



# A Possible Turning Point for Climate Change Solutions

## HOW INNOVATIONS IN INVESTMENT, TECHNOLOGY AND POLICY ARE NEEDED FOR EMISSIONS STABILIZATION

A White Paper and Workshop Summary from the Montreal Strategic Climate Change Workshop on Sub-National Strategies for Clean Energy Investment, Technology Deployment and Innovation, held at Château Vaudreuil, Montreal, October 3–5, 2005.

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Dear Reader:

The aim of this white paper is to highlight the significant opportunities to develop a technology-based approach to complement the target-based Kyoto process. If we are to stabilize greenhouse gas emissions, we must replace our polluting power, heating and transportation systems through a global clean energy transformation. To do so, we need to forge new global policies and agreements that focus more directly on technology innovation to build on the existing cap-and-trade system. For years, sub-national actors—states, regions, NGOs and the private sector—have developed models for climate technology investment, innovation and deployment that could be used to create such a technology-based approach to climate stabilization.

Clean Energy Group (CEG) and the Heinrich Böll Foundation (HBF) recently convened a high-level strategic sub-national climate change workshop to discuss these new global approaches to clean energy technology innovation. This white paper reviews the outcomes of that workshop regarding these fundamental technology commercialization and deployment questions, whose answers might hold the key to climate stabilization. The workshop participants committed to work together to review the current state of interest in technology-focused climate policy, and to take a closer look at new approaches to investment and innovation concerning low-carbon technologies. Perhaps most important, the meeting brought together advocates for cap-and-trade and for technology agreements, and in doing so created a new collaborative commitment to strengthen each approach with complementary strategies.

We hope you will join our efforts to explore the development of new technology-based climate strategies to accelerate climate stabilization. We believe these approaches can successfully complement existing emissions-based strategies, and lead to a more productive global dialogue on how we take climate action while providing greater economic benefit.

Sincerely,

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December 2005



Clean Energy Group (CEG) is a leading nonprofit advocacy organization, active in the U.S. and internationally on a variety of clean energy and climate change issues. CEG works directly with various public fund managers, private investors and business academics to develop more effective and transferable models for change in the clean energy sector. In 2002, CEG was instrumental in the formation of a new alliance of U.S.-based, public clean energy funds, the Clean Energy States Alliance, or CESA *(www.cleanenergystates.org)*. This coalition includes 17 clean energy funds that will invest nearly $4 billion in the next ten years to support clean energy technology markets. CEG is the nonprofit manager of CESA and assists its member funds in multi-state strategies to develop and promote clean energy technologies and to create and expand the markets for these technologies. For more information about CEG, go to *www.cleanegroup.org*.

The Heinrich Böll Foundation (HBF) is a political nonprofit organization striving to promote democracy, civil society, equality, and a healthy environment. Headquartered in Berlin, Germany, it has 24 offices worldwide and is affiliated with the German Green Party. For more information about the Heinrich Böll Foundation, go to *www.boell.org*.

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"Too much of the debate over climate change has become polarised between those who advocate compulsory targets and those who advocate technology. For me this is a false choice. The technology is the means by which we will achieve those targets."

Prime Minister **Tony Blair**, November 19, 2005 op-ed, *The Independent*[1]

## Executive Summary

We stand at a crossroads for climate change policy. A timely series of events transpired in 2005 that, through a combination of disparate forces, could provide the necessary momentum and direction to move forward on international climate stabilization through technology-based agreements.

Much like a tipping point, this confluence of elements suggests an opportune environment for collaborative action on climate change—one that is grounded in achieving low-carbon climate solutions on economic development terms through policy, investment and clean technology[2] innovation and diffusion—not only at the international level, but also at the sub-global level.

Over the past few years, a growing body of academic literature and theories on technology- and investment-based climate agreements has developed in parallel to the often tumultuous negotiations of the Kyoto Protocol. Rather than focusing exclusively on results by setting targets and timetables for greenhouse gas emissions reductions, these technology-finance-policy approaches focus on investment and innovation actions to mitigate climate change. Whether by intention or later interpretation, many of these "alternative" approaches were initially viewed by some as a strategic threat to the Kyoto Protocol. Some felt that recognition or adoption of a model other than Kyoto would weaken international commitment to the climate treaty. Others maintained that many of these theories would have been complementary to the "targets and timetables" approach embraced by the Kyoto Protocol.

With the mounting recognition[3] that much deeper cuts in emissions[4] will be required beyond Kyoto measures to achieve climate stabilization, these technology-investment-innovation-based approaches to climate mitigation are again in the spotlight. This call for innovative strategies has been echoed in the outcomes of the G8 Summit at Gleneagles and its follow-up ministerial, as well as in statements and publications from the UK Department for Environment, Food and Rural Affairs, to the European Environment Agency to one of the most conservative members of the U.S. Senate. Taken together, these events signal a sea change in the willingness of the international community to move toward consideration, development and adoption of a complementary technology-investment-innovation-based approach to climate.

It is clearly evident that there is a growing interest in complementary approaches to climate change

mitigation. However, recent developments attest that climate policymakers have yet to comprehensively figure out how to approach the critical elements of what a technology-investment-innovation-based climate agreement might look like. There are many pieces to this complex puzzle (see *Global Questions* box).

In October 2005, in an effort to address these fundamental questions and possible avenues toward solutions, the Clean Energy Group and the Heinrich Böll Foundation convened The Montreal Strategic Climate Change Workshop on Sub-National Strategies for Clean Energy Investment, Technology Deployment and Innovation.

From October 3 to 5, 2005, this multidisciplinary transatlantic workshop was held to seize upon the aforementioned development in thinking on climate policy and to prepare for the international discussion in Montreal on a post-2012 climate policy approach (see summary, Appendix I).[5] This seminar built on a transatlantic dialogue between U.S. states of the Clean Energy States Alliance and German Länder that began in October 2003 with a workshop at the German Embassy in Washington, DC, which led to the participation of a delegation of eight U.S. states in the first International Conference on Renewable Energies—Renewables 2004—in Bonn, Germany.[6]

The Montreal Strategic Climate Change Workshop broadened this initial dialogue beyond Germany and the United States to include experts from Canada, Italy and the United Kingdom, including policymakers and experts from the Battelle/Joint Global Change Research Institute and National Council on Science and the Environment; British Consulate-General, Boston and Montreal; British High Commission Ottawa; Carbon Trust, California Energy Commission; Carl Duisberg Society; Ecologic; Embassy of the Federal Republic of Germany, Ottawa; Environment Canada; Federation of Canadian Municipalities; Federal Ministry for the Environment, Germany; Fondazione Eni Enrico Mattei; Green Party of Schleswig-Holstein; Izaak Walton League/Xcel Energy Renewable Development Fund (Minnesota); Massachusetts Renewable Energy Trust; Ministry of Natural Resources and Wildlife, Province of Quebec; Ohio Environmental Council; UK Department of Environment, Food and Rural Affairs; UK Department of Trade and Industry, University of California at Davis, and the Wuppertal Institute on Climate, Energy and the Environment.

After three days of dynamic debate, several key issues were identified and agreed upon by the participants (see *Outcomes* box, p.4).

