Supporting Effective Participation in the Climate Change Debate: The Role of System Dynamics Simulation Modeling

Sustainability Institute

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Summary

For policy makers and citizens to be able to weigh the effectiveness and value of acting on the threat of climate change, they need to have a good understanding of the basic mechanics of natural systems, an appreciation of the implications of uncertainty about key features, and a clear vision of the viability of potential solutions. Recent studies have strongly suggested that most people do not have a good understanding of the climate system and, in particular, persistently underestimate the momentum of the climate system. We believe that there is an opportunity for system dynamics based learning experiences to help build people's understanding of the climate system in visceral ways in order for them more effectively to assess the need for and adequacy of proposed solutions. This document lays out our current thinking along these lines and describes in rough form the partners needed and process required to help create a more informed debate on climate change.

The Missing Link between Warning and Action

The international mainstream scientific consensus is that global warming is real – the trapping of greenhouse gasses (GHGs) is having, and will continue to have, significant impacts on global ecosystems and economies. Furthermore, taking action to reduce GHGs will reduce impacts in the future.

Here in the U.S., it appears that most people concur that global warming is real. A Harris poll conducted in August 2001 found that 75 percent believe that it is real, compared with 19 percent who do not.[1]

So does it follow to most U.S. citizens and policy makers that action is necessary?

No. Anecdotal and poll evidence suggest that most people in the U.S. do not believe that the scientists' conclusions necessitate much serious preventative action. For example, a Center on Policy Attitudes poll in November 2000 shows that:

- only 39 percent agreed that "global warming is a serious and pressing problem [and] we should begin taking steps now even if this involves significant costs,"

[1]Quoted in "Cloudy skies: assessing public understanding of global warming." System Dynamics Review, Sterman and Booth Sweeney, Vol. 18 No. 2, Summer 2002, p. 237.

- while 19 percent agreed that "until we are sure that global warming is really a problem, we should not take any steps that would have economic costs"
- and another 39 percent agreed that "the problem of global warming should be addressed, but its effects will be gradual, so we can deal with the problem gradually by taking steps that are low in cost."

President Bush's administration supports the third of these points, supporting a "wait and see" policy that the country should "slow the growth of greenhouse gas emissions (GHGs), and – as the science justifies – stop, and then reverse that growth."[2] With a few notable exceptions, the public statements of most leaders in U.S. industry concur.

Thus, while there is broad consensus of the existence of a climate change problem, the findings of the mainstream scientific community have not convinced mainstream U.S. people that action is necessary.

Our Working Hypothesis – Uninformed Inaction

Why the missing link between warning and action?

One view holds that people have filtered the scientific findings with their accurate common sense intuition about the issue, weighed that against their intuition about socio-economic costs of taking action, and have advocated for "wait and see." Perhaps people thought it through clearly for themselves and decided to wait and see; call it "well-informed inaction."

We are exploring the possibility that this view is sound in one sense – many citizens and policy-makers think through issues for themselves to some degree independently of pressures. However it is wrong in another sense – most people's "common sense intuition" about this complex scientific issue is flawed in at least two important ways. First, the issue is dynamically tricky – common sense intuition fails to capture the significant momentum and delays in the carbon-and-climate system. Second, the pervasiveness of uncertainty regarding some aspects of the climate challenge leads people inappropriately to ascribe uncertainty to the entire possibility of a significant threat. We are exploring the possibility that these two misunderstandings – momentum and uncertainty – are pushing many people into a level of complacency and inaction that do not match their goals for the future.

Misunderstanding Number One: Poor Intuition about Dynamics and Momentum

Prof. John Sterman and Linda Booth Sweeney of MIT and Harvard recently published findings regarding peoples' misunderstandings of the dynamics of global warming in the System Dynamics Review.[3]

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[2] G. Bush, 2/14/02
[3] Cloudy skies: assessing public understanding of global warming. System Dynamics Review, Sterman and Booth Sweeney, Vol. 18 No. 2, Summer 2002, pp. 207-240. Available at web.mit.edu/jsterman/www/cloudy_skies.html. See the abstract in the appendix of this document.

