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Corporate Strategy and Climate Change: Heterogeneity and Change in the Global Automobile Industry

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The Global Environmental Assessment (GEA) project is a collaborative team study of global environmental assessment as a link between science and policy. The Team is based at Harvard University. The project has two principal objectives. The first is to develop a more realistic and synoptic model of the actual relationships among science, assessment, and management in social responses to global change, and to use that model to understand, critique, and improve current practice of assessment as a bridge between science and policy making. The second is to elucidate a strategy of adaptive assessment and policy for global environmental problems, along with the methods and institutions to implement such a strategy in the real world.

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Publication abstracts of the GEA Project can be found on the GEA Web Page at http://environment.harvard.edu/gea. Further information on the Global Environmental Assessment project can be obtained from the Project Associate Director**,** Nancy Dickson, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, 79 JFK Street, Cambridge, MA 02138, telephone (617) 496-9469, telefax (617) 495-8963, Email nancy_dickson@harvard.edu.

FOREWORD

This paper was written as part of the Global Environmental Assessment Project, a collaborative, interdisciplinary effort to explore how assessment activities can better link scientific understanding with effective action on issues arising in the context of global environmental change. The Project seeks to understand the special problems, challenges and opportunities that arise in efforts to develop common scientific assessments that are relevant and credible across multiple national circumstances and political cultures. It takes a long-term perspective focused on the interactions of science, assessment and management over periods of a decade or more, rather than concentrating on specific studies or negotiating sessions. Global environmental change is viewed broadly to include not only climate and other atmospheric issues, but also transboundary movements of organisms and chemical toxins. (To learn more about the GEA Project visit the web page at http://environment.harvard.edu/gea/.)

The Project seeks to achieve progress towards three goals: deepening the critical understanding of the relationships among research, assessment and management in the global environmental arena; enhancing the communication among scholars and practitioners of global environmental assessments; and illuminating the contemporary choices facing the designers of global environmental assessments. It pursues these goals through a three-pronged strategy of competitively awarded fellowships that bring advanced doctoral and post-doctoral students to Harvard; an interdisciplinary training and research program involving faculty and fellows; and annual meetings bringing together scholars and practitioners of assessment.

The core of the Project is its Research Fellows. Fellows spend the year working with one another and project faculty as a Research Group exploring histories, processes and effects of global environmental assessment. These papers look across a range of particular assessments to examine variation and changes in what has been assessed, explore assessment as a part of a broader pattern of communication, and focus on the dynamics of assessment. The contributions these papers provide has been fundamental to the development of the GEA venture. I look forward to seeing revised versions published in appropriate journals.

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ABSTRACT

Transportation accounts for nearly one-third of US greenhouse gas emissions, so any mitigation strategy requires the constructive engagement of the automobile industry. The task of strategic planning for low-emission technologies by automobile companies is particularly demanding, however, in the face of environmental issues such as climate change, due to their long-term, market transforming potential, and the high level of uncertainty concerning environmental science, technological and market developments, and policy responses. It is not surprising, in this context, that there is considerable variation in responses across companies in the same industry. We examine differences between response strategies between auto companies in the US and Europe. While economic and market structures partly explain the greater tolerance in Europe for carbon emission limitations, we argue that perceptions of corporate strategic interests are premised upon attitudes toward climate science, the prospects for low emission technologies, anticipations concerning consumer responses, and expected policy responses. These expectations and understandings are shaped and constituted through a company's own institutional structure and history, as well as interactions with the external institutional environment, including industry associations, universities, the media, and national and international governance structures. In this paper we also discuss a number of economic, political, organizational, and technological factors that have caused a dramatic shift in climate strategies in recent years.

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List of Abbreviations

AAMA	American Automobile Manufacturers' Association
ACEA	European Automobile Industry Association
BCSE	Business Council for Sustainable Energy
CAFE	Corporate Average Fleet Efficiency
CARB	California Air Review Board
CO2	Carbon Dioxide
EU	European Union
FCCC	Framework Convention on Climate Change
GCC	Global Climate Coalition
GCM	Global Circulation Model
GHG	Greenhouse Gases
GM	General Motors
IPCC	Intergovernmental Panel on Climate Change
NAM	National Association of Manufacturers
NOAA	National Oceanographic and Atmospheric Administration
PCAST	President's Council of Advisers for Science and Technology
SAR	Second Assessment Report
VDA	Automobile Industry Association of Germany
WRI	World Resources Institute

Introduction

The possibility that human emissions of greenhouse gases are changing the world's climate constitutes a global environmental issue with massive, market transforming potential. Controls on emissions of carbon dioxide (CO2), released from the combustion of fossil fuels and the main contributor to global warming, would threaten oil and coal companies, as well as industries dependent on these fuels, particularly transportation and electric utilities. In addition, higher energy prices would raise input costs for a range of energy intense industries, including aluminum, chemicals, cement, paper, cement, and steel. The impact would extend to the commercial and retail sectors, which use large amounts of energy for heating and cooling. According to Mansley (1995), the financial markets have not yet incorporated the prospect of regulatory controls in asset prices.

A number of factors exacerbate industry's perception that greenhouse gas controls pose a threat to their interests. The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer demonstrated how quickly environmental issues might move from scientific concern to drastic, internationally coordinated controls. International controls pose a particular threat to fossil fuel and automobile companies, most of whom are multinationals, because they would affect operations and markets simultaneously in multiple countries, obviating the traditional multinational advantage of diversification and mobility.

Climate change presents a much greater strategic challenge to industry than did the ozone depletion issue, with which it is often compared (Levy, 1997). A number of analyses have pointed out that Dupont, the leading US producer of CFC gases, ended up supporting the Montreal Protocol because it held an advantageous position with HFCs and HCFCs, chemical substitutes that do not deplete the ozone layer (Benedick, 1991; Parson, 1993; Rothenberg & Maxwell, 1995). Our analysis needs to go beyond a firm's current market positioning and capabilities, however, and ask why some companies are more willing than others to undertake investments in risky low-emission technologies. We have to examine how a company assesses the prospects for environmental regulation, the technological and market potential of alternative products, and the company's own capacity to succeed with these new products. The position of Dupont concerning CFCs illustrates this point. Until the mid-1980s, Dupont expressed strong opposition to international controls on CFC production, but by September 1986 it was in a position to manufacture the CFC substitutes and was supporting US proposals for a 50% reduction in production. Why did Dupont make the investments to put itself in this position? Three factors are probably involved; Dupont had the internal scientific capability to understand that ozone was a serious problem that would generate a strong policy response (Parson, 1993); it had the technical capacity to innovate alternatives, which would draw from its existing strategic assets in chemical engineering and production process technologies; and it had the market power and distribution system to ensure a profitable market for the new, high-margin products, at a time when CFCs were rapidly becoming low-margin commodities (Maxwell & Weiner, 1993).

Investments in R&D for low-GHG products and processes appear, by contrast, highly risky, because of the uncertainty regarding climate science, regulatory responses, and the potential market for low emission technologies. The technologies associated with low-emission automotive products and processes will require radically new capabilities, such as expertise in electric drive trains, high-capacity batteries, and fuel cells, that threaten to undermine the competencies and strategic assets of existing companies, and open the industry to new entrants. Although the long-term nature of these issues affords companies a window of time to adapt strategies and invest in

new technologies, it is unclear to what extent car companies can “reinvent themselves” as providers of transportation, just as it will be difficult for BP and Shell to succeed in renewable energy technologies such as wind and solar. Moreover, the unpredictable path of technological evolution makes the task of choosing among competing technologies a treacherous business. Finally, although energy and automotive industries are concentrated, no single company possesses the market power to establish new standards and ensure success for new products.

In the climate issue, some companies saw not just an economic threat but a broader ideological challenge to the industrialized way of life and the role of private automobiles. As a former VP of Government Relations of a US auto company put it, “there are people who have cast the automobile as a villain. It is a puritanical view, that we are having too much fun, that we have too much mobility and freedom, that suburban sprawl is bad. They think we should all live in beehives. So when scientists say that CO2 is a greenhouse gas, they jump on board.” There was an explicit fear among automobile industry managers that the climate issue touched emotional chords that could be exploited by activist environmental groups, and might lead US regulatory agencies to tighten Corporate Average Fuel Economy (CAFE) standards, which were deeply resented as an intrusion on corporate autonomy regarding product plans.

The climate issue poses a number of strategic dilemmas. Companies can attempt to postpone regulation by debating the science of climate change and the economic cost of GHG controls, or they can attempt to invest in new low-emission technologies. This “debate or innovate” decision is not a strict dichotomy, as companies may engage in a hedging strategy, or attempt to postpone regulation until they are better prepared. A related question is whether a firm should attempt to invest early and gain first mover advantages, or wait until the technological turmoil and regulatory uncertainty has subsided. R&D resources can be directed toward incremental improvements to existing technologies or radically different ones. Companies also need to decide whether to commit substantial resources to a single technology, or adopt a portfolio strategy, alone or with partners.

There is considerable variation in the strategic responses exhibited by automobile companies based in different geographic regions. US-based companies responded relatively early to the issue, aggressively challenged the scientific need for emission controls, and have tended to invest in more radical, long-term technological approaches to emission reductions. European companies, by contrast, have been less engaged in public debates about climate science, have accommodated regulatory demands for significant emission reductions, and have invested in more incremental, short term improvements to conventional internal combustion engine technology. The different economic and market environments in each region offer only a partial explanation for these divergent strategic responses. There are also differences within regions; Ford, for example, has been more outspoken than GM against mandatory emission controls.