## Global Questions Relating to Technology-Based Measures to Climate Change Mitigation

- How do we achieve mainstream commercialization of low-carbon technologies? What are the best policy instruments to achieve this?
- How do we link commercialization strategies among various technologies to leverage deep emissions reductions and catalyze growth in low-carbon technology markets?
- How do we integrate an economic development approach within technology-investment-innovation-based climate strategies to ensure success?
- How do we better coordinate joint activities among current and future clean energy investors and practitioners to greatly accelerate clean energy commercialization?
- How do we apply technology innovation principles to clean energy and climate activities?
- How do we create complementary and synergistic relationships between federal, state, international and private sector low-carbon technology investment-innovation-diffusion activities?
- How do we rapidly create new dedicated streams of capital for low-carbon technologies?

## Outcomes from the Montreal Strategic Climate Change Workshop on Sub-National Strategies for Clean Energy Investment, Technology Deployment and Innovation

- There is a severe disconnect between international energy policy and climate policy efforts
- More needs to be done to increase the environmental effectiveness of the current international climate architecture
- A target-based approach to reduce emissions of greenhouse gases and a technology-based approach are ultimately dependent on each other—they are not mutually exclusive, and both pathways must be pursued—we need international action and on-the-ground action
- Targets are an important driver for governments to introduce policies for the broad use of clean energy technologies (e.g. carbon taxes, emission trading systems, feed-in laws, renewable portfolio standards, tax incentives for low-carbon technologies), and targets create long-term signals and security for low-carbon technology investors
- Without increased on-the-ground deployment and diffusion of clean energy technologies, international targets alone will not yield enough greenhouse gas reductions to stabilize the climate
- To date, there is no effective global effort aimed at deployment of low-carbon technologies to achieve greenhouse gas reductions of the magnitude necessary to stabilize the climate
- Technology-based agreements, in addition to the Kyoto Protocol, could provide a complementary path forward to achieve long-term climate stabilization

## Next Steps for Joint Work Stemming from the Montreal Strategic Climate Change Workshop

- Define the exact problem (i.e., when considering possible technology agreement pathways and solutions, there is a pressing need to define the problems we are trying to address and to consider what we are trying to achieve. For example, input or outcome, push or pull, cooperative or competitive, evolutionary or revolutionary approaches—as articulated by Siobhan Peters of DEFRA)
- Define elements and a portfolio of options for a model "technology protocol" or technology-based agreement on climate change
- Further explore the concept of an "architecture of parallel regimes" to identify "overlapping networks of different solutions" for climate change through low-carbon technologies (a concept offered by Ambassador Richard Benedick of Battelle/Joint Global Change Research Institute and the National Council on Science and the Environment)
- Develop and integrate a clean energy technology "theory of innovation" so that any resulting technology policy agreement respects time-tested patterns of technology innovation
- Identify means to develop more effective provisions in the existing Kyoto Protocol on R&D, deployment and technology transfer
- Expand the workshop group to include other innovation experts, technology developers, finance and market specialists, and developing country experts

There was interest to continue collaborative efforts to begin to address these issues through new joint research, writing and future workshops (See *Next Steps* box).

Workshop participants decided to form a working group to carry on further thinking and develop a research agenda to tackle these questions through additional analysis, writing and modeling. It was also proposed that this work be included in a major "KyotoPlus" conference in Germany planned by the Heinrich Böll Foundation, WWF Germany, the European Climate Forum and Wuppertal Institute for the fall of 2006.[7]

For a detailed summary of presentations and sessions of the Montreal Strategic Climate Change Workshop, please refer to Appendix I of this paper.

## Sub-National Clean Energy Investment and Deployment Models Lead the Way

As climate policymakers contemplate avenues for technology-investment-innovation-based climate approaches, are there models that already combine elements of investment in low-carbon technologies and deployment strategies that could be explored for lessons and options?

We think so. Several models of clean energy investment, technology deployment and collaboration are already working at the sub-global level—in states, provinces and regions—that could provide options for climate action going forward.

In the U.S. alone over the last five years, state clean energy funds have invested and obligated more than $1.5 billion through a growing variety of public finance instruments including grants, rebates, loans and equity investments to spur the development and deployment of clean energy technologies. In the coming decade, these state funds are currently budgeted to invest another $2.5 billion. Some states are also focusing their technology investment activities to take advantage of related economic development and technology innovation opportunities by investing directly in clean energy companies.

These emerging sub-national investment models could inform any future technology-investment-innovation-based climate agreement, especially an approach based on collaborative investment and technology innovation for low-carbon technologies. Yet far more discussion is needed, especially in the area of technology innovation, if we are to develop investment-innovation-diffusion strategies that will lead to climate stabilization. Indeed, there is a massive gap between clean energy technology commercialization and deployment strategies and an operational framework for climate stabilization.

Furthermore, the complexity of the problem and the nature of the solutions require that this debate should take place at various levels (international, sub-national, etc.) and within multiple frameworks (i.e., fora for sub-national stakeholders as well as the United Nations Framework Convention on Climate Change or the G8 Dialogue on Climate Change, Clean Energy and Sustainable Development). *To be clear, the intent here is not to challenge the approach or institutions agreed to under Kyoto or the G8 Plan of Action on Climate Change, Clean Energy and Sustainable Development*; rather, we believe there is a distinct role for sub-national actors, such as the state clean energy funds, to inform these processes.

It is critical to advance the dialogue that began at the Montreal Strategic Climate Change Workshop to discover how investment and commercialization strategies for clean energy technologies could play a part in any future technology-investment-innovation-based agreement aimed at climate stabilization. It is in this spirit that we hope others will join our efforts to chart out options and answers for this complementary approach.

## Prevailing Factors— The G8 and Other Recent Developments in Context

There is now a well-developed academic literature on technology-investment-innovation-based approaches to achieve climate stabilization. This work comes from various scholars and diplomats including Scott Barrett at the Johns Hopkins School of Advanced International Studies, Carlo Carraro and Barbara Buchner at Fondazione Eni Enrico Mattei (FEEM), Thomas Schelling at the University of Maryland, Richard Benedick at Battelle/Joint Global Change Research Institute and the National Council on Science and the Environment, Robert Socolow and Stephen Pacala at Princeton University, and Jonathan Pershing and Robert Bradley at the World Resources Institute (WRI), among others.

In short, this growing body of writing recognizes the importance of strategically incorporating technology solutions into the climate end-game. These authors support the viability of a new approach to climate change policy grounded in low-carbon technology innovation and diffusion. Some of their key findings include:

- The Kyoto model is linear, with one agreement following the last in succession. A better approach, in my view, would be to adopt a number of different, mutually reinforcing protocols—agreements that would need to be adjusted and amended over time. To make a difference to the climate, a treaty has to create incentives for longterm technical innovation (Barrett, 2005).
- [Various papers explore] the idea of replacing international cooperation on greenhouse gas emission control with international cooperation on climate-related technological innovation and diffusion... More radical proposals are based on the observation, largely shared by climate scientists, that without a real technological breakthrough it will be very difficult to achieve the stabilization of GHG concentrations. Therefore, an effective climate regime should be based on measures that enhance climate friendly technology innovation and dissemination (Buchner and Carraro, 2004).
- When the OECD countries do get serious about climate change, they should focus on actions—policies, programs, taxes, subsidies, regulations, investments, energy technology research and development … (Schelling, 1997).
- Serious global climate change can be averted only if, first, we develop a new generation of cost-effective technologies that dramatically reduce dependence on fossil fuels and/or that capture and sequester carbon...What is needed now is a farsighted strategic vision that explicitly addresses issues of technology research, development, and diffusion, aimed an nothing less than a technological revolution in energy production and consumption (Benedick, 2001).
- Humanity already possesses the fundamental scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half-century. A portfolio of technologies now exists to meet the world's energy needs over the next 50 years and limit atmospheric $CO_2$ to a trajectory that avoids a doubling of the preindustrial concentration...Humanity can solve the carbon and climate problem in the first half of this cen-

tury simply by scaling up what we already know how to do (Pacala and Socolow, 2004).

