Clean Energy Group
Innovation in Finance, Technology & Policy

From Here to Stabilization

A CALL FOR MASSIVE CLIMATE TECHNOLOGY INNOVATION

Lewis Milford
President, Clean Energy Group

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"In the longer term, technological breakthroughs will be required…"
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INTRODUCTION

While the problem of human-induced climate change may well be an "inconvenient truth," there are numerous unspoken truths about the climate threat unspoken truths about the climate threat—that the problem will be much harder to solve than is sometimes suggested, that the tools at hand like the Kyoto Protocol will not by themselves address the problem, and perhaps most telling, that we do not yet know how to bring about the massive technology changes that will be needed to solve this problem within the timeframe that is the most critical. These unspoken truths inform what we need—a radical new strategy to address climate change and an aggressive new approach to technology development.

This paper takes as a given that massive low carbon technology innovation on an unprecedented global scale is needed to achieve anything approaching greenhouse gas emissions stabilization. It suggests that Kyoto "price signals" alone will not be enough to drive long-term, disruptive technology change. It assumes that many kinds of clean energy, including renewables and clean fossil technologies, will have to be developed. It advocates for cross-disciplinary work in new areas such as biotechnology, genomics and nanotechnology. It acknowledges that there is much we do not know about how to create technology change, but argues that there is much we can learn from other fields.

It poses what we believe are the major environmental challenges of this century: *how* do we accelerate innovation and commercialization of these low carbon technologies, and then *how* do we finance them into commercial success—and *how* do we accomplish this within the next few decades?

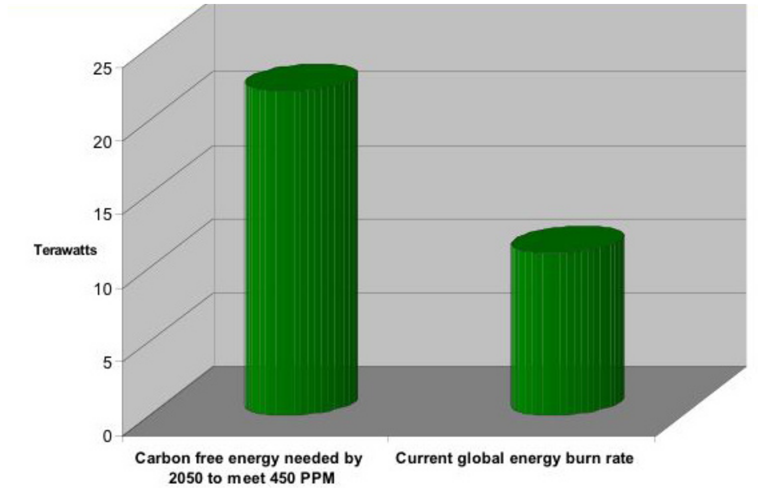
As with many issues in the environmental field, the debate is largely over means and not ends. The desired end result of nearly all parties to the debate, whether convinced or skeptical of the urgency of the climate threat, is a low carbon technology revolution. But the means proposed to date focus chiefly on only two approaches—either a mandatory Kyoto emissions cap favored by many environmentalists or the country-to-country voluntary technology partnership favored by the Bush Administration.

We propose another complementary path to a low carbon technology revolution. We contend that the missing piece of the climate puzzle is a global technology innovation infrastructure of key actors working together on practical ways to make massive low carbon innovation happen, and happen quickly in the real world.

Scope of Problem Demands New Approaches

The key to any effort of this kind is to honestly match the enormous scale of the problem with the urgent need for massive commercial-ready technological solutions. The scale and extent of the climate emissions problem are actually far more serious than most politicians and even environmental advocates will publicly admit.

