Community Development in a Time of Climate Crisis

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I. Background.

The Scientific Context. Earth's climate is a complex deterministic system (*e.g.* Hansen *et al.* 1997). This is another way of saying it is a "chaotic" system, or, one which follows Newtonian laws of causality, but whose internal mechanisms are so complicated that its behavior can be difficult to predict. Such a system is also characterized by both positive and negative internal feedbacks. A positive internal feedback is a reaction within the system that tends to amplify changes to the system that have been introduced from the outside. A negative internal feedback, also called a dampening effect, is one that tends to mute changes to the system introduced from the outside. Both types of feedback arise from the interaction of internal components of the system, and from the system's interactions with the external environment (*e.g.* Crutchfield *et al.* 1986).

Complex determinism produces quasi-stable states (Ruelle 1981; Lorenz 1995). In the language of mathematics, these are called "attractors." This can be illustrated by imagining a bowling ball sitting in a valley. On either side of the valley are hills, beyond which are more valleys, also bounded by hills. When an internal force pushes the bowling ball partly up one of the hills, gravity, acting as a negative feedback, returns the bowling bowl to its position in the valley. This return is energetic, since the bowling ball will oscillate back and forth between one hill and another on either side of the valley, before eventually coming to rest on the valley floor. In this example, gravity has acted as a restoring force, pushing the system back to its *original* resting (quasi-stable) state.

If the external force were to push the bowling ball completely to the top of one of the hills on either side of the valley, the ball might roll down into the neighboring valley, rather than returning to its original position. Once again, this is an energetic process, as the ball is likely to oscillate back and forth between the hills surrounding the neighboring valley before finally settling into place. In this case, gravity has acted to amplify the change imposed by the external force, acting as a positive rather than a negative feedback. After the process is complete, the system is once again in a quasi-stable condition, but it is a *different* quasi-stable state that it was in before the process began.

This example illustrates another property of chaotic systems: *They often have more than one quasi-stable state.* Negative feedbacks can return the system to its original state, provided the external force is not large enough to overcome them. However, beyond some point, an externally-imposed change will be amplified by positive feedbacks in the system, and it will flip to a new, and possibly quite different, quasi-stable state.

The main external forces in Earth's climate are astronomical, which cause variations in the intensity of sunlight reaching Earth's surface. These "Milankovitch Cycles" (named after Serbian geophysicist and engineer Milutin Milankovitch) describe the variations in the shape of Earth's orbit around the Sun, the location of the Perihelion (the lowest point in Earth's orbit around the Sun), the tilt of its axis, and the direction in which the axis points. There are four main cycles, ranging in duration from 26 thousand to 100 thousand years. They never add up evenly, or in the same way, and thus Earth's climate is "forced" by the combination of these cycles in a constantly changing way (Climatica 2019; Open Source Systems 2019).

Earth's climate system became unstable about three million years ago (we call this period the Quaternary), when South and North America collided, creating the Central American isthmus, and cutting off direct flow between the waters of the equatorial Atlantic and Pacific oceans. But water continues to evaporate from the surfaces of both oceans, and the easterly equatorial wind (meaning wind blowing *from* the east *toward* the west) carries water vapor from the sky above the Atlantic to the sky over the Pacific Ocean, where it condenses and rains out. The net effect is *removal* of water from the Atlantic, and the *addition* of water to the Pacific, making the Atlantic saltier and the Pacific fresher. Since salt water is denser than fresh water, the waters of the Atlantic are slightly denser than the waters of the Pacific (NASA Earth Observatory 2019).

Gravity and sun-driven currents do the rest, working to undo the density difference between the two major ocean basins. But because of the two American continents, and the land bridge of Central America, the waters of the Atlantic are forced to take a long route to the Pacific. The route begins in the North Atlantic, off the coasts of Greenland and Iceland, where cold airmasses moving toward Europe from Canada come into contact with warm water at the north end of the Gulf Stream. The airmasses draw both heat and water vapor from the surface of the Atlantic, leaving behind colder, saltier surface water. This dense water sinks to a depth of several kilometers, while the moderated airmasses continue eastward, making Scotland and Norway far warmer and wetter than they would be without this mechanism (Stommel and Arons 1959; Broecker 2002).

The dense water created by this process, called North Atlantic Deep Water (NADW), flows southward along the east coasts of North and South America, and into the Southern Ocean (which forms a ring around Antarctica). It continues eastward at depth, across the southern reaches of the Indian Ocean, and into the South Pacific. From there it turns northward to the North Pacific, eventually reaching the Aleutian Islands – a wall of volcanoes blocking deep-water transport further north. This is the indirect route nature has found to undo the density difference between the two major ocean basins (Stommel and Arons 1959; Broecker 2002).

Once reaching the Aleutians, the NADW gradually upwells to the surface of the Pacific, and begins the long route back to its point of origin off the coast of Greenland. The return journey, along the ocean surface, mirrors the journey outward, and takes just as long. We call the final stretch of the return flow the Gulf Stream, where a river of warm, salty water apparently originates in the Gulf of Mexico and flows northward along the Eastern Seaboard of the United States. This entire closed circuit, sometimes called the Great Ocean Conveyor Belt (but more properly the Thermohaline Circulation[1]), is, like the climate system itself: Quasi-stable and chaotic (Stommel and Arons 1959; Broecker 2002).

When the Conveyor Belt is running quickly, it takes a thousand years to complete a circuit. During an ice age, it slows significantly or comes to a complete standstill. And the global climate system and Conveyor Belt are linked: Each affects the other, and can act as controls. If the Conveyor Belt is stopped, it can induce a period of global glaciation: An ice age. This has happened at least once in the last 15 thousand years – a period in our history called the Younger Dryas Event (YDE)[2]. The YDE was a 1,300-year return to ice age conditions, after the Milankovitch Cycles had induced a warmer world, and ending a major ice age more than a thousand years earlier in time. The Conveyor Belt acted as an internal feedback mechanism that acted as a damper on the externally-forced warming of Earth's climate. It

[1] Thermo = Temperature; Haline = Salt.

[2] The last 11 thousand years is the period of the Holocene, the current interglacial. It began about 15 thousand years ago but was interrupted by the YDE. There have been approximately eight interglacials in the last 800 thousand years. Each interglacial lasts between 10 and 15 thousand years, while ice ages last between 120 and 140 thousand years. The majority of the last 800 thousand years has been ice age.

currently acts as a positive feedback, enhancing warming in the high latitudes of Europe, by transporting warm water to the North Atlantic, where it interacts with eastward-moving Canadian airmasses, moderating their temperatures (Broecker 2002).

Another important feedback in the Earth system is the cycling of methane (CH_4). This is a powerful greenhouse gas created by the decay of organic matter, and billions of tons of it are stored in the permafrost of the tundra surrounding the Arctic Ocean, and in the form of ice-like hydrates under the floor of the Arctic Ocean. When externally-forced warming is strong enough to melt the permafrost and warm the waters of the Arctic Ocean, the methane stored in these two reservoirs can escape and enhance the warming. This mechanism is the most plausible mechanism we currently have to explain the Paleocene-Eocene Thermal Maximum (PETM), a global "hot house" lasting about 200 thousand years, which occurred about 55 million years ago. The PETM was a mass extinction event (*e.g.* Zachos *et al.* 2003).

The net effect of the Milankovitch Cycles forcing the system from the outside, and the internal feedbacks in the system (such as the behavior of the Conveyor Belt and the methane cycling), is that, during the Quaternary, there have been two quasi-stable modes (like the valleys discussed above) in the climate system. The dominant mode is the ice-age mode, when sea level is hundreds of feet below its current height, and the interiors of most of the continents are covered by glaciers. For a minority of this time, the second mode – called interglacials – have been active. The last 11 thousand years of written history have all taken place during the most recent interglacial we call the Holocene. From history we also know there's a third stable mode: The global hot house. The PETM was one example, occurring millions of years ago.

We have inadvertently stepped into this inherently unstable situation, adding our own climate forcing signal (*e.g.* Hansen *et al.* 1997). The anthropogenic signal is primarily in the form of excess carbon dioxide (CO_2) gas from the combustion of fossil fuels[3], but also consists of other combustion, industrial, and agricultural by-products such as CH_4 and NOX variants, as well as the destruction of natural greenhouse gas (GHG) removal mechanisms, such as tropical and temperate forests. In doing so, we have changed the chemical composition of the atmosphere, and the planet's resulting radiative balance[4], triggering a collapse of the quasi-stable Holocene, and pushing the climate system toward some *other* quasi-stable state. The bowling ball has been pushed out of the valley, to the top of the hill on either side.