- ...There is arguably a need to look for other avenues for concerted action, provided such action is consistent with or complementary to the aims and processes of Kyoto. With this perspective in mind...constructive agreements should be explored at the sub-global level that would have the advantage of producing real emission reductions while at the same time paving the way for engagement at the larger global level by countries whose ultimate participation in a global regime is imperative (Pershing and Bradley, 2005).

The idea of a technology-investment-innovation-based approach to climate is undoubtedly gaining ground with international climate change policy-makers. The year 2005 witnessed several new developments and directions that further solidify the need for an approach to climate change mitigation that is grounded in technology, economic development and innovation.

## Climate as Economic Development

In June 2005, as part of the U.S. Senate deliberations on the Energy Bill, the Senate voted against the passage of the McCain-Lieberman amendment on climate change.[8] This proposed legislation would have imposed limitations on greenhouse gas emissions in the United States through a cap-and-trade system. In lieu of this legislation, a Sense of the Senate Resolution on Climate Change was passed, stating that such legislation should be enacted at some point in the near future, and confirmed a majority view that action on climate change is needed.[9]

Our purpose here is not to discuss the merits or approach of this legislation. Instead, we call attention to a statement made by Republican Senator Mike DeWine of Ohio—one of the more conservative members of the Senate—that was offered during the McCain-Lieberman bill discussion. In a floor speech, Senator DeWine advocated a new willingness to take action on climate change through a progressive, technology-based approach:

> As the world's biggest emitter of greenhouse gases, the United States has an obligation to take the lead in efforts to control climate change. We have an obligation to be an engaged global player. We have an obligation to urge other nations to join efforts to lower emissions.
>
> It is time for our Nation to get into the driver's seat and take the lead in developing the technology and the alternate energy sources that will become an inevitable part of our economy. Right now, we are falling behind. Japan and Europe are well on their way to developing the very technologies that will be necessary to retrofit our power plants and make our cars environmentally friendly. We should be the ones developing that technology. We should be the ones designing and creating and inventing the tools we need to adapt and adjust to the future. Let me repeat: Climate change is happening, Mr. President, and a shift to a new global energy economy is also happening. We cannot avoid it. It is inevitable. And, without question, we are going to have to change operations and clean up our power plants

> and find alternatives to oil and gasoline. Do we want to be the buyers of the technology that gets us there? Or rather, do we want to be the sellers?[10]

The senator's statement provides further evidence of the acceptance of climate action through a technology-investment-innovation-based approach (especially because he is not a member of the usual chorus of climate change policymakers). Senator DeWine's remarks are a bellwether for increased understanding of the importance of economic development and potential job growth related to what he terms the "transition to the new energy economy." This statement is a strong and timely signal that there is a momentous change taking place—we are moving beyond the stalemate of the uncertainties related to climate change toward a consensus view that there are significant economic development benefits that can stem from climate innovation.

## The G8 Connection

In July 2005, G8 ministers met at the Gleneagles Summit, with climate change as a central focus of the ministerial dialogue. Following the summit, the G8 issued an action plan and communiqué on climate change, clean energy and sustainable development affirming that climate change was a serious and urgent challenge and setting out actions to promote the transition to cleaner energy. A Dialogue on Climate Change, Clean Energy and Sustainable Development involving the G8, China, India, Brazil, South Africa, Mexico and a number of other countries with significant energy needs was established to guide the implementation of the action plan and to explore the challenges further. The G8 Leaders pledged at Gleneagles to:

> Support a market-led approach to encouraging energy efficiency and accelerating investment and the deployment of cleaner technologies which will help transition to a low-emission future; adopt, where appropriate market-based policy frameworks which:
>
> - support re-investment in capital stock turnover;
> - remove barriers to direct investment;
> - leverage private capital for clean development; and
> - use standards, or use pricing and regulatory signals to provide confidence in the near and long-term value of investments, so as to reduce emissions of greenhouse gases and/or pollutants.
>
> We will promote dialogue on the role, suitability, potential synergies and timing of various policy approaches within the context of each country's national circumstances, including:
>
> - developing long-term sectoral, national or international policy frameworks, including goals;
> - market-based instruments including fiscal or other incentives for the development and deployment of technologies... (G8, 2005).

At a follow-up ministerial on November 1, 2005, Prime Minister Tony Blair stated:

> I think in the world after 2012 we need to find a better, more sensitive set of mechanisms to deal with this problem…Now it has been extremely important to have the Kyoto Treaty…but in the end this will never be dealt with properly unless we manage to find the answer to this problem…
>
> And so the question really is this. How do we bring people together to get them working, one on developing the science and technology that is necessary to tackle this problem; two, on doing it on a basis that is compatible with economic growth; and three…how do we get the right framework beyond 2012 to enable us to carry on taking action?
>
> What we need to do is try to develop the right partnership, and then the right framework, so we are developing the science and technology that we need," (remarks by Prime Minister Tony Blair, November 1, 2005, follow-up climate change negotiations to G8 summit).

Following this statement, Blair wrote in an op-ed in *The Independent* on November 19, "Too much of the debate over climate change has become polarised between those who advocate compulsory targets and those who advocate technology. For me this is a false choice. The technology is the means by which we will achieve those targets."

The G8 Leaders' commitment to continue this formal dialogue to discuss these approaches is encouraging. Yet the G8 debates and resulting text are limited by nature. Reliance upon global institutions such as the World Bank, the Global Environmental Facility and the International Energy Agency (and their respective programs and investment mechanisms) to carry out this work is of concern unless a broader stakeholder process is incorporated into current plans.

While the results of the G8 process are indeed a step in the right direction, the G8 Communiqué is also limited in that it does not provide directly for new investment funds to support the work called for by the action plan. As an interim step, G8 Leaders invited the World Bank to lead in creating a framework for energy investment, bringing together existing sources of concessional finance with carbon finance and private sector funding, to enable developing countries to tackle sectoral clean energy issues at scale. This is expected to significantly increase the funding available for low-carbon infrastructure from its current base, and may also help to identify where additional financial tools are needed. The results of this work will be presented at the Spring Meetings of the World Bank in 2006. Regional development banks and institutions such as the Economic Commission of Latin America and the Caribbean have responded warmly to this move, and Mexico City and other municipalities are considering putting forward pilot projects in the transport and energy sectors.

However, it is clear that further sources of capital will be needed to support a systematic transition to a low-carbon economy. The inclusion of sub-global stakeholders is vital for the critical innovative measures needed to move clean energy technology markets.

## Another Call to Action from the EEA, Sub-Global Technology Options from WRI

Another recent publication echoes the G8 outcomes and calls for technology-based agreements to mitigate climate change. "Climate Change and a European Low-Carbon Energy System," was released by the European Environment Agency (EEA) in June 2005. This report emphasizes the need to go well beyond Kyoto measures to achieve climate stabilization. The EEA states that major investment in low-carbon technology is needed on top of a global carbon tax to reach climate stabilization levels:[11]

> There needs to be greater support for research, development and demonstration into sustainable energy technologies in order to support and promote innovation...R&D on the emerging sustainable energy technologies such as renewable energy, carbon capture and storage, energy efficiency, hydrogen and fuel cells could yield significant cost reductions and performance improvements over time. R&D expenditure should address a variety of low-carbon technologies on the supply and the demand side in order to keep different options open ...Making commitments to innovation in low-carbon technologies would have the added benefit of introducing a new element to the international dialogue on policies for addressing climate change, which may appeal to some of the countries that are sceptical of the Kyoto Protocol. An innovation-oriented technology and climate action could also contribute to the creation of a lead market, resulting in future economic benefits ("first-mover advantage"), (EEA, 2005, p. 57).

