Climate Policy and Actor Networks:

Interactive Climate Simulators - A Missing Actant

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Abstract

A new approach to visualizing data may enable the next step towards effective climate policy. Before climate policy can be enacted and implemented, citizens, scientists, and policymakers must arrive at a consensus or compromise. Yet, in some societies where mistrust and misunderstanding exist among these communities, we find no agreement, and often little action in addressing anthropogenic climate change. By visualizing sound climate science, interactive climate simulators offer compelling visuals of climate science that allow policymakers and citizens to view the results of proposed policies in real-time.

One such simulator is Climate Rapid Overview And Decision Support (C-ROADS), developed by scientists and policy analysts in partnership with MIT. C-ROADS has been gaining attention at UN Climate Change conferences, in academia, and in governments around the world. By applying the Actor-Network Theory (ANT) developed by the discipline of Science and Technology Studies (STS), I identify some of these impediments through the ANT analysis of the climate policy network and assess whether C-ROADS can help fill the gaps and address such impediments. The ANT analysis reveals that visualization technologies such as C-ROADS, if used more broadly, can fill some of the roles of a missing "actant" in forming a stable climate policy network. Such an informed, effective network will enable experts and societies to motivate changes in human behavior and technology to mitigate the risks of climate change, in a manner more constructive than the climate policy actor-network today.

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I. Introduction

Because the Kyoto Protocol is scheduled to expire in 2012, the Secretary General of the United Nations Ban-Ki Moon has called for renewed efforts to stabilize emissions in order to mitigate the possible consequences of climate change. Clearly, climate policy is not quite a success story in domestic or international politics. Although global agreements were reached in the form of Kyoto in 1997, local action and execution need further attention. Due to domestic disagreement, the U.S. has yet to ratify the Kyoto commitments. Clearly, impediments as such need to be overcome in order to achieve successful climate policymaking. By applying the Actor-Network Theory (ANT) developed by the discipline of Science and Technology Studies (STS), we can identify some of these impediments through the ANT analysis of the climate policy network. We can evaluate the parts of the network that need further attention, and identify agents that would address some of the impediments from a techno-science perspective.

For instance, a new approach to visualizing data may enable the next step towards effective climate policy. Before climate policy can be enacted and implemented, citizens, scientists, and policymakers must arrive at a consensus or compromise. Yet, in some societies where mistrust and misunderstanding exist among these communities, we find no agreement, and often little action in addressing anthropogenic climate change. By visualizing sound climate science, interactive climate simulators offer compelling visuals of climate science that allow policymakers and citizens to view the results of proposed policies in real-time.

One such simulator is Climate Rapid Overview And Decision Support (C-ROADS), developed by scientists and policy analysts in partnership with MIT. C-ROADS has been gaining attention at UN Climate Change conferences, in academia, and in governments around the world. My work examines the arrival of this real-time climate policy visualization tool using the ANT. I use ANT to model and analyze the formation of the climate policy network, identify network deficiencies, and assess whether C-ROADS can help fill the gaps and address the impediments that exist in the network today. The ANT analysis reveals that visualization technologies such as C-ROADS, if used more broadly, can fill some of the roles of a missing "actant" in forming a stable climate policy network. Such an informed, effective network will enable experts and societies to motivate changes in human behavior and technology to mitigate the risks of climate change, in a manner more constructive and realistic than the climate policy actor-network today.

II. Actor-Network Theory

The Actor-Network theory (ANT) has become one of the major theoretical frameworks in the discipline of Science and Technology Studies (STS). ANT was developed by three sociologists, Michel Callon in 1986, Bruno Latour in 1987, and John Law in 1987.[1] ANT attempts to understand science and technology in a social context. Since its initial development, the application of ANT has been extended beyond technoscience, into the fields of social psychology, geography, economics, and management studies.[2] Recent literature applying ANT begins to discuss climate change policy, discourse, and perspectives. I use ANT to analyze the formation of the climate policy network and identify the deficiencies and weaknesses of this network. With the sources of instability in mind, I assess whether C-ROADS could potentially

[1] Sismondo, Sergio. *An introduction to Science and Technology Studies*. Malden: Blackwell Publishing, 2004, 65.
[2] Michael, Mike. *Reconnecting culture, technology and nature.* New York: Routledge, 2000, 19-20.

function as an actant that could help stabilize the climate science and policy network. First, I discuss the concepts of ANT, which are the bases of my analyses.

There are essentially three pillars to ANT: the concept of actants, networks, and interests. Broadly speaking, ANT is a theory of liaison, through which the processes of "doing" science and technology really are composed of alliances between scientists and engineers.[3] Such alliances are called *networks*. Within these networks, the actors, or elements that contribute to forming and maintaining such networks are called *actants* that do not have to be human.[4] Actants are heterogeneous, and nonhuman actants are given equal significance.[5] This concept is called generalized symmetry. Each network and each individual actant – whether human or not – has an *interest*.[6] Interests are objectives of the actant's involvement or the network's existence. Having identified an existing network or the need for a network and assembled the concerned actants and their respective interests, the ANT analysis moves to discuss the interactions among actants, interests, and the network at large.

ANT provides an analytical framework to study the interactions among actants, their interests, and the network itself. ANT analyzes the political dynamics of the emergence, stabilization, and destabilization of networks and alliances.[7] Once the problem is defined and the actants and their interests identified, ANT analysis identifies a process that aligns their interests. Such interests many not be easily aligned, so actants must cross a threshold in order for some of their interests to be aligned, to an extent sufficient for the actant to enroll. The threshold, called the *obligatory passage point,* where actants must convince one another that they have what they

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[3] Sismondo, *An introduction to Science and Technology Studies*, 65-67.
[4] Ibid., Michael, *Reconnecting culture, technology and nature,* 21.
[5] Ibid. Sismondo, *An introduction to Science and Technology Studies*, 65.
[6] Ibid.
[7] Tomblin, David. *A Brief Primer on Actor Network Theory (ANT).* Course Notes, College Park: Science, Technology, and Society Program, 2011.

need and can satisfy their respective interests, partially or fully.[8] This negotiation process also defines the respective roles of the actants in the network, which of course are dynamic and subject to change. Successfully passing the passage point indicates that interests are aligned, and thereafter actants agree or *enroll* to take part in the network.[9] A network, such as the climate policy network, may need to enroll and mobilize new supporting actants to maintain the stability of the network. This interaction paradigm between the human and nonhuman actants, in which they are assembled and their interests are aligned is called *translation.*[10] The concepts of ANT highlight how science is ultimately a social phenomenon and provides a theoretical framework for applications and analyses of science and technologies.

Many applications of ANT have appeared in STS literature, including studies on fisheries and engineering. Some quintessential examples of ANT application include Callon's observation of electric car engineering and scallop fishery in France.[11] Bruno Latour applied ANT to the dawn of the diesel engines.[12] By and large, ANT is a method of *a posteriori* reasoning that scrutinizes the formation, stabilization or destabilization of networks. By analyzing the formation and the current state of the climate policy network, I first make an *a posteriori* argument and identify sources of instability.

To facilitate smooth translation among citizens, policymakers, and scientists, an actant may be necessary to help make climate science and policy "interessable" to non-scientist actants. After identifying the deficiencies of the current network, I make an *a priori* argument and reason that a real-time policy and science visualization interface could fill the some of the roles of the missing actant. However, even with a new actant, the translation process may still be subjected to

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[8] Ibid.
[9] Ibid.
[10] Sismondo, *An introduction to Science and Technology Studies*, 65-67.
[11] Ibid., Tomblin, *A Brief Primer on Actor Network Theory (ANT).*
[12] Sismondo, *An introduction to Science and Technology Studies*, 65-67.

the existence of *a priori* belief, which includes diverse social paradigms, political belief, and religious belief. To form a stable network for climate policy, the interactive policy simulator, as an actant, must remain respectful of *a priori* beliefs while returning the sovereignty of policy and action to the policymakers and citizens. C-ROADS as an actant can theoretically help stabilize the climate policy network, by facilitating interest alignment so that more actants can enroll and result in the meaningful changes. Next, I introduce C-ROADS, the climate policy simulator of concern, before I proceed to analyze the formation and the current state of the climate policy network.