US automobile companies have dramatically shifted their climate strategies in the years since the Kyoto Protocol in December 1997 toward a more proactive stance. Companies are moving toward accepting the scientific case for precautionary action, are softening their political opposition to emission control measures, and are beginning to invest substantial sums in a range of low emission technologies. Ford and Daimler-Chrysler have each invested several hundred million dollars in a fuel cell joint venture with the Canadian company Ballard, while GM has formed an alliance with Toyota to invest in a range of technologies. The scale and risk of these investments is one factor driving the current wave of mergers and alliances, reshaping the economic structure of these industries. Given the high level of uncertainty concerning policy measures, technological developments, and competitor reactions, these investments could not yet be justified on the basis of expected rates of return using conventional capital budgeting techniques. With ratification of

Kyoto an unlikely prospect in the US in the near term, and little fear of strict CAFE style controls on carbon emissions, there is no single obvious explanation for this shift in industry strategy. There have been no technological breakthroughs, nor have consumers showed any sign of wavering in their demand for ever larger vehicles.

This paper employs a case study approach to explore the climate strategies of the two remaining major American automobile manufacturers, GM and Ford, and two European companies, Daimler-Chrysler and Volkswagen. We attempt to explain the different response strategies of European and American companies, as well as the changes over time in the strategies of American companies. Data were collected from a series of interviews in the U.S. and Europe with senior corporate managers, industry associations, government agencies, and environmental NGOs. Interviews were conducted with a cross-section of firm employees, including environmental staff, strategy, product development, marketing, and R&D. Some interviews, particularly with ex-employees that focused on more historical data, were performed over the phone, using a pre-developed semi-structured telephone interview format. Additional material was gathered through an extensive review of secondary source material. Case study methodology is most appropriate to this area of research because of the complex relations among the actors and variables. Case studies can provide the breadth and depth of information to allow descriptive, causative, and inductive analysis to be performed (Eisenhardt, 1989; Miles & Huberman, 1984; Yin, 1989).

The paper develops a theoretical framework that draws from and synthesizes three theoretical streams that relate to our understanding of strategy making under conditions of technological and regulatory uncertainty. Insights from institutional theory (DiMaggio, 1988; Scott & Meyer, 1994)are applied to make the case that strategy is embedded in institutional environments, meaning that strategic decisions are premised upon perceptions of economic interest which are constructed in an institutional context. The case study illustrates how perceptions of interests are affected by attitudes toward climate science, the prospects for low emission technologies, anticipations concerning consumer responses, and expected policy responses. These expectations and understandings are shaped through a company's own institutional structure and history, as well as interactions with the external institutional environment, including industry associations, universities, the media, and national and international governance structures. With this institutional lens, we can see that companies do not simply join industry organizations such as the Global Climate Coalition (GCC) to pursue their objective economic interests; rather, membership in such organizations helps to construct corporate perceptions of climate science and economic interests. Although institutional arguments are traditionally adduced to account for conformity and stability, here we argue that institutional processes can also lead to heterogeneity and change (Hoffman, 1999; Oliver, 1991).

The second theoretical stream locates corporate strategic decision making in the context of complex social-technological systems . Such systems are themselves institutions, which become stabilized as regimes that exhibit significant inertia. Technological development within such systems is viewed as an evolutionary process characterized by punctuated equilibrium, embedded within social, political, organizational, and cultural contexts (Abernathy & Clark, 1985; Anderson & Tushman, 1990; Nelson, 1995). Automotive technologies, for example, have evolved and stabilized in the US under historically specific conditions of infrastructure investments in roads and suburban housing, consumer behaviors and attitudes, government taxation and subsidies, and automobile industry structures (Truffer et al., 1999). Insights from complexity theory suggest that while the overall social-technological regime might be quite resilient to small disturbances, it also has the potential for rapid and dramatic change, just as the horse-based transportation system of the 19th century gave way to trains and cars (Holm, 1995; Levy, 1999 forthcoming; Stacey, 1995).

This theoretical perspective also highlights the indeterminacy of technological change; just as there was no economic or technological inevitability to the triumph of the gasoline internal combustion engines over rival electric, diesel, or steam technologies at the beginning of the 20th century, so it is unclear which low-emission technologies will be at the heart of the dominant social-technological regime of the next century (Arthur, 1989).

The interaction of corporate political and product strategies constitutes the third theoretical stream to which this study contributes. Baron (1997) has described the integration of market and non-market strategies in the context of traditional strategic analysis, but here we consider corporate political activity as part of the institutional response to challenges to the broader social-technological system. We draw from the neo-Gramscian literature to argue that dominant and stable social-technological regimes rest on three pillars, which, when aligned, can reproduce themselves and mutually reinforce each other (Cox, 1987; Gill, 1993). One pillar is the economic and material base of profitable production and sales; the second is the network of organizations operating within the system, including companies, government agencies, industry associations, and elements of civil society. The third pillar is the discursive structure of meaning and symbolism, both cognitive and normative, that guides behavior and lends legitimacy to organizations and practices within the system. The study demonstrates that corporate political strategy is integrated in the sense that it addresses all three pillars, in an effort to protect not just specific products or markets but a wider social-technological regime. In a broader sense, it is argued that a company's relation to such a regime confers systematic advantages and is thus itself political; in this sense, all strategy is political.

A number of significant managerial implications derive from the application of this theoretical framework to the case study. To the extent that the institutional environment constitutes an "iron cage" (DiMaggio & Powell, 1983) that constrains and channels management's perceptions, consideration of strategic alternatives will also be limited. It is suggested here that the reaction of US-based automobile companies to the climate issue has been premised on a number of assumptions that need to be questioned. For example, US companies have until quite recently viewed the prospects for regulation of CO2 emissions and consumer acceptance of low-emission vehicles primarily through an American lens of low fuel prices and an aversion to strong government intervention. Moreover, skeptical perspectives toward climate science have become institutionalized within these companies, potentially causing them to underestimate the likely regulatory response. Finally, companies tend to take the current social-technological regime for granted and do not fully account for the possibility of rapid, dramatic change.

The research also bears some important policy implications. Transportation accounts for nearly one-third of US greenhouse gas emissions, so any mitigation strategy requires the constructive engagement of the automobile industry. The major automobile manufacturers control vast technological, financial, and organizational resources, which, if applied appropriately, could have significant impacts on emissions of greenhouse gases. These companies are, to extend Lipskey's (1980) phrase, the "street level bureaucrats" to whom will fall the task of formulating and implementing mitigation strategies. Understanding the institutional embeddedness of strategy and its relation to the broader social-technological system would facilitate the development of policy that goes beyond energy taxes and R&D subsidies and is more concerned with changing corporate perspectives on climate science, mitigation technologies, and regulatory responses.

Corporate Strategy and Climate Change: the US Response

US-based fossil fuel-related industries responded relatively early to the climate issue, providing time and organizational resources to develop an effective political strategy against mandatory emission controls. On the organizational level, the three major US automobile companies, as well as the American Automobile Manufacturers Association (AAMA) worked largely through the Global Climate Coalition (GCC), which was formed in 1989, initially under the auspices of the National Association of Manufacturers (NAM), but reorganized as an independent entity in 1992. The GCC represented about 40 companies and industry associations, primarily major users of fossil fuels such as the oil, automobile, and electric utility sectors, but also including other energy intense sectors such as cement, aluminum, iron and steel, chemicals, and paper. A senior GCC staff member, discussing motivations for the creation of the GCC, expressed the view that industry had "been caught napping" by the ozone issue, and that there was also considerable dissatisfaction with the Clean Air Act process. As he expressed it, "Boy, if we didn't like the Montreal Protocol, we knew we really wouldn't like climate change! This is the mother of all issues!"[1] Although the GCC was constituted as a U.S.-based organization and was focused on domestic lobbying, a number of US subsidiaries of European multinationals also joined, and the GCC quickly rose to be the most prominent voice of industry, both in the US and in the international negotiations.

A key discursive component of the GCC's political strategy has been to challenge the science of climate change, pointing to a spectrum of opinion rather than consensus among scientists, and highlighting the uncertainties. Several scholars have noted that industry can attempt to protect itself from regulation with the authority and credibility of science, by invoking the high standards of proof required to accept a new scientific theory. Shackley (1999a) describes "scientism" as "the belief that what effective policy formulation and implementation most needs is robust knowledge (with physics as the gold standard)." Edwards and Lahsen point to the strategic deployment of this belief (p.12) "Economically powerful groups targeted by possible regulations, such as the fossil fuel industry, are well aware that closure of debate can be delayed by challenging key scientific results, or, sometimes even more effectively, by raising the level of certainty required of scientific knowledge". Industry's preference for "sound science" is discussed by Jasanoff (1987) as part of the political negotiation of boundaries between science and policy. The GCC makes this explicit in its mission statement: "A bedrock principle for addressing global climate change issues is that science -- not emotional or political reactions -- must serve as the foundation for global climate policy decisions." While there is clearly a strategic component in industry's challenge to climate science, the case study also suggests that these perspectives were institutionalized and integrated into the value and meaning systems of the companies.

The GCC's efforts to challenge the science of climate change took a number of forms. It actively promoted the views of climate skeptics such as Patrick Michaels, Fred Singer, and Richard Lindzen in its literature, press releases, and congressional testimony, and would direct press inquiries to these people. It sponsored a number of reports, such as Accu-Weather (1994) and Davis (1996), and would also use reports from other sympathetic organizations, notably the Marshall Institute. The GCC regarded favorably the voluntary approach of the US Climate Action Plan [House, 1993 #51], and in December 1994 asserted that "the state of the science does not justify adopting any additional commitments or actions at this time. Key aspects of the science,

[1] Interview by author with official of the Global Climate Coalition, February 1999.

particularly climate and regional weather effects, remain highly uncertain " (Global Climate Coalition, 1994) p.30. A GCC *Backgrounder* (undated) presents a detailed critique of general circulation models (GCMs), pointing to their well-known limitations in modeling complex phenomena such as cloud cover, regional processes, and ocean circulation (Shackley, 1999b). This skeptical approach to GCMs stands in ironic contrast to the credibility the GCC has bestowed on general equilibrium economic models such as that used by the WEFA Group(1996), which predict a high cost for GHG mitigation, even though these models are even more complex and rest on less secure theoretical foundations than GCMs.