They report experiments assessing people's intuitive understanding of climate change, and conclude that their (actually, **our**) intuition is quite poor regarding how CO_2 in the atmosphere and global temperature would respond to changes in CO_2 emissions. People's "mental models" of the climate system don't match the real system well – subjects thought, incorrectly, that climate system is non-delayed and responsive, a system where if emissions fell, temperature would promptly fall, too. They did not account for the system's momentum. For example, when asked to project the future of CO_2 in the atmosphere if CO_2 emissions were to fall to zero, "only 22 percent of the CO_2 trajectories drawn by the MIT students were correct."[4] The authors explain how such a mismatch could lead to inaction regarding climate:

> The majority of Americans believes warming is real and should be addressed. But, as we have seen, people's intuitive understanding of even the simplest dynamic systems is poor. As long as people's common sense tells them that stabilizing emissions is sufficient there can be little political will or public pressure for policies that could stabilize climate and prevent further warming. As long as people believe the delays in the response of the system are short, they will conclude it is best to "wait and see" if warming will occur and if it will be harmful before taking action. Such heuristics may work well in everyday tasks with low dynamic complexity, where delays are short, outcome feedback is unambiguous and timely, the opportunities for corrective action frequent, and the costs of error are modest. But none of these conditions hold in systems with high dynamic complexity, where delays between actions and impacts are long, outcome feedback is ambiguous and delayed, many actions have irreversible consequences, and the costs of error are often immense. The same decision making heuristics that serve us well in simple systems may lead to disaster in complex dynamic systems such as the climate.[5]

Overall,

> The errors and misperceptions exhibited by highly educated adults constitute a serious challenge to informed debate over climate change policy.[6]

Sterman and Booth Sweeney argue that there is no clear culprit who is maintaining the gap between scientists and citizen/leaders. Instead, most citizen/leaders are struggling unsuccessfully to understand a complex, counter-intuitive, tricky system that behaves markedly differently from most of the systems they interact with day-to-day. They blame the system.

Misunderstanding Number Two: Uncertainty

A second part of our thinking involves uncertainty and action. There is much uncertainty about climate change. For example, we do not know the exact future global temperature change, the exact impacts of temperature changes on local ecosystems, the feedback responses from the changes, or the exact economic cost of changes required to address the problem. At the same time, there is much certainty that is emerging from the

[4] Ibid, p. 219.
[5] Ibid, p. 234.
[6] Ibid, p. 209.

scientific communities. We believe that, amidst the media maelstrom of information about climate, the existence of **any significant uncertainty** has led to the perception with many that the **whole premise** of climate change is uncertain. Simply developing an understanding of what is uncertain and what is fairly solid may help people better decide about the value of waiting for additional certainty.

Misunderstanding Number Three: Exaggerated costs of solutions

A final misunderstanding is that the initial solutions to reducing greenhouse gas emissions will be expensive. Work by Rocky Mountain Institute and other organizations suggests that investments in energy efficiency, solar energy, wind power and other sources can be low cost and may be able to reduce emissions in the U.S. by up to 30%. So while the cost of the full reduction in emissions is unknown, we do know cost effective ways to get started.

Addendum: Retaining Hope

In our experience, even when someone grasps the basic mechanics and role of uncertainty in climate science, and their implications for humanity, they have difficulty retaining sufficient hope and engagement in the issue to take action. Some of the loss of hope, we believe, is due to the exaggeration of the difficulty and expense of cutting GHG emissions. Good news stories about energy efficiency and renewable energy solutions that can bring substantial progress may be able to build hope.

Overall, we do not see citizens and policy makers taking a position of "informed inaction" on climate change. Instead, we believe that two specific misunderstandings and the difficulty of retaining hope (wrapped up, of course, amidst media pressures of many types) are creating a position of "uninformed inaction."

Perhaps, then, if more people better understood the dynamics of the climate system, better appreciated the role of uncertainty, and could retain hope, the country would witness an informed debate about what actions to take and would be able to take actions based on the results.

What Is Needed: Informed Public Participation in the Climate Debate

What needs to happen in order to increase the number of people who understand the dynamics of the climate system, appreciate the role of uncertainty, and are able to take action based on that understanding?

A large number of people in key positions would need to go through an experience with three key ingredients:

1. The capacity to help people clearly understand the dynamics of the climate system, the role of uncertainty, and the availability of solutions;
2. Maintain hope and a sense of possibility so understanding leads to action; and
3. Assuming that the understanding will need to spread, people will have a set of skills for engaging other people with different mindsets and disseminating their learning and commitment.