- Many climate scientists believe that warming the planet more than 2 degrees Celsius beyond pre-industrial levels marks a point that could change the planet beyond human experience. A number of leading scientists are concerned that the earth's climate is already undergoing an abrupt change, leading some experts to now assert "the climate system has exceeded a critical threshold…"[1] As an example, the first six months of 2006 were the warmest on average in the United States since 1895, when temperature records were first kept.[2]



Source: Hoffert, M., Caldeira, K., et al, "Energy implications of future stabilization of atmospheric CO2 content," *Nature*, Vol. 395, October 1998 at page

- Due to the 100+ year residence time of CO_2 in the atmosphere, about 75% of this 2 degree warming is already locked in—*roughly half from warming to date and half from warming already in the pipeline*—even if all GHG emissions sources were cut off today. In short, we have very little headroom left within which to solve this problem.
- We also have very little time. The key climate models suggest that limiting warming to 2 degrees Celsius will require stopping CO_2 emissions growth in the next decade, and beginning a rapid descent in CO_2 emissions from current levels by 2050—all while the projected energy needs of the planet grow by two to three fold over this same period. As a result, if we are to meet world energy demand growth and stabilize the climate, we must triple the planet's current energy-producing capacity by 2050, and do so with only carbon-neutral energy sources.
- Most of the new energy demand and CO_2 emissions during this period will come from coal-reliant India and China; China is building the equivalent of the United Kingdom's power grid annually, by itself adding a country's worth of CO_2 emissions each year. India is not far behind. These countries are unlikely to curb their emissions unless cost-effective climate-neutral technologies are available to them.
- To put it starkly, to achieve stabilized levels, *we would need to have available twice as much net "carbon free" energy within five decades as ALL energy consumed today throughout the world*. And we need to it soon-probably *within the next twenty to thirty years*.
- In short, to innovate our way out of this problem, we are going to need new, rapidly scaleable and powerful technologies in the next 10–20 years that fundamentally "change the game."

WHAT'S NOT WORKING

Despite the centrality of the technological game change, little is being done to effectively facilitate it:

- In policy circles, a principal focus to date has been on reducing energy demand through energy efficiency and deploying traditional renewable sources. These solutions by themselves may well be overwhelmed by the scale of global energy demand growth.

- The other principal policy focus has been on imposing carbon caps in the OECD, thus setting a "carbon price." Both experience and theory instruct that these carbon price incentives are unlikely to call forth game-changing technology innovation at most, and importantly they will only likely bring forward "already on the shelf" technologies and processes.

TECHNOLOGY INNOVATION LAYS FOUNDATION FOR FUTURE EMISSIONS POLICY

To meet this challenge there is a growing consensus that, independent of caps, climate recovery demands a separate process that drives technology innovation. This is important for two related reasons. First, there is the simple political fact that governments will not agree to caps that cannot be achieved by currently available technology at reasonable projected costs. Second, any caps established likely will be insufficient to drive deep and radical innovation; they will generally drive incremental technical improvements and marginal cost reductions.

The need to go beyond incremental change through Kyoto was recognized by Tony Blair, perhaps the Western world's foremost advocate of binding greenhouse gas limits. Urging the world to reconsider the "Kyoto only" approach, Prime Minister Tony Blair noted,

> The truth is, no country is going to cut its growth or consumption substantially in the light of a long-term environmental problem.... I would say probably I'm changing my thinking about this in the past two or three years. I think if we are going to get action we have got to start from the brutal honesty about the politics of how we deal with it.[3]

A new survey of business leaders throughout Europe conducted in early 2006 also agreed that separate policies on climate and clean energy are needed to create serious emissions reductions.

> Generally it was agreed that, at least at present, separate policies are needed for emissions reductions and clean energy development. The price of carbon is not yet high enough or the market developed enough to drive renewable energy investment…[4]

Many have called for an integrated set of emissions caps and a separate technology innovation process. A dual track is supported by noted experts because it is likely to be the most *cost effective* approach.

> To promote [induced technological change] and reduce GHG emissions most cost-effectively, two types of policies are required: policies to reduce emissions and incentives for technological innovation… Technology incentives can deal with the market failure created by firms' inabilities to capture all the returns on their R&D investments. Direct emissions policies (such as carbon caps or carbon taxes) can deal with the market failure created by climate-related externalities. Attempting to address the climate change problem with only one of these policy approaches cannot fully

> correct both market failures. As a result, adopting one approach is likely to involve higher costs than utilizing the two approaches in tandem.[5]

In other words, direct emissions caps that typically encourage least cost technologies such as energy efficiency (so called "no regrets" policies) do nothing to reduce the costs of *future* technology solutions. In contrast, advancing technology innovation measures can drive down the current cost of more expensive technologies, which could make it possible to adopt tougher emissions policies in the future. Ironically, because it does not reduce technology costs, pursuing only cap and trade in its current form may make it *harder* to adopt tougher emissions policies in the future.