The appeal to “sound science” and rejection of emotional criteria for environmental decision-making reflects an effort to shape the climate debate through gendered discourse. Advocates of precautionary action are labeled as emotional, irrational, even hysterical, overly anxious about the risks associated with industrial "progress", and implicitly unfit to participate in the masculine realm of public decision-making. A number of other discursive themes recur throughout the industry literature. One is that the greenhouse effect is natural and life sustaining. A second theme is that human emissions of greenhouse gases are relatively small compared to the total carbon cycle and to the radiative forcing due to water vapor. A final theme is that higher CO2 concentrations might increase “ plant productivity”, which is perhaps an argument geared toward the agricultural and forestry industries. This notion was made a centerpiece of a film titled *The Greening of Planet Earth* by the Western Fuels Association, a utility association and former member of the GCC, and was also repeated in a series of 1993 advertisements titled “Repeal Rio”.

In an effort to challenge the organizational legitimacy of the Intergovernmental Panel on Climate Change (IPCC), the group of more than 1000 international scientists charged with assessing the current state of knowledge concerning climate change, the GCC mounted a public attack on the IPCC’s review process for the Second Assessment Report (SAR). At a symposium in Rayburn House, Washington DC, in May 1996, Don Pearlman of the Climate Council and William O'Keefe of the GCC and the American Petroleum Institute accused IPCC lead authors Ben Santer and Tom Wigley of secretly altering the IPCC report to reduce the expression of uncertainties, particularly in chapter 8. This chapter was the source of the oft-quoted IPCC statement that “the balance of evidence suggests that there is a discernible human influence on global climate” (Intergovernmental Panel on Climate Change, 1995). The GCC placed advertisements in the Washington Times and Energy Daily, stating that "unless the management of the IPCC promptly undertakes to republish the printed versions...the IPCC's credibility will have been lost." (Gelbspan, 1997) p.78. Fred Seitz of the Marshall Institute followed with an op-ed piece in the Wall Street Journal on June 12, which became the forum for a spirited exchange (Edwards & Schneider, 1997).

The strategy of challenging climate science was quite successful in securing the support of a key group of Republican Congresspeople in the 1994-96 House, including Dana Rohrabacher from California, Chair of the House Science Subcommittee on Energy and Environment, Tom DeLay of Texas, the House Majority Whip and a member of the Appropriations Committee, John Doolittle of California, and Robert Walker of Pennsylvania, Chair of the Science Committee and a member of the Budget Committee. Perhaps most notable were the series of hearings before the House Subcommittee on Energy and the Environment in Fall 1995, pointedly titled "Scientific Integrity and the Public Trust" (Gelbspan, 1997) pp.64-78. (Brown, 1996). Rohrabacher presented skeptic Patrick Michaels as a heroic dissenter in the image of Galileo, bravely confronting the scientific priesthood, and openly derided the testimony of climatologists such as Jerry Mahlman, director of NOAA's Geophysical Fluid Dynamics Lab. These hearings illustrate

what Hajer (1995) terms a "discourse coalition" among the fossil fuel industry, the climate skeptics, and key Republican congresspeople.

As a result of US industry's political efforts, federal funding for climate research has been constrained, and the US State Department, the agency primarily responsible for the international negotiations, opposed mandatory international GHG emission controls until 1996. Even after the US accepted the idea of an international protocol in principle at the Geneva negotiations in July 1996, the US advocated no more than a freeze on emissions at 1990 levels, while the European Union was pushing for 15% reduction below those levels. The US agreed to a 7% reduction in emissions at the Kyoto Protocol of December 1997, though the administration has made it clear that it will implement this commitment through flexible, market based measures, and does not plan to impose substantial new gasoline taxes or increase CAFE standards, which currently stand at 28 mpg.

Response by European Automobile Industry

Far from having political allies, European firms found themselves in a context in which politicians were looking to the auto industry for substantial, early emission reductions. Unlike the US, where the auto and oil industries had forged an alliance within the GCC, in Europe the auto industry stood alone. Germany had unilaterally committed to significant GHG reductions during the Framework Convention on Climate Change (FCCC) negotiations in Berlin in 1994 and had pushed the German auto industry association, the VDA, into a "voluntary" agreement to reduce CO2 emissions from new cars by 25%. Concerned that these constraints might affect the competitiveness of its national automobile companies, Germany then pushed the EU to adopt similar measures. While the US had entered the Kyoto negotiations advocating a freeze on GHG emissions at 1990 levels, the EU was calling for a 15% cut, and was sensitive to charges that it talked a tough position but lacked any will to implement. The European Commission introduced a proposal to reduce average CO2 emissions from new cars from 186 grams/km to 120 g/km by 2005 (equivalent to about 45 mpg). The European Parliament called for even stricter limits, with a figure of 90 g/km being mentioned. European automobile companies avoided direct challenges to the scientific need for GHG controls, with various managers calling any such effort "futile" and "inappropriate". After three years of negotiations, in 1998 the European Automobile Industry Association (ACEA) accepted a voluntary agreement to reduce emissions to 140 g/km by 2008, while maintaining the 120g/km target for 2012. European companies have responded to these pressures by introducing very small, light-weight cars such as Daimler-Chrysler's SMART car, and investing substantial amounts in a range of technologies from diesel to fuel cells.

Explaining US-European Strategic Responses

The Emergence of Climate as a Strategic Concern

The notion that human emission of greenhouse gases might warm the earth's climate dates back to the work of Baron Jean Baptiste Fourier in 1827, and Svante Arrhenius first published estimates of the amount of warming caused by greenhouse gas related radiative forcing in 1896. The development of the scientific, institutional, and political dimensions of the climate issue have been detailed in a number of studies (Agrawala, 1998; Alfsen & Skodvin, 1998; Bodansky, 1994; Edwards & Lahsen, 1999; Kruck, Borchers, & Weingart, 1999). Scientific resources devoted to the issue grew rapidly during the 1960s and 1970s, and policymakers began to turn significant attention to it during the early 1970s. Corporate attention to the climate issue picked up speed only in the late eighties, and US companies responded much earlier than did European ones,

suggesting the importance of national institutional contexts. Research divisions at Ford and GM had been aware of the issue since the late 1970s, but managers and scientists at both companies recalled James Hansen's testimony before the US House Energy Committee in June 1988 as the catalyst that catapulted climate change onto corporate radar screens. Hansen, from NASA, testified during an unusually hot spell in the eastern U. S. that he was "99 percent certain" that recent warmer temperatures were attributable to greenhouse gas induced climate change, a claim which generated considerable media attention (Edwards & Lahsen, 1999). As a result of this testimony and the high level of attention to the issue in the popular press, Ford's climate specialist described his shock at how quickly "climate went from zero to sixty". Ford began sending a representative to IPCC meetings, and took a lead role in reviewing chapters of the IPCC's Second Assessment Report on behalf of the GCC and the AAMA.

It is notable that the US automobile companies paid much more attention to the national mass media political events in Washington DC than to the development of scientific concern around greenhouse gases or to early interest in the policy community. The President's Science Advisory Committee had discussed greenhouse gases and climate as far back as 1965, and in the early 1970s, two major scientific studies, according to Edwards, put climate firmly on the US policy agenda. The White House proposed a US climate program in 1974, leading to the National Climate Program Act of 1978, which authorized $50 million annually in research funding. The US Department of Energy initiated a CO2 research and assessment program in 1977, and in 1979 the White House Office of Science and Technology Policy requested a study on climate from the National Research Council. The ensuing Charney report predicted global warming in the range 1.5 C to 4.5 C, a forecast which has remained remarkably stable over two decades. In 1983, the US EPA published a rather alarming report on climate based on Hansen's modeling work. One reason cited by managers for the attention to climate in 1988 was the rapidity with which the ozone depletion issue had moved from scientific concern to the Montreal Protocol in 1987, mandating a 50 percent reduction in CFC production. Indeed, attention to CFCs in the mid 1980s might have diverted industry attention away from greenhouse gases. To the extent that corporate managers take their cues from the US media, with its rather parochial national focus, they would be less likely to hear about major international conferences on climate. Although Detroit is closer to Toronto than to Washington D.C., almost none of the managers interviewed recalled the June 1988 Toronto Conference on the Changing Atmosphere, which culminated in a call for a 20% cut in greenhouse gas emissions by 2005 from 1987 levels. Even less known was the earlier series of workshops in Villach, Austria, held from 1980 to 1985.

Without Hansen's Congressional testimony during a hot summer as a stimulus, European industry did not pay serious attention to the issue until the summer of 1992. Interviewees from Ford, Daimler-Chrysler, VW, and Opel all mentioned the UNCED conference in Rio de Janeiro as the crucial event that spurred corporate attention, although the ozone issue had sensitized managers to global environmental concerns. By this time, the Framework Convention on Climate Change (FCCC) had been signed and the Second Assessment Report (SAR) of the IPCC was already underway. Consequently, there was almost no European industry involvement in the SAR. There also appears to have been pressure from other industries that had already been alerted. One Volkswagen anager recalled a board member of a large Swiss chemical company saying "we are doing our job on CO2; why don't you do yours?"