Internal feedbacks, such as the outgassing of methane from the sub-Arctic permafrost and Arctic Ocean floor, are now taking over, enhancing the artificially induced warming (*e.g.* Gray 2018, Science Daily 2019). The initiation of these positive feedbacks means that, even if we somehow magically completely halted the emission of excess GHGs today, warming, and all of its accompanying ills, will continue to worsen for several hundred more years. But the Conveyor Belt is also slowing, meaning that a negative feedback has been triggered as well (Rahmstorf *et al.* 2015). This means that, the future may be either a global hot house or an ice age, but in any case it will certainly be quite different from the familiar climate of the Holocene. (The hot house is the more likely scenario, at least for the next century.) And our entire economic and political system, including the production of food and energy, is premised on Holocene climate remaining in effect.

I shouldn't describe the threat of the runaway greenhouse with quite so much certainty, but the scientific consensus at the moment is that, if we haven't crossed the line yet, we will quite soon. Steffen *et*

[3] The World Meteorological Organization estimates that we have added 1,400 gigatons of carbon dioxide to the atmosphere since 1850.
[4] The difference between incoming solar radiation (primarily in the form of visible light), and outgoing terrestrial radiation (primarily in the form of infrared light).

al. (2018) illustrate this nicely with the images shown in Figure 1 (below). They explain that "there is a planetary threshold that, if crossed, could prevent stabilization of the climate at intermediate temperature rises and cause continued warming on a 'Hothouse Earth'," even with substantially reduced anthropogenic GHG emissions. They further state that the exact temperature increase at which this threshold exists is uncertain, but it could be quite close to the 1.5 – 2.0°C mark, which is well within the target set by the Paris Accord (Steffen *et al.* 2018).

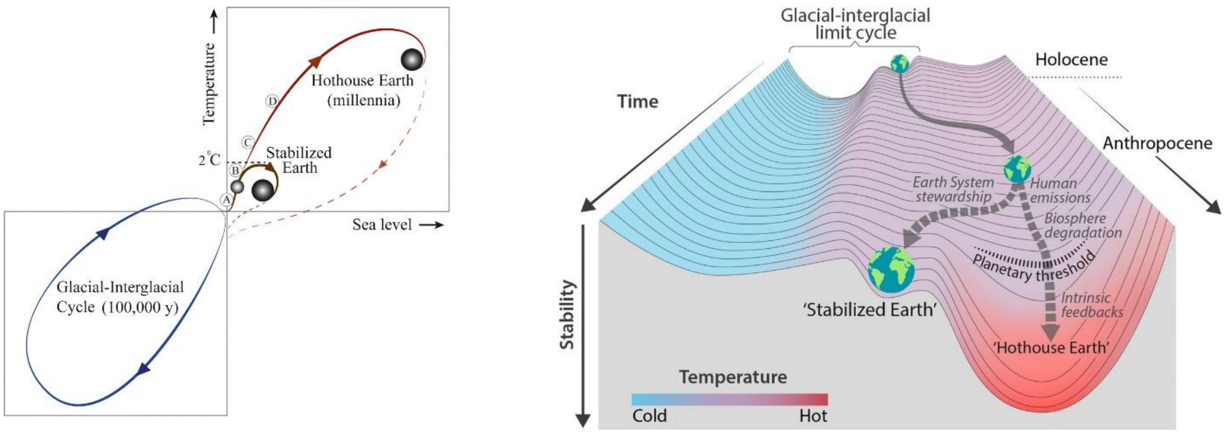

Fig. 1: Schematics illustrating past and near-future trajectories of the Earth system (Steffen *et al.* 2018). Left: Temperature-sea level diagram illustrating quasi-stable climate modes. The Holocene is at the origin of the coordinate system. Right: Possible future pathways, and the possible location of the threshold for a runaway greenhouse. The "valleys" and "hills" discussed above are clearly visible.

This new geologic period, in which human influence on Earth's climate becomes the dominant effect, has been named the *Anthropocene*, and is distinct from the Holocene (*e.g.* Stromberg 2013). The Anthropocene is (or will soon be) characterized by a long list of consequences that threaten to overwhelm our ability to cope (*e.g.* IPCC 2014; Reidmiller *et al.* 2018; Stern 2007). Because of the positive feedbacks now operating in the climate system, of which induced methane emissions are only one, and the global failure to address the growing problem over the last 30 years, the onset of these consequences has either already begun, or is almost certain at some point in the next few decades. Among them are:

- Increasingly severe and frequent tropical storms
- Sea-level rise
- Extreme drought and extreme (acute) precipitation events
- Levels of heat that tax human endurance beyond the breaking point
- Shifting climatic zones and consequent ecosystem collapse
- Invasions of tropical diseases and insects into the middle latitudes
- Failing agricultural systems
- Economic depression
- Heightened international tension and open conflict
- Hundreds of millions of environmental refugees

What we must do if we are to continue. Working with Mindi Messmer (a clean water activist, geologist, and former member of the New Hampshire House of Representatives), and referring to the findings published in the Fourth National Climate Assessment (Reidmiller *et al.* 2018) and an additional study by the Union of Concerned Scientists, I developed a list of actions necessary for minimal adaptation in the Anthropocene. To be clear, I believe that we must put all of these into action, or we will be faced with circumstances that will overwhelm our ability to adapt, and the human population of the world will be faced with extreme hardships beyond anything we've experience in the last several thousand years.

Broad categories of these actions include a *rapid* transition to low-carbon fuels, but this alone is woefully inadequate. Our entire interlocking global infrastructure of critical systems must be re-engineered for greater resiliency in the face of both the acute and chronic effects of the Climate Crisis. Among the systems that must be reconfigured for greater resiliency are:

- Coastal flood control and defenses against sea-level rise
- Fresh water management
- Wildlife, forest, and fire management
- Food production and distribution
- Energy generation and transmission
- Transportation
- Public health
- Border controls for the *humane* and *ethical* reception of immigrants and refugees

Who will act? These recommendations, along with references, were transmitted by letter to our newly-elected member of the U.S. House of Representatives, Chris Pappas. Unfortunately, Mr. Pappas' response was typical of most of our national political actors: I received a phone call from his office in Washington, thanking me for the letter, but was given no pledges of any kind of action whatsoever. A much more detailed version, with a long list of specific actions to be taken for New Hampshire under each category, was produced by request for an individual running for New Hampshire Governor. That individual then proceeded to soft-peddle the issue, and refused to explicitly include them in his campaign platform. He explained that he was afraid of "scaring people." (Both the letter and the more detailed document are included in the appendices to this paper.)

With few exceptions, our elected leaders seem to still be unwilling to grapple with the magnitude and implications of the developing Climate Crisis, and international efforts (limited as they have been) to address the problem are useless without binding agreements and the cooperation of the world's wealthiest nation and historically-largest polluter: The United States. China is currently the largest polluter, and the U.S. has fallen into second place, but the United States is historically responsible for the greatest amount of anthropogenically-added CO_2 in the atmosphere (Gillis and Popovich 2017).

It has become painfully obvious to me that we cannot expect a rational, forward-leaning political response to this growing Climate Crisis at the national or global level. Large, vested global economic interests in the Anthropocene are too politically and culturally influential, and have so far successfully resisted calls for large-scale collective mitigative and adaptive efforts that they believe might reduce their monetary wealth and the power that wealth brings. To many of them, even acknowledging the existence of the Climate Crisis seems to be a bridge too far. This is a form of pathology, brought about by an economic system obsessed with monetization and short-term profit. Unless this situation changes, our paralysis in the face of the Climate Crisis could result in the near or total collapse of human civilization within the next several decades (Spratt and Dunlop 2019).

With these assumptions as a starting point, we are left with the possibilities of action for adaptation and mitigation spanning the scale from the individual to the state (or provincial) level. Given my experience with the politics of climate change at the state level, it is not clear to me that this level is viable either, although there are other states (such as California and Washington) where the reception has been better (Tobuchi 2017; NYTimes Editorial Board 2019). The tools provided by the community development community *may* be the appropriate means to pursue such action, although there is no guarantee that efforts to adapt to and mitigate the crisis at these levels will succeed either. We have no choice but to try, and we have no time left to waste.

II. Theory of development in the context of the Climate Crisis.

Definitions of "development" and related terms. Based on a review of the literature, a general definition of development might be "the process by which a unit of civilization (UC) is improved."

- A "UC" may be an individual, family, neighborhood or tribe, town, county, state (or province), country, or the world as a whole. It may also be a bioregion, which can span the geographic scale from county (or province) to country (Vilhena and Antonelli 2015).

- "Improved" means an increase in one or more aspects of the UC's biological (or psychological), environmental, political, economic, or cultural well-being. In the present context, this means that the aspects under consideration become better adapted to cope with the acute and chronic effects of the Climate Crisis. In other words, "improved" implies "increased resiliency[5]."