III. Genesis of C-ROADS and the Climate Interactive Effort

The Climate Rapid Overview and Decision Support (C-ROADS) simulator was developed by Tom Fiddaman of Ventana Systems, John Sterman of the MIT System Dynamics Group and Lori Siegel, Beth Sawin, Andrew Jones, Phil Rice of the Sustainability Institute.[13] It was developed on Vensim, a dynamic simulator software developed by Ventana Systems, aiming to provide real-time simulations for non-scientists to simulate the effects of various climate policy decisions.[14] It was created to improve understanding of climate dynamics, which had shown to be commonly misunderstood by the public, even highly educated adults trained in science, technology, engineering and mathematics disciplines.[15] Its user-friendly interface allows policy makers to simulate and appreciate the effects of various policy proposals with different time steps and magnitudes of change.[16] From the conception and development to the

[13] Jones, Andrew. "Non-Technical Flyer for C-ROADS." *Ventana Systems.* 2009. http://www.ventanasystems.com/related_files/c-roads-flier-v5.pdf (accessed December 7, 2011).
[14] Ventana Systems. *C-ROADS - Climate Simulation for Decision Makers.* 2009. http://www.ventanasystems.com/examplepage.php?exampleID=18 (accessed December 7, 2011).
[15] Sawin, Elizabeth R., Andrew P. Jones, Tom Fiddaman, John Sterman, and Lori S. Siegel. "C-ROADS Simulator Reference Guide." *Climate Interactive.* June 2011. http://climateinteractive.org/simulations/C-ROADS/technical/technical-reference/resolveuid/640b5e49ec90f9ca95cd7ef7c42f3307 (accessed December 7, 2011).
[16] Ibid.

dissemination of C-ROADS, we later see that C-ROADS emerges from problems in translation and interestment of the Climate Policy Actor-Network to fill a much-needed niche of a new actant. First, I discuss the genesis and development of the C-ROADS simulator.

C-ROADS is essentially a decision-making visualization tool and supplement. We tend to intuitively underestimate the degree of emissions reductions that are needed to stabilize atmospheric carbon dioxide levels.[17] Many different stakeholders are charged with making decisions related to climate change, from climate professionals, corporate and government leaders, and citizens, many of whom may broadly and intuitively understand the emissions reduction proposals of their respective nations, for example, UNFCCC proposals.[18] However, they often lack the tools for appreciating the collective impact of these climate policy proposals on future atmospheric greenhouse gas concentrations, temperature changes, and other climate impacts.[19] C-ROADS enables the users and stakeholders to see current authoritative scientific data displayed in a simple visual format. Moreover, they can run simulators under different scenarios to see the possible, predicted impact of their chosen policy decision to the climate and emissions level.[20] It functions as a simple assessment tool for presentations and negotiations, which may help to build a consensus in policy. These scenarios are broken down further into different types action, such as the rate of afforestation. One can also change the emissions change for developing and developed countries to appreciate the effects of greenhouse gas emissions reduction for countries at different stages of development.

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[17] Ibid.
[18] Sawin, Elizabeth R., Andrew P. Jones, Tom Fiddaman, Lori S. Siegel, and Diana Wright. "Current Emissions Reductions Proposals In The Lead-Up To Cop-15 Are Likely To Be Insufficient To Stabilize Atmospheric Co2 Levels: Using C-Roads – A Simple Computer Simulation Of Climate Change – To Support Long-Term Climate Policy Development." *Analysis of Current Proposals.* March 10, 2009. http://www.climateinteractive.org/simulations/C-ROADS/simulation-media/publications/C-ROADS%20Analysis%20of%20Current%20Proposals090311.pdf/at_download/file (accessed December 7, 2011).
[19] Ibid.
[20] Sawin, Jones, et al., C-ROADS Simulator Reference Guide 2011.

The simulation process is perhaps the most unique feature of C-ROADS and it is the first of its kind in the climate policy arena. The interactive simulator allows one to run different cases and proposals on climate policy proposals and with an extremely fast processing time, one can see the effects of this proposal over time in terms of GHG concentration, temperature, and sea level rise. This allows presenters to demonstrate in real-time what kinds of effects are likely their proposal will create in the future, backed by sound science and prediction trends. C-ROADS's ability to assist real-time negotiation has been demonstrated in various settings, from academia to public policy. C-ROADS have since appeared in many domestic and international climate policy platforms including Copenhagen and Cancun climate summits, European Environmental Agency, State Department, NOAA and EPA presentations, for example, EPA's "Integrated Modeling to Characterize Climate Change Impacts and Support Decision Making."[21] Senator John Kerry has quoted C-ROADS results in front of Congress.[22] Among businesses, Morgan Stanley Office of Sustainability and Ericsson of Sweden have all begun using C-ROADS simulators.[23] In academia, Tsinghua University, China helped develop the Chinese version of C-ROADS. Other institutions using C-ROADS for teaching or policy purposes include Brown, Tufts, and Washington Universities.[24]

In order to better facilitate the communication of climate science policy and its effects, developers of C-ROADS formulated the Climate Interactive (CI) group to offer different formats of C-ROADS. CI has created a Climate Scoreboard that synthesizes C-ROADS simulation in a very simple and succinct climate policy and goal comparison Flash visual.[25] CI has developed a

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[21] Climate Interative. *EPA's Climate Impacts Modeling Conference 2011*. http://www.climateinteractive.org/resources/course-materials/epas-integrated-modeling-conference-2011 (accessed December 7, 2011).
—. *Quotes From Users and Others* . http://www.climateinteractive.org/simulations/C-ROADS/user-quotes (accessed December 7, 2011).
[22] Ibid.
[23] Climate Interactive. *Climate Interative Introduction.* October 2010. http://climateinteractive.org/about/CI%20Introduction%20Oct%202010.pdf/ (accessed December 7, 2011).
[24] Ibid.
[25] Ibid.

C-LEARN format, which is also available on the web browser without the need of downloading and installing software to run simple simulation scenarios, unlike the C-ROADS itself, which requires dynamical modeling software to run its simulations. Recent developments include the Climate Momentum simulation - a Flash-based simulation built using Edward Tufte's information design approach, which is hoped to help spread the CI effort "virally."[26] The C-ROADS is the most sophisticated format of the CI products, which requires more prerequisite knowledge in computer technology than the others. The range of products can be categorized in four broad categories: motivators, negotiators, regulators, and investors.[27] They are each created for different user audiences for their respective purposes, to facilitate negotiations of policy, visualization of regulation impacts, motivate action, political will and public interests, as well as encourage investment in carbon mitigation technologies and help businesses make sound choices.[28]

The C-ROADS and Climate Interactive developers attributed their effort to four root factors.[29] First, the system dynamics modeling science began at MIT Sloan School of Management in the 1970s, lead by Prof. John Sterman.[30] In 1997, Tom Fiddaman, now at Ventana Systems and the principle modeler for the C-ROADS, wrote his PhD Dissertation on "Feedback Complexity in Integrated Climate-Economy Models," on which the idea of an interactive climate policy simulator was rooted.[31] Second, "open architecture sharing" and open source development allowed C-ROADS to be developed in transparency and open to scrutiny.[32] The original developers of C-ROADS and Climate Interactive envisioned a way to impact the world with accessible simulation models by making them available for adaptation and

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[26] Ibid.
[27] Ibid.
[28] Ibid.
[29] Climate Interative. *Our Roots.* http://climateinteractive.org/about/Our%20Roots (accessed Decemeber 7, 2011).
[30] Ibid.
[31] Ibid.
[32] Ibid.

extension.[33] Third, the context for use and learning were inspired by the participation and dissemination of simulations built by various institutions, including MIT and Sustainability Institute.[34] Role-play based simulation exercises such as the Beer Game, Strategem, and FishBanks Ltd. by system dynamics scientists formed a model context for learning and usage for the C-ROADS and subsequently the Copenhagen Climate Exercise, now called the World Climate, a role-playing climate simulation designed by CI and MIT, which provides groups of 6-80 people a negotiation experience of reaching a global climate agreement.[35] Though C-ROADS itself is not a multi-player simulator, it can be adapted in such a way to simulate a session of informed group decision-making. Lastly, the Climate Interactive and C-ROADS effort entered the domestic and international policy arena through partnership development with academic institutes and philanthropic organizations.[36]

As you can see, C-ROADS was created to address some ambitious goals. The genesis and its development demonstrated the discovery of a problem in climate change policy action and collaboration. Hence, there is a climate policy network in play. We see that amongst scientists, policymakers, and citizens, there exists a gap of understanding. Scientists have worked on large integrated assessment models with many equations, rigorous modeling and peer-reviewing work, produced complex results and reached a consensus on climate science amongst scientists. However, the climate science is not quite well understood by the public, by policymakers, citizens alike who have training in science and engineering. There is a lack of translation of the complex Integrated Assessment Models (IAM) and Global Circulation Models (GCM) into easily understandable graphics that help citizens and policymakers understand climate science and the policy implications. C-ROADS attempts to translate these models based on sound

[33] Ibid.
[34] Ibid.
[35] Ibid.
[36] Ibid.

science into an interactive climate policy simulation tool. With easy-to-comprehend visual discourses that provide authoritative science and policy simulations, citizens and policymakers are more likely to come to a mutual understanding and consensus on climate policy. To understand the development of the C-ROADS simulator using ANT, we must first define the climate policy network at hand, assemble the actants and assess the stability of such a network. Then, we would be able to assess whether C-ROADS qualifies as an actant that help maintain stability of the climate policy network.