> …even though 'no regrets' might be attractive as a short term response, restricting actions to such low-cost alternative alone may entrench existing technologies and constrain the development of new technologies needed to reduce the costs of *future* abatement actions. This may in effect also reduce the opportunity for the global community to define more ambitious emission reduction targets for future commitment periods.[6] (Italics in original.)

But with this consensus on "what" needs to be done, there has been remarkably little attention paid to "how" this low carbon technology innovation process could be designed and implemented in the real world.

HOW TO BRING ABOUT A TECHNOLOGY REVOLUTION

As surprising as it may sound, while leading experts agree on the need for new clean energy technology strategies, they admit that little is known about "how" to achieve this technology transition. As one scholar has noted,

> Relatively little effort has gone into questioning how to stimulate the beneficial innovation that can shift the path of technological changes towards a low-polluting system.[7]

Rather than hard-headed analysis of how to create an innovation-based, long-term sustainable energy future, one skeptical energy critic remarked on what usually passes for critical thinking in this field:

> Books on the global energy system are replete with utopian visions: the nuclear future, the solar future, the efficiency future, the hydrogen future, and the 'small-scale technologies are beautiful' future. All too often, these visions are described in detail, but the path for getting there is left vague. This reminds me of the cartoon of two mathematicians at the blackboard gazing in satisfaction at a complex set of equations on the left, the simple elegant solution on the right, and an incomprehensible jumble of equations in the middle to link both sides, all of which are crossed out except for the statement somewhere about here a miracle happens.[8]

Even the international body that developed the science supporting climate change—the Intergovernmental Panel on Climate Change (IPCC)—recognized the need for new approaches to innovation and technology change.[9] But the IPCC offered little practical advice on how to put this innovation process in place.

So it seems time for a new look at "how" to bring about this low carbon technology innovation revolution. The most pressing question remains: what is the best approach that would lead to long-term low carbon technology innovation?

A new school of leading economists that study technology change maintains that learning networks and distributed tools are the most effective way to accelerate a low carbon innovation process.

> [I]mportant aspects for improving long term response capability are to facilitate learning and capacity building, create nursing and bridging markets and to overcome institutional or market barriers; all of which may prove crucial to the evolution of new and environmentally benign technologies.[10]

As another expert describes it,

> The basic message is that innovative milieus and their institutional background in the form of clusters and networks are a decisive precondition for the sustainability of innovation…[11]

The assumption is that the technology solutions for long-term emissions stabilization are likely to come from unexpected sources—from the "connections" between a wide range of industry, academic, government and technology sectors and disciplines.

At this stage, the major challenge is *to build the cross-disciplinary infrastructure for innovation,* thereby enabling the conditions for major transformative change in economic, technological and financial fields that could achieve emissions stabilization.

Technology Innovation Could Be Basis for New More Effective Climate Policies

A new technology innovation initiative from the bottom up, if successful in creating new breakthrough technologies, also could produce new climate policy recommendations. New policy approaches might have several characteristics:

- They are not necessarily global in scope, but bottom up in nature, more regional and local than global.
- They are based on the notion that real work must focus on the barriers keeping technology from moving into mainstream commercial markets—that reality will inform the work to be done.
- They will be highly collaborative and cooperative, involving key private and public partners.
- The mechanisms for the work should closely mimic the market, in its flexibility, experimentation and adaptation.
- All the work is empirically based—the facts should lead the policy, rather than the other way around.

Here are a few new approaches to climate policy that are worth exploring.

1) Disaggregate the Climate Problem

The climate policy debate almost always starts with the assumption that it is a "global" problem in need of a "global" policy solution. That is the justification for the Kyoto Protocol: a global treaty that requires all relevant parties sign on to an identical set of commitments. However, experts such as former Ambassador Richard Benedick who was the lead negotiator for the Montreal Protocol, the most successful environmental treaty in the world that led to the global ban of chlorofluorocarbons (CFCs), take a different view.