- The relative value of "well-being" can be defined as the levels of self-determination (or autonomy), freedom, durability, resiliency, coordination and decentralization, skill, and creative capacity in the UC. "Decentralization" is explicitly added as an Anthropocene adaptive strategy, since the highly-integrated, global economy in which we are now operating is extremely dependent on the continued and profligate use of fossil fuels (which is unsustainable). "Coordination" means intentional cooperative efforts between smaller, autonomous units, such as sharing of information, physical assets and other resources, and mutual efforts toward common goals.

Existing theoretical basis. I have been easily able to identify two existing theoretical frameworks that are either adaptable to or *already* directly applicable to the problems of the climate crisis. The first framework is that of the Grameen Bank (GB) developed by Yunus (2007). The assumptions are that access to credit is a "human right," that the well-being of all can be achieved by empowering women, and that the poor of the Global South can lift themselves out of poverty through mutual accountability and trust, creativity, and wide-scale participation.

[5] The United Nations lists development in the era of climate change as Goal 13 of its "sustainable development" program, and will convene a Climate Action Summit in California, in September 2019. Controlling emissions and building resilience are explicitly listed as the goals of the conference. For more, see https://www.un.org/sustainabledevelopment/climate-change/.

- GB defines "assets" as "strengths," which may be "tangible" or "intangible." Tangible assets are those with a physical manifestation, such as a building, high-grade topsoil, farm animal, or cash. Intangible assets are skills, knowledge, or social and political connections. In all, the assets held by a UC consist of spiritual and human (intangible), social (intangible), political (intangible), natural (tangible), physical (tangible), and financial (tangible) (Yunus 2007).

- From this perspective, the well-being (see above) of a UC is increased by increasing its assets. Therefore, from the perspective of the Climate Crisis, improving one or more of these assets improves the *resiliency* and *durability* of the UC in question.

The second is that of the Kresge Foundation, which discusses urban development for the Anthropocene (*e.g.* Vogel *et al.* 2016). Their theory focuses on increasing the resiliency and durability of urban communities, with the expressed expectation that the Climate Crisis will produce both acute and chronic problems.

- Acute effects of the Climate Crisis are described by Kresge as "shocks" (Kresge Foundation 2018). Climate "shocks" include sudden, extreme, often-unprecedented weather events, such as catastrophic outbreaks of tornadic thunderstorms, or land-falling tropical cyclones, either repeated, or at a new level of extremity, or in regions that have not experienced these types of events in recent history.

- Chronic effects include drought, extended heatwaves, and long-term changes in the patterns of seasonal rainfall or ocean circulation.

- Both acute and chronic effects may result in financial and economic crises, disruptions to or the collapse of food or energy production, severe economic hardships, unprecedented waves of refugees and migrants leaving affected areas, political extremism, and warfare. The Syrian civil war was, in part, triggered by desertification – an effect of climate change. The waves of refugees it caused triggered extremist reactionary political movements in Europe.

- Kresge refers to a report by the Urban Land Institute[6], explaining "10 Principles for Building Resilience," published in 2017. The principles include (with parenthetical comments added to explain applicability to climate change):

    1. Understand vulnerabilities (in this case, threats such as extreme heat, sea-level rise, and other negative aspects of the Anthropocene)
    2. Strengthen job and housing opportunities (generally applicable to all threatened communities)
    3. Promote equity (*i.e.* justice and fairness, rather than replacing one system of dominance with another)
    4. Leverage community assets (as defined by Yunus 2007; *i.e.* begin adapting using a given community's existing strengths)

[6] For more, see: https://americas.uli.org/research/centers-initiatives/urban-resilience-program/ten-principles-building-resilience/.

5. Redefine how and where to build (to reduce vulnerability to threats such as sea-level rise)
6. Build the business case (so that private enterprise makes key contributions to absorbing costs, and distributing the benefits)
7. Accurately price the cost of inaction (that is, understand the future costs of trying to save money by *not* acting before the onset of an unmanageable crisis)
8. Design with natural systems (a fundamental aspect of permaculture design[7])
9. Maximize co-benefits (defined as positive benefits related to the reduction of greenhouse gases and other forms of mitigation and adaptation, such as improved human health from cleaner air)
10. Harness innovation and technology (which is self-explanatory)

Integration of sources. The Kresge Foundation assumptions can be linked to the theoretical basis of Grameen Bank via the assumption that "assets" are "strengths," and, by assuming that increasing one or more of a UC's strengths will increase its Climate Crisis resiliency and durability. Additional common-sense concepts include the same sensibilities that motivate people to be prepared for difficulties (such as purchasing insurance policies and hiring fire departments). From these flow an integrated theory, suggesting actions to be taken primarily at the community and state (or provincial) level.

- Communities must begin taking actions *now*, rather than waiting until the symptoms of the crisis become so great that their ability to cope is overwhelmed.

- Key assets (strengths) are leadership and cooperation at the neighborhood and city levels, as well as direct (and frequent) involvement of all stakeholders. Among the stakeholders are businesses and ordinary citizens who may not have been historically involved in cooperative community efforts, but whose involvement is essential if mitigation and adaptation efforts are to succeed.

- Educational efforts are key: Communities must engage in conscious efforts to help their citizens understand that, while the challenges posed by the Climate Crisis are large and growing larger, they can probably be managed if everyone contributes to the effort.

- Communities should play to their strengths (using and enhancing existing assets), by (1) using existing administrative structures where possible, (2) building up their physical infrastructure (such as buildings, roads, and networks for communications, power production and distribution, water distribution, and waste disposal) and reserve resources (such as stored electricity, food, and water); (3) enhancing the capabilities of their broadly-distributed first response personnel and equipment for *acute* events; and (4) improving their resilience during *chronic* climate events.

- Immediate planning should also involve eliminating the demand for dirty energy and other brown technologies, and replacing them with clean energy and green technologies (*mitigation*). This implies rapidly restructuring transportation, energy-production, manufacturing, and agriculture.

[7] See (for example) Bane and Holmgren (2012).

- Longer-term planning should include decentralization and relocalization of food, energy, and commodity production. This implies establishment of community-level agriculture, power production, and manufacturing. These efforts will reduce the demand for energy consumption to support long-range transportation and therefore reduce emissions (*mitigation*), and make continued survival possible at a local level when chronic drought or other symptoms of the Climate Crisis strike centralized or distant production facilities (*adaptation*).

- All aspects of the mitigation and adaptation plan should be revised as needed as progress is made toward each goal.

Predictions arising from the integrated theory. The theory discussed above naturally leads to several predictions about the nature of successful community-scale mitigation and adaptation efforts. The following list includes a few of them. (There are probably others.)

1. Communities that begin efforts now, rather than waiting until the Climate Crisis creates overwhelming conditions, will be the most successful at adapting.

2. All communities have existing assets (strengths) that can be brought to bear on the problem. Some have more than others.

3. A community that uses existing administrative structures (an existing asset), such as city councils and zoning ordinances, will be able to more quickly put mitigation and adaptation efforts into place.

4. A community that engages all stakeholders will be more successful than one that takes a strictly "top-down" approach. Among stakeholders are ordinary citizens and businesses. This requires negotiation and compromise. Without these, efforts to mitigate and adapt are likely to get bogged down in bickering and unnecessary competition.

5. Successful development plans will be flexible, with built in methods of self-correction when new data become available, or unforeseen circumstances arise.

6. Efforts to mitigate the causes of climate change and adapt to its effects will have a better chance of succeeding if they also address pre-existing problems that stakeholders are already working on, such as poor infrastructure maintenance and unjust distribution of wealth and income.

7. A community that engages in an ambitious effort to educate its members will have a better chance of successfully adapting, than a community that assumes its stakeholders already fully understand the implications of the Climate Crisis.

8. A successful community development plan for the Climate Crisis will include both immediate and longer-term goals. Immediate goals involve mitigation of the causes of climate change, and adaptation to its short-term effects, such as excessive heat and extreme precipitation events. Longer-term goals include adaptation to the chronic effects of climate change, such as extended drought and shortages of drinking water. Even longer-term goals include engaging in

decentralized production of food and energy (although these would be very difficult to test given information available today).

III. Case studies. Vogel *et al.* (2016) discusses 17 case studies of community-scale climate change adaptation efforts. The communities involved in these projects are all in U.S. states, including Alabama, Arizona, California (2), Colorado, Florida, Massachusetts, Maryland, Michigan, Montana, New Jersey, Ohio, Oklahoma, South Carolina, Texas, Virginia, and Washington. In the interests of brevity, not all of them will be summarized here. Following a review of three case studies, I'll discuss principles derived from these case studies, and then a list of tactical recommendations made by the authors. (Most of the content from the case studies below is paraphrased from the original document, although it's pretty close to quotes. To keep things readable, I'll leave out the quotes for the remainder of this section.)

