	11	22	21	31	9	**94** (14%)
High	16	30	24	42	22	**134** (20%)
Very high	24	21	33	69	27	**174** (26%)
Total	**77** (14%)	**118** (21%)	**128** (23%)	**169** (30%)	**67** (12%)	**559**

P-value for Pearson X^2: **0.000** Cramér's V: **0.1505** z-stat for Kendall's tau-b: **0.172** (**5.21**)

Table 3.6. Natural Gas Price Expectations vs. Preferences, 2006 (RESPONDENTS WITH MORE THAN 4 YEARS INVOLVEMENT IN WIND INDUSTRY)

(a) Expectations 1 year out

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	0	1	0	0	0	**1** (1%)
Low	0	0	0	0	0	**0** (0%)
Somewhat low	2	3	6	13	7	**31** (25%)
Somewhat high	3	9	11	39	8	**70** (56%)
High	2	2	2	7	3	**16** (13%)
Very high	0	3	0	2	1	**6** (5%)
Total	**7** (6%)	**18** (15%)	**19** (15%)	**61** (49%)	**19** (15%)	**124**

P-value for Pearson X^2: **0.308** Cramér's V: **0.1919** z-stat for Kendall's tau-b: **-0.428** (**-0.49**)

(b) Expectations 5 years out

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	0	1	0	0	0	**1** (1%)
Low	1	1	0	1	0	**3** (2%)
Somewhat low	2	2	5	12	5	**26** (21%)
Somewhat high	0	7	6	18	9	**40** (32%)
High	3	5	6	22	4	**40** (32%)
Very high	1	2	2	7	1	**13** (10%)
Total	**7** (6%)	**18** (15%)	**19** (15%)	**60** (49%)	**19** (15%)	**123**

P-value for Pearson X^2: **0.506** Cramér's V: **0.1977** z-stat for Kendall's tau-b: **-0.0201** (**-0.26**)

(c) Expectations 10 years out

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	1	1	0	0	0	**2** (2%)
Low	0	0	2	1	0	**3** (2%)
Somewhat low	2	4	1	4	2	**13** (10%)
Somewhat high	0	1	5	18	5	**29** (23%)
High	1	7	6	15	6	**35** (28%)
Very high	2	5	5	22	5	**39** (31%)
Total	**6** (5%)	**18** (15%)	**19** (16%)	**60** (50%)	**18** (15%)	**121**

P-value for Pearson X^2: **0.050** Cramér's V: **0.2547** z-stat for Kendall's tau-b: **0.0656** (**0.82**)

(d) Expectations beyond 10 years

Expectations	Preferences					
	Very low	Low	Middle	High	Very high	Total
Very low	0	1	0	0	0	**1** (1%)
Low	0	0	1	2	0	**3** (2%)
Somewhat low	1	3	3	2	1	**10** (8%)
Somewhat high	0	1	1	11	3	**16** (13%)
High	1	3	3	12	6	**25** (20%)
Very high	0	7	8	25	7	**47** (38%)
Total	**2** (2%)	**15** (15%)	**16** (16%)	**52** (51%)	**17** (17%)	**102**

P-value for Pearson X^2: **0.354** Cramér's V: **0.2309** z-stat for Kendall's tau-b: **0.0609** (**0.72**)

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Appendix A

Categorizing Respondents According to Climate Policy Beliefs

I. Scoring Responses to Individual Questions

Scoring for all questions: 0 represents the most strict policy belief; 4 represents the most lax policy belief.

Policy when?

Scoring for "Policy when?" combines answers to questions CP 1 and CP 2. "No" for CP 1 becomes "Never", and other responses are taken from CP 2. If respondents answered "Yes" for CP 1, but gave no substantive answer for CP 2, they were assigned score 1 (this represents a slightly more conservative score than the average for "Yes" cases, which is 1.5). No opinion was assigned when both CP 1 and CP 2 were marked "No opinion" or when one was marked "No opinion" and the other was blank.

Score	Policy when?	Responses
0	Next 5 years	248
1	Next 6-10 years	298
2	Next 11-20 years	91
3	More than 20 years	12
4	Never	88
	No opinion	24
	Partial answers	
1	Yes	13

Grandfathering?

Scoring for "Grandfathering?" combines answers to questions CP 3 and CP 4. "All plants equally" for CP 3 becomes "No", and other responses are taken from CP 4. If respondents answered "Differentially" for CP 3, but gave no substantive answer for CP 4, they were assigned score 2 (this represents a slightly more conservative score than the average for "Yes" cases, which is 2.5). No opinion was assigned when both CP 1 and CP 2 were marked "No opinion" or when one was marked "No opinion" and the other was blank.

Score	Grandfathering?	Responses
0	No	175
1	Plant online	115
2	Plant under construction	143
3	Plant permitted	146
4	Early development/Planning	26
	No opinion	62
	Partial answers	
2	Yes	18

Who pays?

Scoring for "Who pays?" is done for each case separately: utility-owned plants (question CP 5a); plants under PPA (question CP 5b); and merchant plants (question CP 5c).

Most "Other" responses could be recategorized according to the open-ended response (for example: "energy consumer" was considered to be "ratepayer," and "pass-through with some user subsidies" was considered to be "ratepayer" plus "government"). Those "Other" responses that could not be easily recategorized ("the US economy," "let the market decide," "depends on type of policy," "will depend on terms of PPA") were assigned a conservative score representing a combination of payers.

Since these were mark-all-that-apply questions, the respondent could mark any combination of "plant owner," "offtaker," "ratepayer," and "government." In scoring all the possible combinations, the degree of payment risk for the investment decision-maker was considered:

i) investor only

ii) shared between investor and one other entity

iii) shared among investor and two or more other entities

iv) pass-through to other entitie(s), where entitie(s) include entity one step away from investor

v) pass-through to other entitie(s), where all entitie(s) are at least two steps away from investor

The idea behind the distinction between (iv) and (v) is that pass-throughs to an entity only one step away may not end up being 100%, whereas pass-throughs to entities two or more steps away are more likely to do so (i.e., more buffer between investor and payer).

CP 5a

For utility-owned plants, owner and offtaker are the same entity, so answers with either or both marked are considered equivalent ("utility"). Even though "ratepayer" represents a pass-through, since ratepayers are only one step away from the utility, this was scored more strictly than "government only."