IV. The Climate Policy Actor-Network: Assembling the Actants

Previously, I have introduced the Actor-Network Theory, the theoretical basis of my analysis, as well as C-ROADS, the simulator of concern, against a climate policy network. This section serves to explain and analyze the formation and existence of such a climate policy network and argues how the network is deficient and that major obstacles prevent enrollment of actants into the network. I first survey the construction of the climate policy network, explain to what specific network I am referring and how this network was formed. Then, I outline the current state of this network and assemble the actants most relevant today. Finally, I discuss the gaps and impediments to building an effective climate policy network

There is a consensus among scientists that our climate system is unequivocally warming and that anthropogenic effects are responsible for the significant warming in recent years.[37] Throughout the last fifty years, we have progressed from conducting the science to reveal that climate is changing, to identifying the factors that are responsible, and to showing that anthropogenic forcings are significant.[38] As the scientists arrive at results about our climate

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[37] Sommerville, Richard C.J., and Jean Jouzel. "The global consensus and the Intergovernmental Panel on Climate Change." In *Facing Climate Change Together*, edited by Catherine Gautier and Jean-Louis Fellous, 12-30. Cambridge: Cambridge University Press, 2008, 25-28.
[38] Ibid., 12-17.

system that are attributable to human causes, the realm of policy is invited to discuss methods to address and mitigate these human causes. In the language of climate science, we have achieved "detection" and "attribution" of a scientific problem and arrive at the table for "remediation" and "mitigation".[39] With policymakers discussing the implications of these results, citizens are of course going to be concerned, perhaps not at first, but eventually when policymaking has actual impacts to the citizens' lives and welfare. I use citizens here to denote the general population who do not assume the aforementioned roles as scientists and policymakers. Citizens hereafter includes consumers and producers of the economy, or in general, any user of the earth and climate system, which encompasses firms and businesses, farmers, teachers, parents, and children, and many more equally important subgroups of our population.

Now that we have assembled three important and broadly defined actants, which forms the basis of the climate policy network, we have to make a few remarks for the purpose of our analysis. First, the interactions between all three actants exist, between scientists and citizens, scientists and policymakers, policymakers and citizens. However, the magnitude and directness of these relationships may differ, and therefore so does the respective discourse, which is important to interest and enroll more of each actant groups into the climate policy network. Second, we note that within scientists (encompassing many sub-disciplines), politics (which consists of many different branches of government at local, central, and international levels) and citizens there exist networks too. In fact, the formation of the climate science network gave rise to the climate policy network, and the scientist network today remains a functional and effective network itself. We are more interested in the entirety of climate policy as a whole, therefore, the interaction between and enrollment of actants are more important. Though gaps and deficiencies within the sub-networks are important, we are more interested in the interaction between

[39] Ibid., 20-23.

scientists, policymakers, and citizens, and how the alignment of their interests formed a fragile network that needs reinforcement. Therefore, we forgo analysis of the network within climate science, which is a well-established network body as a unit actant. With gaps of knowledge and trust between actants, there may be a need for a new actant – or a "missing" actant to help close these gaps, improve enrollment and stabilize the climate policy network as a whole. Climate, ultimately, is as much a social issue as a scientific one.[40]

Formation of the Climate Policy Network

The earliest effort to examine the human dimension of climate change began in the USA. Though the science on climate change began much earlier in the mid-twentieth century (some would argue earlier), climate science's entrance into American politics did not begin until the 1980s. During the previous decade, the modern environmental movement was initiated with the enactment of laws to protect air, water, and environmental quality in the United States.[41] However, these laws addressed visible environmental concerns that had acute and imminent impacts to health and safety with clear causes. Climate change is a chronic problem of a complex, interconnected system. The indiscrete sources accumulate emissions over time to produce health and environmental damage. These effects of climate change are uncertain and may be slowly realized over a long time horizon. With time, the climate system may reach a threshold and result in rapid warming events, a hypothesis that is still being researched in modern earth systems research.[42] The uncertain and long-term nature of climate science inherently diminishes confidence in climate studies and policies.

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[40] Bakstad, Roberta, and Jean-Charles Hourcade. "Climate and society: what is the human dimension?" In *Facing Climate Change Together*, by Catherine Gautier and Jean-Louis Fellous, 204-216. Cambridge: Cambridge University Press, 2008, 216.
[41] Percival, Robert V., Christopher H. Schroeder, Alan S. Miller, and James P. Leape. *Environmental Regulation: Science, Law, and Policy (6th ed.).* New York: Aspen, 2009, 88-91.

[42] Weart, Spencer R. *The Discovery of Global Warming.* Cambridge: Harvard University Press, 2008,174-5.
Sommerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 23.

In 1980, Congress asked the National Academy of Sciences (NAS), which is the chief scientific authority and adviser of the U.S. government, for a study on carbon dioxide effects in the atmosphere.[43] The NAS was "deeply concerned" about the effects of carbon dioxide, and an EPA study reported similar findings but were more anxious, which were dismissed as alarmist by some.[44] At the federal forefront of environmental enforcement, the EPA have acquired an agency culture that consists of pessimistic environmentalists, which to a certain extent polarizes, and poisons, the environmental debate at hand. Nonetheless, the public was alerted that global warming is a possibility because of these reports.[45] Subsequently, further studies in climate change science, as well as the socio-economic impacts began.[46]

The interdisciplinary study of climate science – though at first fragmented – became more unified as scientists, both natural and social scientists, figured out some of their differences.[47] Even without complete paradigm alignment,[48] an international entity for climate research was born when WMO launched a World Climate Research Unit.[49] The conferences and international meetings began to gather ideas and build consensus.[50] In 1985, a global consensus was reached at the Villach World Climate Conference among scientists that there is an imminent need to address global warming, and governments need to act.[51] Scientists made an unusual call for activism in government because the dire physical and socio-economic consequences have become clear, and that future warming could be exacerbated by policy.[52] The enrollment of politics into the network, at least at the international level, was achieved through international dialogues in these conferences.

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[43] Weart, *The Discovery of Global Warming*, 141.
[44] Ibid., 141-2
[45] Ibid., 142-3.
[46] Ibid., 143.
[47] Ibid., 144-145.
[48] Bakstad and Jean-Charles Hourcade, "Climate and society: what is the human dimension?," 211.
[49] Weart, *The Discovery of Global Warming*,145-6.
[50] Ibid.
[51] Ibid.; Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 24.
[52] Ibid.

The conferences of scientists and international officials without a doubt functions as an important actant that bridge the science actant and politics actant, where information can be presented, ideas can be exchanged, and negotiations and recommendations can be discussed. Scientists actants formed allies in international and domestic bureaucracies to articulate their research and seek further funding.[53] At the same time, the interessment of policymakers was one of motivated by profit, not in a monetary sense, but by personal benefit. The policymakers that can profit from enrolling into the climate network are "especially quick to accept evidence and argue for policy change.[54]" The first climate conferences, alongside with Montreal Protocol, gave rise to the Intergovernmental Panel for Climate Change (IPCC) effort.[55]

Another important actant in forming the network was the Montreal Protocol, often characterized as the international environmental success story. The Montreal Protocol addressed the ozone problem, which consisted of a much more visible, and certain, problem that requires international attention. The presence of a "hole" in the ozone layer alarmed many and raised public health concerns. The nature of the ozone problem is quite different. There is better certainty in the cause and effects, and solutions, of the problem; there is a single, not disperse or multiple, contributor to the problem – namely the Chlorofluorocarbons or CFCs; we can see the problem manifesting as a "hole" in the ozone layer through visualization technologies; and the public health effects are serious and urgent. Subsequently, a quick agreement was reached to ban CFCs through the Montreal Protocol of 1987, raising global attention to problems of global climate change.[56] Thus, the Montreal Protocol became the precursor to the later Kyoto Protocol,