1. **Chula Vista, California.** Chula Vista is the second largest city in the southernmost part of California (after San Diego), and has developed a climate planning (and adaptation) process that focuses on:

    - Energy use
    - Urban heat-island (UHI) effect
    - Public health
    - Creating a local, "green" economy

    To implement the city's climate plan, they created a process involving several steps. These steps included (1) developing a road-map that outlined tasks for a Climate Change Working Group, establishing a time-frame, and identifying stake-holders; (2) engaging stakeholders; (3) collecting information on engineering standards and expected climate change impacts in the region; (4) analyzing options; and (5) selecting and recommending specific options. Recommendations were made to the City Council by the Working Group.

    Their plan explicitly recognizes that, even with *mitigation* efforts (such as reductions in energy use), the climate will continue to change (see my discussion of the internal dynamics, including feedbacks inherent in the system, above). With this in mind, the working group was directed by the City Council to reconvene and consider strategies for *adaptation*. The working group then developed 180 different adaptation actions that could be taken, of which the City Council adopted eleven.

    Among the adaptation options chosen were those that will reduce the severity of the UHI. The city adopted local ordinances to mandate the use of reflective (or cool) materials for roofs in new residential buildings. Chula Vista also adopted a policy that mandates the planting of shade trees to further reduce UHI, with the objective of covering at least 50 percent of car parking stalls within 5 to 15 years. Both policies were developed and approved by the City Council in 2010, and were operational until 2013, but were then put on hold so that they could be rewritten, and made compatible with state-wide standards. As of 2015, they were still under revision.

    It's important to note that the people of Chula Vista had a heightened sense of the gathering Climate Crisis following wide-spread wild fires, triggered by the Santa Ana winds in 2003 and 2007. These fires burned more than 740 thousand acres in San Diego County alone, destroying more than 4,200 private residences and other structures. Twenty five people were killed. Together, (1) the method that Chula Vista adopted to begin the adaptation process (using existing governmental means and involving stakeholders), and (2) the fact that the people were ready for a pro-active policy on the Climate Crisis following severe wild-fires, illustrate two important tactical principles discussed below.

2. **Seattle, Washington.** The Seattle Public Utilities (SPU) commission serves more than 650 thousand people and 64 thousand businesses with drinking water, sewer, and other services in the city of Seattle, and, 700 thousand additional customers elsewhere in the Puget Sound region with drinking water. SPU's operations are highly vulnerable to fluctuations in weather, such as incidents of extreme precipitation and drought. During the decades of the 1980s and 1990s, both types of incidents affected SPU's water supply and drainage operations. After evaluating these incidents in terms of climate science, SPU planners engaged in further studies of how climate change might affect their future operations. This work eventually led to the conscious integration of climate change science into four levels of the commission's planning and operations:

    - Organization-wide strategic planning
    - Planning at the water, drainage, and sewer divisions
    - Decisions about capital investments
    - Day-to-day operational decision making

    By the late 1990s, few SPU projects had been modified based on projected *future* changes in climate. The leader of SPU's Climate Resiliency Group at the time explained that some aspects of their operations might not be affected by climate change, and that those that eventually are could be adapted in the future, as the impacts became obvious. This illustrates a fundamental barrier delaying actions in the present that might help adapt to problems in the future: People are often reluctant to act on threats they consider merely hypothetical. It sometimes requires one or more galvanizing incidents to overcome individual and institutional inertia. (See the Chula Vista discussion, above.)

    Near the end of the last century, SPU planners realized that their water management methods were inadequate in the face of extreme climate variability. At that time, rainfall variability brought on by the El Niño Southern Oscillation (ENSO) was the immediate problem, but by the early 2000s, SPU began considering the broader problem of global climate change. Major drought, flooding from extreme precipitation, and years with drastically-reduced winter snowpack (a reservoir of water SPU uses during the warm months) had in the past resulted in either too much or too little water in the system – problems that are projected to worsen in the future. SPU now utilizes a wide variety of activities to reduce its vulnerabilities. Among these activities are (1) investing in "green" infrastructure, (2) expanding its ability to manage flooding by increasing the capacity of its storm drain system, (3) promulgating programs for water conservation and reuse, (4) working with homeowners and developers to manage storm water where it falls, (5) engaging in public education, and (6) working to maintain and improve land quality in the watershed. In spite of the earlier reluctance of some SPU members, it has since become a leader in ensuring that it is able to meet the current and future water management needs of its customers.

Seattle's improved water management activities illustrate another general principle necessary for adapting to the Climate Crisis: It requires a *comprehensive* approach, engaging with every aspect of the problem at hand. Merely addressing individual symptoms is completely inadequate. The SPU has implemented a system where considerations of climate change science are mandated when making decisions at all levels, which has incidentally helped reduce its vulnerability to extreme weather events.

3. **Boston, Massachusetts.** In the past, Boston has been protected from storm surges by 34 harbor islands, which break up and dissipate the surges. Because of this relative safety, the filled tidelands of Boston are within 8 feet the *present* high tide mark, but by 2100 CE will be at chronic risk of salt water flooding. Climate change is contributing to this growing problem via (1) sea level rise (increasing the elevation of the tides), and (2) increased inland (fresh water) flooding from extreme precipitation events (such as tropical storms)[8]. Projections indicate that flooding from both causes is likely to increase in the Boston area in the coming decades.

   The city's initial efforts on the issue of climate change involved *mitigation*, including a city-wide effort to reduce greenhouse gas emissions. By the 2000s, it had become apparent that mitigation alone would not solve the problem, and in 2013, the Boston Redevelopment Authority (BRA) began the process of rule-making for *adaptation*, mandating that climate change be considered as part of the review process for large new development and renovation projects. (This sequence of events is familiar.) An existing portion of the zoning codes were revised to require that all private property owners proposing new buildings over 20,000 square feet, and renovations of existing properties over 100,000 square feet, identify how climate change will affect the project's (and its inhabitants) survivability, integrity, and safety. To this end, they created a Climate Change Preparedness and Resiliency Checklist (also known as simply "the Checklist"). The completed checklist is submitted to the BRA as part of the project's approval process. Like the Chula Vista City Council's methods, this illustrates the use of existing administrative structures to manage the process of adaptation.

   The city has introduced additional initiatives for both mitigation and adaptation, including the Complete Streets Program, green infrastructure installations, improved urban forestry, education initiatives, and more improved rulemaking around wetlands and floodplains. Like Seattle's, Boston's approach illustrates the importance of a comprehensive approach to the Climate Crisis.

Conclusions derived by Vogel *et al.* (2016) from their case studies. Collectively, the case studies in Vogel *et al.* (2016) answer four "key questions," resulting in seven "conclusions" and eleven "tactical recommendations." The four <u>questions</u> are:

1. **What motivates communities to take adaptive action?** They find that these actions are taken to "promote, and sustain community values," and that responding to the Climate Crisis was "not

[8] Warmer air can hold more water vapor without becoming saturated (increasing its ability to transport vapor), and warmer sea-surface temperatures increased the rate of evaporation that provides greater amounts of vapor. The recondensation of water vapor, and the subsequent release of latent heat, is the energy source that powers tropical storms. (This makes them different from midlatitude storms, which are ultimately powered by latitudinal differences in temperature.) Greater amounts of vapor therefore mean that, when precipitation events occur (either through tropical or midlatitude mechanisms), there are both higher rainfall *rates* and rainfall *totals*. This implies both increased land erosion and inland fresh-water flooding.

typically the exclusive justification" for them. They also find that, when a community *does* experience an extreme climate event, it can serve as the final impetus needed for either getting adaptation efforts moving, or for speeding up already-existing efforts.

2. **What are communities doing to adapt?** Vogel *et al.* (2016) find that communities "are attempting to tangibly reduce their vulnerability to climate variability, [including] extreme events…" In some cases, community action is aimed at "reducing exposure," but that, more often, the goal of the work is to "reduc[e] sensitivity and [build] adaptive capacity."

3. **How are actions implementing adaptation actions?** Vogel *et al.* (2016) report that communities are deploying a wide range of strategies that often use "conventional policy tools" that mainstream "adaptation into existing efforts…" They find that the strategies employed "often capitalize on effective leadership and consciously build community support."

4. **What are communities achieving through adaptation?** They find that communities are successfully "reducing their vulnerability to *current* climate impacts" (emphasis added), while "a few are also explicitly reducing their vulnerability to *future* climate impacts" (emphasis added). Some of these adaptive strategies are limited in scope to a narrow range of vulnerabilities, but "frequently go hand-in-hand with progress on other community priorities."

Seven <u>conclusions</u> derived by Vogel *et al.* (2016) are:

1. Community-level efforts at adaptation are successfully "reducing vulnerability to climate variability and extreme [weather] events, and possibly to climate change."

2. If efforts address only climate variability and extreme weather events, they may not be as effective at adapting to long-term climate change.