Yet the EEA findings do not go so far as to indicate a clear path for how the international community should develop investment and commercialization strategies for low-carbon technologies. The report indicates a willingness to move toward a technology-investment-innovation-based approach but offers no substantive suggestions as to how that would be achieved. Furthermore, the report does not place much attention on the importance of going beyond R&D agreements to also focus on the critical funding needed for deployment and commercialization.

One step in the direction of outlining specific technology options is found in a paper from Jonathan Pershing and Robert Bradley of WRI. "A Climate Solution Concept," which was released in conjunction with the G8 deliberations in July 2005, offers three possible sub-global technology options for the new G8 Climate Working Group to consider. These include: 1) loan guarantees for $CO_2$-capture-ready Integrated Gasification Combined Cycle (IGCC) plants, 2) promoting biofuels through the diversion of agricultural subsidies, and 3) stimulating the market penetration of highly efficient vehicles (Pershing and Bradley, 2005). Pershing and Bradley favor such sub-global approaches to both inform the G8 process, and serve as a testing ground for real emissions reductions and implementation of investment and technology deployment policies. They recommend that, "...action at the sub-global level should be explored with vigor and commitment."

## A Closer Look at Options: Sub-National Strategies and Other Trends

Historically, the "laboratories of experimentation" have been most commonly found at the sub-global, or state, level. States often play the essential role of bringing R&D (developed at federal or state level) to the critical stages of deployment and commercialization.[12] Perhaps more importantly, a growing number of states already view economic development and climate protection through the same lens. In these terms, states see low-carbon technologies as a large market growth opportunity over the next decade. It could be the most significant energy growth sector in the medium term for U.S. and European generation and energy investment markets.

Annual U.S. installations of renewable energy are expected to increase by a factor of five in the next ten years. Decades of research and development advances, driven largely by government investments, have led to a proliferation of clean energy technologies. Recent growth rates of over 20 percent per year are common in the wind and photovoltaic industries. Fuel cell markets are also growing, with the technology providing reliable, high-quality power for critical facilities such as police stations and hospitals, among other applications.

These prospects for growth are attracting both public and private investment capital. In addition to states, venture firms, state pension funds and other private investors have begun to explore ways to invest. In 2004, $900 million was invested in U.S. energy technology companies from venture capital funds, increasing the share of all VC clean technology investing to 4.5 percent for that year. By comparison, 2003 levels were $428 million, or roughly 2.4 percent of all VC investment.

Pension funds and other institutional investors are considering investments in clean energy technologies.[13] This year's $1 billion commitment by members of the Investor Network on Climate Risk to invest in clean technologies over the next year is indicative of the enormous capital potential these investors can bring to clean energy markets.[14]

There is similar low-carbon investment and innovation activity taking place across the globe at both national and sub-federal levels:[15]

- In Europe, organizations such as the Carbon Trust in the United Kingdom are fostering clean technology innovation through a range of grants and equity investments to move the UK toward a low-carbon economy.
- In Germany, states such as North Rhine-Westphalia and Schleswig-Holstein have supported renewable energy technology projects and companies through state support, in addition to public support at the national level through the successful German feed-in tariff.
- In Canada, the Climate Change Plan includes billions in new funding for climate change mitigation through the use of cleaner technologies. For example, the $250 million (CAD) Partnership Fund will provide federal-provincial support for major technology and infrastructure strategic investments. Support for large Canadian greenhouse gas emitters will come through a long term Greenhouse Gas Technology Investment Fund to make strategic investments in new, innovative technologies or processes to reduce emissions.

- China is taking an economic development approach to clean energy through groundbreaking renewable energy legislation introduced in 2005. In addition to a feed-in tariff for renewable energy, China will support a technology fund for the development of clean energy projects and companies.

While these trends in clean energy investment and technology adoption are encouraging, the current scale for low-carbon technologies remains extremely small. While solar and wind power in the last five years have surged with over 30 percent annual growth, they still represent less than 1 percent of global electricity generation. Including small-scale hydroelectric and fuel cells, the overall figure for clean energy today is between 3–4 percent of total electric generation in the U.S.

A low-carbon future will not be self-executing. Even if a new technology-investment innovation-based climate agreement were to outlay major new sources of capital today, we currently do not have a sound strategy to invest those dollars tomorrow in the manner that would accelerate innovation of current low-carbon technologies—and yield future generations of those technologies—that would stabilize our climate. It may be necessary to develop a variety of complementary options that go beyond conventional environmental treaty-based agreements to achieve the level of action and investment required for change.

## The Technology Commercialization and Innovation Challenge

Despite positive growth in clean technology deployment and uptake, most current technologies face daunting issues of power density, scalability and economics. In "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years With Current Technologies," Stephen Pacala and Robert Socolow of Princeton University identify a portfolio of existing technology "wedges,"[16] already in various levels of deployment that, with greater effort, could lead to climate stabilization.

These technology wedges include:

- renewable electricity and fuels
- energy efficiency and conservation
- fuel switching
- nuclear fission
- forests and soils
- $CO_2$ capture and storage

Pacala and Socolow maintain that we already know "what" technologies to use. The fundamental question then, if we indeed hold all the right technologies in hand, is "how" to overcome the multiple barriers that are hindering their commercialization. How do we set a strategy to bring these low-carbon bridge technologies to scale through near- and long-term approaches?

There are various options on the drawing board. Near term (3-25 year) global approaches could include efforts to:

- Stop expanded development of conventional coal plants.
- Expand use of natural gas.
- Commercialize integrated coal gasification combined cycle (IGCC) technologies.
- Increase terrestrial carbon sequestration.

- Conduct universal retrofit of existing diesel vehicles and widespread deployment of both hybrid drive systems biofuels.
- Maximize deployment and utilization of clean energy technologies such as renewables and fuel cells.
- Enhance the integration of "best practice" energy efficiency design elements into the power generation, transport, manufacturing and real estate sectors.
- Set ambitious, dynamic efficiency standards for electric appliances and stimulate markets through public procurement policies.

Long term (2030–2050) technology strategies could include:

- A transition to low- or no-carbon mobility approaches (new fuels like electricity with advanced batteries, hydrogen, or hydrogen-rich liquids) as well as strategies for modal shift to public transportation and new urban development patterns.
- Application of biotechnology to fuels production, $CO_2$ capture and mineralization.
- Operational deployment of widespread fossil energy system carbon capture and geologic sequestration.
- Deployment of very high efficiency fossil fuel generation technologies.
- Widespread use of renewable technologies (PV, wind, biomass, geothermal, small hydro, wave and tidal, etc.) in distributed and central generation applications.
- Mainstream application of fuel cells and combined heat and power in distributed generation systems.

How do we radically innovate the current stable of low-carbon technologies and further catalyze a major technological shift in the interest of achieving climate stabilization? On the demand side, how can we improve uptake and adoption of these technologies? Can we better employ outside lessons on technology innovation to accelerate commercialization of low-carbon technologies? Are there approaches we can borrow from established innovation business principles?