[53] Weart, *The Discovery of Global Warming*, 146-7
[54] Ibid., 147.
[55] Ibid.,147-9, Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 24.
[56] Weart, *The Discovery of Global Warming*, 147-150

but the differences in the nature of the problem destabilize the still-adolescent climate policy network.[57]

Media was undoubtedly another important actant in forming the climate policy network. The heat wave of 1988, which devastated many regions of the United States, created much media attention in climate change. Although individual weather phenomenon does not imply long-term changes in climate on its own, the event, albeit with some misunderstanding, was of great political utility to achieve awareness in the greenhouse effect among citizens and politicians.[58] In a way, it is an "extraordinary novelty" that global warming became a political question, because the issue at hand requires acceptance of the complex reasoning and invisible long-term consequences of climate change.[59] Nonetheless, the media actant enrolled into the climate policy network through the dramatization of weather events. As a result, attention among citizens and politicians surged high and scientists received funding for new research.[60] The public can relate easier to rapid weather events than a gradual warming. As the infamous analogy of the frog and the beaker of boiling water tells us, we are more likely to react immediately if a drastic change in temperature is experienced. The media actant, who helped improve the education and awareness of policymakers and citizens, also exacerbated some misunderstanding of climate change. At the same time, conservatives and skeptics distrusted the science and media-led environmental effort and preferred that government representatives become more involved in the climate issue,[61] as to limit the normative role of the climate science actant.

In 1988, the Intergovernmental Panel on Climate Change was created to carry out, based on available science, assessments on physical, natural, technological, and socio-economic

[57] Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 24.
[58] Weart, *The Discovery of Global Warming*, 149-151
[59] Ibid., 151.
[60] Ibid.
[61] Ibid., 152.

implications of emerging climate change.[62] The IPCC consists largely of government representatives from around the world and expert scientists in the field, which can be viewed as a government-scientist hybrid body.[63] IPCC serves to advice policy bodies and not to prescribe solutions.[64] It helped to translate scientific information to policymakers.[65] As a result, the policymaker actant and the scientist actant form a united forefront – at least at the international level – where international government delegates endorse of climate science and associated recommendations. With increasing public concern, the scientists seek funding to publish results and inform policymakers, while journalists pass the latest findings, newsworthy ones, to public. The IPCC represented a trust-developing actant amongst scientists and policymakers at the international level.

However, at the domestic level, the newly installed paradigm received resistance. In the U.S., this resistance is primarily due to a disconnect between international agreements and domestic policy, and the ability and readiness of corporations to react and protect their interests in light of possible regulation. Curbing carbon dioxide emissions and other greenhouse gas emissions may result in very costly regulations; some argued such regulatory framework would be “extraordinarily costly.”[66] Corporations report to stockholders, whom are citizens that seek profitability in their investment. So, it is only logical that in light of possible government intervention in profitability, the corporations voice their opposition through various means. Given scientific uncertainties, some characterizes greenhouse gas regulation as premature action and claim that a strong economy should be the priority to overcome problems that are plausible

[62] Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change,” 24.
[63] Weart, *The Discovery of Global Warming*, 152-154.
[64] Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change,” 24-25.
[65] Bakstad and Hourcade. "Climate and society: what is the human dimension?," 213.
[66] Weart, *The Discovery of Global Warming*, 160

in the future.[67] Acceptance of a long-term climate problem is slowly demonstrated, but the contention lies in whether action is needed now. Policymakers are less decisive and unianimous over precautionary actions because the effects may be realized over a much longer time horizon after their term expires. Their actions are also bounded by interests of their constitutions, whom may be corporate dominated and deny needs for action. On the other hand, remedying actual catastrophes that have visible transpired and created some impacts seem to be more appealing in the short-term. Take Superfund Law or Montreal Protocol ratification for example, imminent environmental disasters achieve better immediate attention than a longer-term problem like climate change, especially when the uncertainties, such as criticisms of the rigor of modeling work, create room for doubt and speculation.

Computer modeling was an important actant in forming the climate policy network. Serving as a tenet of climate science, computer modeling in General Circulation Models (GCMs) and Integrated Assessment Models (IAMs) continue to gain sophistication and improve in compatibility. As computer access becomes more widespread, the public's trust in big computer models improves, as they no longer seem like distant and mythical technologies. This helped enroll citizen actants as they at least can develop an appreciation of computers as a reliable technology. Nonetheless, the uncertainty due to computer modeling did engage skeptics and doubtful scientists in developing alternate hypotheses and strong criticisms.[68] The existence of controversy can be good material for the media and challenge the public to critically evaluate the opposing views, but on the other side it helps dilute trust between the science, the scientists, the citizens, and policymakers, especially when they are doubtful that humans have collectively caused climate change to start with. From accepting there is a greenhouse effect to humans are

[67] Ibid., 158.
[68] Ibid., 167-172.

responsible for global scale warming is a strong mistrust threshold because people tend to not like to think that they are responsible for a problem.

As models continue to advance and IPCC conferences continued to take place, soon a key international agreement was reached at Kyoto in 1997, where countries worldwide assumed responsibility to curb carbon dioxide emissions, starting with already developed and industrialized countries through a few different mechanisms.[69] The United States, the country where climate change studies began, negotiated the treaty but did not ratify it domestically, primarily on the grounds that China and India were not required to participate.[70] As (the former) highest contributor to greenhouse gases, the U.S.' non-ratification created a major setback for international cooperation in climate change. Instead, voluntary approaches were promoted domestically.[71]

Through the history of forming the climate policy network, we can see some of the major difficulties in enrolling different actants and aligning their respective interests. After the increased investment and attention in climate science, politics entered the network albeit unwillingly, through the attention of extreme weather events and visible atmospheric ozone depletion. The weather events of warming were not experienced consistently, which diluted the media attention climate change had received. Intermittent warming events caused fluctuations in public opinion, where Western Europeans became more worried and attention declined in the U.S..[72] The media, though helped raise attention to climate change, failed to provide a convincing picture of global warming and weakened maintenance of trust between the public and science.[73] It has further polarized the climate issue with catastrophic and apocalyptic products

[69] Gerrad, Michael B., ed. *Global climate change and U.S. Law*. Chicago: American Bar Association, 2007, 17-18.
[70] Ibid., 19.
[71] Ibid., 19-20.
[72] Weart, *The Discovery of Global Warming*, 184-5.
[73] Ibid., 198-200.

and uninteresting scientific reports,[74] neither of which are appealing to improve enrollment and trust within the network and increases dismissal of climate change as a problem that needs immediate attention. Not only has most products been unrealistic, media did not address what the public and citizens can do, rather, it has focused on dramatizing the effects at the expense of articulating possible personal actions.[75]

Finally, we see through the construction of the climate policy network, a major problem for citizens is that people found climate change quite difficult to relate to. They care little about average temperature trends, and instead would like to know more about regional impacts.[76] Recent advances in integrated assessment and regional modeling will continue to address these concerns.[77] As unequal regional effects are likely, the problem of free riding is another concern, where citizens as rational economic actors assume that since they will not be impacted as much, therefore they would not need to do as much. On the other hand, the macrostructure of climate policy invited little citizen input and provided little information on whether they can personally make a difference. A deeper social impediment for taking action is due to perception and personal memory, which are shaped by science, policy, and media.[78] The citizens' lack of connectedness to climate needs to be remedied so that they can more easily agree to take action as consumers, change behavior, and exert adequate pressure on firms and government.

While awareness of climate change as a plausible problem had generally been adequate, historical gaps and mistrust in building the climate policy network centered on the difficulty in achieving effective public understanding, of both the problem at hand and the solutions the one

[74] Ibid., 186-8, Bolin, Bert. *A History of Science and Politics of Climate Change.* New York: Cambridge University Press, 2007, 211-213.
[75] Ibid.
[76] Weart, *The Discovery of Global Warming*, 172.
[77] Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 19-20.
[78] Weart, *The Discovery of Global Warming*, 200-201.

could take. Next we look at the current state of the already fragile climate policy network, and assess and prioritize the gaps that continue to persist.

The Climate Policy Network and the Actants today: What's after Kyoto

After developing an understanding on how the climate policy network was constructed, I develop a deeper appreciation on the actants IPCC, Kyoto Protocol, simulation technology, and the media, all of which pertain to the stability of the climate policy network today.