3. Community actions to adapt to climate change can begin now.

4. Barriers to action can be overcome, opportunities to begin adaptation can be identified, and adaptation efforts can begin.

5. Adaptation efforts to explicitly address long-term climate change are still in the early stages.

6. Their community case studies provide the basis for defining a "hypothetical, well-adapted community." Figure 2 (below) reproduces a graphical depiction of this model.

7. Both community "champions" of adaptation, and professionals in the field, should focus on reducing vulnerability when assessing and facilitating progress toward adaptation.

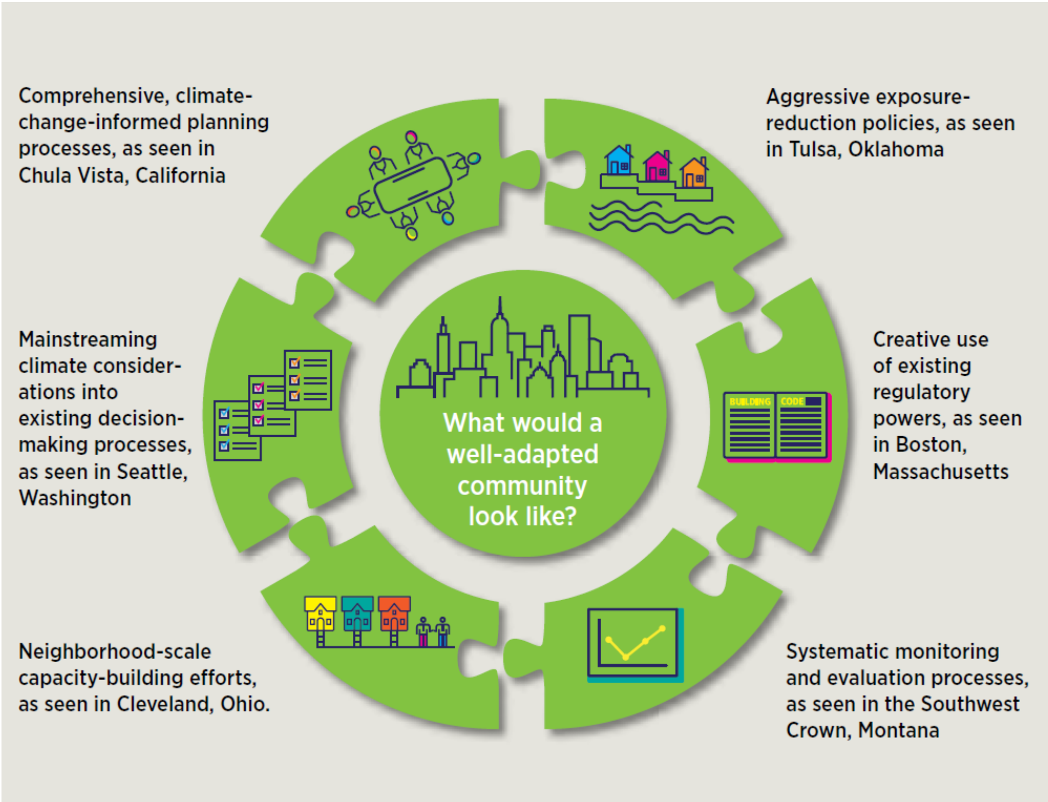

Fig. 2: Conceptual model of a "well-adapted community," reproduced from Vogel *et al.* (2016).

Eleven tactical recommendations by Vogel *et al.* (2016) are:

1. **Start now.** Waiting wastes valuable time. To this I add, *we have zero time left to waste.*

2. **Look for co-benefits, cross-sector leveraging, and opportunities to "piggyback" climate adaptation onto other relevant community issues.** Put another way, communities should focus their climate change adaptation efforts on projects that solve multiple problems simultaneously.

3. **Employ commonly used policy tools to mainstream adaptation.** Tools such as ordinances, permits, zoning and others already exist. There is no need to re-invent the wheel.

4. **Use windows of opportunity to advance climate adaptation.** The best time to promote adaptive projects is right after an event has occurred that focuses public attention on the issue.

5. **Build flexibility into policies, projects, and programs.** Programs should be able to readily adapt to changing fiscal and environmental circumstances.

6. **Consider both the needs and capabilities of more vulnerable populations.** Planners should focus on the most vulnerable groups, which are "often the poorest, those already overburdened by pollution, those who lack economic opportunity, and individuals facing disenfranchisement

and racism." At the same time, there are often committed leaders within these groups whose talents can be put to use in adaptive efforts.

7. **Creative outreach and community engagement efforts build community support.** This is essential to build "buy-in" and support among a broad spectrum of the population.

8. **Take "prudent" risks and adjust over time.** Some level of risk-taking is essential.

9. **Consider the local context when deciding to overtly frame actions in terms of climate change.** Be aware of cultural barriers that "can constrain action," in other words, an outspoken population (or well-known public figures) identifying as "skeptics."

10. **Provide leadership.** This may include "conventional" leaders, such as mayors and city council members, but may also be NGOs, grassroots activists, and lower-level municipal staff.

11. **Work with partners.** Singular actors are often faced with limited time and financial resources.

IV. Evaluation of the proposed theory. Below, I repeat the eight predictions of the integrated theory, along with comments on each one based on the results of Vogel *et al.* (2016).

1. *Communities that begin efforts now, rather than waiting until the Climate Crisis creates overwhelming conditions, will be the most successful at adapting.*

   Vogel *et al.* (2016) state this as the first of their tactical recommendations. All three of the case studies discussed here involve early efforts to mitigate and adapt. In the Seattle case, early efforts were engaged to adapt to the natural climate variation caused by ENSO, but as the reality of anthropogenic climate change became indisputable, their efforts were broadened to include long-term planning for its consequences. However, because the worst of the long-term consequences of the Climate Crisis have yet to arrive, I think we'll have to judge the validity of this prediction as "undecided" for now. In 50 years we can look back and decide if this prediction is correct.

2. *All communities have existing assets (strengths) that can be brought to bear on the problem. Some have more than others.*

   Vogel *et al.* (2016) report that communities are using "conventional policy tools" that bring efforts to adapt into already existing work. All three of the communities discussed in the case studies reviewed here are fairly large, so it is difficult to make a comparison of the relative assets of one community over another based on these data. However, it follows naturally that some communities are wealthier than others, and some are better organized than others. I think the validity of this prediction can be judged as "leaning toward correct."

3. *A community that uses existing administrative structures (an existing asset), such as city councils and zoning ordinances, will be able to more quickly put mitigation and adaptation efforts into place.*

   In all three case studies discussed above, pre-existing city management structures took up the causes of mitigation and adaptation. In Chula Vista, it was the City Council. In Seattle, it was the Seattle Public Utilities commission, responsible for water and sewer management (among other things). In Boston, it was the Office of the Mayor and the Boston Redevelopment Authority. Additional case studies of communities that have tried mitigation and adaptation efforts by creating new administrative structures would be required to determine whether this prediction is accurate.

4. *A community that engages all stakeholders will be more successful than one that takes a strictly "top-down" approach. Among stakeholders are ordinary citizens and businesses. This requires negotiation and compromise. Without these, efforts to mitigate and adapt are likely to get bogged down in bickering and unnecessary competition.*

   Vogel *et al.* (2016) list this as their No. 7 tactical recommendation, noting that "creative outreach and community engagement efforts…are essential to build buy-in and support among a broad spectrum of the population." Their No. 9 tactical recommendation further states that the "local context" should be considered, when deciding whether to frame the work strictly in terms of the Climate Crisis. No. 10 states that "conventional leaders" should be involved, but also NGOs, grassroots activists, and lower-level municipal staff. I understand that tactical recommendations are not the same as empirical evidence, but it appears that Vogel *et al.* (2016) came to the same conclusion as I have. Perhaps we can judge the validity of this prediction as "undecided."

5. *Successful development plans will be flexible, with built in methods of self-correction when new data become available, or unforeseen circumstances arise.*

   Vogel *et al.* (2016) state, in their No. 5 tactical recommendation, that "policies, projects, and programs" should be "flexible" and "readily adapt to changing fiscal and environmental circumstances." The Chula Vista case study illustrates the need to adapt local plans to higher-level policies (in their case, California building standards). Seattle's plans did not initially include preparing for long-term climate change, but were revised when the science became indisputable. Boston was initially primarily concerned with emissions reductions, but expanded significantly when it was realized that mitigation alone would not prevent disaster. Again, it is difficult to judge whether this prediction is accurate based on the available evidence, however it follows from other contexts (such as hiring a fire department before a building catches on fire) that it is "probably correct." It also follows that Seattle and Boston will be more prepared to adapt as new circumstances arise than cities that have refused to engage in preparatory efforts.

