



CONFERENCE REPORT

CITRIS-Copenhagen Research Conference on Climate and Energy

August 18, 2008

I. INNOVATION, RISK, AND ENERGY TRANSFORMATION

The IPCC has made clear that global climate change, caused by greenhouse gas emissions and other human-induced influences, has the potential to introduce significant changes to the Earth's environment over the next century, with adverse impacts to patterns of human economic, social, and political life. Our present understanding of how to confront these changes is less well-developed. Carbon pricing and other policy instruments may provide incentives to stop our most damaging behaviors. Technological innovation can provide new tools, but its rate of progress and outcomes are by their very nature unpredictable. Business model changes can bring new technologies to bear, but what models will work best can't be known ahead of time.

In this context of significant risks and uncertain responses, the conference proposed that all aspects of the problem are best considered as a question of insurance. Current debates on the costs and benefits of responding to climate change focus on discount rates – of when and how much to consume. But the nature of climate change introduces significant unknowns that make this comparison difficult. Rather, we need to protect ourselves against future risks, risks that can best be mitigated by buying in early to a portfolio of investments in policy, technology, and business that maximize our chances of success.

Climate change mitigation presents a new kind of technology problem, for which the portfolio approach to investment is a natural response. Earlier technology problems, whether sending men to the moon or delivering the atomic bomb, had limited scope, discrete intermediate goals, and few price constraints. But the low-emissions economy of the future demands no less than a fundamental reordering of the energy basis of the economy. The steps to get there are not clear. Maintaining prosperity, and allowing others to achieve prosperity, means we must take these steps in a cost-constrained environment. Doing this successfully will require policy involvement but it is not, as some have suggested, a matter of picking winners in a command economy. Rather than picking a few "silver bullet" technologies to receive special attention, we must, as with insurance, diversify the portfolio of investments to increase the chances of choosing good candidates and insulate ourselves from the failure of others.

The conference proposed that these portfolios of investment are best thought of as changes in the *Production, Distribution, and Use* of energy. Across these domains, solutions will require coordination of policy initiatives, business model changes, and technological innovation. The conference introduced the concept of a Climate Navigator to aggregate and synthesize knowledge and analysis across these domains and the sectors

within them, with the goal of improving the establishment and ongoing management of investments as worldwide mitigation efforts commence. The Navigator proceeds from the belief that, given long-term goals and regular reassessment, it is possible to make intelligent choices about the alternatives for a low-emissions future and to support their development and deployment in the market.

II. CONFRONTING THE RISKS, MANAGING THE UNCERTAINTIES

A diverse group of conference presenters, ranging from CEOs of major energy companies to leading environmental economists, policy analysts, and politicians, concurred with this framing of the problem. Discussions of technology innovation, policy measures, and business model adaptation expanded on the implications of the themes introduced above: that policy must be broad-based and flexible, that policy business models must adapt if they are to make best use of the possibilities of technological innovation (and vice versa), and that the technological transformation ahead is of a scope not seen since the industrial transformation of the 19th and early 20th centuries.

II.1 – Technology

II.1.1 – The Scope of the Technology Problem

The technology discussions generally made two points clear: many technologies, if imperfect, are available for deployment now, given the right incentives. But the wholesale transformation of the energy economy will require significant new advances, and funding levels and approaches are not presently supporting this scale of technological change.

Steven Chu, Nobel Laureate and director of Lawrence Berkeley National Lab, argued that the technological transformation ahead will be as comprehensive as the communications revolution that began with the switch to digital technologies. But to pull this off, he noted that the technologies that will pave the way – solar and wind, carbon sequestration and power grid efficiency, biofuels and transportation systems – currently lag behind the scope of the problem.

Other panelists noted a range of technology stories that underscored the fundamental nature of the economic transformation described by Steve Chu. Paul Wright, Director of the conference sponsor CITRIS and professor of engineering at UC Berkeley, noted that data centers are on track to process a thousand times more data in a decade than they do now; without major efficiency gains in how data centers are managed, this will mean a thousand-fold greater energy footprint. Only a transformation in relevant microtechnologies will help us manage this energy requirement. More broadly, such transformations in microtechnology, as well as changes to the way we invest in technology, changes to sensor systems that turn consumers into active players by shortening feedback cycles, and changes in how our technology systems collect and use information, can have profound impacts on consumer and industry energy consumption.