IPCC has become the "de facto voice of mainstream scientific community."[79] The IPCC actant assumes the role of translation by providing a platform for science and policy as actants and identities to align their interests through interactions. It is often characterized as the most important influences to motivating global efforts in addressing climate change. However, employing the generalized symmetry idea of ANT, IPCC is not a privileged actant by any means. The actant itself was formed and created as a result of the climate policy network in the first place, which now functions as a translator. The role of IPCC is well defined, as a body to produce "authoritative results from climate science as input to policymakers," which "assess research," and outputs the policy-relevant implications but do not assume imperative or prescriptive roles.[80]

The IPCC is to provide the UNFCCC (United Nations Framework Convention on Climate Change), the intergovernmental non-binding treaty opened to signature in 1992, with information to aid the negotiation of binding global agreements, such as the Kyoto Protocol, in order to stabilize greenhouse gas emissions.[81] The IPCC actant provides a great translation service to help stabilize the network and enroll more policy and science actants, but it can be destructive at the same time. How the public understands the IPCC results and outcomes remain

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[79] Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 24.
[80] Ibid., 24-5.
[81] Ibid., Gerrad, Michael B., ed. *Global climate change and U.S. Law,* 33-35.

a major issue with the IPCC actant, because the translation of science and its relevance to the public realm may be deficient. Frustrated by the lack of scientific knowledge and technological prerequisites, the IPCC actant may also destabilized the climate policy network by preventing enrollment of actants such as citizens who have not satisfied such prerequisites.

The government representatives negotiate through Conference of Party (COP) meetings, which are "super legislature" bodies that meet and build new commitments.[82] One of the products of the COP meetings was the Kyoto Protocol in 1997, which aims to stabilize GHG concentrations "at a level that would prevent dangerous interference with climate." Signatories were divided into Annex I and II countries, which broadly consist of developed countries in Annex I, and developing countries in Annex II.[83] Annex I countries have more commitments due to their higher historic accumulations.[84] 55 parties were required for Kyoto to come into effect, and it took eight years for countries to sign on and ratify the treaty.[85] The U.S. Senate refused to ratify the protocol, which delayed the Kyoto from coming into force.[86] The Protocol has come into effect in 2005 and scheduled to expire in 2012.[87] However, it is unclear what kinds of commitment will continue after 2012.[88] Though the system is thought to comprise of a robust compliance system,[89] renewed momentum and improved accountability will be needed to ensure long-term stability of the climate policy network.

Since then, many COPs have taken place and IPCC continued to produce its assessment reports. Ten years after the negotiation of the Kyoto Protocol, in 2007, the Forth Assessment

[82] Ibid.
[83] Ibid.
[84] Ibid.
[85] Ibid., 36-37.
[86] Ibid., 36-37, 63-64.
[87] Ibid., 31-32.
[88] Ibid., 37-38, Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 27-28.
[89] Gerrad, Michael B., ed. *Global climate change and U.S. Law,* 32

Report was released and firmly states that the "warming of climate system is unequivocal,"[90] an extraordinary discourse choice that strongly affirms the existence of a warming phenomenon. As IPCC readily represents trusted and rigorously conducted and reviewed science, such a statement is almost as powerful as the actant itself as it utilizes the maximum effect the actant could possibly induce within the climate policy network. It continues to state that it is very likely, over 90% certainty, that anthropogenic greenhouse gas concentrations are responsible for the warming of the climate system.[91]

One important technology the climate science and policy realm has long relied on is computer simulation, which remains an important actant today in representing rigorous science and making predictions and projections. Global Circulation Models, or GCMs, are a class of models developed to incorporate climate system as a whole, including temperature, ocean, atmosphere, and land.[92] Since one cannot perform a reasonably controlled experiment on the dynamic earth system, our modeling work relies on simulations.[93] Moreover, scientists can explore the consequences of hypothetical future scenarios, to see how the climate system will respond to different emissions regime.[94] The concept of modeling and simulation is extremely important. Modeling incorporates the best scientific understanding of these systems but do not replicate them completely. Simplifications are made and relationships between systems are identified.[95] They provide a simplification of reality and useful relationships to identify possible future effects. Scientists have devised many different models to see the differences between them to achieve better predictions. The nature of modeling and simulation leaves room for mistrust; they require actants to believe in the scientific method that produces results that are not easily

[90] Somerville and Jouzel, "The global consensus and the Intergovernmental Panel on Climate Change," 24-25.
[91] Ibid.
[92] Ibid., 18-19.
[93] Ibid.
[94] Ibid.
[95] Ibid.

accessible empirically. If causes and effects were linear, then the climate problem may well be easier to understand and the climate network would be much stronger. But dynamics is difficult to see and comprehend, and the basis of modeling and simulation requires actants like policymakers and citizens to invest a lot of trust in technologies and methods that are poorly understood and consequences that are unclear, which prevents the enrollment of actants altogether. Skeptics take advantage of this requisite trust to prevent further enrollment into the climate policy network.

Finally, another most important actant that remains is the media actant. The way media portrays climate change as a problem today remains polarized.[96] The media actant assumes two primary functions in a *de facto* manner, without definition. The media has always been a bridge that helps transform government policy into local action, and local concerns into government action. Media also build trust into the network as it is most able to permeate all the actants effectively through the dissemination of its media products in forms that are easily digested and understood. We previously discussed the media has painted vivid catastrophes and emphasis on dangers rather than realistic solutions. Visualizations are powerful tools to engage other actants, and will remain an important medium through which media articulate information and opinion regarding climate change. Films like "The Day After Tomorrow" were powerful in conveying a looming disaster, but it fails to convey a realistic one.[97] Al Gore's "An Inconvenient Truth" on the other hand articulates results of science better, employing effective hyperbolical demonstrations, such as the infamous "off the chart" demonstration.[98] Still, the media actant is an active actant, in that the citizens and policymakers receive its products passively. With little conveyed regarding how we can individually change our behaviors, the media fails to maintain

[96] Bolin, Bert. *A History of Science and Politics of Climate Change,* 211-3.
[97] Ibid.
[98] Ibid.

that bridge that translate government action into local action. The media also played a somewhat poisonous role in exaggerating the Climategate incidents, which further derails the already fragile trust prospective actants have gained and eroded away the authority of the science actant itself.

Upon Kyoto's expiration, the continuation of the IPCC effort is ever more important to stabilize the climate policy network so we can build more meaningful legal framework to tackle the issue of climate change. As models and simulations develop sophistication, we must allow the actant to build authority, a quality that requires respect and trust from other actants. At the same time, the issue of climate change as a social construction also requires the media to communicate possible personal actions and enable trust in the science and solutions agreed upon by international experts. Despite internal requirements of the scientific method of transparency and rigorous review and even if summaries are provided to the policymakers and citizens, science must cross a trust building threshold in order for actants to enroll into the climate policy network. The IPCC, Kyoto Protocol, the computer simulation, and the media undoubtedly were significant contributors to the climate policy actor-network present today.

Impediments and problems to a stable climate policy network

Through the examination of the climate policy network we have assembled many relevant actants and highlighted some of their deficiencies and successes in maintaining the stability of the climate policy network. To summarize, I argue that there are three major impediments in maintaining a stable climate policy network. First, there is a lack of understanding of climate change as a problem amongst citizens and policymakers. Second, there is a lack of understanding in personal responsibility, that is, whether one can make any kind of difference. Third, there is a prevalence of passiveness among the prospective actants. All three impediments can be characterized as obligatory passage points, at which enrolled actants must align interests for prospective actants to enroll in the network. Although these three impediments appear to be arranged sequentially, they have to be executed simultaneously to maintain and strengthen the climate policy network.