Although the automobile industry generally appears to have been taken by surprise by the swiftness with which greenhouse gas concerns moved up the public agenda, interviewees took pains to point out that the climate issue did not initially appear to require any major strategic change of direction. In Europe, high fuel taxes and concerns about resource depletion had kept fuel consumption on the agenda for twenty years. US industry was already subject to CAFE

standards under the Clean Air Act and its amendments, and the California Air Review Board (CARB) was mandating zero emission vehicles in the longer-term. As a result, explained GM's former VP for Research, Robert Frosch, the reaction to climate change from product developers was:

we're already running as fast as we can in that direction. Essentially if someone had said, lets do R&D that will help us with the CO2 problem, the reaction was 'well, we're already doing that. I'm already trying to figure out how to lightweight the vehicles and make the engine more efficient, and look at all the new fuels and so on. So how would it affect me?

Helen Petrauskas, VP of Ford concurred: " There was already huge pressure for reduction of smog precursors. So climate did not require a step function change in strategy; it was more of an organic evolution."

Over a period of time, companies came to appreciate that while improvements in fuel efficiency addressed global CO2 concerns and local air quality issues, many technological approaches involved trade-offs. Electric vehicles, for example, might be zero-emission where the car is driven, but can be worse than conventional vehicles in terms of GHG emissions depending on the fuel mix and efficiency of electricity generation. Similarly, the introduction of catalytic converters during the early 1980s, which dramatically reduced SOx, NOx, and hydrocarbon emissions, caused a noticeable decrease in fuel efficiency. Given these tradeoffs, and a regulatory environment where controls on non-GHG emissions were still being ratcheted upwards, it was not easy for companies to shift their technology strategies toward carbon reduction.

The Political Environment in the US and Europe

According to Edwards (1999) the SAR Chapter 8 controversy represented the particularly legalistic character of climate politics in the US, and the concerns were largely ignored in Europe. The US Congressional hearings on climate exemplify the adversarial, legalistic courtroom style through which the scientific basis for regulation is developed and contested. This contrasts sharply with the approach found in Europe, and particularly in Germany, which is often characterized as more integrated and consensual (Jasanoff, 1991; Kruck et al., 1999). The institutional governance structures in the US cause companies engaged in contested policy arenas to make their case in a vociferous, public manner. As GM's Frosch put it, "The Hill works by compromise, so you need to go to the extreme. The more strident one side gets, the more the other side must. It ends up completely polarized." A former VP of Government Relations made the case that the automobile industry ended up with CAFE in the first place because of a misplaced strategy of conciliation: "The Neville Chamberlain approach doesn't work. We offered voluntary fuel economy goals, but the government turned around and made it mandatory. If we offer to do X, they will demand two X." Helen Petrauskas, a VP of Ford, compared the situation with Europe: "In the US, it doesn't help to have Al Gore getting up and saying that people are dying in Chicago because of climate change. We are forced to be strident to counter that misinformation. In Europe, with some balance between the Commission and the Parliament, it's possible to have meaningful discourse."

While US industry was able to forge alliances with sympathetic elements in Congress and faced a public antagonistic toward fuel taxes, European firms lacked political allies and faced consumers more concerned with environmental issues. Moreover, US companies tended to be wary of international regulatory initiatives over which they had little control (Levy & Egan, 1998), while European car companies were not entirely unhappy with harmonized emissions regulations at the regional level. A Ford Europe manager explained that:

> There was a concern that national legislative initiatives in '94-95 would unravel EU harmonization efforts and would fragment the market. Both the Commission and industry did not want to have a patchwork of regulations and standards. At the end of the eighties, the emissions situation was a strategic nightmare. We wanted harmonization, because otherwise we face the nightmare of managing product mix by country.

As a result of the political and cultural environment in Europe, challenging the scientific basis for regulation was seen as futile. An official with the German environmental ministry said:

> it's not like the United States. Here the companies make some comments in presentations or interviews, but nothing serious because they know public opinion would be against them. If they would argue in the way they do in the States, it would create an image disaster. And they wouldn't argue the science to me or I would kill them.

Perhaps reflecting a more general cynicism about business influence in Europe, a representative with the VDA, the German auto industry association, commented that "if the auto industry were to support a specific study, the people would think that scientists were bought by the industry and they would not believe them." Regarding negotiations with the EU over automobile emissions of CO2, a manager in a European subsidiary of a US-based company commented that:

> my boss in Detroit said we should argue about the science and the economics. It was an education process to get them on board. We had to explain that it's not constructive to challenge the science in Europe, and if we want to influence the debate we cannot move back. Here, the IPCC reports are accepted without question by policymakers. We would be thrown out of the room if we challenged them.

A Ford Europe executive with experience in the US pointed to differences in the political process that led to this outcome:

> You have to understand the process by which the 120 g/km target entered the currency of the debate. In the US there is a long period for public input and delay, and economic interests can be balanced against environmental concerns. Here, there is little balance or accountability. The 120 target was proposed by the EU Environmental Council, which consists of only the environmental ministers of member states. We said that they needed to talk to the economics, finance and labor ministers, but the environmental ministers have power to initiate legislation on their own. The Environmental Council simply said this is the target and other ministers were cut out of the loop. The Environmental Council then tasked the Commission to develop a strategy to achieve the 120 target. The Directorates General for Energy and Industry had little influence.

These negotiations also highlighted the difference between the technocratic policy process in the US and the lack of technical capacity of the EU institutions. Policy battles in the US were waged on the basis of detailed technical studies: indeed, the Clinton Administration's climate policy had become mired in conflicts within an inter-agency task force examining the economic costs of various GHG policies, and a final report was never published (US Interagency Analytical Team, 1997). In Europe, the Commission's demand for a 120g/km standard was not based on any analysis of technical feasibility, environmental need, or economic costs. ACEA commissioned a report from the consultants A.D. Little, which provided technical justification for the industry's position that the target was not technically or economically feasible in the timeframe. Although one might expect that the Commission's lack of technical capacity would give industry the upper

hand in negotiations, auto executives involved asserted that the Commission was not very interested in a policy grounded in technical analysis. One executive summed up the Commission's reaction to the AD Little analysis as, "a very nice report, but what are you going to do about the 120 target?"

Perspectives on Climate Science

Most descriptions of industry's challenge to climate science present them as cynical manipulations of the public discourse. While there clearly has been a strategic component to corporate political activities in this arena that reflect pre-existing conceptions of economic interest, it is argued here that skeptical perspectives on climate science became institutionalized in the automobile companies, particularly those based on the US, and these perspectives helped to constitute perceptions of strategic interest. All three major US automobile companies, through their industry associations and independently, questioned mainstream climate change research and advocated a "wait and see" attitude. Ford's Trotman and Chrysler's Eaton were especially vociferous in the early '90s, through speeches and editorials, in castigating concerns about climate change and emphasizing the high cost of precipitate action in the face of uncertainty. The interviews revealed that these views were not just those of top management, but had permeated throughout various departments and management levels. One manager at Ford commented, "We have followed the science as a company and we would like to see more science and less hot air! What we'd like to see is good science driving good policy."

Managers in European car companies also demonstrated some skepticism toward climate science. A Daimler manager stated that he was still a skeptic, even though the company publicly accepted that CO2 is a problem. In his words, "I doubt that there is significant danger. There are two types of truth: one is natural science. The other is public opinion of science. In either case, you have to react to what the public thinks the truth is and not necessarily what the science says." Generally, however, less skepticism concerning climate science was evident among the European companies. One reason for this might be the sources of information used by European companies, which were notably different than for US ones. US companies tended to rely on American scientists, and included quite a few skeptics. The German car manufacturers primarily relied on German scientists, especially from the Wuppertal Institute, but had also invited in people from Greenpeace, from the German environmental ministry, and Amory Lovins from the Rocky Mountain Institute, an ardent supporter of technological solutions to environmental problems. European companies generally lacked internal scientists who were directly engaged with atmospheric science, and provided little input into the IPCC process. Nevertheless, both VW and Daimler maintained close contacts with local university scientists, and regularly conducted workshops on various related subjects.

Corporate scientists adhere to the norms objectivity, rationality, and free investigation while being embedded in the business culture of bottom-line accountability and hierarchical subordination. This bridging of two cultures necessitates a subtle process of negotiation of identity for these scientists, who are not quite at home in either setting. The corporate scientists interviewed were particularly emphatic about their objectivity and independence, relating stories to demonstrate their refusal to be curtailed by narrow corporate interests. Ruth Reck, who had been a scientist with GM, was on an EPA advisory committee, and in her words "GM desperately wanted to remove me from it. They thought I was not toeing the GM line. But I was an independent scientist and I have refused ever to be bought in my whole life. I was never on anything representing General Motors." Although not threatened with her job because of her independence, Reck "just knew there was dissatisfaction. There just had to be." With their loyalty to the corporation in some doubt, corporate scientists needed to negotiate the border

between these two cultures with some careful diplomacy. Reck recalled that "you had to speak strictly in terms of facts. Lots of people got into trouble for saying controversial things. I lived by the rule that anything you say might appear on the front page of the New York Times. Anything I said could always be backed by a reference."

Corporate scientists felt even less trusted in the public realm. Ford's Shiller recounted an incident during an IPCC plenary session that was negotiating text of the Second Assessment Report, in which he suggested a particular change, which was supported by one of the lead authors and then endorsed by a plenary vote. According to Shiller, the IPCC chair, Bert Bolin later took that lead author aside and warned him not to support other industry interventions. Daimler's Fischer recounted a similar story concerning his participation in the German Enquette Commission, a national assessment process on climate change. Fischer was invited to speak and thought that he would be respected due to his research, but his opinion was very much not welcome at the hearings and he felt very negative about how he had been handled by the members of the commission.