Score	Who pays? (Utility)	Responses
0	Utility only	29
1	Utility + 1	42
2	Utility + 2	30
3	Ratepayer [and Gov]	519
4	Government only	19
	No opinion	19
	Partial answers	
1	Other	3

CP 5c

At the other end of the spectrum, for merchant plants, the plant owner is the only entity of concern surrounding payment risk. Even though "offtaker" represents a pass-through, since offtakers are only one step away from the plant owner, this was scored more strictly than "ratepayers" or "government." Unlike utility-owned plants, since both ratepayers and government are both at least two steps away from the investor, these were scored equally strictly.

Score	Who pays? (Merchant)	Responses
0	Owner only	149
1	Owner + 1	31
2	Owner + 2 or 3	46
3	Offtaker and Ratepayer/Gov	12
4	Ratepayer/Gov only	315
	No opinion	28
	Partial answers	
2	Other	3

CP 5b

For plants under PPA, as with merchant plants, the plant owner is the primary investment decision-maker and therefore the primary entity of concern surrounding payment risk. However, because the plant owner is under contract with the offtaker and depends on this contract to secure financing, payment risk for the offtaker matters, too. Pass-throughs were scored in two ways: i) as with merchant plants, considering ratepayers to be two steps away from the investor (owner); and ii) as with utilities, considering ratepayers to be only one step away from the investor (owner/offtaker). The latter, more conservative, approach is the scoring ultimately adopted.

	(1) liberal		(2) conservative	
Score	Who pays? (PPA)	Responses	Who pays? (PPA)	Responses
0	Owner only	87	Owner only	87
1	Offtaker [and Owner]	90	Offtaker [and Owner]	90
2	Owner [and Offtaker] and Ratepayer/Gov	68	Owner/Offtaker and Ratepayer/Gov	98
3	Offtaker and Ratepayer/Gov	30	Ratepayer [and Gov]	324
4	Ratepayer/Gov only	342	Government only	18
	No opinion	36	No opinion	36
	Partial answers		*Partial answers*	
2	Other	5	Other	5

CP 5a, b, c

			(1) liberal			
Score	Who pays? (Utility)		Who pays? (PPA)		Who pays? (Merchant)	
0	Utility only	29	Owner only	87	Owner only	149
1	Utility + 1	42	Offtaker [and Owner]	90	Owner + 1	31
2	Utility + 2	30	Owner [and Offtaker] and Ratepayer/Gov	68	Owner + 2 or 3	46
3	Ratepayer [and Gov]	519	Offtaker and Ratepayer/Gov	30	Offtaker and Ratepayer/Gov	12
4	Government only	19	Ratepayer/Gov only	342	Ratepayer/Gov only	315
	No opinion	19	No opinion	36	No opinion	28
	Partial answers					
1	Other	3				
2			Other	5	Other	3

Score	Who pays? (Utility)		(2) conservative Who pays? (PPA)		Who pays? (Merchant)	
0	Utility only	29	Owner only	87	Owner only	149
1	Utility + 1	42	Offtaker [and Owner]	90	Owner + 1	31
2	Utility + 2	30	Owner/Offtaker and Ratepayer/Gov	98	Owner + 2 or 3	46
3	Ratepayer [and Gov]	519	Ratepayer [and Gov]	324	Offtaker and Ratepayer/Gov	12
4	Government only	19	Government only	18	Ratepayer/Gov only	315
	No opinion	19	No opinion	36	No opinion	28
	Partial answers					
1	Other	3				
2			Other	5	Other	3

As expected, "investor only" has fewest responses for utility-owned plants, more for plants under PPA, and most for merchant plants, as the ease of passing costs through is perceived to become progressively more difficult. Not as obviously, the most lax score of 4 is far more prevalent for merchant plants than for either utility-owned plants or plants under PPA. This is because overwhelmingly, the majority of respondents marked "ratepayers" only in their responses to all three plant types, but "ratepayer" is considered to represent less payment risk for merchant plants than for the other two. In terms of final scores, this difference in treatment of ratepayers has some effect on the size of the "somewhat strict" subgroup, but negligibly for the "strict" subgroup. For example, it translates into the smallest "somewhat strict" subgroup for merchant plants, despite having the largest "strict" subgroup (and similarly impacts the size of the "somewhat strict" subgroup for the liberal vs. conservative scoring of PPA plants).

II. **Total Scores for Each Type of Plant**

Utility-owned plants

Score	Policy when?	Grandfathering?	Who pays?
0	Next 5 years	No	Utility only
1	Next 6-10 years	Plant online	Utility + 1
2	Next 11-20 years	Plant under construction	Utility + 2
3	More than 20 years	Plant permitted	Ratepayer [and Gov]
4	Never	Early development/Planning	Government only

Category	Score	Count	Total	Percent
Strict	0	3	**39**	5.50%
	1	11		
	2	25		
Somewhat strict	3	77	**77**	10.86%
Lax	4	227	**593**	83.64%
	5	124		
	6	120		
	7	85		
	8	23		
	9	13		
	10	1		
	>10	0		
No opinion	no op	5	5	
Inconclusive		48	48	
Subtotal			**709**	
Total			762	

Plants under PPA (liberal)

Score	Policy when?	Grandfathering?	Who pays?
0	Next 5 years	No	Owner only
1	Next 6-10 years	Plant online	Offtaker [and Owner]
2	Next 11-20 years	Plant under construction	Owner [and Offtaker] and Ratepayer/Gov
3	More than 20 years	Plant permitted	Offtaker and Ratepayer/Gov
4	Never	Early development/Planning	Ratepayer/Gov only

Category	Score	Count	Total	Percent
Strict	0	11	**71**	10.23%
	1	23		
	2	37		
Somewhat strict	3	59	**59**	8.50%
Lax	4	210	**564**	81.27%
	5	106		
	6	91		
	7	80		
	8	55		
	9	15		
	10	7		
	>10	0		
No opinion	no op	6	6	
Inconclusive		62	62	
Subtotal			**694**	
Total			762	

Plants under PPA (conservative)

Score	Policy when?	Grandfathering?	Who pays?
0	Next 5 years	No	Owner only
1	Next 6-10 years	Plant online	Offtaker [and Owner]
2	Next 11-20 years	Plant under construction	Owner/Offtaker and Ratepayer/Gov
3	More than 20 years	Plant permitted	Ratepayer [and Gov]
4	Never	Early development/Planning	Government only

Category	Score	Count	Total	Percent
Strict	0	11	**76**	11.14%
	1	23		
	2	42		
Somewhat strict	3	107	**107**	15.69%
Lax	4	214	**499**	73.17%
	5	111		
	6	85		
	7	65		
	8	16		
	9	6		
	10	2		
	>10	0		
No opinion	no op	6	6	
Inconclusive		74	74	
Subtotal			**682**	
Total			762	