Relatively little academic research has been conducted to apply historical models of technology innovation to low-carbon technologies. In one of the first publications to conduct such an analysis,[17] Andrew Hargadon, of the University of California at Davis, finds that successful development of clean energy will require attention not just to advances in basic and applied sciences, but also to the commercial dynamics that surround emerging technologies and represent the "tipping point" signaling rapid and widespread adoption (Hargadon, 2004).

> Technical advances alone are not enough to trigger rapid adoption. The revolution depends upon the slow accumulation and maturation of complementary technologies (whose recombination brings about new and innovative capabilities), but also depends upon the details through which they are ultimately introduced: the design of the new venture. To date, efforts to direct and develop alternative clean energy technologies have taken place largely within the domains of science and social policy. The need exists for better research aimed at effecting change through commercial ventures (Hargadon, 2004).

This leads to another fundamental question: If the international community indeed stands ready to develop complementary technology-investment-innovation-based climate change approaches, how do we incorporate this critical missing link—the

leap from technical possibilities to commercial application—into the equation?

In "Global Clean Energy Markets: The Strategic Role of Public Investment and Innovation," Clean Energy Group outlined several suggestions to guide joint action:

1. **Develop global networks of clean energy practitioners.** Much greater coordination, cooperation and joint activities among clean energy practitioners are needed to accelerate clean energy commercialization. Rigorous networks of practitioners can begin to create the "social process" of clean energy innovation that is needed for global change.
2. **Understand processes of technology innovation for clean energy.** Coordination...will yield only uninformed chaos without a common understanding of our shared purpose. There is a vast wealth of knowledge about technology innovation that has not been applied to clean energy.
3. **Organize federal, state, international and private sector activities to create complementary and synergistic relationships.** Currently, various federal, state and private players in the U.S. and elsewhere are operating at different places in the technology innovation process. Each has a unique and valuable role, but there is little communication among the players to develop any complementary strategy for how these roles could work better together to leverage each other's success.
4. **Create new public and private funding streams and investment vehicles.** Any successful innovation network will require that more capital be mobilized to accelerate clean energy deployment. In order to bring about the billions of dollars in new capital required to bring clean energy to scale, new funding sources must be created (Brooks, Milford and Schumacher, 2004).

The massive gap between clean energy technology commercialization and deployment strategies must be addressed if we are to successfully employ technology-investment-innovation-based approaches to climate stabilization. We know that there is no "silver bullet" solution that is waiting to be discovered to guide the formation of such a climate protocol. We do know there are many questions to be answered and that it will take unprecedented work by different stakeholders to develop these technology-investment-innovation-based approaches.

We will need to go beyond the climate and clean technology community to engage other fields, most notably experts in finance and technology innovation, to develop solutions to bring about the massive technology and economic transformation needed to create a low-carbon economy.

## Conclusion

There is a need to complement the top-down, emissions-based Kyoto approach with new market, technology and finance solutions that are firmly rooted in an economic development approach. There needs to be a massive technology innovation leap, and a parallel finance revolution to mobilize unprecedented levels of public and private capital. No one has worked out a strategy for how that will happen and how the complementarity of both approaches can be developed to the fullest.

The Montreal Strategic Climate Change Workshop on Sub-National Strategies for Clean Energy Investment, Technology Deployment and Innovation started these critical discussions. We call upon more academics, clean energy funders, leading business innovation scholars, the investment community and NGOs to join with us to cross-pollinate the current practice of clean energy funding with ideas of a technology-investment-innovation-based approach to climate stabilization. We envision a bottoms up approach by focusing on what needs to be done to address these challenges and, most importantly, on the economic opportunities to advance these new low-carbon technologies.

It is not sufficient for countries to continue to linger in the middle of this conversation. The time is right to seize upon this willingness to try complementary approaches to the target-based approach, and to set sights on developing concrete options that will yield real results. The Montreal Strategic Climate Change Workshop and this paper are only the beginning of the effort, and we look forward to engaging others in this work going forward, and within the context of the KyotoPlus Conference planned for late September 2006 in Berlin.

## References and Further Reading


Barrett, S. (2005), "Kyoto Plus," in D. Helm (ed.), *Climate Change Policy*, Oxford, Oxford University Press, ch. 13, pp. 282–303.

Benedick, R. (2001), "Striking a New Deal on Climate Change," *Issues in Science and Technology*, Fall, pp. 71–76.

Brooks, C., Milford, L. and Schumacher, A. (2004), "Global Clean Energy Markets: The Strategic Role of Public Investment and Innovation," a report from Clean Energy Group.

Buchner, B. and Carraro, C. (2004), "Economic and Environmental Effectiveness of a Technology-Based Climate Protocol," Fondazione Eni Enrico Mattei, Working Paper, Milan.

European Environment Agency (2005), "Climate Change and a European Low-Carbon Energy System," EEA Report Number 1/2005, Luxembourg, Office for Official Publications of the European Communities.

G8 Presidency (2005), "Gleneagles Plan of Action: Climate Change, Clean Energy and Sustainable Development," obtained from *http://www.number-10.gov.uk/output/Page7882.asp*.

Hargadon, A. (2004), "Clean Energy and Fuel Cells: Implications for Innovation Strategies from Historic Technology Transitions," a report from the Public Fuel Cell Alliance, Clean Energy States Alliance.

House of Lords Select Committee on Economic Affairs (2005), Second Report of Session 2005–06, "The Economics of Climate Change," London, The Stationery Office Limited.

Pacala, S. and Socolow, R. (2004), "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years With Current Technologies," *Science,* Volume 305, pp. 968–972.

Pershing, J. and Bradley, R. (2005), "A Climate Solution Concept," Center for American Progress.

# Appendix I

## The Montreal Strategic Climate Change Workshop on Sub-National Strategies for Clean Energy Investment, Technology Deployment and Innovation

Presentations can be viewed at: *http://www.cleanenergystates.org/international/meetings.html*

**Summary of Sessions and Presentations:**
The workshop was opened with welcome remarks by **Michel Lesueur**, Policy Advisor, Quebec Ministry of Natural Resources and Wildlife, highlighting climate and renewable energy policies in the Province of Quebec, as well as by **Jean Boutet**, Senior Policy Advisor to the Canadian Environment Minister Stéphane Dion, who outlined the role of sub-national governments in global climate change policies during the parallel sub-national conference to the Eleventh Conference of the Parties and the First Meeting of the Parties in Montreal in December 2005.

The main focus of the first afternoon session of the workshop was an historical perspective and long-term view on technological innovation in the context of climate stabilization. **Andy Hargadon**, Associate Professor of Technology Management and Director of Technology Management Programs at the Graduate School of Management at the University of California, Davis, highlighted that while discussions and policies are needed on a global scale, any implementation will be local. Hence the existing gap between international discussions and sub-national or local practices needs to be bridged.

By providing an historical review of how technological innovations have made a successful transition to the market, Hargadon posited that major developments such as Ford's Model T or the recent Apple iPod were not successful solely due to their revolutionary technology, but rather through the new combination of existing technologies.

While there needs to be research to lead to the development of "not yet existing" clean energy technologies, promising short- and mid-term solutions already exist, though the right strategy for their commercialization needs to be developed. Hargadon referred to cases of technology breakthroughs that rely upon critical social networks in which technological, intellectual and financial capital flows to create momentum and opportunities for new technologies. He supported this approach by describing how venture capitalists have employed such social networks for references to decide which product or company to invest in, and he also cited how the evolution of Silicon Valley serves as a prime illustration of how social networks can create the foundation for an entire industry sector.