<u>1) Lack of understanding of the nature of climate change</u>

It is difficult or people to engage in understanding the nature of climate change as both a scientific and social issue. The chief reason why this obligatory passage point remains a difficult threshold because of some historical paradigm stagnancies. Although *Limits to Growth* and other neo-malthusian literature stimulated concerns in the population over the problems of the way our society operates, technological optimism nonetheless dominate the current social paradigm. The continued belief in the human resource seems to illustrate a view that nature has a progressively more limited influence on human activity.[99] However, to successfully enroll actants and maintain the climate policy network, we must achieve better understanding among prospective actants. While the IPCC effort helps dissemination of knowledge together with media, these actants require prospective citizen actants to align interest with scientific results that may not be comprehended. Effective climate policy will be dependent on the citizen's acceptance of scientific information about the causes, future trajectories, and consequences of climate change.[100] Citizen actants are more comfortable in enrolling if unanimity and certainty were demonstrated among scientists and policymakers about the state of the climate and respective solutions. Citizen actants' interest are best aligned with personal experience than indirect

[99] Bakstad and Hourcade. "Climate and society: what is the human dimension?," 208-10.
[100] Lundqvist, Lennart J., and Anders Biel. "From Kyoto to the Town Hall: Transforming National Strategies into Local and Individual Action." In *From Kyoto to the Town Hall: Making international and national climate policy work at the local level*, edited by Lennart J. Lundqvist and Anders Biel, 1-12. Sterling: Earthscan, 2007, 4-5.

evidence.[101] We must devise ways to enhance individual citizens' trust in climate information, not only in content information, but also in the organized governance associated with climate policy. The media actant must also remove poisons to the climate information dissemination, including exaggeration of weather events and polarization of the climate debates. The apparent disconnect between policymakers and citizen to climate science requires the possibility for better personal experiences and engagement in the climate change science, effects, and solutions. The prospective actants must claim the knowledge of climate science themselves, rather than having the knowledge superimposed from one authoritative entity.

2) Lack of understanding on the role and urgency of personal actions

Even with pervasive understanding of climate change as a problem, it does not imply that the actants themselves would choose to act personally to help remedy the problem. That is another obligatory passage point, a threshold that requires, in addition to understanding the problem, an understanding in the value and urgency of personal actions. It is without question that actions of individuals and groups are needed and their accumulated effect is what we hope would mitigate the possibilities of climate change. Actants in the network must help prospective actants understand the importance of shared responsibilities and participation. To remedy this network deficiency, network must respectfully engage prospective actants in personally understanding the role of their own actions beyond the abstract science of climate. The sovereignty over how the information regarding personal actions – "how one can make a difference" – needs to be discovered interactively so that the actant can see and trust that there is some value and urgency in taking part personally. So knowing the existence and the nature of

[101] Ibid.

climate change of a problem is not enough, actnats must also accept personal responsibility and understand the role and urgency of their actions and how they can make a kind of difference.

3) Passiveness

Lastly, even if actants understood the climate problem and how they can make a difference, it does not mean that they will actually take action. The final obligatory passage point in maintaining a functional climate policy network requires motivation.[102] It is clear that the identification of the problem and search for solutions occurred the global level while the execution, by and large, requires local action. How enrolled actants can translate global agreements into local action depends on the availability of motivation. The prospective actants must be motivated and overcome their inherent passiveness in joining the network. This threshold is perhaps the most difficult one, because fairness and justice questions greatly prevent actants from enrollment. There exist a clear free rider problem as climate is a global public good. All actants must agree to participate in order to overcome the free rider problem, where actants benefit from other's action. With this in mind, actants become reluctant to enroll due to the philosophy that "since someone else is doing it, therefore I don't need to" and benefit from the improved or mitigated climate system. . And of course, as climate change manifests over a long time horizon, the investment today may not benefit the actant in many years, or even over generations. On the other hand, all the actants already taking part also are discouraged from further continuation, as they must accept that their contribution will be benefiting others. Therefore, policy should give clearer and more precise directions to motivate changes in behavior, which can include command-and-control type of regulation or use of market incentives. In addition to use active policies, policy should also encourage a bottom-up development from

[102] Ibid., 6-8.

local communities themselves. Ultimately, interessment is strongest when actants actively devise their own terms of enrolling into the network taking into account their utilities and feasibility. The idea of personal satisfaction and participation in the policy process, where actants can realizing themselves that their community initiated and made effective changes will help maintain the climate policy network better than citizen actants following orders prescribed by policymaker actants.

Climate change is difficult to understand. The network is troubled when there lacks sufficient understanding of the complexities and uncertainties of climate itself. Actants tend to relate to short-term, dramatic weather events better than long-term climate events. Uncertainty and the media maintain distrust in climate science and policies. To maintain a successful post-Kyoto climate policy network, we must address the three obligatory passage points. For the stability of the climate policy network, we must improve personal participation in discovering climate change as a problem, engage actants in realizing the role and value of personal action, and provide the momentum for actants to engage in making these actions proposed into reality, which is best executed if activeness roots from the actants themselves. With these impediments to the climate policy network in mind, we assess whether the introduction of C-ROADS and the Climate Interactive effort help address these sources of network instability, and whether such a product qualify as an actant, perhaps a missing one to that matter.

V. C-ROADS as an actant

The Climate Rapid Overview and Decision Support simulator, created under the principles of system dynamics and inspired by Dr. Tom Fiddaman's dissertation and subsequent work at Ventana Systems, aims to engage citizens and policymakers in climate policymaking by providing an interactive policy simulator. Users are able to run various scenarios of climate policy, whether we continue "business as usual" or commit to carbon emissions reductions of various magnitudes, and visualize the effects of such policy changes instantaneously. Users can see immediately the plausible effects and results of implementing their policy decisions on the climate, on graphs of carbon emissions, on temperature change and on sea-level rise. C-ROADS can help users understand long-term effects and potentials of international agreements on the climate system.[103] Climate Interactive offers a few product variants of C-ROADS. The main variants of C-ROADS are C-ROADS Common-Platform (C-ROADS CP) and C-LEARN. Both C-ROADS CP and C-LEARN perform essentially the same functions, with CP geared more towards policymakers and negotiators, and C-LEARN designed for the general public.

C-ROADS products enable policymakers and citizens to use the graphical interface of the software to simulate the effects of policy decisions on the climate system instantaneously. As you can see in Table 1, by modifying a set of inputs and running the simulation, a set of output variables are displayed in graphic form.

Table 1 C-ROADS Inputs and Outputs

Inputs

Variable	Function	Options
Reference scenario (Can change in CP/Vensim version only)	Provides emissions and variable baseline and trajectories employed in the simulation	18 different reference scenarios
Regional aggregation (3 region default in C-LEARN)	Allows variation in country groups by level of development	1, 3, 6, 15 region groupings
Emission reduction CO_2 (Afforestation, deforestation, landuse, fossil fuels, etc) CH_4 NO_x	Varies the change in target emissions of different GHGs.	Various target measures: Annual Relative to base year Relative intensity per GDP Per capita

Outputs

Variable	Function	Options
Sea level rise	To see how sea level rise can be	Comparison with historical

[103] Sawin, Jones, et al., C-ROADS Simulator Reference Guide 2011.

	mitigated by the policy changes	levels
Temperature	To see if proposals can reduce temperature rises with time	Baseline industrial With uncertainty bounds
CO_2 Emission concentrations	To see how carbon dioxide concentrations can be changed with policy proposals	Cumulative Share per region Relative intensity per GDP Per capita

From Table 1, C-ROADS simulations can be run under different "reference scenarios," or baseline data and trajectories, or under a default dataset corresponding to an IPCC Assessment Report scenario "A1FI." Users can also modify "regional aggregation," which groups different countries in different ways, in one, three, six, or fifteen different blocs of countries.[104] The regional groupings choice depends on the level and scale of the desired policy simulation, whether a user wants to simulate policy action at a more detailed regional level or a general global scale. In other words, C-ROADS offers users the capability to run different situations and projections of climate effects under policy proposals for different geographic groupings.

To see the possible effects of policy proposals on future emissions, users input the desired policy changes in terms of reductions in emissions, as expressed by variables. Users can specify emissions reductions as a chosen annual rate (e.g., x%/year, beginning in a specified year), a target for emissions as a reduction relative to a specified base year (e.g., x% below 1990 by 2050), a reduction relative to a reference scenario (e.g., x% below the reference scenario by 2050), a reduction in emissions intensity relative to that in a base year (e.g., reducing emissions per unit of real GDP x% below today's level by 2050), or a reduction in emissions per capita (e.g., x% below today's level by 2050).[105] The policymaker and citizen users can also manipulate non-carbon greenhouse gas emissions and forcings including nitrous oxides and methane, or sub-categories of GHG emissions such as land use emissions, deforestation and afforestation targets,

[104] Ibid.
[105] Ibid.

in order to simulate a portfolio of policy actions to address climate change. Users are able to choose when the policy proposed will be enforced, the target years, and other attributes.[106] Users may also simulate specific sets of commitments, such as those under discussion by national governments, or those proposed by academic or advocacy groups.[107] These variables replicate the conventional comparative statements used by stakeholders when characterizing and choosing among policies.