The Opportunity of Learning Experiences Based On System Dynamics

To create informed public participation in the climate debate, the first thing needed is solid, well grounded scientific research into the dynamics of the climate system and the role of uncertainty. Climate change will never be "fully" understood. However, we believe sufficient understanding exists today.

What is missing is **a vehicle for conveying those ideas to the public and policy-makers**.

One vehicle that has proven to be effective in helping people build intuition about a wide range of complex systems – from business to economics to policy – is experimentation with system dynamics simulation models that are designed with a focus on inquiry-driven learning.

System dynamics models compress time and space so that users, alone at a computer, in a small group, or in a large facilitated forum, can quickly experience the results of their assumptions and policies over a long time scale – in the case of climate, hundreds of years. They can also help connect user's actions as individuals to the behavior of the economy and climate as a whole.

To be effective at promoting learning, such models need the following characteristics:

- **Focus on learning**. These models have the central purpose of engaging users to understand principles that have been derived from other research and help those users take effective action (or well-reasoned inaction) on a policy question.
- **Transparency**. When the goal of a model experience is learning, a user must be able to understand and change the assumptions that drive behavior.
- **Parsimony**. For a user to improve her understanding of a system's structure, the structure must present only the relevant essence of the system.
- **Interactivity**. Learning is an iterative process, so a model must allow for changes by a model user. Better yet, they can be turned into an interactive exercise.[7]
- **Attractiveness**. Whatever the medium, a model must engage a user.
- **Focus on causal thinking**. A model must help a user understand what connects to what in a system.
- **Inquiry-driven**. When the issue at hand is contentious, a model must support and improve the thinking of a user more than focus on trying to change the user's mind.

We believe that such models may have an important role to play in translating scientific research and helping improve people's understanding of climate change. There are other roles that must be played as well. However, in this next section we would like to describe how experiences with such models might be able to help.

[7] Good examples include Fish Banks Ltd., Strategem, The Manufacturing Game, and AgLand (http://www.extension.umn.edu/agland/).

The key contribution that system dynamics models could make regarding the missing link between scientific warning and broad policy action are twofold.

First, we see system dynamics being used to present previously published, well-grounded, scientific research findings to a policy audience or lay audience to improve their understanding of three features of the climate challenge:

1. The structure of the climate system – what effects what and in what ways
2. The dynamics of the system – how the climate system is likely to behave over time and how it might respond to various policy changes
3. The state of the science – where there is uncertainty and where there is not

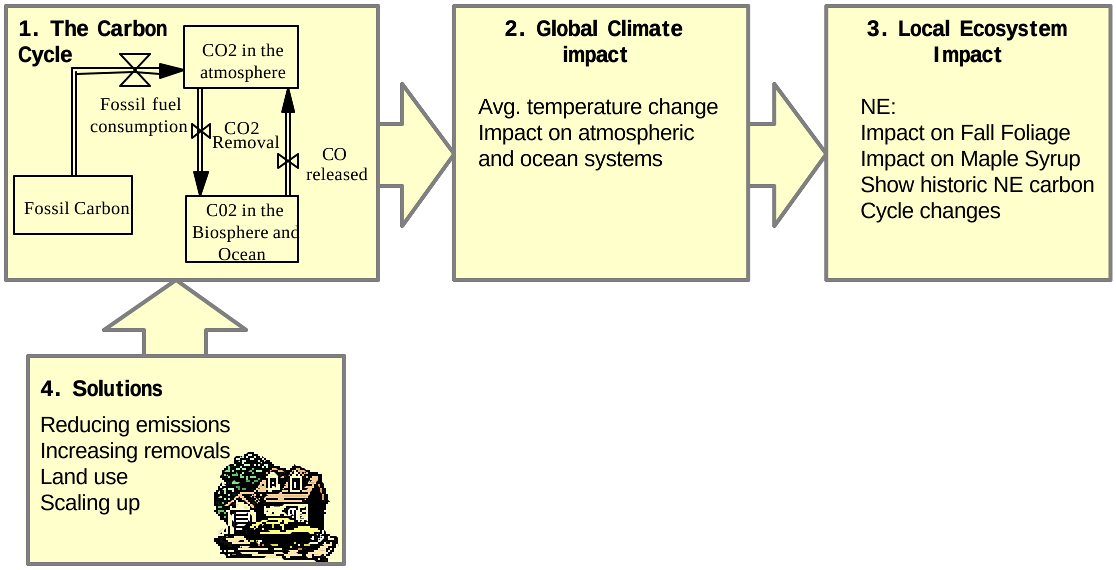
Second, this approach can make scientific findings attractive and compelling to a wide range of people through techniques of graphical design, interactive simulation design, and creation of physical and role-play exercises.