This discussion on technology innovation proved that such social networks also exist in the field of climate change and renewable energies on various levels, but that they currently do not sufficiently overlap to mutually benefit each other. Hargadon concluded that certain networks in the climate change finance and business community have insufficient interaction with political and civil society networks, which leads to the gap between political strategy and practical experience. The primary conclusion of this workshop segment was the strong need for overlapping climate social networks to better

combine ideas and experiences to facilitate the innovation process.

The second day of the workshop began with an introduction by **Lewis Milford**, president of the Clean Energy Group, who highlighted the need to branch out to new constituencies for climate stabilization among private corporate players, institutional and others in the investment community, and public agencies—all with more focus at the sub-national level. Disruptive technologies must be accompanied by accelerated commercialization, massive deployment and innovation in order to get clean energy technologies to scale. Technology agreements between countries as well as sub-national actors could help set the stage for stronger international cooperation on deployment and diffusion of low-carbon technologies, going beyond the focus of current international efforts that are generally limited to research and development. Milford concluded that to accompany a push to a low-carbon economy, a culture of "climate capitalism," grounded in new investment vehicles and economic development approaches, is imperative.

**Ambassador Richard Benedick**, who previously served as the lead U.S. negotiator for the Montreal Protocol on ozone depleting substances, and currently serves as president of the National Council on Science and the Environment and senior advisor to the Battelle Joint Global Research Institute of the Pacific-Northwest National Laboratory, provided a keynote address on the necessity of further action beyond the Kyoto climate regime. He noted that existing Kyoto net emission targets are both unrealistic and ineffective; and that the drastic future emissions reductions required can only be achieved through aggressive efforts to increase energy technology research, development, and deployment to developing nations. In comparing the success of the Montreal Protocol with Kyoto, Benedick expressed his strong belief that an important part of the underlying problem with the Kyoto Protocol is "its attempt to solve all problems for all countries in the same forum." He suggested that Kyoto need not be the only game in town, and that addressing the complex issue of climate change would actually benefit by "disaggregating" the problem and achieving partial (e.g., sectoral) solutions through smaller constellations of agreements involving like-minded countries along with state and local governments, and private industry. "In other words," said Benedick, "an architecture of parallel regimes under the global umbrella of the UNFCCC." This disaggregated approach would be more manageable than a global mega-process, where efforts on renewable electricity, efficiency, transportation, carbon capture and storage, and biofuels, among others, would benefit from cooperation on many levels and across regions.

In his response to Ambassador Benedick's remarks, **Hermann Ott**, head of the Berlin Office of the German Wuppertal Institute, supported the need for massive technological cooperation and for international technology agreements. However, Ott emphasized that a target- and timetable approach, such as the Kyoto Protocol, was absolutely necessary for science and business to have a long-term goal and security for planning. Ott concluded that target-based approaches and technology-based approaches are not only compatible, but they depend on each other: "Targets show the way; technology agreements get the job done."

■ **SESSION I: An Overview of Clean Energy Investment at the Sub-National Level –Sub-National Strategies for Development and Deployment of Innovative Technologies: Wind, Solar and Biomass/BioFuels**

This session included three presentations from John Geesman, Commissioner of the California Energy Commission; Klaus Müller, former Environment

Minister of the German State of Schleswig-Holstein and currently Member of the State Parliament for the German Green Party; and Jonathan Holyoak, Head of the Emerging Technologies Division at the UK Department of Trade and Industry. The presenters comparatively addressed strategies, programs and mechanisms of U.S. states, German Länder and the United Kingdom to increase development and deployment of clean energy technologies with a focus on wind, solar and bioenergy technologies.

**John Geesman** gave an overview on renewable energy development in California, which he described as "a work in progress." California's electricity consumption has remained relatively stable for the past decades, while it has increased 50 percent in the rest of the United States. California has been most successful in wind energy development, and has additional potential for geothermal to the north of San Francisco and east of the Sierra Nevada. Biomass technologies have not been thoroughly developed and deployed due to a lack of effective state government policies. Geesman outlined the recent progressive climate and renewable energy policies by Governor Arnold Schwarzenegger, including a renewable portfolio standard of 33 percent by 2020. He compared California's market incentives for solar energy to the German model of feed-in tariffs. Geesman also emphasized broad public support for renewable energy in California and support for action on the federal level, an approach which has been successful in the past, where early actor states like California have been laboratories for policies that are later replicated nationwide.

**Klaus Müller** explained how renewable energy policies and measures on the state level in Germany would not have been possible without the legislative framework created by the German federal government. He described the German Renewable Energy Sources Act as a combination of push and pull strategies. As a state between two seas with immense costs for coastal protection, Schleswig-Holstein had been in the forefront of climate change policies in Germany. The state has optimal conditions for wind energy, and as a mostly agricultural state, it is also developing its biomass potential. Currently, 31 percent of the energy mix in the state stems from renewable energy with a future potential of up to 50 percent. Renewable energy has proven to be a considerable factor in economic development with revenue of €350 million in 2004, and in employment, with approximately 5000 people working in the renewable sector in a state of 2.8 million. While there is broad public support for the development of renewable energy, project siting has been a concern of citizens. The state allocated just 1 percent of land for wind energy, which has largely been developed. Future developments are planned for offshore wind and through repowering existing wind installations.

**Jonathan Holyoak** introduced the UK Energy white paper from 2003, which articulates the UK's goal to decrease $CO_2$ emissions by 60 percent by 2050 to maintain reliability, promote competitive markets and achieve affordable heating and electricity supply. More specific targets include a share of renewables in the electricity supply of 10 percent by 2010 and 20 percent of renewables by 2020. Generally, it is assumed that a share of 30 percent renewables by 2050 is needed to meet the envisaged reduction targets. This results in a business opportunity of about £150 billion by 2050.

The British government supported R&D for renewables by setting long-term targets, in particular the Ten Year Science and Innovation Framework. Importantly, this ten-year period extends beyond both political and budgetary cycles, allowing the framework to promote collaboration, pull innova-

tive technologies and support the achievement of economies of scales and international collaboration. As instruments, the UK government chose intervention in the areas of research, development, demonstration and deployment, thereby creating both technology push as well as market pull. Interventions are specifically tailored for each low-carbon technology. For example, tidal technologies face the challenge to demonstrate reliable production and commercial viability. The UK pushed the research through the Marine Council Program, a collaborative government research program, which deploys a mix of grants and revenue support, plus infrastructure support and environment analysis. As a market pull, portfolio standards for electricity utilities (the Renewables Obligation, or RO) were introduced in April 2002. Holyoak concluded that the biggest challenge for low-carbon technologies has been the demonstration phase, as funding in the pre-commercialization phase is extremely scarce.

■ **SESSION II: Economic Development and Job Creation through Innovative Renewable Energy Technologies**
This session discussed the role of renewable energy and climate technologies in regional economic growth and employment opportunities. It highlighted successful cases, such as Massachusetts' Clean Energy Innovation Cluster and the role of cities in Canada, with presentations from Karl Jessen, Program Director for Industry Support at the Massachusetts Renewable Energy Trust, and Elizabeth Arnold, Director of the Center for Sustainable Community Development at the Federation of Canadian Municipalities.