Despite their adherence to the scientific norms of objectivity and independence, we found that with the exception of GM's Reck, the internal scientists in the US tended toward the skeptical end of the spectrum of legitimate opinion among respected climate scientists (Morgan & Keith, 1995). They all interpreted scientific uncertainties in a conservative manner, viewing them as a rationale for further research rather than seeing the potential for climate shocks from positive feedback or threshold affects. They pointed to the long time frame of atmospheric accumulation of GHGs as a comfortable margin of time for reducing uncertainty rather than an urgent reason for early precautionary action.

These conservative viewpoints appear to be constituted in a subtle process of negotiation between two conflicting institutional discourses, the scientist as independent researcher, and the employee as loyal servant of corporate interests. As GM's Frosch expressed, "There is social pressure. They are around people who don't pay attention to the climate issue and don't want to hear it…. People on the operational side are more conservative." He also suggested that there might be some element of self-selection in terms of who is willing to be a corporate scientist. GM's former chief economist Marina Whitman discussed the pressure to adopt a bottom-line perspective. "There is a need for credibility with the line guys. We were the cost center, they were the profit center."

Managers in different functional areas generally adopted perspectives consistent with their departmental interests, demonstrating how institutionalization operates at multiple levels. People responsible for advanced automotive technologies tended to see climate change as an opportunity. According to GM's Frosch, "The spirit of the research labs is, we will show top management we can do it – we can change things." While the R&D people had a vested interest in developing solutions to problems, and tended to view these solutions as technologically feasible, others in the organization were likely to take a more conservative approach. Managers responsible for product divisions and strategy were particularly concerned about the high cost of low emission technologies with little value to consumers. These tensions had bedeviled the development of GM's electric vehicle during the early 1990s (Shnayerson, 1996).

Managers in government relations and regulatory affairs departments traditionally have seen their jobs as opposing governmental regulation and mandates. They were frequently concerned that the company might encourage more stringent regulation by demonstrating technological capabilities for reducing emissions, even if these technologies might be costly and unappealing to consumers. According to GM's Reck, "Jimmy Johnston was a skeptic. He had to assume this position because he was the chief lobbyist. I understand where he was coming from." A Daimler manager

made a similar comment about the company's PR manager: "Of course, he denies that climate change will happen, because he is in Public Relations. Look at us, we make big cars. So it's difficult for him to believe that."

The implication of this discussion is that corporate perspectives on science are not purely strategic, but are in part constituted in light of conceptions of economic interest. More skeptical perspectives toward climate science became institutionalized within the American companies, which perceived climate change as more of an economic threat; in turn, the companies relied on these skeptical perspectives in anticipating a weak regulatory response and in formulating their R&D strategies. These institutionalized conceptions are not easy to change, and risk becoming an "iron cage"(DiMaggio & Powell, 1983) that constrains consideration of a full range of strategic options.

Perceptions of Market Viability for Low Emission Technologies

European car companies, facing high fuel prices and narrow, congested roads, have traditionally tended to specialize in smaller, fuel efficient vehicles in comparison with US producers. Porter (1990) has argued that the competitive advantage of companies is molded by home country conditions, so European companies might consider themselves to be in a superior strategic position to deal with demands for lower emissions be more open to regulatory initiatives, and be quicker to invest in low-emission technologies in order to build on these strengths.

It is not just historical country-specific conditions that have shaped the current competitive capabilities of automobile companies in some objective sense. Here we draw from Callon (1998) to argue that corporate expectations concerning markets for low-emission technologies are more influenced by institutional location than by some objective assessment of current corporate strengths and market positioning. In any event, corporate capabilities in a hypothetical future market are not easy to measure; all the major auto companies have made significant efforts toward fuel efficiency since the first oil price shock in late 1973. If anything, European companies might find it relatively harder to squeeze additional weight and efficiency out of their product range.

Although the major auto companies are all multinationals and have been active in each other's markets for many years, the management of U.S.-based auto companies displayed a remarkably national orientation to their cognitive maps. In numerous interviews, corporate managers in Detroit, many with worldwide responsibilities, spoke about the difficulty of reducing emissions with gasoline near $1a gallon, consumers who care little for fuel economy and are hungry for large SUVs, and a Senate unlikely to ratify Kyoto. These views are reinforced through membership in industry associations such as the GCC, which are dominated by U.S.-based companies. Ford and GM's climate teams were both based in Detroit, though regular telephone conferences were held with European subsidiaries, especially during the ACEA negotiations.

Due to this domestic orientation of US auto companies, managers in their European subsidiaries felt that their local product needs were not always met by the R&D priorities established in Detroit. In particular, European managers had to push Detroit for more investment in smaller, fuel efficient vehicles. Although European subsidiaries conducted a substantial amount of R&D in their own facilities, the lion's share, especially for major projects, was still controlled from Detroit. This situation only began to change for Ford and GM during the mid 1990s, as management structures became more international. Ford implemented its Ford 2000 project which pushed toward the rationalization and integration of production and management worldwide, and GM began to move in a similar direction. Ford Europe, for example, became

responsible for the Fiesta-size class of small cars worldwide, as well as for the development of advanced diesel technology. By 1998, top management in both companies included a number of people with significant overseas experience. According to one Ford Europe manager,

> What has changed is the global focus. In the old days, senior management in the US spent some of their careers in Europe. Alex Trotman had a European pedigree. But now we have global managers in top management, people who grew up in other cultures. Ford understands the importance of Europe now, and this really puts pressure internally on the U.S. focus.

Another manager noted that the global perspective had taken hold within European operations as well: "the Ford 2000 project affected the way we thought about these negotiations with the EU Commission. We had to think about the implications for the US market."

All the companies considered that consumer acceptance was the single biggest hurdle facing innovation efforts, though American companies tended to focus more on current consumption patterns and downplayed the potential for dramatic change. American companies were particularly critical of regulation such as the CAFE standards which they saw as coming between the company and consumer requirements. Marina Whitman, GM's former chief economist, expressed the widely held view that consumer sovereignty would eventually triumph in the marketplace: "Consumers find a way around regulation. The shift from cars to trucks is an example, as consumers can find features on trucks that have been stripped out of cars."

The impact of low-emission technologies on price was seen as a problem even in Europe. A Daimler manager commented that "it has always been very important for us to understand if this is acceptable to the customer. The customer sees specific benefits in low consumption vehicles, especially in Europe, where fuel efficiency offers more significant savings on fuel costs. But these days cost is the most critical point to bring advanced technology into the market. Products which have really low fuel consumption and which are lightweight generate lots of costs. If you can't fulfill the price expectations, you can't go into the market, because sales would be very low. We constantly do this analysis in the product planning department, to find out if product concepts are viable in the marketplace. A Ford Europe manager noted that "customers won't pay a premium for fuel economy. It's a mid-level concern for consumers, not in the top three, but not nine or ten as in the US, where concern for fuel economy is fifteen years away.

Companies related a number of experiences in which consumers reacted negatively to cars that pushed the environmental envelope, and these experiences appeared to have become a part of corporate conventional wisdom. At GM, the decision to downsize luxury vehicles was commonly referred as the "Cadillac disaster", and GM managers expressed the view that Ford's greater profitability in the late 1990s was mainly due to its decision to keep a range of full size cars and trucks. In Europe, Daimler had investigated the market for a new class of vehicles with special paint technologies and better recycling capability, and was surprised by the lack of consumer interest. Daimler, Opel, and VW all had introduced lightweight, fuel efficient vehicles that had met limited demand.

The barrier to new technology was not just the price. Daimler had found that people were fearful of the limited range of electric vehicles, even though consumers could change their usage habits to overcome these vehicle limitations, especially if it served as a second car. Hesse argued that the problem was "a psychological fear, because people have experiences of devices with batteries going empty, mobile phones, laptop computers. There is a fear that you cannot take away." VW had tried to introduce a hybrid in which the drivers could hear the engine cut in and out. A

marketing manager explained that customers didn't like it "because their heart stops beating when the engine stops." Hesse thought that there would need to be a substantial change in infrastructure, consumer usage patterns, and attitudes for its small, lightweight SMART car to sell in volume: "If you look at typical European inner city traffic situations, small vehicles allow you mobility concepts that classical products cannot fulfill. The SMART car is not so much yet integrated into new mobility concepts, for example, dropping the car at the train station and picked up on the way back, which would ease traffic in the downtown area." Through comments such as these, the European managers demonstrated a greater awareness of the social embeddedness of technology.

A notable difference between producers was that US-based companies tended to focus on current consumer preferences and infrastructure as an exogenous constraint which might only be changed in the long run through fiscal policies, while European companies were more aggressive about changing consumer preferences and behavior in the medium term, in the context of integrated transportation systems. A VW executive noted that "we are more active in trying to change consumers. You cannot force people to buy certain things, but what we are trying to do is just keep on presenting it to the market, and try to convince people to buy these type of products." One Ford Europe manager noted that diesel engines, which offer approximately 25% fuel efficiency compared with gasoline, were increasingly seen as "hip and green" in Europe, while US executives were convinced that American consumers would remember the noisy, dirty, shuddering diesels of the 1970s and shun them even if these problems could be overcome. A related factor was the expectation concerning how consumer preferences would change as incomes grow. Daimler's Hesse expressed optimism, based on market research, that economic growth would allow more consumers to pay a price premium for low-emission cars, while American companies tended to think that higher incomes would just lead people to buy bigger SUVs, vans and trucks.