Merchant plants

Score	Policy when?	Grandfathering?	Who pays?
0	Next 5 years	No	Owner only
1	Next 6-10 years	Plant online	Owner + 1
2	Next 11-20 years	Plant under construction	Owner + 2 or 3
3	More than 20 years	Plant permitted	Offtaker and Ratepayer/Gov
4	Never	Early development/Planning	Ratepayer/Gov only

Category	Score	Count	Total	Percent
Strict	0	12	**86**	13.31%
	1	29		
	2	45		
Somewhat strict	3	45	**45**	6.97%
Lax	4	203	**515**	79.72%
	5	98		
	6	80		
	7	67		
	8	46		
	9	13		
	10	8		
	>10	0		
No opinion	no op	6	6	
Inconclusive		110	110	
Subtotal			**646**	
Total			762	

Appendix B

Comparing Climate Policy Belief Subgroups

I. <u>Demographic and Professional Characteristics</u>

The "Strict," "Somewhat strict," and "Lax" subgroups were compared in terms of professional experience and demographic characteristics. The data used in this analysis is based on 14 survey questions:

a. Experience by fuel source (coal, gas, wind, etc.)
b. Years of experience in electric power
c. Experience by sector (public, private, nonprofit)
d. Experience by type of wholesale power market (regulated, bilateral, deregulated)
e. Association with buy vs. sell side of wholesale power markets
f. Region of world where work focuses (U.S., Europe, etc.)
g. Professional positions held over course of career in electric power (utility, developer, lender, etc.)
h. Types of analysis used in work (financial, technical, legal, etc.)
i. Age (20s, 30s, etc.)
j. Gender
k. Region of world for primary education
l. Level of education
m. Field(s) of university education
n. Political views

With the exception of years of experience, I converted all data to dummy variables (extensive experience with coal: yes/no; extensive experience with deregulated markets: yes/no; graduate degree in economics: yes/no; etc.). In all, this generated 88 binary variables and one continuous variable (years of experience) for a total of 89 independent variables.

Regressing "subgroup" on these 89 variables (which would be done using a multinomial logit model, since my dependent variable is categorical, not continuous) is not suitable, because I have incomplete data. Although most respondents answered most questions, most also left some answers blank or partially blank (which they were free to do, since the survey did not require responses). Furthermore, there is no consistent pattern to which questions were left blank. Solving the incomplete data problem for this type of regression involves one of three suboptimal approaches (or a combination of the three): 1) dropping incomplete observations; 2) reducing the number of independent variables to include only "important" variables (arguably, primary education in Australia or graduate degree in humanities (2 and 13 respondents in my entire dataset, respectively) could be dropped – but where does one draw the line?); and 3) assuming that no response equals a "no" response (reasonable in some cases but questionable in others).

Instead, I chose two alternative approaches to multinomial logit regression. Since my goal in this case is to *compare* the three subgroups (are they different?) rather than to *explain* people's beliefs (the usual purpose of running a multinomial logit model), this made sense, especially considering the problems inherent in trying to run one big regression on incomplete data. My data *is* sufficiently complete, however, to treat the 89 variables separately (and then combine the results).

II. <u>Test of Means</u>

First I conducted a simple test of means comparing the strict and somewhat strict subgroups with the lax subgroup. Since 88 of my variables are binary, I used the binomial distribution (years of experience is the one variable not included in this test). For each type of power plant (utility-owned, PPA, merchant), I tested each variable for each subgroup comparison (= 88 variables x 2 subgroup comparisons x 3 plant types). Tables B-1 to B-3 show the significant variables (p-value < 0.05) for each type of power plant. Table B-4 shows complete results for all variables: the percentage of respondents in each subgroup answering yes and the p-values for each comparison.

This approach tends to overemphasize differences among the subgroups, since each variable for each comparison is treated independently. Still, it is a useful first cut.

Table B-1. Test of Means: Significant Variables for Utility-Owned Plants

Question		Strict vs. Lax		Somewhat Strict vs. Lax	
		More likely	Sig level	More likely	Sig level
YP 4	Experience by type of wholesale market				
	Fully regulated market			Somewhat	5%
	Bilateral-multiple buyers	Strict	1%		
	Fully deregulated market	Strict	5%		
YP 6	Work focus by world region				
	Europe - non-EU	Strict	5%		
YP 7	Professional positions held				
	Plant ownership/active equity			Lax	5%
YP 8	Work focus by type of analysis				
	Financial			Lax	5%
	Economic/market analysis	Strict	5%		
YD 1	Age				
	20-29			Lax	1%
	40-49			Lax	5%
	50-59			Somewhat	1%
YD 2	Gender				
	Male			Somewhat	5%
YD 3	Primary education by world region				
	Other America [non U.S.]			Lax	5%
YD 5	Graduate degree by field				
	Public Policy/Social Science	Strict	5%		
YD 6	Political views				
	Left	Strict	5%		
	Right	Lax	5%		
	All right	Lax	5%		

Table B-2. Test of Means: Significant Variables for Plants Under PPA

Question		Strict vs. Lax		Somewhat Strict vs. Lax	
		More likely	Sig level	More likely	Sig level
FS 3	Experience by fuel source				
	Natural gas	Strict	5%		
	Wind			Somewhat	5%
YP 3	Experience by sector				
	Private sector	Strict	5%		
YP 4	Experience by type of wholesale market				
	Fully regulated market	Strict	0.1%		
	Bilateral-single buyer	Strict	5%		
	Bilateral-multiple buyers	Strict	0.1%		
	Fully deregulated market	Strict	0.1%		
YP 6	Work focus by world region				
	Europe - non-EU	Strict	1%		
	Asia			Somewhat	5%
YP 7	Professional positions held				
	Passive equity	Strict	5%	Somewhat	1%
	Equipment supplier	Lax	5%		
	Construction/transportation	Lax	5%		
	Academia/research			Lax	5%
YP 8	Work focus by type of analysis				
	Financial	Strict	5%		
	Economic/market analysis	Strict	1%		
	Technical/engineering	Lax	5%		
YD 1	Age				
	50-59			Somewhat	5%
YD 2	Gender				
	Male	Strict	5%		