Our ideas about misunderstandings of dynamics and uncertainty are the result of our latest thinking about what is needed. However, it is critical that a learning model for climate change synthesize the insights from many different research efforts and thus be developed with a team of scientists who might have different ideas about what is needed in this issue area. Our goal in working with other partners would be first to identify the key lessons from climate research and second to draw from existing research to develop a model that conveys the lessons.

Based on our previous experiences, we can imagine two potential vehicles for using a model to meet the needs we have described: a computer-based learning environment and interactive workshops.

Computer based learning environment

We could reach the greatest number of people via a web-based, text-supported simulation model. The best existing examples are available via the "Story of the Month" by High Performance Systems (http://www.hps-inc.com) or, in the business world, "Broadcast" by Forio Business systems, (http://broadcast.forio.com). Sustainability Institute has also constructed such a "learning model" on our corn economy research (available from SI). We imagine a Climate Simulation where users can immerse themselves in learning about and experimenting with the climate system. The simulation experience would be based on a "learning pathway hierarchy" that contains a number of organized learning experiences that the user can choose from a guiding set of questions or challenges. The content of the underlying model would cover the carbon cycle, overall global climate change, potentially local ecosystem impact, and solutions.



The carbon cycle, the greenhouse effect, and other key conceptual mechanics in the climate system would be animated to help show the changes over time in the climate system through compelling analogues. Users could create their own scenarios with various levels of complexity (depending on the learning pathway they are on), and the simulation model will play out the future that would unfold from that scenario. Climate impacts could be conveyed in familiar formats: weather charts, fishing reports, and even mock advertisements for potential products.

Two key characteristics of the climate simulation are that it would be based on a *systems thinking* approach and an *inquiry driven* learning environment. The systems thinking approach conceptually places human actors, and the decisions that we make, within the climate system. This allows user to more viscerally experience being part of the feedback loop between our daily decisions, the resulting emissions, their impact on the carbon cycle and the climate, and finally the potential impact of climate on our own decisions. For this reason we are going to place "the home" and our daily decisions at the center of learning about sources of emissions and potential solutions. Different emissions scenarios can be created and experienced by "scaling up" from choices made at the home, learning about the impact of the rest of the country, or the whole world following that set of choices.

The inquiry driven learning environment is created by building a very flexible interface that allows a user to both choose what area they want to learn about and to design their own experiments within that module. The learning pathways could be organized around the set of questions that a person might have about climate change, such as:

1. Are human generated GHGs accumulating in the atmosphere?
2. Do GHGs in the atmosphere trap heat?
3. Does trapping heat lead to ecological changes?
4. Do ecological changes lead to local or global problems that warrant action?

5. If I think action is warranted, is there anything that can be done to address the problem?

Interactive workshops

Interactive, model-based workshops can also provide an opportunity for participants to improve their understanding of the climate system's dynamics and the role of uncertainty in studying it, towards building their commitment to take effective action. Ideally, we would draw in people from all sides of the issues to use the basics of climate change as a foundation for good conversation about the issue.

We would also include training in communication skills to help participants share their new understanding with other people.

The advantages of workshops over the stand-alone experience are two-fold: first, a trained facilitator can more successfully explain to model users why the model is behaving the way it is and second, we have found that, as learning is a social experience, people tend to be more likely to change their thinking and acting when in conversation with trusted peers.

Many interactive workshops will focus directly on policy issues. Others will involve role-playing and "gaming" in order to create a unique learning environment. Possible interactive "gaming" experiences to help people build intuition about mechanics of and solutions to climate change include:

- **The Solutions Initiative** – participants role-play a country's or region's stakeholder groups – e.g., energy, transportation, forestry – and work together to design solutions to the climate challenge.

- **International Negotiation Exercise** – participants play the role of countries such as the U.S., China, Nigeria, and Brazil as they confront the equity and development issues inherent in climate issues.[8]

- **Bathtub Climate Mechanics Workshop** – participants work in teams on a range of thinking, graphing, and physical challenges that help them understand the "bathtub" mechanics of the carbon cycle.