These different perspectives on consumer preferences explain, in part, the different innovation strategies of European and US companies. US-based companies were focusing on longer-term more radical approaches to emission reduction, such as fuel cells and hybrids, but without sacrificing car size, comfort, or other features. The car of the future would not require any change in transportation patterns, road infrastructure, or social conceptions of cars; rather, all the burden of emissions reduction would be placed on advanced automotive technologies. European efforts were more balanced with investments in short to medium term emission reductions through substantial weight and size reduction and incremental improvements to existing diesel and gasoline engines. Consumers were expected to play their part in adapting to the new vehicles.

Companies took different positions on the benefits of being a first mover in emerging low-emission technologies, consistent with the theoretical ambiguity described earlier. Experiences with alternative technologies had made the American companies wary about their prospects for the future. GM, for example, had invested an estimated $500 million in its electric vehicle, of which less than 1000 had been sold. Although a few GM managers thought that the company had gained valuable expertise in electric drive chains, company managers generally interpreted the experience as a commercial mistake. Similarly, GM managers felt that they had rushed too quickly to downsize their vehicles in response to earlier oil price shocks. Ford had invested an estimated $500 million in sodium-sulfur batteries, only to abandon the project because of safety concerns and because nickel metal hydride looked more promising. With this shared experience, being a first mover was not seen as an attractive proposition. Ford's top managers were quite explicit in stating that they would not be the leader on carbon reduction, although they would be prepared to follow quickly. Chrysler, for its part, had abandoned any significant R&D activity

after the government bailout, helping to explain CEO Eaton's vociferous opposition to GHG emission controls.

Daimler, by contrast, had taken a strategic decision to be a leader in fuel cell technology. The justification for this decision, of necessity, employed rhetorical strategies as much as any objective analytical framework. Hesse discussed "the need to stay in the driver's seat, to prepare for a future that is not the status quo". While he acknowledged that this was a risky technology that might not come into mainstream use until 2020 or later, the investment was largely seen as a learning exercise:

> If you spend a lot of money at the beginning, it is difficult to earn it back, but it helps to generate knowledge of what is possible, and this prevents you getting nervous and making mistakes and not knowing what you're doing. And at the moment we know very well what we are doing because we know where we are with the technology. Of course we will lose a lot of money at the beginning, but gaining as much experience as early as possible enables us to make business decisions which assess all the details and all the aspects.

Institutional Dynamics and Strategic Change

The fossil fuel industry appears to be in the midst of a remarkable shift in position on the climate issue. Firms that formerly poured scorn on concerns about greenhouse gases are now more muted, and an increasing number of companies are accepting the principle of taking precautionary action in the near term rather than wait for more scientific evidence. Companies are adjusting their strategies accordingly, investing in a range of low-emission processes and products. The Kyoto Protocol in 1997 was clearly a watershed, but here we argue that the international treaty did not, by itself, change corporate perspectives and strategies; after all, the treaty is unclear on many details, does not spell out regulatory mechanisms, and is unlikely to gain ratification in the US in its present form. Companies do not have much more information post-Kyoto on which to base estimates of the future price of carbon permits or markets for low-emission technologies. Instead, we argue that institutional and political dynamics have been undermining the existing social-technological regime, leading companies to begin preparing for the possibility of a major upheaval.

The now famous speech by British Petroleum's Group Chief Executive, John Browne at Stanford University on May 19, 1997 represented the first major fissure in the fossil fuel industry's position on the science of climate change. He stated that "there is now an effective consensus among the world's leading scientists and serious and well informed people outside the scientific community that there is a discernible human influence on the climate, and a link between the concentration of carbon dioxide and the increase in temperature." While acknowledging that considerable uncertainties still exist, Browne explicitly invoked the precautionary principle by saying "The time to consider the policy dimensions of climate change is not when the link between greenhouse gases and climate change is conclusively proven, but when the possibility cannot be discounted and is taken seriously by the society of which we are part."

We do not know the motives for John Browne's landmark shift in position on climate. European oil companies were probably subject to political and cultural pressures similar to those described for the European automobile industry, but we also cannot rule out John Browne's personal experiences and beliefs. One explanation might be the emerging scientific consensus since the Second Assessment Report (SAR) of the IPCC in 1995 and the strategic benefits for companies to "board the train" once it was seen to be leaving the station. By 1997, the business press in the US and Europe was conveying the impression of consensus. (Raeburn, 1997; Stipp, 1997; The

Economist, 1997). From the perspective of Jon Holdren's, a Harvard scientist engaged with the issue, advances in basic science were fundamental: "the whole fingerprint argument has become much stronger since the SAR. You've got the empirical data of record warmth, and the arguments about satellite measurements and solar effects have been resolved in refereed scientific publications." On the other hand, there had been no decisive scientific evidence equivalent to the discovery of the “ozone hole” over Antarctica in 1987 and little coverage of new scientific understanding in the US mass media. Similarly, there had been no breakthrough in low-emission technologies during this period. Moreover, the growing body of scholarship in the field of science, technology, and policy should make us wary of any simple linear connection between knowledge generated in the institutions of the scientific establishment and societal responses.

Whatever his motives, Browne’s the speech generated substantial publicity and prodded other companies to reexamine their positions. The US automobile companies also toned down their criticism of climate science as Kyoto approached. According to the trade journal *Automotive Industries*, (Sorge & McElroy, 1997) when the three US auto CEOs and UAW president Steve Yokich met with President Clinton in the Oval Office in early October 1997, “they never questioned whether global warming was a scientifically proven concept.” Ford’s Trotman recalled that “We did not argue the science with the President. We didn't think that was a good use of his time or ours. It's generally agreed that the CO2 in the air has increased in the last decades and that there's cause for concern, and that we should be doing something." One possible reason for this change in stance is that, despite the tendency within both US companies to institutionalize conservative perspectives on climate change, at the very top levels of management in both companies there did appear to be a growing concern to “know the truth”. As Ford’s Petrauskas put it, “The trick from a management standpoint is how to get information through the layers of the organization and be able to make a judgement. We want to know what’s really going on, not just what we want to hear.” Top management began to arrange briefings directly with outside scientists, including some who were known as climate advocates. Managers acknowledged that if the more pessimistic forecasts were borne out, the Kyoto commitments would need to be substantially strengthened, with drastic implications for the industry. GM’s Frosch commented on how top management prefers certainty, even if the news is unwelcome: “If the scientists were able to say ‘I saw the data and its certain’, the industry would breathe a sign of relief…. but as it stands, we are uncertain about the science and what the politicians are doing.”

Just a few weeks after Browne’s speech, a split within US industry ranks on the climate issue became evident. On June 8, 1997, the Business Roundtable sponsored full-page advertisements in the US press signed by 130 CEOs which argued against mandatory emissions limitations at the forthcoming Kyoto conference, citing scientific uncertainties and the high cost of action. It was no accident, however, that the other 80 Business Roundtable members did not endorse the advertisements. Monsanto had led an unsuccessful effort to draft an alternative text, which acknowledged that sufficient scientific evidence had accumulated to warrant concern, and that industry should be constructively engaged in developing precautionary measures. This industry division was brought to President Clinton's attention at the June 1997 meeting of the President’s Council of Advisers for Science and Technology (PCAST), at which a report on energy R&D options was presented. According to Jon Holdren, chair of the PCAST panel responsible for the report, the President’s awareness of the minority industry faction had significant political ramifications: “We actually did get the President off the dime at that meeting. He mobilized an interagency task force, and started a process which eventually converged on a set of policy recommendations for Kyoto.”

The split in US industry can be traced to pre-existing tensions in US industry over corporate political strategy. The challenge by the GCC and the Climate Council in May 1996 to the

revisions in Chapter 8 of the IPCC SAR marked a turning point. Some industry interviewees considered this a successful effort to open up the IPCC process, which led to greater efforts to include industry authors and reviewers for the Third Assessment Report and introduced Review Editors to the process, whose role was to ensure that authors at least considered comments submitted by external experts, NGOs, and industry. In broader political terms, however, the challenge to IPCC's credibility fell short. Levy (1998) argues that the challenge had little impact on the international negotiations because of the relative autonomy and legitimacy of the IPCC institutions. Moreover, the US delegation, under pressure to respond, chose to distance itself from the fossil fuel lobby.

After the Chapter 8 affair, industry became much more circumspect about challenging the fundamental science of climate. In planning its campaign in the run-up to Kyoto in December 1997, the GCC decided to shift the focus from scientific uncertainties toward the high costs of mitigation and the lack of developing country commitments. This decision was based, in part, upon market research that suggested the public was not engaged with the scientific debates and did not find industry a particularly credible source. Moreover, the oppositional approach risked industry's credibility and legitimacy in national and international negotiations. Environmental groups in Europe and the US seized upon the lobbying and public relations efforts of the fossil fuel industry, emphasizing connections with, and in some cases funding of, the climate skeptics, and a number of reports were issued that attempted to frame the issue as big business using its money and power to distort the scientific debate (Corporate Europe Observatory, 1997; Friends of the Earth International, 1997; Gelbspan, 1997; Hamilton, 1998). Ford’s VP of Economics and Strategy, Michael Kaericher, acknowledged that "appearing negative hurts. We lost the first round of battles. We are now trying to be more positive with the science, while still pointing to the high cost of precipitate action before scientific uncertainties are resolved. Our actions will be less strident in the future.”