Table B-3. Test of Means: Significant Variables for Merchant Plants

Question		Strict vs. Lax		Somewhat Strict vs. Lax	
		More likely	Sig level	More likely	Sig level
FS 3	Experience by fuel source				
	Natural gas	Strict	0.1%		
	Wind			Lax	5%
YP 3	Experience by sector				
	Public sector	Strict	5%		
YP 4	Experience by type of wholesale market				
	Fully regulated market	Strict	1%	Somewhat	5%
	Bilateral-multiple buyers			Somewhat	5%
	Fully deregulated market	Strict	5%		
YP 6	Work focus by world region				
	Europe - non-EU	Strict	5%		
YP 7	Professional positions held				
	Plant O&M	Lax	5%	Lax	5%
	Passive equity	Strict	5%	Somewhat	1%
	Integrated utility			Somewhat	5%
	Equipment supplier	Lax	1%	Lax	1%
	Construction/transportation	Lax	5%	Lax	1%
	Financial analyst	Strict	5%		
YP 8	Work focus by type of analysis				
	Economic/market analysis	Strict	5%		
	Technical/engineering	Lax	1%	Lax	1%
	Legal	Strict	5%		
	Regulatory/legislative	Strict	5%		
YD 3	Primary education by world region				
	Other America [non U.S.]	Lax	5%		
YD 5	Undergraduate degree by field				
	Economics/Business			Somewhat	1%
	Natural Science/Engineering			Lax	0.1%
YD 5	Graduate degree by field				
	Natural Science/Engineering	Lax	5%		
	Public Policy/Social science	Strict	0.1%		
	Humanities			Somewhat	5%
YD 6	Political views				
	Slightly left			Somewhat	5%
	All left	Strict	5%		
	All right	Lax	5%		

Table B-4. Test of Means: All Variables for All Plants

Question	Answer	Utility-owned Plants			Plants under PPA			Merchant Plants			P-Value: Strict vs. Lax			P-Value: Somewhat Strict vs. Lax		
		Strict	Some	Lax	Strict	Some	Lax	Strict	Some	Lax	Utility	PPA	Merch	Utility	PPA	Merch
FS 3	How much professional experience do you have with the following fuel sources? [percent responding "Extensive"]															
	Respondents	*39*	*76*	*575*	*75*	*105*	*483*	*85*	*45*	*500*						
	Coal	31%	33%	30%	35%	33%	29%	34%	24%	30%	0.514	0.179	0.236	0.324	0.203	0.262
	Natural gas	49%	36%	40%	49%	41%	38%	55%	38%	37%	0.171	0.015	0.001	0.250	0.276	0.535
	Petroleum	21%	17%	17%	15%	19%	16%	18%	18%	17%	0.311	0.419	0.462	0.493	0.264	0.492
	Nuclear	13%	17%	15%	19%	13%	15%	16%	7%	15%	0.462	0.237	0.397	0.346	0.365	0.078
	Hydro	21%	12%	16%	17%	17%	16%	21%	7%	15%	0.290	0.399	0.096	0.194	0.386	0.069
	Wind	36%	39%	35%	29%	46%	34%	38%	24%	38%	0.389	0.214	0.537	0.249	0.011	0.042
	Solar	13%	7%	8%	9%	10%	7%	7%	13%	8%	0.187	0.326	0.530	0.448	0.256	0.124
	Geothermal	10%	3%	6%	9%	7%	5%	8%	7%	5%	0.170	0.055	0.097	0.198	0.203	0.343
	Biomass	13%	4%	10%	11%	10%	9%	13%	9%	9%	0.316	0.327	0.126	0.060	0.430	0.567
YP 1	How many years of work experience do you have involving the electric power sector?															
	Respondents	*36*	*70*	*533*	*68*	*100*	*447*	*81*	*42*	*455*						
	Years (mean)	16.3	17.0	15.4	16.5	17.3	15.3	16.0	15.7	15.5						
YP 3	To what extent is your experience with the electric power sector associated with theÉ [percent responding "Very much"]															
	Respondents	*38*	*69*	*528*	*69*	*100*	*442*	*80*	*41*	*454*						
	Private sector	71%	80%	78%	86%	77%	78%	83%	78%	78%	0.181	0.049	0.229	0.465	0.416	0.462
	Public sector	32%	25%	25%	29%	25%	24%	34%	22%	25%	0.223	0.200	0.043	0.537	0.444	0.424
	Nonprofit/NGO sector	11%	7%	8%	6%	9%	8%	11%	10%	7%	0.358	0.354	0.110	0.527	0.396	0.327
YP 4	How much experience do you have with the following types of wholesale power markets? [percent responding "Extensive"]															
	Respondents	*36*	*66*	*506*	*67*	*94*	*428*	*76*	*40*	*437*						
	Fully regulated market	31%	47%	35%	57%	38%	32%	47%	48%	31%	0.376	0.000	0.003	0.025	0.098	0.024
	Bilateral-single buyer	19%	27%	26%	33%	29%	24%	29%	35%	23%	0.258	0.031	0.154	0.430	0.147	0.064
	Bilateral-multiple buyers	53%	32%	31%	52%	33%	29%	38%	45%	29%	0.005	0.000	0.060	0.463	0.227	0.025
	Fully deregulated market	47%	29%	31%	55%	34%	28%	41%	40%	29%	0.034	0.000	0.017	0.377	0.081	0.086
YP 5	With which side of the wholesale power business are you personally most closely associated?															
	Respondents	*38*	*73*	*539*	*72*	*102*	*453*	*82*	*42*	*464*						
	Buy side	13%	21%	13%	19%	16%	13%	13%	14%	14%	0.573	0.063	0.517	0.052	0.209	0.546
	Sell side	26%	27%	34%	33%	32%	33%	33%	36%	33%	0.207	0.496	0.468	0.144	0.520	0.300
	Both equally	29%	27%	25%	31%	24%	26%	29%	26%	25%	0.347	0.215	0.206	0.364	0.344	0.475
	Not applicable	32%	25%	28%	17%	28%	29%	24%	24%	28%	0.360	0.012	0.275	0.323	0.506	0.340

Table B-4. Test of Means: All Variables for All Plants (cont.)