He calls for "disaggregating" the climate problem—breaking it down into discrete problems to be solved, and then to commit to a series of "parallel regimes" to solve each of those problems. He recommends that

> …the climate negotiation process could be disaggregated into smaller, mutually reinforcing, more manageable, and potentially more productive components—a search for partial solutions rather than a comprehensive model: in other words, *an architecture of parallel regimes*.[12]

These "parallel regimes"—perhaps one could call them a "distributed climate negotiation" process—could involve the following policy approaches areas, according to Benedick:

- More research and development through "an open forum for like-minded countries –North and South—who would commit both to increase their energy research budgets and to collaborate in technology development and diffusion."
- Call on the major automotive companies to convene together and "hammer out a schedule for introducing low-carbon and then no-carbon vehicles." He notes that this kind of collaboration was fostered by the Montreal Protocol among chemical companies in the race to eliminate CFCs.
- He calls for a "similar process of collaborative technology research, development and diffusion… [in] power generation."
- "Relevant governments and industries could collaborate on development of biofuels, biomass, and land-use and agricultural practices to promote carbon absorption."
- "Separate protocols or collaborations, involving flexible coalitions of governments, industry, universities and civil society could be envisaged to promote other technological innovations…"
- Governments and industries could collaborate on joint "fleet procurement, building standards and other commercial policies."
- To move beyond the global focus, regional forums on technical and policy cooperation could be encouraged.

In the end, Benedick proposes these ideas not be a replacement for Kyoto, which will continue in some form, but rather as a "complementary and supportive structure to develop the essential technological and policy conditions for the much steeper emissions reductions that will be necessary in the coming decades."

In effect, he is proposing, as others have, a "coalition of the willing"—of partners who want to solve the problem, rather than a global negotiation stymied by those who do not.[13] Eventually, more countries could be brought into the discussion, but initially, progress is more important than universal participation.

2) Carbon "Lock-in" and Strategic Niche Management

The existing emissions trading scheme will likely have little impact on radical technology innovation needed to create a low carbon future. The pricing mechanism incorporated in Kyoto, at best, may lead to incremental, least-cost solutions that could produce negligible emissions reductions.

One reason for the enormous difficulty of creating such a technology transition is a technological "carbon lock-in." Because industrial economies have been locked into fossil fuel based energy systems through a long, historical process of technological and institutional co-evolution, persistent market barriers and failures that inhibit the introduction of low carbon technologies have been created.[14]

How to escape this "carbon lock-in" is the climate challenge. Given the enormous roadblocks, it is really no surprise that the Kyoto Protocol would be ineffective at addressing the long-term stabilization challenges—it is a bit like trying to kill a lion with a fly swatter, the tool is not suited to the problem at hand.

Rather, an effective policy must be based on the way that technologies develop in the marketplace, on sound principles of innovation and technology diffusion.

Policy design and implementation needs to reflect the systemic, dynamic nature of the innovation process. Consequently, greater understanding of how innovation systems actually work is needed, relating to the actors involved; the flows of knowledge and influence between them; the drivers and barriers for innovation; and the ways in which the current systems fail to promote movement of more sustainable technologies along the innovation chain. Policies must then be designed to address these 'system failures,' which will include but are not limited to conventional market failures.[15]

In other words, policy must take account of the complexity of the innovation process where

> …successful innovation and take up of a new technology depends on the path of its development —so called "path-dependency, including the particular characteristics of initial markets, the institutional and regulatory factors governing its introduction and the expectations of consumers.[16]

Climate policy must be more than a top-down, theoretical market mechanism to be effective. Climate technology policies must be directed at overcoming these path dependent technology problems if new technology is to replace the "locked-in" technology.

That sounds obvious, but it is not the animating principle behind climate policy today. Rather treaty-based efforts are focused on negotiating emissions limits rather than on the means to bring about reductions, which is low carbon technology.