Such stories are playing out in many sectors of the global economy. Dan Kammen, Director, Renewable and Appropriate Energy Lab, University of California, Berkeley, made the point that good decisions on technology investment and deployment mean not just the physical technologies, but much-improved modeling techniques for understanding the efficiency gains, costs, and benefits ahead of time. Jay Keasling, professor of bioengineering at UC Berkeley and head of the Joint BioEnergy Institute, predicted that, just as we engineer proteins today to make newer, better drugs, we will also engineer plants and algae in the future to produce new and better carbon-neutral biofuels. And Finn Strøm Madsen, President of Technology R&D at the Danish wind leader Vestas, said that despite the efficiency gains he and his firm have made in wind turbine technology, its scope will remain limited if power transmission continues to be plagued by high transmission losses: capturing the full potential of wind requires revamping the entire power grid. This scope of technological innovation – from data center design to mathematical modeling to bioengineering to power grid design and beyond – presents a new kind of technical challenge for governments, researchers, and firms.

These new technological models present new uncertainties that will require innovation in policy and business to support them. Carbon sequestration, perhaps the only way to make coal a feasible power source, will have all kinds of risks, such as leakage or long-term degradation. Piloting these technologies is as important to the technological development process as basic R&D, but will succeed not just on its technical merits, but on the basis of outside support.

But in turn, technological transformation can serve as a key enabler of policy implementation; better policymaking will itself be partly based on better technology. For example, the modeling and monitoring technologies on which policymakers depend, first to understand what might happen and then to determine what did happen, remain underdeveloped. Energy and emissions models are often poor pictures of real-world dynamics. The deployment of monitoring equipment remains spotty. The kind of informed and flexible policymaking that conference attendees advocated will require substantial improvements to modeling and monitoring, and the need for such improvements was a recurring theme across multiple topics. Otherwise, a willingness to be flexible could be hamstrung by the inability to construct policies that assume flexibility or alter policies based on regular feedback.

II.1.2 – Specific Development Needs

Conference discussions also dealt with technology-specific development needs for climate mitigation. While these discussions were not intended to provide a comprehensive rundown of relevant technical issues and challenges, some of the particulars discussed are noted in Appendix A.

II.2 – Policy

All conference participants, regardless of their place in the economy, agreed that a low-emissions future would require more than just a global agreement at COP-15 and a global price on carbon. Examples from Denmark in particular played a big role. Efficient

combined heat/power systems are economical and have very high market penetration in Denmark, and play a big role in Danish energy efficiency. But, as discussants in the second panel of Day 1 noted, getting there required not only the carrot of cost savings, but also coordination between the power companies and government on how to build the infrastructure. As the conference case study on energy-efficient buildings suggested, these kinds of coordination problems are present across many different technology and industrial domains. Governments will be challenged to find constructive roles in resolving them.

The specific form these policies may take was the subject of some debate. Many conference participants, including Jim Rogers, CEO of Duke Energy, believed that a carbon price would play a central role. But Michael Hanemann, professor of economics at UC Berkeley, challenged the prevailing wisdom of carbon pricing as a primary solution. Democracies of all stripes, he noted, tend to dislike taxes, so it was unlikely that any developed economy could sustain carbon taxes at a level high enough to make permanent changes in emissions patterns. Furthermore, much of the research and development that would be needed to make a low-emissions economy possible would require the kind of basic research that only governments are inclined to fund. Thus, he argued, we must look at how government engages in productive regulation of emissions and subsidy of technological innovation, in ways that don't force the government to pick technological winners.

At the international level, panelists offered two cautions. First, we should be careful about taking too many lessons from earlier attempts to create global institutions. Erika Mann, Member of the European Parliament, and John Zysman, professor of political science at UC Berkeley, both noted that, unlike the system of world trade and economic management institutions, the system of climate treaties will be built at a time when the global economy is in flux. The entry of China, India, and Brazil, the relative decline of the United States, and potential conflicts between national sovereignty and management of the global commons make this problem new. Second, several participants, including Laura Tyson, Jay Keasling, and Jim Rogers, stressed that the developed world has both instrumental and ethical reasons to make sure that the needs of the developing as well as the developed world are addressed.