Question	Answer	Utility-owned Plants			Plants under PPA			Merchant Plants			P-Value: Strict vs. Lax			P-Value: Somewhat Strict vs. Lax		
		Strict	Some	Lax	Strict	Some	Lax	Strict	Some	Lax	Utility	PPA	Merch	Utility	PPA	Merch
YP 6	On which regions of the world has your work with the electric power sector focused? (Mark all that apply)															
	Respondents	*38*	*73*	*539*	*72*	*102*	*453*	*82*	*42*	*464*						
	U.S.	95%	99%	97%	99%	98%	97%	99%	98%	97%	0.259	0.104	0.288	0.431	0.386	0.637
	Other America	42%	25%	31%	33%	26%	31%	28%	29%	31%	0.098	0.385	0.356	0.148	0.182	0.462
	Europe - EU	37%	25%	25%	31%	27%	24%	29%	24%	25%	0.065	0.136	0.220	0.546	0.260	0.512
	Europe - non-EU	18%	10%	6%	15%	9%	6%	13%	2%	7%	0.010	0.003	0.020	0.195	0.155	0.220
	Asia	24%	14%	18%	19%	25%	16%	22%	21%	17%	0.216	0.264	0.162	0.239	0.019	0.292
	Australia	13%	10%	9%	10%	12%	9%	15%	5%	9%	0.247	0.427	0.065	0.477	0.167	0.255
	Africa	11%	5%	4%	6%	7%	4%	6%	2%	5%	0.078	0.321	0.314	0.379	0.112	0.428
YP 7	Over the course of your professional experience involving the electric power sector, what ÒhatsÓ have you worn? (Mark all that apply															
	Respondents	*38*	*73*	*539*	*72*	*102*	*453*	*82*	*42*	*464*						
	Plant development	34%	37%	28%	28%	33%	29%	33%	24%	30%	0.255	0.458	0.265	0.065	0.204	0.227
	Plant O&M	26%	15%	17%	13%	16%	19%	11%	7%	21%	0.113	0.093	0.014	0.363	0.222	0.015
	Plant ownership/active equity	21%	10%	18%	22%	13%	17%	21%	12%	18%	0.374	0.166	0.274	0.036	0.142	0.224
	Passive equity	13%	15%	12%	19%	19%	10%	17%	24%	10%	0.491	0.013	0.036	0.262	0.007	0.008
	Project lending	8%	10%	16%	14%	13%	15%	10%	21%	15%	0.130	0.475	0.112	0.093	0.317	0.173
	Insurance	0%	0%	2%	1%	0%	2%	0%	2%	2%	0.425	0.526	0.140	0.193	0.103	0.635
	Power marketer	26%	19%	19%	24%	21%	19%	16%	26%	19%	0.192	0.209	0.272	0.545	0.400	0.168
	Integrated utility	24%	32%	24%	24%	28%	25%	27%	36%	24%	0.563	0.494	0.307	0.093	0.208	0.028
	T&D	18%	8%	12%	14%	12%	12%	10%	19%	12%	0.149	0.354	0.352	0.236	0.557	0.118
	Electric retailer	3%	14%	9%	11%	13%	8%	6%	14%	9%	0.136	0.233	0.258	0.113	0.072	0.163
	Grid operator	8%	1%	4%	6%	3%	3%	1%	2%	4%	0.149	0.216	0.168	0.267	0.562	0.512
	Fuel supplier	8%	7%	8%	7%	9%	7%	9%	7%	7%	0.577	0.571	0.336	0.492	0.325	0.561
	Equipment supplier	5%	19%	13%	6%	12%	14%	6%	2%	16%	0.119	0.017	0.006	0.078	0.281	0.006
	Construction/transportation	3%	8%	12%	4%	8%	12%	5%	0%	13%	0.057	0.017	0.011	0.251	0.103	0.002
	Legal services	3%	10%	6%	6%	6%	6%	5%	7%	6%	0.332	0.508	0.382	0.142	0.519	0.516
	Consultant	39%	32%	38%	32%	41%	37%	33%	29%	39%	0.469	0.219	0.145	0.168	0.225	0.103
	Financial analyst	16%	11%	19%	25%	14%	18%	26%	26%	16%	0.415	0.074	0.017	0.054	0.182	0.061
	Rating agency	3%	3%	3%	0%	5%	3%	2%	7%	3%	0.632	0.145	0.629	0.569	0.135	0.094
	Government agency	18%	12%	14%	14%	12%	14%	16%	7%	15%	0.272	0.539	0.426	0.428	0.281	0.118
	Media/reporter	8%	4%	4%	7%	3%	4%	4%	5%	3%	0.166	0.111	0.497	0.512	0.512	0.396
	Academia/research	5%	11%	15%	8%	9%	15%	11%	14%	15%	0.061	0.058	0.205	0.213	0.036	0.564
	Advocacy	5%	15%	9%	8%	10%	10%	10%	10%	9%	0.316	0.443	0.467	0.065	0.536	0.535

Table B-4. Test of Means: All Variables for All Plants (cont.)

Question	Answer	Utility-owned Plants			Plants under PPA			Merchant Plants			P-Value: Strict vs. Lax			P-Value: Somewhat Strict vs. Lax		
		Strict	Some	Lax	Strict	Some	Lax	Strict	Some	Lax	Utility	PPA	Merch	Utility	PPA	Merch
YP 8	What types of analysis does your own work involve? (Please indicate any you spend at least 25% of your time doing)															
	Respondents	*38*	*73*	*539*	*72*	*102*	*453*	*82*	*42*	*464*						
	Financial	53%	47%	60%	67%	60%	56%	62%	69%	56%	0.225	0.048	0.175	0.014	0.270	0.067
	Economic/market analysis	76%	59%	60%	76%	60%	58%	70%	62%	59%	0.011	0.001	0.028	0.473	0.418	0.395
	Technical/engineering	42%	30%	35%	25%	32%	37%	27%	19%	40%	0.220	0.019	0.010	0.235	0.176	0.003
	Environmental	37%	29%	24%	31%	27%	25%	29%	31%	25%	0.055	0.146	0.193	0.212	0.278	0.214
	Legal	18%	22%	18%	22%	20%	18%	28%	19%	17%	0.515	0.192	0.010	0.206	0.341	0.440
	Regulatory/legislative	39%	44%	39%	40%	45%	37%	50%	29%	38%	0.526	0.328	0.016	0.220	0.059	0.143
YD 1	How old are you?															
	Respondents	*39*	*69*	*550*	*70*	*99*	*464*	*80*	*43*	*474*						
	Under 20	0%	0%	0%	0%	0%	0%	0%	0%	0%	1.000	1.000	1.000	1.000	1.000	1.000
	20-29	8%	0%	7%	4%	6%	7%	9%	9%	6%	0.547	0.280	0.171	0.005	0.471	0.228
	30-39	18%	16%	19%	23%	15%	20%	18%	19%	20%	0.503	0.322	0.378	0.189	0.136	0.525
	40-49	33%	25%	35%	27%	29%	34%	34%	37%	34%	0.492	0.136	0.526	0.045	0.187	0.358
	50-59	31%	46%	30%	37%	39%	30%	28%	30%	32%	0.498	0.128	0.204	0.001	0.032	0.447
	60 or over	10%	13%	9%	9%	10%	9%	13%	5%	9%	0.446	0.575	0.152	0.145	0.378	0.269
YD 2	Are you:															
	Respondents	*39*	*68*	*546*	*70*	*98*	*460*	*80*	*43*	*469*						
	Male	92%	93%	86%	93%	91%	87%	86%	91%	88%	0.086	0.036	0.380	0.038	0.148	0.388
	Female	8%	7%	14%	7%	9%	13%	14%	9%	12%	0.207	0.084	0.380	0.087	0.148	0.388
YD 3	Where did you receive most of your primary and secondary education?															
	Respondents	*38*	*69*	*548*	*70*	*99*	*461*	*80*	*43*	*472*						
	U.S.	82%	91%	87%	90%	90%	86%	94%	81%	88%	0.226	0.141	0.055	0.182	0.116	0.162
	Other America	11%	0%	5%	4%	3%	5%	0%	7%	4%	0.104	0.536	0.026	0.035	0.267	0.299
	Europe - EU	3%	4%	6%	3%	4%	6%	3%	7%	6%	0.341	0.194	0.176	0.422	0.275	0.425
	Europe - non-EU	0%	1%	0%	1%	0%	0%	1%	0%	0%	0.870	0.141	0.156	0.223	0.807	0.913
	Asia	5%	3%	1%	1%	3%	2%	3%	5%	1%	0.106	0.657	0.333	0.267	0.247	0.134
	Australia	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.870	0.859	0.712	0.777	0.807	0.833
	Africa	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.870	0.738	0.712	0.777	0.650	0.833