There is a body of expert advice generated from Europe on this new form of direct climate technology policy—it is loosely called "Strategic Niche Management or SNM." In its pure form, SNM is based on the work of Harvard Business School professor Clayton Christensen, described above, involving the development of "niche" markets for technologies that can be expanded to compete in mainstream markets.

> Studies of past innovations suggest that a new technology will typically first commercialize in niche markets, where the particular technology's advantages are strongest. These markets allow the technology to benefit from learning effects, so that costs reduce the technology's performance can improve. If this occurs sufficiently, the new technology then may become competitive with the existing technology in the wider market. Shifts to new technological regimes then occur through the accumulation of niches, which gradually swell and coalesce to form a new regime.[17]

Several European experts have begun to incorporate these "niche" academic theories into real world policy measures to promote cleaner technologies. This approach has been put in place by the Dutch government.

> It seeks to combine the formation of a vision and strategic goals for long-term development of a technology area, with steps forward called experiments, that seek to develop and grow niches for more sustainable technological alternatives. [18]

3) Transition Management

To put this in a larger policy context, the leading thinkers behind this approach, chief among them Rene Kemp of Maastraicht University in the Netherlands, call this policy effort "Transition Management" or TM—a policy "steering concept that relies not on specific outcomes but rather with "mechanisms for change." It offers an

> …interesting model for policy combining the advantages of incrementalism (do-able steps which are not immediately disruptive) with those of planning (articulation of desirable futures and use of goals).[19]

At best, it might be useful to summarize the characteristics of this new policy approach:

- The policy discussion looks at historical transitions such as the shift from sailing ships to steamships, the demographic transitions from high to low births, and the shift from coal to natural gas in residential heating, to learn lessons for sustainable development transitions.
- It makes use of "bottom-up" developments, with learning and institutional change as key elements.
- Collective choices are made along the way based on learning experiences at different levels.
- It does not consist of a plan but of adaptive policies and portfolios.
- Key elements of transition management cycle are: anticipation, learning, and adaptation. The government acts as a process manager, with a responsibility for the undertaking of strategic experiments and programmes for system innovation.

- Areas for integration on policy include science policy, fiscal policy, innovation policy and regulation.
- Overall, learning for policy is institutionalized.
- What makes TM different is that it "does not rely on blueprints but relies on iterative decision making in which goals may change. Decisions are made on the basis of experience and new insights."[20]

The basic rules that Kemp applies for managing transitions are the following:

- **Be careful not to get locked into sub-optimal solutions**. This calls for anticipation of outcomes and the use of markets for coordination and context control instead of planning. A second way of circumventing lock-in is …through portfolio management. One should not bet on one horse, but explore a wide variety of options, both incremental and radical.
- **Embed transition policy into existing decision-making frameworks and legitimize transition management**. It should be politically accepted and a joint concern of policy makers and society.
- **Take the long view of a dynamic mechanism of change**. The lack of positive results should not end the process, the process is itself a policy objective to capture learning.
- **Engage in multi-level coordination**. Bottoms up initiatives should be structured to inform top-down efforts, and there should be strategic experimentation for system innovation.[21]

In ways similar to what has been proposed elsewhere in this paper, the partners in the Netherlands have created "transition-arenas" or "transition networks" in various areas to formulate joint goals and develop common strategies. In effect, for these areas, they are striving to create a new structure of collective governance emerges whereby government is at the same time facilitator and one of the players.[22]

Instead of setting hard goals for policy in the energy area, the government set up transition paths of 30 technology and societal options that will be explored in various "transition coalitions: coalitions between technology developers, companies, researchers, NGOs and government."[23]

4) Adaptive Management and Technology Learning from Montreal to Kyoto

So far, for forging a new policy direction on climate, we have discussed a disaggregation of the problem into smaller parts, a policy focus on developing niche markets and then a broader transition management strategy that turns policy into a learning experiment.

We now get more specific, with a detailed look at some novel policy approaches that could be applied directly to the climate technology challenge we face.