One point echoed by multiple speakers – including Dan Kammen, Shankar Sastry, Katherine Richardson, and others – is the fact that fundamental transformations of the type discussed in the technology section above require systemic solutions. Such solutions involve coordination of changes to multiple different economic elements simultaneously. Shai Agassi's electric car model will require improved power grids, a network of battery distribution points, and a new method of making cars. To reach full effectiveness, the wind technology pioneered by Vestas needs more efficient power grids and storage systems capable of handling intermittent power generation. These systemic changes will require coordination among multiple industries to deliver the technologies needed. But, as in the past, major changes to the way power is generated and used will face regulatory and market hurdles that informed government policy can help overcome. Policy efforts must support such systems-level transformations, both in terms of

technological development and business or social changes. Government intervention to cushion or absorb up-front risk involved in major changes may also be key.

Standards could play a central role here. Shai Agassi, whose Project Better Place advocates a reorganization of the transportation energy industry, argued that even minimal standards – like a common plug for batteries in electric cars – would help companies develop and deploy new technologies confident that the market could accept them. His company has been asking governments for just this kind of minimal standard. Open, minimal standards can become competition-enablers, where closed comprehensive standards would be devices to lock out new entrants. As Arun Majumdar, professor of mechanical engineering at UC Berkeley and Director, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, pointed out, other kinds of standards, such as performance metrics, can also form the basis of effective policy; but they must be based on actual performance rather than modeled projections.

Regardless of the specifics of the policies, discussion among participants reflected the tension between the need for policy stability and policy flexibility. Jim Rogers and others from the business community stressed the need for policy stability so that their companies could make the investments in low-carbon energy sources and energy efficiency measures, confident that the markets would continue to exist as those investments came on-line.

But Shankar Sastry, dean of engineering at UC Berkeley, invoked the example of the Semiconductor Industry Association Roadmap to demonstrate the need for policy flexibility in the face of new information. The point of the Roadmap, which has laid the groundwork for more than two decades of success in delivering on Moore's Law, was not to develop and deploy a rigid plan. Rather, it was to provide a framework for repeated re-evaluation of decision-making, technological innovation, and deployment. Planning to re-plan, he argued, was the key – whether in the kinds of technologies to support, the way to support basic R&D, or the configuration of subsidies for early deployment. For a problem like climate change, that would take a generation or more to confront, policy breadth and flexibility would be central to policy success. Recent history in climate policy and commodities pricing – for instance, the effects of biofuels on food prices – has given regulators and entrepreneurs pause to think about unintended policy consequences. Effects like these reinforce the difficulty of getting any first-generation policy right the first time, and the necessity for flexibility in both policy and business models.

Nick Rowley, former science advisor to Prime Minister Tony Blair, reminded the conference that policies were mere means to an end – that end being the behavioral and market changes that were needed to confront the challenges posed by climate change. In that regard, the science and business communities needed to help policymakers, not just ask for policies that helped them. As Michael Hanemann pointed out, successful climate policy is sustained climate policy, and that is difficult in democratic societies. Rowley asked the business and science communities to help move the climate policy debate beyond the jargon-filled conversations between elites and towards a vernacular conversation that helped the public at large see a prosperous, sustainable, low-carbon

future as a possibility. How can science and business, as well as government, help to inform voting publics and build support for a willingness to act? How can they communicate both the challenges and opportunities that responses to climate change will bring, and reasonably discuss the level and extent of responses?

Finally, CITRIS director Paul Wright made a concrete call for reframing the policy debate. As he noted, we have spent too long arguing over the wrong things: whether to invest now or later, which “silver bullet” to invest in, how much discomfort we will endure today. We must understand that these debates are not either/or questions: to solve the problem of climate change, we must act now *and* later and invest in multiple parallel potential solutions rather than picking one. If we can accomplish these reframing goals and effectively communicate them, the debate can move on to the truly important issues that confront us.