6. *Efforts to mitigate the causes of climate change and adapt to its effects will have a better chance of succeeding if they also address pre-existing problems that stakeholders are already working on, such as poor infrastructure maintenance and unjust distribution of wealth and income.*

   The first question put forth in Vogel *et al.* (2016) directly addressed this point. They found that communities are better motivated to take action that "promote[s] and sustain[s] community values." They also state that responding to the Climate Crisis was "not typically the exclusive justification" for taking mitigation and adaptation efforts. (Their second tactical recommendation is to "look for co-benefits…and opportunities to piggyback climate adaptation onto other relevant community issues.") Based on this evidence, this prediction is "probably correct."

7. *A community that engages in an ambitious effort to educate its members will have a better chance of successfully adapting, than a community that assumes its stakeholders already fully understand the implications of the Climate Crisis.*

   Vogel *et al.* (2016) address this in several of their tactical recommendations. The first is to "use windows of opportunity" following extreme weather events. An expression often used in this context is "taking advantage of a teachable moment." (People are often more receptive to change following dramatic events. Naomi Klein refers to this as "The Shock Doctrine," in a book by that name.) The second is their suggestion to engage in "creative outreach and community engagement," which can include an educational component. The next is to "provide leadership," which can also include educational components. Again, these are recommendations, not empirical evidence from case studies. However, it follows that informing people about the nature of impending threats and enlisting their involvement in solutions is better than issuing orders without explanation. I think the experience of the United States and Great Britain during World War II may serve as an example of the former approach, but the world has changed since then, and this example is not directly applicable to the prediction. For now, I'd say the validity of this prediction is "undecided" but "probably correct."

8. *A successful community development plan for the Climate Crisis will include both immediate and longer-term goals. Immediate goals involve mitigation of the causes of climate change, and adaptation to its short-term effects, such as excessive heat and extreme precipitation events. Longer-term goals include adaptation to the chronic effects of climate change, such as extended drought and shortages of drinking water. Even longer-term goals include engaging in decentralized production of food and energy (although these would be very difficult to test given information available today).*

   The answer to the fourth question in Vogel *et al.* (2016) states that communities are successfully "reducing their vulnerability to current climate impacts," but that "few are…reducing their vulnerability to future climate impacts." All three of the case studies reviewed here illustrate the difficulties involved. The Chula Vista Climate Change Working Group made 180 recommendations to the City Council, which then proceeded to adopt only eleven of them. Most of them were focused on the immediate problem of the Urban Heat Island effect. Seattle was initially reluctant to make long-term adaptation a priority, but eventually broadened their plan to account for chronic climate change. Boston was initially concerned with emissions reductions, but later began the process of coping with impending sea-level rise, and the possible inundation of a large portion of its land area. It is difficult to evaluate whether this prediction of the integrated theory is correct, since we are at the beginning of the Climate Crisis, and we have decades, even centuries, of continuously worsening conditions to cope with. Once again, the validity of this prediction cannot be determined at this time. In 50 years, we'll be able to look back and determine whether the prediction is accurate.

V. Summary. The global climate is a chaotic and unstable system. It has been inherently unstable for three million years (a period called the Quaternary), and has since oscillated back and forth between two quasi-stable states: Ice ages, which last for more than one hundred thousand years, and interglacials, which last a tenth of that time. A third quasi-stable state is also known from evidence of an event that occurred more than 50 million years ago: A global hot house.

During the Quaternary, the climate system has been forced by astronomical cycles with periods varying between 26 thousand and one hundred thousand years. Feedbacks in the system react to this external forcing, resulting is rapid swings between quasi-stable states. Feedbacks take the form of positive feedbacks, which enhance externally-forced change, and negative feedbacks, which act as a restoring force, dampening externally-forced change. Human activities have changed the composition of the atmosphere, adding a new force to this dynamic system. The Holocene – the interglacial of the last 11 thousand years, in which all of written history has occurred – has been destabilized and replaced by the Anthropocene – a period of time when anthropogenic forcing overwhelms the other forces at work.

This doesn't mean that the system's internal feedbacks or the astronomical forcing mechanisms have stopped functioning. Human activity has triggered a strong positive feedback, in the form of massive methane emissions from melting permafrost and the floor of the Arctic Ocean. This is probably the same mechanism responsible for the Paleocene Eocene Thermal Maximum, the global hot house that occurred 55 million years ago. A negative feedback is also at work, in the form of slowed global ocean circulation into the North Atlantic. This is the mechanism responsible for the Younger Dryas Event, between 13 thousand and 11 thousand years ago. The former is accelerating the warming trend, while the latter is working to dampen it. We don't know the long-term outcome for certain, but continued, rapid global warming is likely for the next several decades to centuries.

Climate change, referred to here as the "Climate Crisis," is the ongoing rapid destabilization that results from global warming. There are many symptoms, including extreme heat, drought, sea-level rise, and extreme precipitation events. These in turn cause other natural and human problems, such as ecosystem extinction and political destabilization. So far, efforts to mitigate and adapt at a national and global level have been inadequate, and there are significant barriers to these efforts in the economic and political system of the United States. Even the minimal efforts agreed to in the Paris Accord have proven to be a bridge too far for our national leadership, and we have withdrawn from the agreement.

This leaves actions spanning from the individual to the state (or provincial) level as our best hope. Many things have to be accomplished in a very short period of time, but efforts are beginning in several locations. Vogel *et al.* (2016) discuss efforts occurring in 17 different locations across the United States, from Florida to Seattle, Washington. The most successful cases have used the tools of community development to involve as many stakeholders as possible, and piggy-back climate change mitigation and adaptation efforts onto already-existing programs aimed at separate issues. They are using existing community assets, such as administrative offices, NGOs, and citizens organizations, to accomplish the work. Many of the projects began more modestly, such as coping with natural climate variability brought on by the El Niño Southern Oscillation, and grew to encompass the larger problems involved in the Climate Crisis.

I attempted to develop a "theory of development" for mitigation and adaptation in the Climate Crisis, by merging ideas proposed by Yunus' Grameen Bank and the Kresge Foundation. From my integrated theory, I made eight predictions and used the case studies (and conclusions and recommendations based on them) discussed in Vogel *et al.* (2016) to try and verify or falsify them. The result was not a crashing success. Of the eight predictions, three were evaluated as "probably correct," one "leaning correct," and four "undecided." None were directly falsified. The most generous interpretation is that the theory is right at least half the time. The reason that the validity of half of the predictions was "undecided" is that the Climate Crisis has not progressed to the point where they can be accurately measured against empirical data. In several decades we'll be able to look back and decide if those predictions were correct.

Our national leaders refuse to act. Global cooperative efforts to mitigate and adapt to climate change are dangerously inadequate. We are left to respond at a more local scale, and many communities are beginning to take action. The methods of the community development community may provide the appropriate means, although there is no guarantee that efforts to manage the Climate Crisis at *any* level will succeed. We have no choice but to try, and we have no time left to waste.

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Appendix 1

LETTER TO REPRESENTATIVE CHRIS PAPPAS

January 2, 2019

Dear Mr. Pappas,

I enclose a copy of the Summary Findings of the Fourth National Climate Assessment, published by agencies of the United States government in 2018. As climate change represents the greatest threat to our civilization in the last 10,000 years (rivaled only by global nuclear war), I respectfully request that you review the document. After reading it, I ask that you please consider ways that you, our elected representative, will respond to further the essential work of adaptation and mitigation.

Some of the findings outlined in the summary are:

- The impacts of climate change are already being felt in the United States in the form of extreme weather events, causing damage to infrastructure, ecosystems and social systems. This will continue, and extreme weather events will increase in both frequency and magnitude.

- The greatest impacts are being experienced by those Americans least able to adapt because of low income and other socioeconomic factors. This will also continue. However, those of us who live in relatively wealthy New Hampshire are not immune. (A recent study by the Union of Concerned Scientists concluded that by 2045 CE, $645M of commercial real estate and 1,900 residences in New Hampshire are at risk due to sea level rise.)

- Without global mitigation and regional adaptation efforts, increases in the frequency and magnitude of heat waves, coastal flooding brought about by sea-level rise, extended drought, extreme precipitation events, and land-falling tropical storm activity will inflict further damage to our economy. By the year 2100 CE, this could result in a net decrease in U.S. economic activity of ten percent. In current figures, that represents a GDP loss of almost two trillion dollars per year.

A policy of gradual conversion from fossil fuels to renewables is, by itself, a woefully inadequate response. In addition to a *rapid* transition to low-carbon fuels, our entire interlocking national infrastructure of critical systems must be re-engineered for greater resiliency in the face of both the acute and chronic effects of climate change.