Table B-4. Test of Means: All Variables for All Plants (cont.)

Question	Answer	Utility-owned Plants			Plants under PPA			Merchant Plants			P-Value: Strict vs. Lax			P-Value: Somewhat Strict vs. Lax		
		Strict	Some	Lax	Strict	Some	Lax	Strict	Some	Lax	Utility	PPA	Merch	Utility	PPA	Merch
YD 4	Do you hold a university degree?															
	Respondents	*39*	*68*	*550*	*70*	*98*	*464*	*80*	*43*	*473*						
	Yes	95%	100%	97%	97%	97%	97%	98%	98%	97%	0.392	0.605	0.532	0.092	0.609	0.602
	No, pursuing	0%	0%	1%	0%	0%	1%	0%	0%	1%	0.700	0.468	0.427	0.537	0.346	0.633
	No	5%	0%	3%	3%	3%	2%	3%	2%	2%	0.262	0.447	0.506	0.173	0.354	0.601
YD 5	In which fields? (Mark all that apply including degrees currently pursuing)															
	Undergraduate															
	Respondents	*37*	*68*	*536*	*68*	*95*	*454*	*78*	*42*	*463*						
	Economics/Business	27%	34%	33%	40%	35%	31%	32%	52%	32%	0.263	0.094	0.503	0.516	0.282	0.004
	Natural Science/Engineering	51%	47%	46%	40%	47%	47%	42%	24%	49%	0.291	0.126	0.150	0.446	0.539	0.001
	Public Policy/Social science	19%	13%	12%	13%	16%	11%	14%	7%	12%	0.058	0.354	0.299	0.387	0.110	0.262
	Law	0%	0%	1%	1%	0%	1%	3%	0%	1%	0.707	0.452	0.091	0.529	0.431	0.761
	Humanities	11%	9%	9%	12%	7%	9%	9%	14%	8%	0.394	0.248	0.461	0.534	0.258	0.127
	Graduate/Postgraduate															
	Respondents	*37*	*68*	*536*	*68*	*95*	*454*	*78*	*42*	*463*						
	Economics/Business	57%	53%	50%	56%	46%	52%	53%	62%	49%	0.256	0.276	0.291	0.358	0.180	0.061
	Natural Science/Engineering	16%	21%	23%	16%	19%	24%	15%	17%	25%	0.223	0.081	0.034	0.384	0.150	0.154
	Public Policy/Social science	19%	15%	10%	16%	13%	10%	22%	7%	10%	0.031	0.062	0.001	0.156	0.208	0.425
	Law	3%	9%	7%	4%	7%	8%	5%	7%	8%	0.239	0.203	0.244	0.374	0.365	0.565
	Humanities	5%	1%	2%	1%	1%	2%	1%	7%	2%	0.151	0.507	0.551	0.637	0.327	0.048
YD 6	In political matters people talk of Òthe leftÓ and Òthe rightÓ. How would you place your views on this scale?															
	Respondents	*39*	*69*	*540*	*67*	*98*	*460*	*78*	*43*	*467*						
	Very left	3%	1%	3%	1%	3%	3%	3%	2%	3%	0.678	0.391	0.585	0.390	0.576	0.629
	Left	31%	13%	15%	19%	14%	16%	21%	12%	15%	0.011	0.275	0.139	0.385	0.375	0.331
	Slightly left	21%	30%	25%	24%	27%	25%	31%	35%	23%	0.341	0.514	0.062	0.172	0.362	0.047
	Slightly right	26%	32%	26%	30%	28%	26%	26%	33%	28%	0.567	0.268	0.403	0.152	0.389	0.284
	Right	8%	16%	23%	18%	18%	22%	17%	12%	22%	0.013	0.249	0.145	0.062	0.219	0.061
	Very right	0%	1%	4%	3%	3%	4%	1%	2%	4%	0.183	0.473	0.169	0.202	0.420	0.473
	No opinion	13%	6%	4%	4%	7%	4%	3%	5%	5%	0.024	0.527	0.255	0.339	0.111	0.632
	All left	54%	45%	43%	45%	44%	44%	54%	49%	41%	0.113	0.476	0.016	0.416	0.524	0.190
	All right	33%	49%	53%	51%	49%	52%	44%	47%	54%	0.011	0.455	0.043	0.321	0.297	0.204

F-test

An alternative approach is to conduct a series of F-tests. This approach still analyzes each *variable* separately (and then integrates them at the end), but it compares the *subgroups* jointly rather than independently. It looks at whether the strict and somewhat strict subgroups add explanatory power to a trait above and beyond the level present in the lax subgroup. The regression equation for each demographic variable y is as follows:

$$y_i = \beta_0 + \beta_1 \text{Strict}_i + \beta_2 \text{Somewhat Strict}_i + \varepsilon_i$$

where the constant β_0 represents the mean of the trait for the lax subgroup and i is the observation number. For each of the 89 variables (this time including years of experience), I tested the joint hypothesis that $\beta_1 = \beta_2 = 0$ (in other words, that the strict and somewhat strict subgroups add no additional explanatory power), resulting in (up to) 89 F-stats with corresponding p-values.