II.3 – Business Models

Shai Agassi, CEO of Project Better Place, provided the conference a useful demonstration of the power of new business models in bringing about a low-emissions future. He noted that electric cars are much more efficient than internal combustion engines, but have traditionally been plagued by three problems: short battery life and range; high battery cost; and inconvenient recharging options. His new company proposes to solve all three problems by selling drivers their car, but leasing them the battery from a network of battery-changing stations. Range ceases to be an issue so long as fresh batteries were always available; battery cost can be amortized over many, many drivers; recharging becomes the concern of the service provider. Moreover, in countries like Denmark or Israel, which have an abundance of intermittent renewable wind or solar power, his cars could run off of cheap, excess power.

This example of how changes to a business model – in this case, by changing the ownership of elements in the car – can enable the introduction of transformative technologies, had analogues throughout the conference. The buildings case study prepared for the conference noted how new companies – ESCOs – that perform energy efficiency retrofits and take their compensation from the energy cost savings have begun to change the economics of building efficiency. Discussion of carbon sequestration suggested that the oil companies might be better positioned than the power companies to deploy large-scale sequestration, given their skills in geology and chemical handling. These business model changes can help confront the kinds of market failures that Laura Tyson observed were omnipresent in issues of energy security. Many low-carbon technologies today – including many in the famous McKinsey / Vattenfall analysis – could be deployed on a cost-negative basis, but aren’t because the benefits aren’t enjoyed by those who pay the costs. Changes to business models would help correct this.

Another example of this effect is in the buildings industry. Under the right model, many incremental emissions reductions goals in this industry could be achieved readily given marginal incentives. The buildings case suggested that 10-15% efficiency gains were, without regulation, cost-effective. Energy-efficient or low-emissions products are possible today. But the structure of business models and value chains often separates

those who make the product from those who benefit from its savings. Business model changes that relocate how those costs and benefits are distributed will help maximize the effect of policy initiatives designed to speed the adoption of efficiency technologies.

This type of effect is not limited to buildings; in the sensor industry, as presented by CITRIS director Paul Wright, the widespread deployment of monitoring and sensor capabilities can assist consumers in making better decisions, and regulators in making better policy. But presently, the information these sensors deliver supplies little value to those who bear the costs of deployment. Reorganizing business models to make the information itself valuable would create new incentives for private-sector deployment of improved monitoring and tracking of energy usage and emissions intensity, laying the groundwork for improvements each.

The reorganization of many business models around increasingly fragmented, international supply chains can also moderate the way in which policy incentives can operate. For instance, R.C. Liang commented that equipment manufacturers (often in developing nations such as China and India) can make large contributions to emissions reduction by creating products that conserve energy better. These companies would like to recoup investment in new design by benefiting from a share of carbon reduction incentives captured by their customers; however, these customers are reluctant to pass these incentives on either directly or in the form of higher prices. Thus equipment manufacturers are incited to create more efficient products only if they can capture the value through increased order volume or through less direct benefits, such as employee morale.

II.4 – Roles for Research, Business, and Policy Advocates

In addition to the specific discussion of Technology, Policy, and Business Models, and the interactions among them, the conference speakers also touched on the contributions that each of these fields could make to the climate debate as a whole. As Michael Hanemann noted, confronting climate change in democratic societies will require ongoing support of the electorate. Building on this theme, Nick Rowley, former science advisor to Tony Blair, called on the conference attendees to help policymakers to describe a low-carbon future that was not one of hardship, sacrifice, or virtuous asceticism. Too often, he noted, policy analysts and scientists decried the political “show” as a distraction from the substantive issues at stake. But without the show, the substantive issues would never make it through the parliaments. Thus, Rowley argued, a new language and a new way of presenting this information are needed. Al Gore showed that it was possible, but that was only the first step. Erik Rasmussen, head of the Danish media group Mandag Morgen, echoed this point, stating that we need to find new ways to communicate so that we can close the communication gap between climate elites and the general public. CITRIS director Paul Wright agreed, arguing that we must move from a government mandate approach to a public engagement approach. In sum, we need to start discussing the climate change problem as something tractable, transformative, and positive; only then can we secure the engagement of the public.

III. TOWARD COP-15: SUMMARY AND CONCLUSIONS

Over the next century, humanity will attempt to confront the potential effects of global climate change. Doing so will require altering economic and social behavior on a scale not seen since the industrial revolution of the 19th century. But successful reactions to the global climate challenge must be more comprehensive and faster than the changes of that earlier era.