Among the systems that must be reconfigured for greater resiliency are:

- Coastal flood control and defenses against sea-level rise
- Fresh water management
- Wildlife, forest, and fire management

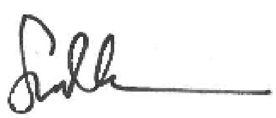
- Food production and distribution
- Energy generation and transmission
- Transportation
- Public health
- Border controls for the *humane* and *ethical* management of immigrants and refugees

The effects of climate change globally – destabilizing entire regions of the world, increasing the threat of war, and triggering waves of refugees – also represent a threat to U.S. political stability and national security. Climate change was one factor that helped precipitate the Syrian civil war, which resulted in more than two million refugees flooding into Europe. This has, in turn, triggered ugly political responses in European countries such as Hungary. If we wait until after the worst effects fully develop to begin the process of adaptation and mitigation, we risk outcomes similar to those in Syria and Hungary.

I understand that the political environment in Washington makes it difficult to openly advocate for action to cope with climate change, and that members of Congress may prefer to pursue more focused policy goals, such as reform of our broken health care system. But I also point out that if we do not make adapting to climate change (*which, because of 30 years of inaction, is now unavoidable*) our number one priority, then efforts in other areas may ultimately prove futile. **We have just 12 years to make massive and unprecedented changes to the global energy infrastructure to limit global warming to moderate levels.** ***And that is just the beginning of what we must do.***

I thank you for your time, and look forward to hearing what you intend to do.

Respectfully,



Dr. Sam Miller, Meteorologist
For *Campton Forward*
Campton, New Hampshire

Appendix 2

RECOMMENDATIONS FOR STATE POLICY IN RESPONSE TO ANTHROPOGENIC CLIMATE CHANGE

Dr. Sam Miller
Professor of Meteorology and AMS Certified Consulting Meteorologist

Mindi Messmer
New Hampshire Professional Geologist and Maine Certified Geologist
Former Member, New Hampshire House of Representatives, District 24
Served on Health, Human Services & Elderly Affairs Committee

28 May 2019

The following summarizes specific policy recommendations that detail how New Hampshire should respond to the climate crisis documented in the Fourth National Climate Assessment Summary Findings. The original document can be found at: https://nca2018.globalchange.gov. Each statement is number and quoted in the Summary Findings, then followed with specific policy recommendations for New Hampshire. (Recommendations are in **bold face** font.). Further information about the basic science of Anthropogenic Climate Change can be found at the Intergovernmental Panel on Climate Change (IPCC) website (https://www.ipcc.ch).

1. "The impacts of climate change are already being felt in communities across the country. More frequent and intense extreme weather and climate-related events, as well as changes in average climate conditions, are expected to continue to damage infrastructure, ecosystems, and social systems that provide essential benefits to communities. Future climate change is expected to further disrupt many areas of life, exacerbating existing challenges to prosperity posed by aging and deteriorating infrastructure, stressed ecosystems, and economic inequality. Impacts within and across regions will not be distributed equally. People who are already vulnerable, including lower-income and other marginalized communities, have lower capacity to prepare for and cope with extreme weather and climate-related events and are expected to experience greater impacts. Prioritizing adaptation actions for the most vulnerable populations would contribute to a more equitable future within and across communities. Global action to significantly cut greenhouse gas emissions can substantially reduce climate-related risks and increase opportunities for these populations in the longer term."

Recommendations:

- **Infrastructure upgrades and reconstruction efforts, with special attention paid to those aspects of infrastructure most vulnerable to coastal flooding, sea-level rise, excessive heat and**

drought, and enhanced extreme precipitation events, including (a) coastal defenses such as sea walls and other anti-erosion structures; (b) flood-control technologies, including those associated with rivers (which are already often at flood stage during spring months) as well as in low-lying coastal areas (for example, dikes and pumping systems); (c) road and bridge repairs and upgrades, including research and installation of improved road surfaces better able to withstand erosion from extreme precipitation events and buckling during heat events[10], and increased elevations for roads leading to bridges.

- **Higher energy efficiency rules for vehicles, structures, and heavy machinery.**

- **Dramatic carbon emission reduction efforts, and sequestration, where practical, with the ultimate goal of zero carbon emissions in all sectors. This includes rapid retirement of power plants that burn coal and other fossil fuels, including natural gas, and any other facilities that emit greenhouse gases. "Negative net emissions" may also be possible to achieve by planting millions of trees (a low-tech form of sequestration) *in addition to significant emission reductions*, but since much of New Hampshire is already forested, this may not be practical[11].**

- **Rapid transition to "green" renewable energy sources, including solar power, wind power (both inland and offshore), and development of new sources such as wave, tide, and geothermal. Note: Nuclear power is not a "green" technology.**

- **Creation of a comprehensive public transportation sector, including electrically-powered light rail and road vehicles, covering as much of the urban and suburban areas of New Hampshire as possible, and connecting to the existing network of Amtrak trains.**

- **Economic incentives to spur small business innovation to address climate adaptation needs (*e.g.* battery technology) and attract and keep young entrepreneurs.**

- **Educate and inform the public about moving away from consumer products that rely on fossil fuels (*e.g.* plastics) to reduce carbon emissions and reduce plastic waste in our marine and freshwater ecosystems.**

- **Facilitate and encourage business and public to achieve zero waste with incentives and programs to educate the public and encourage reuse (*e.g.* coffee cup rental programs, etc.).**

- **Facilitate, through regulatory and financial incentives, community microgrid development to create localized power supply nodes.**

- **Implement regulations that (1) eliminate *new* fossil fuel projects in New Hampshire and encourage industry to innovate with cleaner, more sustainable power sources, and (2) rapidly phase out *existing* fossil fuel projects.**

[10] Consult with the New England Transportation Consortium (NETC) for the current state of road-surface science and engineering.
[11] 89 percent, as of 2012; the highest percentage in the CONUS. See https://www.sciencedaily.com/releases/2012/08/120806130855.htm

2. “In the absence of significant global mitigation action and regional adaptation efforts, rising temperatures, sea level rise, and changes in extreme events are expected to increasingly disrupt and damage critical infrastructure and property, labor productivity, and the vitality of our communities. Regional economies and industries that depend on natural resources and favorable climate conditions, such as agriculture, tourism, and fisheries, are vulnerable to the growing impacts of climate change. Rising temperatures are projected to reduce the efficiency of power generation while increasing energy demands, resulting in higher electricity costs. The impacts of climate change beyond our borders are expected to increasingly affect our trade and economy, including import and export prices and U.S. businesses with overseas operations and supply chains. Some aspects of our economy may see slight near-term improvements in a modestly warmer world. However, the continued warming that is projected to occur without substantial and sustained reductions in global greenhouse gas emissions is expected to cause substantial net damage to the U.S. economy throughout this century, especially in the absence of increased adaptation efforts. With continued growth in emissions at historic rates, annual losses in some economic sectors are projected to reach hundreds of billions of dollars by the end of the century—more than the current gross domestic product (GDP) of many U.S. states.”

Recommendations:

- **Reiteration of all points made under (1), above.**

- **Adjustments to rules regarding insurance, both private and public-sponsored, for economic losses brought about by climate change. Since we cannot expect meaningful action at either a national or international level, the resulting climate-change-fueled natural disasters (and associated economic fallout) represent a significant threat to the continued solvency of insurance programs. Adjustments may include new (or improved) rules for ensuring (a) existing structures are retrofitted for greater durability and resilience (in order to reduce claims against insurance), and (b) new structures are built to higher standards for resisting extreme precipitation and heat. Businesses and public formations should also be financially prepared to weather sudden economic losses, perhaps by increased requirements for maintaining cash reserves.**

- **Support and evaluate additional efforts necessary to protect the marine food chain from collapse. Northern shrimp populations have collapsed, and lobster and other marine life have migrated northeasterly seeking cooler, deeper water. The lobster population in Long Island Sound has collapsed. The New Hampshire Fish and Game is currently evaluation emergency rules to protect the North Atlantic from invasive, non-native bait fish species with the collapse of the herring population. Fishing is an important cultural and economic backbone of New England.**

3. “Climate change presents added risks to interconnected systems that are already exposed to a range of stressors such as aging and deteriorating infrastructure, land-use changes, and population growth. Extreme weather and climate-related impacts on one system can result in increased risks or failures in other critical systems, including water resources, food production and distribution, energy and transportation, public health, international trade, and national security. The full extent of climate change

risks to interconnected systems, many of which span regional and national boundaries, is often greater than the sum of risks to individual sectors. Failure to anticipate interconnected impacts can lead to missed opportunities for effectively managing the risks of climate change and can also lead to management responses that increase risks to other sectors and regions. Joint planning with stakeholders across sectors, regions, and jurisdictions can help identify critical risks arising from interaction among systems ahead of time."