Following on Ambassador Benedick's admonition to focus on energy innovation in a new "disaggregated" form of global negotiations, we look to the lessons learned from his Montreal Protocol success. How that protocol process successfully led to technology innovation is the subject of an excellent book by Edward Parsons, now with the University of Michigan Law School.[24]

As Parson explains, the key to the eventual ban on ozone forming chemicals in the Montreal Treaty was the novel way it handled technology solutions.

Put simply, it created a set of independent technology assessment panels to consider options. These eventually became known as TEAPS—Technology and Economics Assessment Panels. They were set up in haste by the Protocol and were permitted to choose participants, carry out their work, and prepare reports to the parties with little political oversight—"independence that greatly enhanced their effectiveness," according to Parson.[25]

Importantly, TEAPs allowed for significant participation of private sector parties. They organized into separate work groups for each type of ozone-depleting chemical, and they evaluated the potential of specific technologies and operational changes that might reduce chemical use in specific applications. Participants came from industry but also from academia, government, and NGOs.

These TEAPs panels "were strikingly successful."

> In four full assessments, and many smaller tasks, it presented a huge number of specific technical judgments that were, with few exceptions, persuasive, technically supported, and consensual.[26]

Importantly, motivating private sector participation was based explicitly on the private benefits to be derived from the process.

- Companies facing stringent possible reductions mandates needed to comply fast, and the panels were set up with antitrust protection to allow them to evaluate options in a problem solving capacity greater than even the largest firms could do individually.
- They helped manage the business risk of regulations.
- The players gained valuable information that had clear commercial value, which helped participants project market trends and identify new opportunities to sell products.
- This work gained the participants industry prestige in having an elite group of peers throughout their professional careers.
- These processes helped advance the margins of what was feasible, essentially altering the reality of what was being assessed.
- At the same time, a combination of professional norms, explicit ground rules and personal integrity avoided conflicts of interest and bias, it has been uniformly agreed by students of the process.

Oddly, even though the climate process started after the Montreal process had shown some of this progress, the Kyoto Protocol did not adopt this technology innovation approach to climate technologies. Parson tries to explain this strange policy dichotomy.

> Policy debate on global climate change is deadlocked. Why? One major reason is that assessment of options for reducing greenhouse gases has been strikingly ineffective. The Intergovernmental Panel on Climate Change (IPCC), which produces respected and successful assessments of atmospheric science, has applied the same approach to the fundamentally different problem of assessing technological and managerial options to reduce emissions. The predictable result has been options assessments that are broad, vague, and disconnected from practical problems. One reason is that IPCC has, crucially, failed to draw on private-sector expertise. Yet such expertise could inform policy and promote emission reductions directly, as one prominent recent success demonstrates. That notable success is the assessment of technological options to reduce ozone-depleting chemicals under the Montreal Protocol. An assessment process similar to that used for ozone-depleting chemicals can be applied to problems of mitigating greenhouse gas emissions and may represent the best near-term opportunity to ease the present policy deadlock.[27]

While Parson acknowledges the differences between the issues, he still believes that such differences "need not preclude the application of the model of technology assessment developed for ozone" from being applied to climate.[28]

As Parson notes, "identifying specific pieces of the greenhouse gas problem that appear most promising would likely require separate preliminary consultation and assessment, updated periodically, in response to changing technological, economic and policy conditions." Structurally, Parson recommended having these bodies operate outside the formal strictures of the IPCC, which he believes makes it "incapable of conducting assessments of the type proposed."

- "Separate ad hoc assessment bodies for particular problems could operate as consultants to an intergovernmental body…Such an advisory relationship would provide the official status helpful in gaining policy attention and administrative continuity, while the group's independence can be protected…"
- "Alternatively, assessment bodes could be established as independent NGOs, which could seek joint sponsorship of each assessment by multiple governmental and intergovernmental organizations…"
- "Whatever institutional setting is chosen, a technology assessment process similar to that used for ozone depleting chemicals hold the most promise of harnessing the creativity and energy of private industry toward substantial reductions of greenhouse gas emissions.

As Parson concludes, "even if the initial steps are small…setting these interactions in motion may be the most effective step that can be taken now to chip away at the present policy deadlock."[29]

5) New Source Performance Standards for Greenhouse Gas Emissions

One of the more interesting policy ideas to emerge from the deadlock over emissions caps is to take a tried and true air regulatory approach and apply it to greenhouse gas emissions. The conventional approach is new source performance standards.