The American Petroleum Institute dissented from the GCC’s 1997 decision to downplay the science, and began preparing a new strategy to enroll a group of climate skeptics who were not previously identified with the fossil fuel lobby. In internal documents leaked to the National Environmental Trust and the New York Times (National Environmental Trust, 1998), the API claimed that "those who oppose the treaty have done little to build a case against precipitous action on climate change based on the scientific uncertainty. As a result, the Clinton administration and environmental groups essentially have had the field to themselves." The action plan expressed concern that the US media conveyed an impression of emerging scientific consensus "while industry and its partners ceded the science and fought on the economic issues". The document argued that this stance was a strategic miscalculation because it put opponents of the Kyoto protocol in a weak position; a successful campaign to challenge the science "puts the United States in a stronger moral position and frees its negotiators from the need to make concessions as a defense against perceived selfish economic concerns." GM’s former VP of Government Relations emphasized this point: “Once you concede the science, all that is left is to argue the extent of liability and the timetable for emission reductions. It's a lost cause."

In addition to these inter-industry tensions over appropriate political strategy, cracks were also appearing in the coalition between the fossil fuel industry and key Republican congresspeople. The coalition members originally appeared to share a broad distrust of governmental regulation, a concern that policy be guided by rigorous science, and a suspicion of the ideological roots of climate advocates. On closer inspection, however, a number of revealing discrepancies demonstrate the presence of fault lines and contradictions in this coalition. Statements by congressional committee leaders reveal a deep ideological antagonism toward environmentalism in general; Dana Rohrabacher termed the ozone depletion issue "another basically Chicken Little,

a cry we've heard before when the American people were scared into the immediate removal of asbestos from their schools." Industry, by contrast, after fighting the good fight, demonstrated a more pragmatic, accommodationist approach (Levy, 1997). The common commitment to sound science is also questionable. While one or two of the skeptics, notably Lindzen, are widely acknowledged to adhere to the practices and norms that confer scientific legitimacy and credibility, others such as Patrick Michaels and Fred Singer do not publish on climate in the refereed literature. The politicians, who proclaimed their desire for sound science, expressed distrust for the institutionalized procedures of the scientific community. Representative John Doolittle, when questioned about Fred Singer's credentials, responded that he was "not going to get involved in a mumbo jumbo of peer reviewed documents" (Gelbspan, 1997) p.65. Moreover, the fossil fuel lobby was on record for requesting more research funding, but the Republicans controlling congressional committees were intent on cutting government funding for climate research. At the May 1996 hearing, Rohrabacher called climate change research "money right down a rathole" (Gelbspan, 1997) p.77. One insight to be gleaned from these hearings is that discursive coalitions are incomplete, unstable and contingent affairs.

The emergence of industry associations and organizations supportive of some measure of precautionary action on greenhouse gases provided institutional support and legitimacy for companies leaning in this direction, as well as a vehicle for shaping emerging policy. The highest profile effort to coalesce a corporate bloc in the US supportive of emission reductions was led by Eileen Claussen, a former U.S. Assistant Secretary of State for Environmental Affairs and negotiator at the climate change negotiations, who formed the Pew Center on Global Climate Change in April 1998. Thirteen companies joined immediately, including BP, Toyota, Boeing, Lockheed, Enron, United Technologies, American Electric Power, Whirlpool, Maytag, and 3M. These companies signed on to a series of newspaper advertisements stating that they "accept the views of most scientists that enough is known about the science and environmental impacts of climate change for us to take actions to address its consequences" (Cushman, 1998). Claussen was forthright in explaining the benefits of membership: "Joining Pew gives companies credibility, and credibility means political access and influence. Reputation is especially important for companies in consumer markets". This message was not wasted on Dale E. Heydlauff, environmental VP of American Electric Power, who announced on joining the Pew Center that his company had a better chance of avoiding disaster "if we acknowledge there is legitimacy to the issues and have a hand in writing the policies" (Carey, 1998). The value of being perceived as the moderate, constructive voice of industry had been apparent at the first Conference of the Parties in Berlin in 1995, where the final conference document reflected the principles contained in a draft provided by the ICCP to the U.S. delegation (Newell & Paterson, 1998). Ford’s Kaericher also recognized this potential: “If you move to the front of the class, you have a more credible voice in helping to shape policy.” The highest priority policy concerns for the US automobile industry were to avoid a tightening of CAFE standards and to obtain credit for early action (Financial Times, 1998).

The reaction facing companies attempting to move ahead of their industries and become more proactive publicly on the climate issue demonstrates the significant institutional pressures that stabilize an organizational field and create resistance to change. GM, for example, had been invited to join the Pew Center at the outset, but was unwilling to break ranks with the GCC, whose goals were considered by Claussen to be incompatible with Pew. Those companies that did step out publicly, such as BP, were criticized and even found themselves somewhat isolated within their industry associations. When AEP joined the Pew Center, the reaction of fellow utility executives ranged “from shocked and confused to pretty vitriolic” (Carey, 1998). Resistance to these moves is often expressed internally as well. According to Claussen, “these decisions have left a lot of blood all over the companies’ meeting rooms”. Corporate members of the PCAST

that advocated action on climate also reported facing flak from their organizations. As an alternative to the Pew Center, GM joined an initiative of the World Resources Institute called Safe Climate, Sound Business in October 1998, and expressed the position that climate was an issue of sufficient concern that precautionary action needed to be taken. Reaction from the Detroit press, competitors, and congressional allies was hostile, and in a rhetorical dance, GM attempted to clarify that it was still firmly opposed to the Kyoto protocol (Mastio, 1998). This was not the first time that GM had faced institutional discipline for straying from the industry position. When Louis Hughes, executive vice-president of GM's international operations, voiced support for a gasoline tax increase of at least 50 cents per gallon in October 1997, an editorial in the *Oil and Gas Journal* (Editorial, 1997) warned that "companies should not join politicians in steamrolling opposing views on the issue."

The institutional environments in which companies are embedded can generate pressures for strategic change as well as inertia. Membership in an association that is more proactive on climate, such as the Pew Center, or the Business Council for Sustainable Energy (BCSE), confers legitimacy on the voices of corporate managers and scientists who concur with the view that serious action is required to reduce greenhouse gas emissions. Even companies that are not members are exposed to the shifting discourse, through meetings, conferences and the media. Michael Marvin, director of the BCSE, organized a series of roundtable discussions in Washington D.C. in 1998 and 1999 on topics ranging from emissions trading, the Clean Development Mechanism, to liability issues. These meetings have been well attended by people from a wide range of companies and industry associations. According to Marvin, "Companies don't come expecting to change their positions, but they do move by a process of osmosis. At our meetings they talk about positive, reasonable solutions. It makes a big splash when Enron, ARCO, and Shell come out ahead on the issue." Clearly, some voices have more power to shift the discourse than others. Even though climate science has not been a specific topic of discussion for Pew or the BCSE, participation in these organizations facilitates a process of convergence around the issue, and they serve to bring together views from disparate industries. According to Claussen, "Most of these people have not sat with each other before. There is a real mix of industries, and it is fascinating watching the dynamic develop. The companies give each other mutual credibility."

The 1997 PCAST panel on energy R&D can likewise be interpreted as a forum in which participants are not just educated as individuals on the subject of climate change, but are also subject to subtle social and institutional pressures. The PCAST panel was particularly potent because of the anticipation of a need to write a consensus report, and because of the technical nature of the subject material and the scientific background of most of the participants. Under these conditions, there was a strong expectation that participants would operate as experts rather than representatives of their industries. The constitution of the panel is deserving of some scrutiny in this context. About one-third of the members were brought from the permanent PCAST group, which does not have representatives from the automobile, coal, or oil industries, but which does have members from companies more open to greenhouse gas control measures, such as Monsanto, a participant in WRI's Safe Climate, Sound Business Initiative. A further fifteen experts were drawn from external organizations, including the coal, oil, gas, and nuclear sectors, as well as from environmental NGOs and academia. People from fossil fuel sectors were therefore in a minority in a panel committed to scientific procedures and norms in a consensual process. The result was a consensus document that recognized the need for precautionary action and recommended a substantial increase in funds for energy R&D, particularly for renewables. Some industry participants mentioned they would probably get flak from their companies and industry associations for signing on, but they did so nevertheless. Holdren noted that Don Paul, the participant from Chevron who held a Ph.D. from MIT in geophysics, clearly shifted his

thinking during the process, and that the past president of EPRI, a chemical engineer who had spent much of his career working on coal technologies, became an effective advocate within the industry faction for the recommendation to put 80 percent of new money into renewals and efficiency.

Perhaps one of the strongest sources of institutional pressure for change is the competitive dynamic of innovation. Toyota's commercial launch of the Prius, a hybrid electric-small gasoline engine car in the Japanese market in 1998, and it's announced intention to introduce the vehicle into the US market in 2000, took the industry somewhat by surprise and caused other companies to accelerate their plans. Most American executives were dismissive of the prospects for the car in the US, recalling that GM's electric vehicle had generated thousands of "pre-orders" which evaporated once the car was on the market in late 1995. Nevertheless, the auto companies were nervous that they might misread the market or fall behind a competitor. Ford's Kaericher remarked that "of course we are concerned about what competitors are doing. We have to build a product that satisfied consumers and any insights into consumer demands are a scarce and valuable commodity. We never want to believe that we have the only insights, maybe we have missed something. - look at what happened with the mini-van, which was a Ford idea that Chrysler made happen."