The results of the simulation are then outputted in real-time almost instantaneously in various graphics. Outputs are available in carbon dioxide concentrations and further defined on a per capita basis, per GDP, or the share of total carbon dioxide emissions. Other variables outputted include sea-level rise and temperature projections, which are all indicators of climate change policy performance aside from carbon concentrations. The results in cumulative form are available as well. In Figures 1 and 2, you can see the interface of both C-LEARN and C-ROADS CP with the respective inputs and outputs sections. As inputs are modified and simulations are run, the output graphs on the right-hand side shifts to indicate the effects of the reduction plans. The arrays of functions in C-ROADS allow users to partake in the decision evaluation process, where they can see how each decision can affect climate change in the long run with interactive visuals. The interaction process helps policymakers and citizens actants pass obligatory passage points and improves enrollment and trust within the climate policy network, because actants are given the opportunity to participate in the translation from climate science to policy.

[106] Ibid.
[107] Ibid.

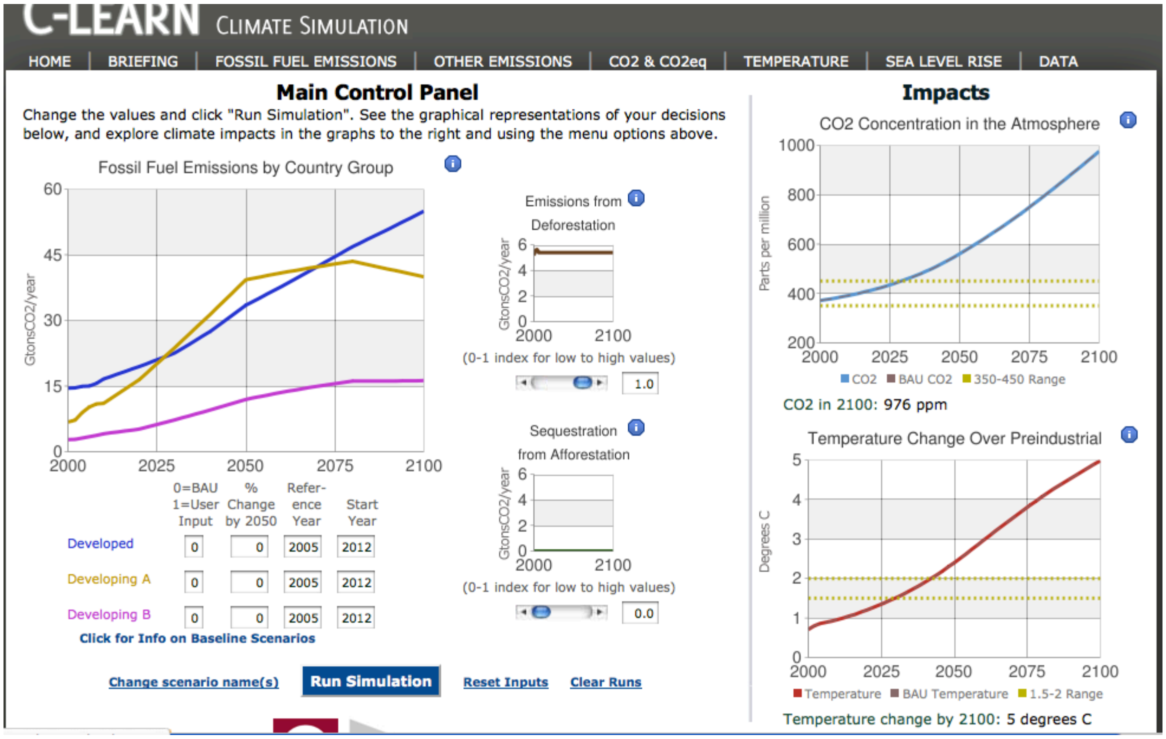

Fig 1. The C-LEARN Web browser-based interface

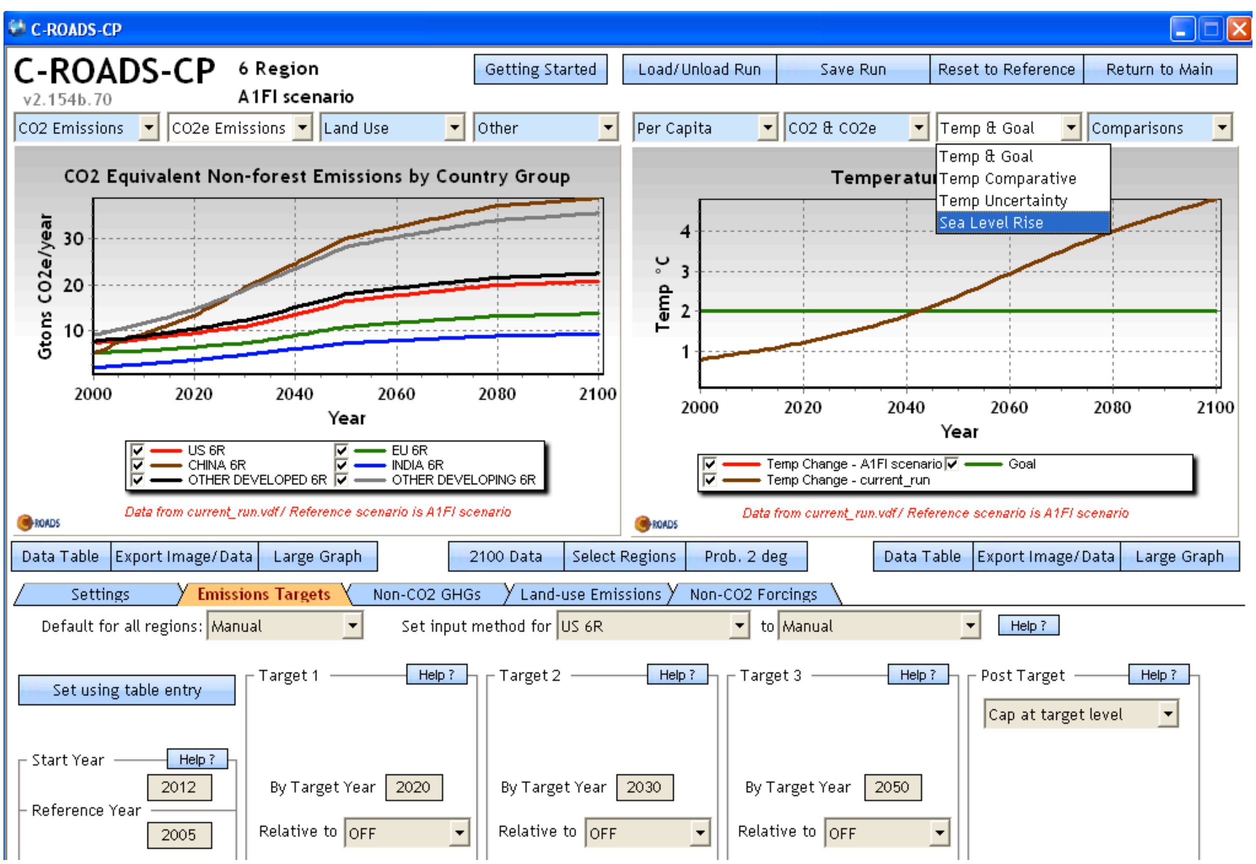

Fig 2. The C-ROADS CP Interface

The two main forms of C-ROADS, C-ROADS CP and C-LEARN, differ in the required technological access, purpose, and complexity. C-ROADS CP is intended for policymakers and offers the regional aggregation mentioned above. Users register with Climate Interactive before downloading the executable file onto a Windows platform. The CP software does not require installation of another software except Microsoft Excel where the reference data is stored temporarily. C-LEARN on the other hand is i ntended for the general public that is less complex to use and requires less technological knowledge to operate. It is essentially a simplified three-region version of C-ROADS. It is available in two forms, through the Internet or as a software download. The advantage of C-LEARN is that it requires much less knowledge in technology. For those interested more in the mechanics behind the models, the open-source softwater basis of the model and its availability as a download allow you to view the backbone system connections among the variables. Moreover, Vensim software is available on both Mac and PC. However, to simulate more complex scenarios with more regional aggregations, the CP version would be useful. The appeal of a lower technological prerequisite is linked with the interessment of actants. The easy to use C-LEARN that provides profound insights to climate policy making is appealing to actants with less training in computer technologies and will be able to understand how to operate and interpret what the simulation achieves. By offering a simpler variant, the alignment of interests between the scientists, citizens, and policymakers is improved. At the same time, the more sophisticated CP version furthers the understanding of policymakers with better working knowledge of climate change science and policy, which affirms, promotes, and strengthens their agency in the climate policy network.