**Karl Jessen** described renewable energy investments in Massachusetts as a "win-win" situation for business and the state's economy. He detailed how the Massachusetts Renewable Energy Trust provides support to in-state clean energy technology companies through the Industry Support program and through the Massachusetts Green Energy Fund. The Massachusetts Renewable Energy Trust is funded by a system benefits charge, part of electricity restructuring legislation in 1998 that provides $25 million annually for the Trust. The Trust's mission is to increase the supply of and demand for clean energy, promote the development of a vibrant Massachusetts renewable energy industry, and maximize benefit to Massachusetts ratepayers. As of December 2004, the Trust has invested more than $119 million in more than 350 projects serving Massachusetts. This includes supporting approximately 226.52 MW of new renewables, planning and siting support for 7 projects expected to result in additional 630 MW, funding for 47 green buildings, and funding for 93 green building feasibility studies.

**Elizabeth Arnold** complemented the discussion with a perspective from Canadian cities and municipal climate change policies. Through the Green Municipal Fund, the Canadian Federation of Municipalities supports investments in clean technologies. Investments are made through an award program, a housing program and climate partnership programs. The importance of cities in climate change policies is obvious in the Canadian context, where cities are responsible (directly or indirectly) for 60 percent of greenhouse gas emissions. The Green Municipal Fund was launched with an endowment of $125 million (CAD) by the Federal Government in 2000. With additional funding, the endowment is now $550 million (CAD). Grants are made for feasibility studies, assessments, field tests and sustainable community plans in the areas of energy and energy services, water, solid waste management, sustainable transportation, sustainable community planning and brownfields redevelopment.

■ **SESSION III: Climate Stabilization and Long-term Clean Energy & Technology Innovation Strategies: Current Approaches, 2012 and Beyond**
This session built on the previous discussions to

look at how regional models and experiences could be multiplied in other regional contexts. It included an economic analysis overview for sub-global climate compacts by Barbara Buchner, researcher at Fondazione Eni Enrico Mattei (FEEM) in Italy; followed by a discussion of the German federal approach, presented by Daniel Argyropoulos from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Siobhan Peters, head of G8 and International Climate Change Policy Unit at the Department for Environment Food and Rural Affairs, who presented the outcomes of the G8 climate change discussions at Gleneagles.[18] The session continued with two case examples: 1) the UK's Low-Carbon Technology Investment Strategy introduced by Peter Mallaburn, head of Government and International Affairs at the Carbon Trust; and, 2) Ohio's Climate Change Road Map presented by Kurt Waltzer, clean air strategy coordinator of the Ohio Environmental Council.

**Barbara Buchner** explained the difficulties of a global climate regime based on the economic modeling premise that global climate is a public good with diverse interests, structural asymmetries and large incentives for free riders, which cannot be balanced out due to the lack of a supra-national enforcement structure. Actions on sub-national levels have been often overlooked in the context of climate policies. Buchner used the multilateral trade regime as an example for FEEM's game-theory model of how an effective future climate regime could be developed. The goal of this research is to evaluate and improve both economic and environmental effectiveness of a future climate regime, which FEEM's analysis finds to be most likely in regional and sub-national contexts with a strong research and development component.

**Daniel Argyropoulos** outlined the national policies for climate protection in Germany, including the federal renewable energy policies as well as the international approach of the German government. While Germany is on track to fulfill its Kyoto commitments, a more long-term transition was initiated in 1998 to increase the share of renewable energy sources and technologies in Germany's energy mix. Through a combination of measures, such as the Renewable Energy Law, market incentive programs, tax reductions for biofuels and investments in R&D, the share increased to 9.3 percent nationwide in 2004. The wind energy sector is particularly well-developed, with roughly 15,000 MW, and photovoltaics account for an additional 750 MW. These measures have created a financial annual turnover of €11.5 billion and have helped create 130,000 jobs in the broader renewable energy sector. They have also resulted in $CO_2$ reductions of 70 million tons. With the International Conference for Renewable Energies—Renewables 2004—in Bonn, Germany, the federal government aimed at creating the environment for a global push for renewable energy and a network of like-minded governments, organizations and businesses to promote renewable energy globally. A follow-up conference was held in Beijing, China in November 2005.

**Siobhan Peters** presented the outcomes of the G8 Summit at Gleneagles, which aimed at fostering cooperative dialogue among world leaders on climate change, clean energy and sustainable development and developing a Plan of Action for international climate cooperation through stronger involvement of business and the promotion of technology cooperation. Key international partners include the World Bank and the International Energy Agency, and the Dialogue will take note of lessons learned from a number of regional technology cooperations, such as the EU-China Partnership (which aims to develop and demonstrate the use of near-zero emissions

coal technology in China and the EU), the EU-India Initiative which will consider case studies in technology cooperation, and the Italian-led Bioenergy Partnership. The Dialogue involves around 20 countries with significant energy needs. Mexico has offered to host a follow-up conference, and Japan has offered to receive a report on this work at the G8 Summit in July 2008. Siobhan Peters concluded her presentation by highlighting a number of questions with regard to testing the effectiveness and potential contribution of any future technology agreements as discussed during this workshop: Should these agreements be input or output oriented? Should they work through market pull or push instruments? Should they build on competition or cooperation? Should these agreements focus on evolutionary or revolutionary approaches?

**Peter Mallaburn** followed by presenting the work of the UK Carbon Trust, which aims, like the German approach, to transition from high carbon-intensive to low-carbon technologies by investing in immediate carbon emission reductions, in R&D, and in analysis of the consequences of climate change. The Carbon Trust also targets policies that bring down costs of new technologies and increase the scale of deployment. In 2005, the Carbon Trust reached a funding capacity of £75 million.

**Kurt Waltzer** presented the Ohio Climate Road Map, which outlines appropriate state-based solutions for Ohio's climate stabilization challenge. Ohio is the third highest GHG emitter in the United States after California and Texas, and Waltzer highlighted that the state needs to address its economic transition to low-carbon technologies independently from a federal climate policy in order to secure and grow its economy. The road map is divided in two phases: 1) to define the scope of the challenge and to find appropriate solutions, and, 2) to develop policy recommendations to implement these solutions. The road map targets the power generation, transportation, heating and industry sectors. The road map shows that climate change solutions have potential in Ohio's key economic and industry sectors, such as manufacturing though the production of low-carbon products, coal through the development of gasification and sequestration, and agriculture through biomass and biofuels.

### ■ SESSION IV: Models for Climate Technology Agreements

This concluding session of the workshop focused on the role and importance of technology-based approaches in a future multilateral climate change agreement in order to move toward low-carbon economies and climate stabilization. There was an understanding among the participants that technology approaches could serve as complementary strategies to the existing Kyoto regime, and that long-term post-2012 solutions should be a combination of targets, timetables and technology approaches. The session included presentations by Barbara Buchner and by Hermann Ott.

Building on her initial presentation, **Barbara Buchner** focused on the environmental effectiveness of technology agreements. In order to achieve a higher effectiveness (i.e., greater reductions of GHG emissions), two steps are necessary: a) increasing the number of cooperating countries, and, b) stringent abatement targets. Again, through two game-theoretic models, Buchner emphasized that technological cooperation cannot replace environmental cooperation. While technological cooperation increases economic development and appears to be more stable in terms of cooperation and compliance than a target-based approach, it does not reduce emissions by itself. Buchner concluded that any future climate regime will have to address and include both components.