With this problem in mind, attendees at the conference on Innovation in Climate and Energy arrived at common themes. First, market mechanisms like carbon prices are necessary, but insufficient by themselves. Second, policy can best promote climate change mitigation through a diverse portfolio of investments in scientific research and development, energy conservation, and education. Third, as with any portfolio, governments and voters must recognize the possibility for missteps, have the will to correct them, and design the institutional flexibility to support such corrections. Fourth, business leaders and firms must look not only to technology and policy, but also to business model changes as ways to both promote efficiency in day-to-day operations and to deliver lower-emissions products to consumers.

These technological, business, and policy innovations will involve fundamental systems changes and novel forms of development. Shai Agassi's concept of a modular car with a battery service plan is a sea change in thinking about who owns what and how transportation energy is supplied. Turkey's climate-friendly development program for East Anatolia suggests that the developing world can take advantage of a greener economy. The essential unpredictability of the success of many of these developments reinforced the view that we must invest broadly and flexibly, bringing all the tools of technology and policy to bear.

But, the conference also noted, innovation cannot be restricted to technological advancement. Individuals will face significant behavioral changes amidst this shifting set of policies, consumer products, and energy costs. The role of the consumer and voter featured heavily in participants' reflections on the future of climate change mitigation. Generating and sustaining momentum for climate change policies will require that people first imagine what a prosperous, low-emissions economy of the future might look like, before they will support the policies needed to achieve it. Imagining such a future will require those familiar with the climate debate to find innovative ways to move that debate beyond specialists and engage the general public.

Thus the conference ultimately concluded that innovation for climate and energy must occur on a much broader scale than we typically consider. Technological advancements are only the starting point. Business engagement and policy sophistication and flexibility must be brought to bear. But this kind of development will only be sustainable given the sustained support from citizens worldwide. Generating that support will require moving the climate change discussion beyond those present at the conference, and into the broader world.

APPENDIX A: Sector-by-Sector Sampling of Necessary Technological Development

Note: this list is not intended to provide a comprehensive review of technological development needs; it represents a sampling of the issues foremost in our speakers' minds.

Production

Biofuels

1. Better understanding and customization of microbes and plants for:
 - a. Dedicated energy crops
 - b. Efficient breakdown of lignocellulosic fuels
2. Improvement of basic diagnostic and measurement tools

Carbon Capture and Storage (CCS)

1. Long-term performance and safety has yet to be established
2. Capture uses a significant percent of the energy generated by the primary process; the efficiency of capture must improve

Consumer Transportation

1. Current transportation energy sources (mainly fossil fuels) have a very low total conversion efficiency
2. Electrification of vehicles requires:
 - a. Improvements in battery technology
 - b. Better grid capacity

Nuclear

1. Development of new generations of reactor technology to allow increases in practical lifespan of nuclear power
2. Expansion of uses for heat byproducts into areas such as industrial processes and hydrogen production

Wind

1. Large-scale deployment of wind-power will require innovations in grid structure that governments can help with

Solar

1. Estimates and models for energy production and GHG footprint are based on outdated assumptions (general problem that effects solar as well); monitoring and modeling technologies must improve
2. Efficiency must improve

Distribution

Electrical Grid

1. A variety of improvements and redesigns are necessary to support capabilities required by new energy production strategies – examples include long-distance transmission and improved storage technologies

Use

Energy-Efficient Manufacturing

1. Further improvement and cost-reduction in manufacturing facility conservation

- technologies
2. Continuing development of energy-conserving products for manufacturers to make

Nanotechnology and Biotechnology

1. Development and use of enzymes can save energy, chemicals, etc. for industrial processes

Buildings

1. Measuring and monitoring: Uncertainty in models of energy efficient design create uncertainty in the value of investing in energy efficiency; lack of information about real performance makes real value uncertain
2. Design and construction of zero-net-energy buildings – involves increases in sensor and control technology as well as others

Sensors, Information, and Communication Technology

1. Development options include micro-technologies, including “pico data centers” based on cell phone technology, optical routing system on a chip, and deployment of microsensors
2. Standardization and integration – we can imagine a world where sensors are the new “cell phone,” relating many kinds of data depending on need, but this requires standards to allow intercommunication