Having outlined the specific functionalities of C-ROADS, we turn to the potential of the simulator to fill the role of a missing actant. C-ROADS possesses a few qualities that would qualify it as an actant, filling some of the translation gaps the fragile climate policy network needs. However, there are weaknesses of C-ROADS that allow it to fill only partially the roles of a missing actant.

Fig 3. Climate Policy Network

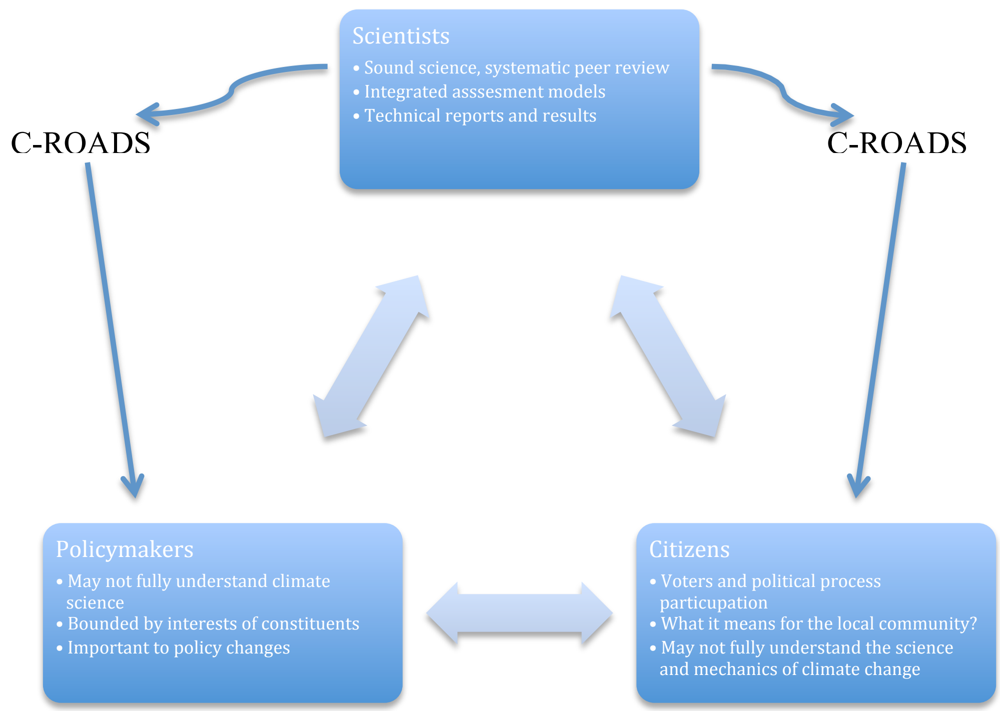

Figure 3 illustrates the potential role of the C-ROADS actant. C-ROADS, itself a product of scientists, helps align the interests of the scientist actant with policymakers and citizens. By addressing some of the impediments identified previously, the climate policy network can become more stable with the introduction of C-ROADS as an actant to the network.

The qualities of C-ROADS that make it an appealing actant for the climate policy network include its open access and transparency, ease of use, and the robust dynamic modeling and application of data sets in the simulator. C-ROADS is essentially available as open source material, in which the mechanisms behind the model and simulator are publicly disclosed and accessible. Amid scandals and distrust in the climate policy network from skeptical scientists, politicians, and Climategate, C-ROADS' commitment to open source helps build trust among the actants in the network with improved transparency. Users can access the full model and see what how the entire model system is linked, variable by variable and multiplier by multiplier. With adequate mathematical and dynamic modeling knowledge, the differential equations and mathematics that underlay the logic of the dynamic system can be identified. Full technical reference guides are available to accompany the use and understanding of the software, in which conceptual flow charts, as well as references and descriptions of data sets, are available. The distrust among actants can hopefully be mended, because alleged secrecy and mysteries are absent in C-ROADS simulators.

Second, the simulator is easy to use. The web-browser version of C-LEARN does not require downloading of any software but the use of your day-to-day web browser. Also, both CP and C-LEARN have user-friendly interfaces. For example, they are equipped with toggle bars, which allow convenient changes in emission targets, and entry boxes, which allow users to key in specifics with ease. The screens are clear and instructions and frequently asked questions (FAQs) are available to assist users. There are also video tutorials for the CP version. The clear buttons, output graphics, and the availability of support resources makes C-ROADS quite easy to operate and manipulate. More importantly, the easy-to-use C-ROADS model provides opportunities for meaningful interactions among the individual, the public, and the climate science and policy. With users actively participating in the creation of information, the acceptance of the efficacy of climate policy proposals is eased, and the enrollment into the climate policy network is improved. Citizens and policymakers can take more charge over their proposed policies, and may feel more personal and less distant to the decision-making process. The ease of use, together with C-ROADS' transparency, make it appealing to increase participation in the climate policy process with an easy tool to see the effects ourselves. We reclaim authority and are able to support our rhetoric over the projected effects of various policies, since we can see how much we do will matter over time with C-ROADS. C-ROADS hence helps address, at least partially, the problem of the role and urgency of personal actions and passiveness, as individuals can see how their actions really matter before their own computer screens.

Third, C-ROADS is developed using robust peer-reviewed science and trusted data sources. The resources available online include detailed descriptions of the simulator's data sources. Climate Interactive is comprised of expert scientists in the field of climate science and system dynamics, who have sought public technical reviewsto establish the model's credibility. It bases its scenarios from IPCC Assessment Reports, which are widely agreed to be an authoritative source of climate science. If the mistrust between actants existed for IPCC results in the first place, one may see the efforts to ensure transparency and appreciate availability of datasets and result in improved enrollment of actants. Thus, C-ROADS does partially fulfill the roles of the missing actant.

The fulfillment of the roles of the missing actant is partial because C-ROADS address some but not all of the impediments to the current fragile climate policy network, and that C-ROADS is primarily based on the IPCC results and it follows that the group of people who reject IPCC science and methodology (note the difference from misunderstand or misinform) will also reject C-ROADS.

While users can clearly visualize the effects of policy proposals, C-ROADS does not explicitly help users improve understanding of the climate system. C-ROADS really does perform the function of simulation but lacks on education. Users can perfectly realize proposed policies but still do not understand the science behind climate policy and have not appreciated any of the system linkages. An impediment in the climate policy network is lack of understanding of nature of climate change. Although the science is complex, if C-ROADS can provide some more educational tools in addition to providing the simulation environment, it will be a better actant in terms of fulfilling the roles of a hypothetical missing actant in the network now.

In addition, while the software returns some control over climate policymaking to the individual, C-ROADS is not enough in motivating personal action. One can see only bundled regional actions and their effects and there is no option of a "microsimulation" - no showing of individual actions and aggregated individual effects to climate change in the long term. Perhaps the regional options could include some family-based or personal scale policy proposal simulation that would couple with the regional policy changes, and see what kinds of personal actions are actually needed. C-ROADS here fails to translate big policy and legal bureaucracies into personally relatable actions, leaving the gap in translation and enrollment in the climate policy network open. In a way, it provides a good holistic macro-perspective but fails to address the individual, micro-level, which was identified as an impediment in the network.

Nonetheless, despite its shortcomings, if widely used, C-ROADS will help fill some of the roles of the missing actant as mentioned above. Recently an iPhone version was launched among a bundle of other products, such as Climate Scoreboard, ENROADS, and related simulation products in varying formats and technicality. The further dissemination and widespread use of C-ROADS products will definitely be beneficial to the climate policy network and improve enrollment of actants into the network. A younger and technologically apt generation may find these models and simulators interesting to use and as a result learn more about climate policy proposals. C-ROADS without a doubt fills some of the roles a missing actant that this climate policy network needs to achieve stabilization, but does fall short in a few aspects.

By applying ANT analysis to the climate policy network, we identified the major actants at play, the associated weaknesses of the current network, and the roles a missing actant should fulfill. We are able to see the intricate relationships between the actants and how C-ROADS does or does not improve the alignment of interests between actants. C-ROADS, still adolescent in its development, is able to achieve some qualities a missing actant would possess to stabilize the climate policy network. Innovative technologies such as C-ROADS will be important testaments to building better collaboration and consensus in climate policy and ensuring sustainability in the future. Whether C-ROADS will become wildly disseminated and used, I appalud the intellectual merit of Climate Interactive’s efforts in producing such a product, with ambitious, yet important goals.