**Hermann Ott** highlighted that the current Kyoto Protocol does include incentives for technological innovation and diffusion, through binding targets, cap-and-trade systems and through project-based mechanisms, such as Joint Implementation and the Clean Development Mechanism. He pointed out that even though discussions appear to be divided, emissions-based approaches and technology-based approaches are not mutually exclusive but rather dependent on each other. He agreed with the complementary nature of these measures described by Buchner and referred to Ambassador Benedick's statement that it often was a matter of political will to take concrete steps in both directions. A careful selection and balancing of approaches that combine positive aspects and avoid interference are necessary. Ott concluded by calling for making full use of existing technology-based mechanisms within the Kyoto framework, and developing parallel measures for technology cooperation on regional, sub-national and sectoral levels.

## Appendix II

### Montreal Strategic Climate Change Workshop Château Vaudreuil Hotel Vaudreuil-Dorion, Quebec, Canada October 3–5, 2005

**List of Participants**

**Daniel Argyropoulos**
German Ministry for the Environment (BMU)

**Elisabeth Arnold**
Federation of Canadian Municipalities

**Richard Benedick**
Battelle/ Joint Global Change Research Institute and National Council for Science and the Environment

**Marc Berthold**
Heinrich Böll Foundation

**Jean Boutet**
Office of the Minister of the Environment, Canada

**Barbara Buchner**
Fondazione Eni Enrico Mattei

**Irene E. Federwisch**
German Foundation for International Development (retired)

**Robert Fenstermacher**
Carl Duisberg Society

**John Geesman**
California Energy Commission

**Bill Grant**
Izaak Walton League/Xcel Renewable Energy Development Fund (Minnesota)

**Andy Hargadon**
University of California at Davis

**Jonathan Holyoak**
Department of Trade and Industry (DTI), UK

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## About the Authors/Workshop Conveners

**Lewis Milford** is President and CEO of Clean Energy Group, a nonprofit organization he founded in 1998. He is the Executive Director of the Clean Energy States Alliance. Prior to founding CEG, Mr. Milford was Vice President of the Conservation Law Foundation. At CLF, Mr. Milford directed the Energy Project where he was responsible for industry and governmental negotiations that led to new electric restructuring laws throughout New England. Prior to joining CLF, he was an environmental attorney in private practice, a NY Assistant Attorney General representing the State of NY in the Love Canal hazardous waste case, and a law professor and director of the Public Interest Law Clinic at American University in Washington, D.C. He has a J.D. from Georgetown University Law Center and is a Phi Beta Kappa graduate of Rutgers College.

**Allison Schumacher** is a Project Director at Clean Energy Group. She directs CEG's International Clean Technology Implementation Network project, which works to facilitate exchange of best practices and innovative financing mechanisms between state clean energy fund managers and their international counterparts. She also manages CESA's joint multi-state activities on clean energy & security and biomass. Prior to joining CEG, Ms. Schumacher was the Senior International Policy Associate at the Business Council for Sustainable Energy. She received her Master of Arts degree in Energy and Environment

Studies, International Economics and International Relations from the Johns Hopkins School of Advanced International Studies (SAIS). She graduated cum laude from the University of Southern California with a Bachelor of Arts degree in International Relations and Broadcast Journalism.

**Marc Berthold** is the Director of the Environment and Global Dialogue Program at the Heinrich Böll Foundation in Washington, D.C. Since 2002, he has managed the Foundation's North American activities on climate change and renewable energy, as well as the office's work on sustainable development, environment and security. From August 2001 to April 2002, he was Project Coordinator for the Foundation's capacity building program for the World Summit on Sustainable Development 2002 in Johannesburg, South Africa. Mr. Berthold holds an M.A. in Political Science from the University of Cologne, Germany.

**Should you have any questions or comments regarding this white paper or the workshop, please contact:**

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## ENDNOTES

1 See *http://comment.independent.co.uk/commentators/article327944.ece.*

2 For purposes of this paper, "clean energy" is defined to include energy production from solar, wind, small hydro, biomass, ocean thermal, tidal and wave, fuel cells, related energy storage and conversion technologies, as well as highly efficient end use devices.

3 We will not replicate the full list of various climate stabilization arguments vis-à-vis Kyoto measures here, as the need for deeper emissions cuts is well-documented. For example, Scott Barrett of the Johns Hopkins University School of Advanced International Studies states in a recent paper (Barrett, 2005), "One thing is clear: Kyoto will not stabilize concentrations at any level, let alone one that avoids 'dangerous interference' with the climate... Stabilization will require deeper cuts, by more countries; and these will need to be permanent. By design, Kyoto's importance lay in creating a foundation upon which further emission reductions could be achieved. Kyoto was intended to be a first step."

4 In March 2005, the European Environment Council recommended climate stabilization levels of 15–30% below 1990 levels by 2020 and 60-80% below 1990 by 2050.

5 The workshop and related writing was generously supported by the Oak Foundation, Rockefeller Brothers Fund, Surdna Foundation, the Embassy of the Federal Republic of Germany, Ottawa, British Consulate-General, Boston, and British High Commission, Ottawa.

6 For more information, please see "Approaches-Challenges-Potentials: Renewable Energy and Climate Change Policies in U.S. States and German Länder-Opportunities for Transatlantic Cooperation and Beyond" at *www.boell.org*.

7 For more information, see *http://www.kyotoplus.org/.*

8 The Climate Stewardship and Innovation Act of 2005.

9 "It is the sense of the Senate that, before the end of the first session of the 109th Congress, Congress should enact a comprehensive and effective national program of mandatory, market-based limits on emissions of greenhouse gases that slow, stop, and reverse the growth of such emissions at a rate and in a manner that 1) will not significantly harm the United States economy; and 2) will encourage comparable action by other nations that are major trading partners and key contributors to global emissions." See the 2005 Congressional Record, Volume 151, page S7033 at *http://www.gpoaccess.gov/crecord/.*

10 Speech by Senator Mike DeWine, given on June 22, 2005; see *http://dewine.senate.gov/pressapp/record.cfm?id=239322.*

11 The EEA report uses the European Environment Council-recommended climate stabilization levels of 15–30% below 1990 levels by 2020 and 60–80% below 1990 by 2050.

12 For further reading on specific public finance mechanisms for clean energy and the role of states in clean energy technology development and deployment, see "Global Clean Energy Markets: The Strategic Role of Public Investment and Innovation," and "Clean Energy States Alliance Year One: A Report on Clean Energy Funds in the U.S. 2003-2004" at *www.cleanenergystates.org*.

13 Several states are working together through the joint CEG-Ceres Clean Energy Investment Working Group to explore the interests of pension funds, institutional investors and other fiduciaries in developing enhanced, environmentally responsive investment strategies in the clean energy subsector that can deliver competitive returns to participating investors.

14 Two California state pension funds, CalPERS and CalSTRS, are leading a wave of institutional investors, having made commitments of $450 million in private equity investment in clean energy technologies. CalPERS has also approved $500 million in investment in environmentally screened stocks.

15 See "Public Finance Mechanisms to Catalyze Sustainable Energy Sector Growth," a new report that provides a thorough assessment of sustainable energy finance mechanisms by the United Nations Environment Programme Sustainable Energy Finance Initiative, the Basel Agency for Sustainable Energy and CEG, available at *www.cleanenergystates.org*.

16 A "wedge" is defined by Pacala and Socolow as an activity reducing the rate of carbon buildup in the atmosphere that grows in 50 years from zero to 1.0 Gt(C)/year.

17 See "Clean Energy & Fuel Cells: Implications for Innovation Strategies from Historic Technology Transitions," at *www.cleanenergystates.org.*

18 Ms. Peters has since become Head of the Review Team for the Stern Review of the Economics of Climate Change at Her Majesty's Treasury.


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