New source performance standards (NPS) set the level of emissions from new sources such as power plants and autos. They are commonly used in the conventional air pollution regime in the United States. There are many controversies about their application but little dispute that they can be effective if fairly applied and the laws are enforced.

So how would NPS standards work in climate?[30]

- NPS CO_2 levels could be set for new coal fired power plants.
- NPS could be set through a schedule of annual new car fleet efficiency (in mpg or CO_2 per mile) standards that become more stringent over time.
- More efficiency standards could be set for appliances and new buildings.
- NPS standards for GHG emissions could be set for new industrial facilities that are major emitters.

Of course, the major limiting factor of these standards is that they would be applied only to new facilities and activities. Although with some success for new sources, a program could be implemented that could be applied gradually to existing sources.[33]

It may be that the Kyoto process is the best that we can do collectively to address this coming global crisis. It may be that central governments will band together at some point in the future to make (and adopt) a treaty 60 times tougher than the Kyoto Protocol is today, and successfully deploy it on a global scale fast enough to stabilize emissions levels in the next few decades. Advocates who work toward that goal should be commended.

But, it may also be true that the new school of economists who study technology transitions is right and that, in addition to top down emission control efforts, we need to focus directly and intently on technology innovation and apply it to climate in fundamentally new ways.

CONCLUSION

In the end, it is pretty clear that this choice between cap and trade or technology innovation is no choice at all. To the first approach, the Kyoto Protocol, society has committed massive public and private resources. That effort will continue, as it should. To the second approach, low carbon technology innovation, we have devoted virtually no resources beyond the disparate clean energy efforts already underway. An understanding of how to create a long-term, low carbon innovation revolution has been relegated to a few academic journals; in the real world, nothing significant has happened to make these ideas a reality.

A January 2006 report from a team of University of California experts is only the latest recommendation that calls for technology innovation policies *in addition to* cap and trade programs to meet long term emissions goals:

> Technology innovation, spurred by a combination of regulations and incentives, will be needed to shift the economy over the long term away from carbon-based fuels… [T]echnological and policy research is needed in order to invent and deploy the new energy system and other technologies needed to mitigate climate change.[31]

This technology approach could provide a note of optimism to the climate debate, to what has been a rather depressing public discussion. As the recent insightful article by Gregg Easterbrook in the September 2006 issue of the *The Atlantic Monthly* put it,

> Americans love challenges, and preventing artificial climate change is just the sort of technological and economic challenge at which this nation excels…But cheap and fast improvement is not a pipe dream; it is the pattern of previous efforts against air pollution. The only reason runaway global warming seems unstoppable is that we have not yet tried to stop it.[32]

The low carbon technology revolution will need to match the intensity and scope of the industrial revolution of the 19th century, as well as the advances in technology from the high-tech revolution of the 20th century, and complete this transformation in perhaps a quarter the time, in order to bring stability to climate, economics, and politics in the 21st century. To solve this problem, entire fields of thought on technology innovation are just waiting to be explored.

ENDNOTES

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Clean Energy Group (CEG) is a nonprofit organization established in January 1998 to increase the use of cleaner energy technologies in the U.S. and abroad through creative financing, business partnerships, public policy and advocacy.

CEG works with state and nonprofit officials from around the U.S. that are responsible for over $4 billion in new clean energy funds. CEG manages the Clean Energy States Alliance (CESA), a new nonprofit organization assisting these funds in multi-state strategies. CEG also works with public officials in Europe interested in transatlantic efforts to build clean energy markets.

CEG, including its related work through CESA, is supported by the state funds, and by major foundations including Oak Foundation, Surdna Foundation, Rockefeller Brothers Fund, and others.

www.cleanegroup.org
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CleanEnergyGroup
Innovation in Finance, Technology & Policy

50 State Street, Suite 1
Montpelier, VT 05602
Phone 802.223.2554
Fax 802.223.4967
Email: ceg@cleanegroup.org
Web: www.cleanegroup.org