For some variables, there was insufficient variability in the subgroups (i.e., all respondents in either the strict or somewhat strict subgroup answered the same way on a question) to conduct a test with both restrictions. This generally happened for questions with very few respondents across the entire dataset answering yes. The average number of respondents (totaled across all subgroups) for these questions was 13, or 2% of the total population (see tables B-5, B-7 and B-9). The regressions for these variables were dropped, yielding 78 results for utility-owned plants, 81 for plants under PPA, and 80 for merchant plants.

Tables B-6, B-8 and B-10 show the significant variables (p-value < 0.05) for each type of power plant. In general, there is some similarity between these results and the test of means results. The main difference is that only the more significant test of means results showed up as significant under the F-test, whereas less significant variables did not come up as significant under the F-test. This is not surprising, since the test of means approach was expected to overemphasize differences among the subgroups.

Overlap in the F-test results across the three types of plants is limited. There is a tendency for the Strict subgroup to have extensive experience in various types of electricity markets, and equipment supplier shows up as a significant professional position in all cases, albeit more likely for the Somewhat Strict subgroup in the case of utility-owned plants and for the Lax subgroup in the case of PPA and merchant plants. Lax respondents are more likely to have construction/ transportation experience in the case of utility and PPA plants and passive equity experience in the case of PPA and merchant plants. There is a tendency in the case of PPA and merchant plants for the Strict and Somewhat Strict subgroups to have an economics focus and for the Lax subgroup to have a technical/engineering focus, whether in terms of university degree or type of analysis used in work. Political views play a role for utility-owned plants: the Lax subgroup is more likely to be on the right of the political spectrum.

When testing this many variables, it is almost inevitable that some will turn out to be significant just by chance. The question is whether the number of significant variables is significant. I used the p-values (78 for utility-owned plants, 81 for PPA plants, 80 for merchant plants) to graph a probability density function (PDF) and cumulative distribution function (CDF) for each type of plant (see figures B-1 through B-3). If the subgroups are similar, one should expect to see a fairly uniform distribution for the PDF and a roughly 45-degree line for the CDF. This is what we see for utility-owned plants and PPA plants; less so for merchant plants. We are most interested in the results for utility plants and least interested in those for merchant plants, since new coal development is not merchant and mostly utility-owned. Therefore I conclude that the Strict, Somewhat Strict, and Lax subgroups are fairly similar in terms of their professional experience and demographic characteristics.

Table B-5. F-Test: Dropped Regressions for Utility-Owned Plants

Question		Yes Responses				Responded to Question
		Strict	Somewhat	Lax	Total (%)	
YP 7	Professional positions held					622
	Insurance	0	0	12	12 (2%)	
YD 1	Age					658
	20-29	3	0	40	43 (7%)	
YD 3	Primary education by world region					655
	Other America [non U.S.]	4	0	26	30 (5%)	
	Europe - non-EU	0	1	2	3 (0.5%)	
	Australia	0	0	2	2 (0.3%)	
	Africa	0	0	2	2 (0.3%)	
YD 4	University degree					657
	None	2	0	19	21 (3%)	
YD 5	Undergraduate degree by field					641
	Law	0	0	5	5 (1%)	
YD 6	Political views					648
	Very right	0	1	23	24 (4%)	

Table B-6. F-Test: Significant Variables for Utility-Owned Plants

Question		Yes Responses				Responded to Question
		Most likely	P-Value	Sig level	Total (%)	
YP 4	Experience by type of wholesale market					608
	Bilateral-multiple buyers	Strict	0.0367	5%	195 (32%)	
YP 7	Professional positions held					622
	Electric retailer	Somewhat	0.0331	5%	59 (9%)	
	Equipment supplier	Somewhat	0.0429	5%	85 (14%)	
	Construction/transportation	Lax	0.0123	5%	69 (11%)	
	Academia/research	Lax	0.0471	5%	91 (15%)	
YD 1	Age					658
	50-59	Somewhat	0.0307	5%	207 (31%)	
YD 6	Political views					648
	All right	Lax	0.0454	5%	332 (51%)	

Table B-7. F-Test: Dropped Regressions for Plants Under PPA

Question		Yes Responses				Responded to Question
		Strict	Somewhat	Lax	Total (%)	
YP 7	Professional positions held					601
	Insurance	1	0	10	11 (2%)	
	Rating agency	0	5	12	17 (3%)	
YD 3	Primary education by world region					630
	Europe - non-EU	1	0	1	2 (0.3%)	
	Australia	0	0	1	1 (0.2%)	
	Africa	0	0	2	2 (0.3%)	
YD 5	Undergraduate degree by field					618
	Law	1	0	4	5 (1%)	

Table B-8. F-Test: Significant Variables for Plants Under PPA

Question		Yes Responses				Responded to Question
		Most likely	P-Value	Sig level	Total (%)	
YP 4	Experience by type of wholesale market					589
	Fully regulated market	Strict	0.0002	0.1%	209 (35%)	
	Bilateral-multiple buyers	Strict	0.0012	1%	190 (32%)	
	Fully deregulated market	Strict	0.0002	0.1%	189 (32%)	
YP 7	Professional positions held					601
	Passive equity	Strict	0.0220	5%	79 (13%)	
	Equipment supplier	Lax	0.0308	5%	81 (13%)	
	Construction/transportation	Lax	0.0168	5%	67 (11%)	
YP 8	Work focus by type of analysis					618
	Economic/market analysis	Strict	0.0071	1%	380 (61%)	

Table B-9. F-Test: Dropped Regressions for Merchant Plants

Question		Strict	Somewhat	Lax	Total (%)	Responded to Question
		Yes Responses				
YP 7	Professional positions held					565
	Insurance	0	1	11	12 (2%)	
	Construction/transportation	4	0	62	66 (12%)	
YD 3	Primary education by world region					595
	Other America [non U.S.]	0	3	21	24 (4%)	
	Europe - non-EU	1	0	1	2 (0.3%)	
	Australia	0	0	2	2 (0.3%)	
	Africa	0	0	2	2 (0.3%)	
YD 5	Undergraduate degree by field					583
	Law	2	0	3	5 (1%)	

Table B-10. F-Test: Significant Variables for Merchant Plants

Question		Most likely	P-Value	Sig level	Total (%)	Responded to Question
		Yes Responses				
FS 3	Experience by fuel source					630
	Natural gas	Strict	0.0104	5%	251 (40%)	
	Hydro	Strict	0.0279	5%	98 (16%)	
YP 4	Experience by type of wholesale market					553
	Fully regulated market	Somewhat	0.0096	1%	192 (35%)	
YP 6	Work focus by world region					593
	Europe - non-EU	Strict	0.0417	5%	43 (7%)	
YP 7	Professional positions held					565
	Plant O&M	Lax	0.0012	1%	109 (19%)	
	Passive equity	Somewhat	0.0434	5%	71 (13%)	
	Equipment supplier	Lax	0.0000	0.1%	80 (14%)	
YP 8	Work focus by type of analysis					578
	Technical/engineering	Lax	0.0014	1%	215 (37%)	
	Regulatory/legislative	Strict	0.0278	5%	228 (39%)	
YD 5	Undergraduate degree by field					583
	Economics/Business	Somewhat	0.0344	5%	193 (33%)	
	Natural Sci/Engineering	Lax	0.0015	1%	269 (46%)	
YD 5	Graduate degree by field					583
	Public Policy/Social Sci	Strict	0.0313	5%	64 (11%)	