Daimler's investment of approximately $400m in the Canadian fuel cell company Ballard had a similar effect. As Hesse expressed it, "we look very closely at our competitors with respect to the fuel cell technology. It is a little schizophrenic. This technology is very difficult to develop for a car and we have a lot of work to do, and it is the same for all the companies. Of course we are not sure that we will be ready in time or achieve a high market share, as there is a lot of uncertainty. Nevertheless, once we started pushing the issue, we found a very strong trend with our competitors to step in and allocate resources and target money to chase us." This "follow-the-leader" behavior has been observed before in the international business literature (Knickerbocker, 1973), and it has been suggested that companies are willing to invest to match competitors' moves even when expected returns are highly uncertain or negative rather than risk ceding strategic advantage; it might be preferable to make the same mistake together than to let another company secure a lead. In institutional terms, a competitor move such as this confers some legitimacy on the technology and creates pressure on others to copy it. Indeed, it may well be part of Daimler's intent to enroll competitors in helping to establish a new technology. Hesse discussed the importance of other companies following its lead in fuel cells:

> We did a general assessment of cooperation and competition, and how we can leverage them. In our cooperation scheme with Ford for fuel cells, the competition issue arises and some things should stay within each of the companies. We developed fuel cells and want to introduce them to the market and we need a fuel. This could be a very risky strategy if nobody follows us, and the market will reject us if nobody provides the infrastructure, and if we can't set a trend into the technology. There is a strong competition element but there is also cooperation. We hope that it will not just be a fad, but that other manufacturers will also want to introduce the technology into the market. This will secure an infrastructure buildup and make it much more possible.

Conclusions

Climate change constitutes a profound strategic challenge to the automobile industry because of the scientific, technological, regulatory, and market dimensions of uncertainty associated with the issue. After a long period of relative stability in the social-technological regime for transportation, we appear to be entering a period of turmoil and upheaval, with little guidance as to the form and

structure that a new, reconfigured regime might take. Under these conditions, companies cannot apply traditional analytical techniques to choose among strategic alternatives; rather, decisions are guided by perceptions and expectations of economic, technological, and political conditions, which are constituted through an organization's interactions with its institutional environment.

The process of strategy making is thus inherently institutionally embedded; there is no clear distinction between institutional and economic environments, as markets and conceptions of economic interests are themselves constructed in social and political contexts. The institutional environment within which innovation strategies are formulated can be characterized as a social-technological regime, with the properties of a complex, dynamic system. Such systems can be temporarily stabilized through the alignment of organizational, material-economic, and discursive structures; perturbations to the system can sometimes be accommodated with relatively minor changes, but occasionally lead to more fundamental reconfiguration of the system before a new regime can be stabilized.

Within such complex social-technological systems, actors behave strategically to constitute institutional structures in particular ways. These efforts are inherently political, as actors strive to secure the organizational, economic, and discursive foundations of a stable institutional regime. Companies and industry associations attempt to shape public opinion about climate science, build alliances with other companies and politicians, and gain acceptance for technologies they are developing. Their perception of economic interests can shift in this dynamic process, even as they pursue them. Organizations such as the Global Climate Coalition the Pew Center on Global Climate Change not only serve as competing vehicles to further their members interests, but also change perceptions of strategic interests. Although industry's efforts to influence the debate over climate science are one component of a political strategy to influence regulation, the case suggests that skeptical perspectives on climate science become institutionalized in a process of reconciliation with perceptions of economic threat. Thus, agents and institutional structures mutually constitute each other, in a process described by Giddens (1984) as "structuration". In a similar way, conceptions of climate science and of economic interests are mutually constitutive.

More fundamentally, the conceptual framework of a social-technological regime developed here suggests that a sharp distinction between political and product strategies is unwarranted. A broader concept of strategy would relate a company's overall position in a number of dimensions, such as product markets, industry associations, consumer reputation, and government relations, to the opportunities afforded by a particular social-technological regime. Companies are systematically and differentially advantaged within such as system, so the relationship among companies is simultaneously political and economic; some have more power to shape the regime to their own advantage than others, and gain the rewards for doing so. A product innovation that changes the contours of the regime in favor of one company can thus be understood to be a political as well as an economic act.

The case study demonstrates how this theoretical approach can account for heterogeneity in corporate strategies. Although institutional theory has traditionally been applied to account for conformity and isomorphism within an organizational field, the case clearly shows that companies are members of multiple, overlapping fields, and therefore subject to different pressures. Multinational companies may have global operations but appear to be subject to local, national institutional influences. Moreover, each organizational field can sustain competing discourses, norms, and practices to which companies can adhere. Some companies believe that emission controls pose a severe threat to their economic interests, while others, adopting an "eco-modernist" discourse concerning climate change, see opportunities in new markets for low-emission products and for selling emission credits. Finally, each company interprets institutional

discourses through the lens of its own organizational culture, structure, and history; those companies that lost substantial sums on earlier investments in low-emission vehicles perceive future prospects in a more pessimistic light.

This theoretical framework can account for the different responses of automobile companies in Europe and the US to the climate issue, as well as for the changes in their positions over time. US companies were alerted earlier to the issue, had more time to organize around the issue, and successfully forged a coalition opposing mandatory controls with powerful industrial and political allies. Investments in low emission technologies seemed extremely risky given the economic environment of low fuel prices, consumer demand for large vehicles, and the lack of will in US policy circles to take aggressive GHG emission policies against industry's will. European companies, by contrast, were faced with a more promising economic environment for low emission vehicles, and a political context in which the EU wished to demonstrate its commitment to significant and early emission reductions.

The nature of the sea change in industry perspectives on and responses to climate change that occurred in the period 1996 to 1998 can be understood in terms of the competitive political dynamics occurring within a social-technological regime entering a phase of instability. A number of disruptions, some of them relatively minor, have pushed the system out of a stable pattern in which organizational, material, and discursive structures could reinforce each other and reproduce the regime in a coherent form. The regulatory threat of emission controls and high rates of effective taxation on carbon fuels is only one pressure for change. In the symbolic sphere we observe the emergence of new eco-modernist discourses of win-win technological solutions, sustainable development, and cooperative private-public arrangements. On the organizational front a number of industry associations representing the traditional fossil fuel alliance show signs of fragmentation, and new alliances are growing that represent companies willing to accommodate emission controls. On a material level, new technologies are emerging that threaten traditional core competencies of incumbent firms, and competitors are already introducing new products such as hybrid electric-gasoline cars. These changes have brought dormant contradictions and fissures in the regime structure to the surface, setting in motion a period of turmoil during which the organizational field is likely to undergo a major restructuring.

The study also deepens our understanding of the relationship between corporate political strategy and more conventional product and innovation strategies. The more obvious interactions involve companies resisting regulation that would adversely affect current lines of business, and advocating regulation that would stimulate demand for existing products. The case also reveals more complex relationships, for example, a company simultaneously opposing emission regulation while investing in low-emission products. This can be interpreted as a hedging strategy, or as an attempt to prolong markets for existing products while technologies and markets for future products are still in their infancy. Some companies dropped their opposition to regulation, despite being poorly positioned to benefit from any regulation, on the expectation that some regulation was inevitable, and cooperation would enable some influence over the outcome. The different political strategies pursued by the US oil industry and the auto companies illustrates that, as for product strategies, there is no *a priori* way of determining an optimal course of action; the choice may have more to do with institutionalized modes of dealing with governmental regulation in each industry.

The study carries a number of implications for managers. The strategies of US companies regarding the climate issue may have been overly conservative because of the institutionalization of skeptical perspectives on the science, a relatively narrow focus on domestic market and regulatory conditions, and a lack of appreciation of the potential for radical change in the social-technological system. Although early recognition of the climate issue in the US allowed industry

to organize effectively, the institutional vehicles created have tended to lock companies into an oppositional stance. Some organizational changes can open up the strategy-making process to a wider range of inputs. The globalization of top management can help ensure that a company is open to multiple perspectives and conditions, and the formation of top-level cross-functional climate teams can assist in this process, as long as the teams have a cross-national element. Companies also need mechanisms to ensure that strategic planning uses a range of plausible scenarios concerning climate science and markets for new technologies. It is important that options such as direct injection diesels are not ruled out as medium term approaches in the US because of assumptions about consumer behavior that were based on an older generation of engines that were noisy, dirty, and lacked performance. Membership in a range of industry associations will expose a company to a broader diversity of perspectives. Similarly, companies need to ensure that they have access to a number of up-to-date and reliable sources of scientific information. IPCC style assessments lack timeliness and do not contain information relevant to companies trying to assess likely regulatory responses. More appropriate channels might include contacts with external scientists and university departments, and ensuring that internal scientists are engaged with this external community.

Given the complexities, time-scale, and uncertainties of the climate issue, appropriate response strategies should reflect flexible, hybrid, portfolio approaches that reduce risks and costs, and provide the capacity for rapid introduction of new technologies. Such a strategy would include modest investments in a range of technologies, without necessarily committing at an early stage to leadership in any single technology or to investing large sums in production vehicles. Similarly, companies need to invest in the technical capacity to engage in science and policy debates in a credible manner, while remaining receptive to new external information. Such strategies are not cheap or risk-free. Mergers, joint ventures, and alliances can generate economies of scale and help to share the costs and risks with other companies, as well as to create acceptance and standards for emerging technologies. Similarly, companies need to work with regulators to ensure that fuels, infrastructure, fiscal incentives, and regulations are supportive of emerging technological solutions.

If policy makers wish to steer the immense technological, financial, and organizational resources of the private sector toward GHG mitigation, then it is important that policy measures are developed within a framework that takes account of the institutional embeddedness of corporate strategy and its relation to the broader social-technological regime. A reliance on purely market mechanisms alone, such as taxes, subsidies, or trading systems, is likely to prove ineffective in the face of systemic inertia, or would require politically infeasible rates of effective carbon taxes. One priority ought to be to reduce the level of uncertainty associated with the future price of carbon, for example, by establishing a mechanism to ensure a floor price for carbon credits in a given period. Fiscal policies also need to be combined with measures that address other elements of the social technological regime. For example, integrated transportation planning initiatives that engage the private sector could assist automobile companies in locating corporate innovation efforts within this broader framework, and provide greater predictability concerning the trajectory of technological evolution, emerging standards, and regulatory priorities.

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