Partners

There are three groups of partners we anticipate working with: research science, networking experts, and partners with networks.

1. Research Science

We will work closely with research scientists to identify the critical insights that must be conveyed and determining how to convey them.

[8] Bert de Vries of RIVM and Tom Fiddaman have developed a version of this, called SusClime.

Currently, our closest research science connection is with SI colleague Dr. Tom Fiddaman. Tom wrote his MIT PHD thesis on a climate-economy system dynamics model and recently published a paper on his results in a paper – "Exploring policy options with a behavioral climate-economy model."[9]

He has simplified his peer-reviewed, complex policy model and turned the carbon cycle sector into a smaller model that would be appropriate for use as a "learning model" – that is, one whose purpose is to improve a user's understanding of the system so that she can take effective actions towards improving the system's behavior. The structure is simplified into several clear stocks (see a slightly more complex version in Appendix II). The output is simplified into three clear graphs. More work is needed, but the viability of creating a "learning model" that is deeply grounded in more extensive, high quality research, has been established.

2. Networking experts

We may want to work with experts in disseminating a set of ideas or learning experiences across a broad network.

3. Partners with Networks

We may also partner with an organization that is already engaged in the climate change debate who can visualize a role our models, process design, and workshops to help their constituents work together in developing policy.

Development Process

We currently have a model prototype – Dr. Fiddaman's carbon sector model, illustrated in the appendix – which serves as an example of how a simulation model could be used to convey a key principle about climate change.

In order to use system dynamics modeling to help link climate change research to policy actions, we can see three steps.

1. Identify goals and audience

Working closely with our research science and networking partners, we would identify our target audience and the best learning approach to fit them. Then, turning to the research science, we would identify the key principles and dynamics that would need to be communicated for people in the target audience to be informed participants in the climate debate.

2. Design model

Again, working closely with partners, we would iteratively develop a model that captures and conveys the key principles. By working with our partner Dr. Tom Fiddaman, we may be able to use his small core model.

[9] "Exploring policy options with a behavioral climate-economy model," Fiddaman, System Dynamics Review, Vol. 18 No. 2, Summer 2002, pp. 243-267.

3. Develop learning experience

We would work together to develop the lecture, model testing, computer programming, diagramming exercises, and/or other components of a learning experience. A typical process is to design the experience, create a prototype, test it in pilot sessions, improve it, pilot it a second time, and then launch it.

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Appendix I: "Cloudy Skies" paper abstract

Cloudy Skies:

Assessing Public Understanding of Global Warming

John D. Sterman
Linda Booth Sweeney

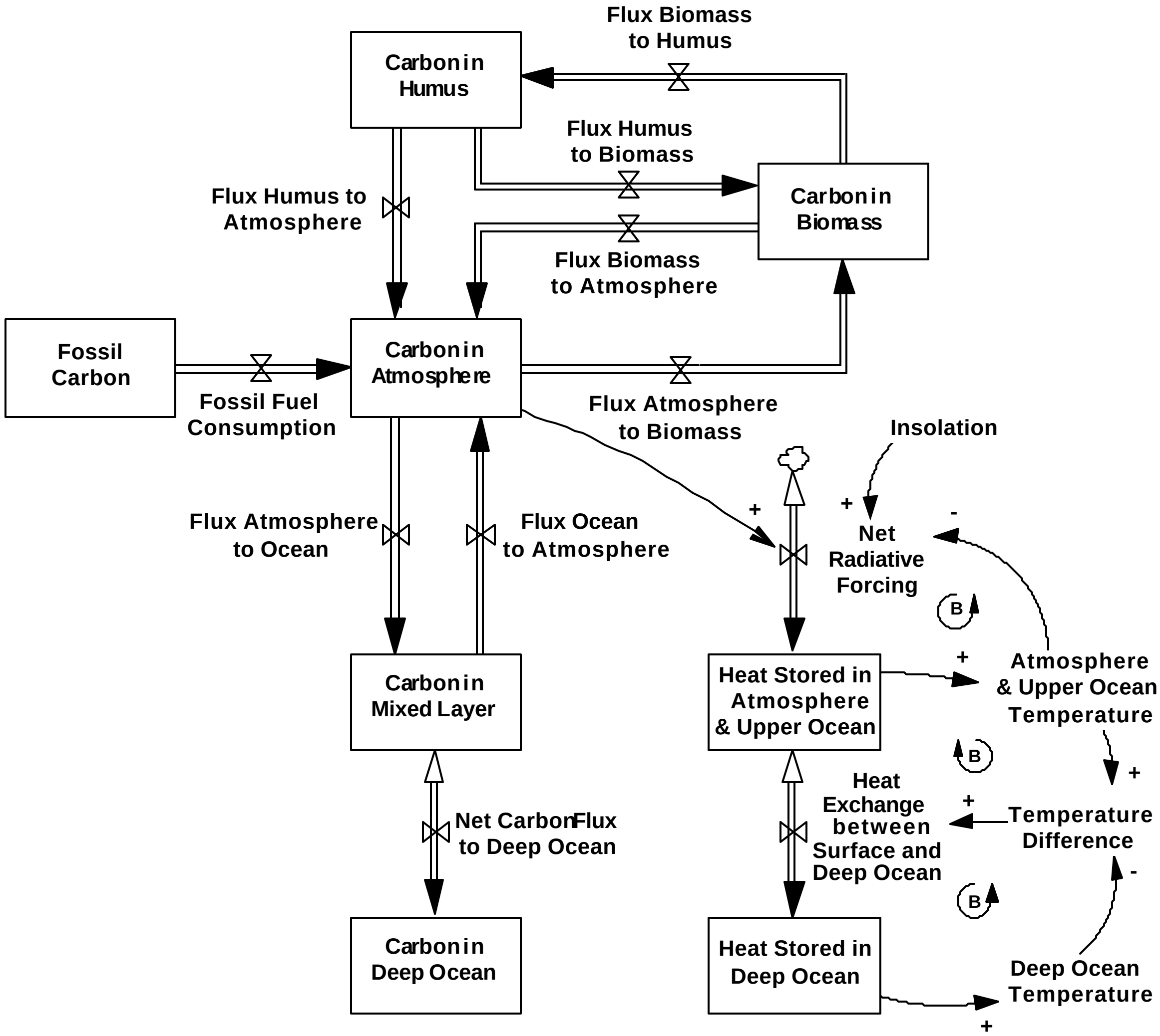
ABSTRACT

Surveys show most Americans believe global warming is real. But many advocate delaying action until there is more evidence that warming is harmful. The stock and flow structure of the climate, however, means "wait and see" policies guarantee further warming. Atmospheric CO_2 concentration is now higher than any time in the last 420,000 years and growing faster than any time in the past 20,000 years. The high concentration of greenhouse gases (GHGs) generates significant radiative forcing that contributes to warming. To reduce radiative forcing and the human contribution to warming, GHG concentrations must fall. To reduce GHG concentrations, emissions must fall below the rate at which GHGs are removed from the atmosphere. Anthropogenic CO_2 emissions now exceed removal by about a factor of two. Emissions must therefore fall by half even to stabilize CO_2 at present record levels. Such reductions greatly exceed the Kyoto targets, while the Bush administration's Clear Skies Initiative calls for continued emissions growth. Does the public understand these physical facts? We report experiments assessing people's intuitive understanding of climate change. We presented highly educated graduate students with descriptions of greenhouse warming drawn from the IPCC's nontechnical reports. Subjects were then asked to identify the likely response to various scenarios for CO_2 emissions or concentrations. The tasks require no mathematics, only an understanding of stocks and flows and basic facts about climate change. Overall performance was poor. Subjects often select trajectories that violate conservation of matter. Many believe temperature responds immediately to changes in CO_2 emissions or concentrations. Still more believe that stabilizing emissions near current rates would stabilize the climate, when in fact emissions would continue to exceed removal, increasing GHG concentrations and radiative forcing. Such beliefs support wait and see policies, but violate basic laws of physics. We discuss implications for education and public policy.

System Dynamics Review, Sterman and Booth Sweeney, Vol. 18 No. 2, Summer 2002, pp. 207-240. Available at web.mit.edu/jsterman/www/cloudy_skies.html.

Appendix II: Carbon Sector Diagram and Output from Fiddaman's Model

Carbon Sector diagram



Control Panel and Output Graphs from a Simplified Version of Fiddaman's model