Appendix C

Measures of Association for Natural Gas Price Expectations vs. Preferences

Table C-1. Measures of Association for Natural Gas Price Expectations vs. Preferences, 2006 (All respondents). This table gives measures of association for natural gas price expectations and preferences for all respondents. This is done for two different scales for expectations (6-point and 5-point) and four different scales for preferences (5-point, 4-point, 3-point, 2-point).

Key for test statistics:

Pearson chi2	Cramér's V	tau-b
P-value	**Cramér's V**	**z**
Pearson chi2		tau-b
df		ASE

	a) Expect 6 vs Pref 5			b) Expect 5 vs Pref 5		
	Pearson chi2	Cramér's V	tau-b	Pearson chi2	Cramér's V	tau-b
1 year Expectation	**0.090**	**0.1038**	**- 1.12**	**0.186**	**0.0881**	**1.12**
	28.90		0.0382	20.81		0.0382
	20		0.034	16		0.034
5 years Expectation	**0.000**	**0.1354**	**4.68**	**0.000**	**0.1316**	**4.70**
	48.81		0.1405	46.11		0.1409
	20		0.03	16		0.03
10 years Expectation	**0.000**	**0.1467**	**5.45**	**0.000**	**0.1444**	**5.42**
	55.21		0.1688	53.44		0.1681
	20		0.031	16		0.031
> 10 years Expectation	**0.000**	**0.1505**	**5.21**	**0.000**	**0.1427**	**5.21**
	50.68		0.172	45.54		0.1719
	20		0.033	16		0.033

	c) Expect 6 vs Pref 4			d) Expect 5 vs Pref 4		
	Pearson chi2	Cramér's V	tau-b	Pearson chi2	Cramér's V	tau-b
1 year	**0.358**	**0.1023**	**- 0.94**	**0.357**	**0.0918**	**0.94**
Expectation	16.36		0.0375	13.17		0.0375
	15		0.04	12		0.04
5 years	**0.000**	**0.1669**	**3.95**	**0.000**	**0.1607**	**3.96**
Expectation	43.18		0.146	40.03		0.1464
	15		0.037	12		0.037
10 years	**0.000**	**0.1736**	**4.84**	**0.000**	**0.1701**	**4.83**
Expectation	44.82		0.1791	43.04		0.1786
	15		0.037	12		0.037
> 10 years	**0.001**	**0.1722**	**4.66**	**0.000**	**0.1674**	**4.64**
Expectation	38.32		0.1816	36.24		0.181
	15		0.039	12		0.039

	e) Expect 6 vs Pref 3			f) Expect 5 vs Pref 3		
	Pearson chi2	Cramér's V	tau-b	Pearson chi2	Cramér's V	tau-b
1 year	**0.092**	**0.1102**	**- 1.32**	**0.208**	**0.0901**	**1.32**
Expectation	16.28		0.0449	10.89		0.0448
	10		0.034	8		0.034
5 years	**0.000**	**0.1727**	**5.50**	**0.000**	**0.1716**	**5.51**
Expectation	39.75		0.1704	39.22		0.1708
	10		0.031	8		0.031
10 years	**0.000**	**0.2002**	**6.25**	**0.000**	**0.1977**	**6.24**
Expectation	51.37		0.1939	50.13		0.1933
	10		0.031	8		0.031
> 10 years	**0.000**	**0.1995**	**5.71**	**0.000**	**0.1877**	**5.71**
Expectation	44.49		0.1941	39.37		0.1941
	10		0.034	8		0.034

	a) Expect 6 vs Pref 5			b) Expect 5 vs Pref 5		
	Pearson chi2	Cramér's V	tau-b	Pearson chi2	Cramér's V	tau-b
1 year Expectation	**0.090**	**0.1038**	**- 1.12**	**0.186**	**0.0881**	**1.12**
	28.90		0.0382	20.81		0.0382
	20		0.034	16		0.034
5 years Expectation	**0.000**	**0.1354**	**4.68**	**0.000**	**0.1316**	**4.70**
	48.81		0.1405	46.11		0.1409
	20		0.03	16		0.03
10 years Expectation	**0.000**	**0.1467**	**5.45**	**0.000**	**0.1444**	**5.42**
	55.21		0.1688	53.44		0.1681
	20		0.031	16		0.031
> 10 years Expectation	**0.000**	**0.1505**	**5.21**	**0.000**	**0.1427**	**5.21**
	50.68		0.172	45.54		0.1719
	20		0.033	16		0.033

Table C-2. Measures of Association for Natural Gas Price Expectations vs. Preferences, 2006 (Respondents with more than 4 years of involvement in wind industry). This table gives measures of association for natural gas price expectations and preferences for respondents who have been involved with the wind industry since before 2002. This is done for two different scales: a) expectations (6-point) vs. preferences (5-point); and b) expectations (5-point) and preferences (3-point).

Key for test statistics:

Pearson chi2	Cramér's V	tau-b
P-value	**Cramér's V**	**z**
Pearson chi2		tau-b
df		ASE

	a) Expect 6 vs Pref 5			**b) Expect 5 vs Pref 3**		
	Pearson chi2	Cramér's V	tau-b	Pearson chi2	Cramér's V	tau-b
1 year	**0.308**	**0.1919**	**-0.49**	**0.344**	**0.1903**	**-0.33**
Expectation	18.27		-0.0428	8.98		-0.0291
	16		0.088	8		0.088
5 years	**0.506**	**0.1977**	**-0.26**	**0.403**	**0.1839**	**0.31**
Expectation	19.24		-0.0201	8.32		0.0257
	20		0.078	8		0.083
10 years	**0.050**	**0.2547**	**0.82**	**0.044**	**0.2561**	**1.03**
Expectation	31.39		0.0656	15.88		0.0866
	20		0.08	8		0.084
> 10 years	**0.354**	**0.2309**	**0.72**	**0.228**	**0.2275**	**0.78**
Expectation	21.75		0.0609	10.56		0.0713
	20		0.085	8		0.092