Recommendations:

- **The formation of a new, overarching public agency or task force, tasked to examine the multi-faceted risks posed by climate change at a state level, and empowered to recommend (to the legislative and executive branches) actions for mitigation and management. This task force should include representatives from across a wide spectrum of private and public organizations, including large and small businesses, disaster management and law enforcement, as well as highly qualified scientific advisors well versed in the projections of the Intergovernmental Panel on Climate Change (IPCC) for the next 50 to 100 years.**

- **Increased efforts at regional cooperation for actions to mitigate and adapt to Anthropogenic Climate Change, involving the governments of the other New England states and adjacent Canadian provinces.**

- **Increased efforts to protect our water infrastructure from pollutants. As sea levels rise saltwater will encroach and impact our aquifers reducing our already limited supply of clean, safe drinking water, especially in coastal areas.**

- **Evaluate whether current regulatory protections are sufficient to protect water and prevent chronic disease and cancer. NH *already* has the highest rates of bladder, breast, esophageal and pediatric cancer in the nation, which could be worsened as fresh water supplies are contaminated by encroaching saltwater, brought about by rising sea levels. The availability of clean air, soil and water is crucial for public health protection.**

- **A substantially increased involvement by our federal representatives in Congress to engage the efforts and resources of the U.S. government in the problem, particularly at a political level, without neglecting the agency level. This should include pressure to rejoin the *Paris Accord* (United Nations Framework Convention on Climate Change), and press for stronger, binding international treaties to address Anthropogenic Climate Change.**

4. "Future risks from climate change depend primarily on decisions made today. The integration of climate risk into decision-making and the implementation of adaptation activities have significantly increased since the Third National Climate Assessment in 2014, including in areas of financial risk reporting, capital investment planning, development of engineering standards, military planning, and disaster risk management. Transformations in the energy sector—including the displacement of coal by natural gas and increased deployment of renewable energy—along with policy actions at the national, regional, state, and local levels are reducing greenhouse gas emissions in the United States. While these adaptation and mitigation measures can help reduce damages in a number of sectors, this assessment

shows that more immediate and substantial global greenhouse gas emissions reductions, as well as regional adaptation efforts, would be needed to avoid the most severe consequences in the long term. Mitigation and adaptation actions also present opportunities for additional benefits that are often more immediate and localized, such as improving local air quality and economies through investments in infrastructure. Some benefits, such as restoring ecosystems and increasing community vitality, may be harder to quantify."

Recommendation:

- **A well-funded state-wide public education effort is required to help the people of New Hampshire understand the gathering and accelerating nature of the risks we face. The focus should be to impress upon everyone the need for early efforts at adaptation and mitigation, before the situation becomes unmanageable, as well as the obvious necessity for rapid reductions in emissions.**

5. "Rising air and water temperatures and changes in precipitation are intensifying droughts, increasing heavy downpours, reducing snowpack, and causing declines in surface water quality, with varying impacts across regions. Future warming will add to the stress on water supplies and adversely impact the availability of water in parts of the United States. Changes in the relative amounts and timing of snow and rainfall are leading to mismatches between water availability and needs in some regions, posing threats to, for example, the future reliability of hydropower production in the Southwest and the Northwest. Groundwater depletion is exacerbating drought risk in many parts of the United States, particularly in the Southwest and Southern Great Plains. Dependable and safe water supplies for U.S. Caribbean, Hawai'i, and U.S.-Affiliated Pacific Island communities are threatened by drought, flooding, and saltwater contamination due to sea level rise. Most U.S. power plants rely on a steady supply of water for cooling, and operations are expected to be affected by changes in water availability and temperature increases. Aging and deteriorating water infrastructure, typically designed for past environmental conditions, compounds the climate risk faced by society. Water management strategies that account for changing climate conditions can help reduce present and future risks to water security, but implementation of such practices remains limited."

Recommendations:

- **Our major water-related risks in New Hampshire are (a) increased risk of drought due to declining snowpack; (b) a related but not insignificant risk to one of our important sources of income – winter sports; and (c) coastal and seasonal inland flooding which threatens the availability of clean, safe drinking water.**

- **Assess the need to secure sources of contamination (*e.g.*, underground and above ground storage tanks) or unmitigated contamination that will pose threats to air, soil and water supplies due to flooding and extreme weather conditions (see https://www.nbcnews.com/news/us-news/texas-chemical-plant-ceo-indicted-reckless-release-following-hurricane-harvey-n897496).**

6. “Changes in temperature and precipitation are increasing air quality and health risks from wildfire and ground-level ozone pollution. Rising air and water temperatures and more intense extreme events are expected to increase exposure to waterborne and foodborne diseases, affecting food and water safety. With continued warming, cold-related deaths are projected to decrease and heat-related deaths are projected to increase; in most regions, increases in heat-related deaths are expected to outpace reductions in cold-related deaths. The frequency and severity of allergic illnesses, including asthma and hay fever, are expected to increase as a result of a changing climate. Climate change is also projected to alter the geographic range and distribution of disease-carrying insects and pests, exposing more people to ticks that carry Lyme disease and mosquitoes that transmit viruses such as Zika, West Nile, and dengue, with varying impacts across regions. Communities in the Southeast, for example, are particularly vulnerable to the combined health impacts from vector-borne disease, heat, and flooding. Extreme weather and climate-related events can have lasting mental health consequences in affected communities, particularly if they result in degradation of livelihoods or community relocation. Populations including older adults, children, low-income communities, and some communities of color are often disproportionately affected by, and less resilient to, the health impacts of climate change. Adaptation and mitigation policies and programs that help individuals, communities, and states prepare for the risks of a changing climate reduce the number of injuries, illnesses, and deaths from climate-related health outcomes.”

Recommendation:

- **Increased public health resources directed to (a) respiratory illnesses resulting from poor air quality (such as ozone, which is directly related to temperature); (b) the influx of insects (and insect-borne illnesses) and diseases usually associated with lower latitudes, (c) higher rates of vector-borne disease due to lengthening seasons from global warming, and (d) heat-stress, as days in New Hampshire with high temperatures above 100 degrees Fahrenheit will increase from about one per year, to as many as 20 per year within the next several decades.**

7.   “Many Indigenous peoples are reliant on natural resources for their economic, cultural, and physical well-being and are often uniquely affected by climate change. The impacts of climate change on water, land, coastal areas, and other natural resources, as well as infrastructure and related services, are expected to increasingly disrupt Indigenous peoples’ livelihoods and economies, including agriculture and agroforestry, fishing, recreation, and tourism. Adverse impacts on subsistence activities have already been observed. As climate changes continue, adverse impacts on culturally significant species and resources are expected to result in negative physical and mental health effects. Throughout the United States, climate-related impacts are causing some Indigenous peoples to consider or actively pursue community relocation as an adaptation strategy, presenting challenges associated with maintaining cultural and community continuity. While economic, political, and infrastructure limitations may affect these communities’ ability to adapt, tightly knit social and cultural networks present opportunities to build community capacity and increase resilience. Many Indigenous peoples are taking steps to adapt to climate change impacts structured around self-determination and traditional knowledge, and some tribes are pursuing mitigation actions through development of renewable energy on tribal lands.”

Recommendation:

- **This is a statement about the effects of climate change on the Indigenous People of North America. The authors of this paper are not qualified to respond, so we suggest consulting people in New England that fall into this category.**

8. "Many benefits provided by ecosystems and the environment, such as clean air and water, protection from coastal flooding, wood and fiber, crop pollination, hunting and fishing, tourism, cultural identities, and more will continue to be degraded by the impacts of climate change. Increasing wildfire frequency, changes in insect and disease outbreaks, and other stressors are expected to decrease the ability of U.S. forests to support economic activity, recreation, and subsistence activities. Climate change has already had observable impacts on biodiversity, ecosystems, and the benefits they provide to society. These impacts include the migration of native species to new areas and the spread of invasive species. Such changes are projected to continue, and without substantial and sustained reductions in global greenhouse gas emissions, extinctions and transformative impacts on some ecosystems cannot be avoided in the long term. Valued aspects of regional heritage and quality of life tied to ecosystems, wildlife, and outdoor recreation will change with the climate, and as a result, future generations can expect to experience and interact with the natural environment in ways that are different from today. Adaptation strategies, including prescribed burning to reduce fuel for wildfire, creation of safe havens for important species, and control of invasive species, are being implemented to address emerging impacts of climate change. While some targeted response actions are underway, many impacts, including losses of unique coral reef and sea ice ecosystems, can only be avoided by significantly reducing global emissions of carbon dioxide and other greenhouse gases."

Recommendation:

- **Ecosystem biologists, agriculture specialists, infectious disease specialists, and U.S. Forest Service (or New Hampshire State Park) personnel should be included in the task force suggested under (3), above.**

9. "Climate change presents numerous challenges to sustaining and enhancing crop productivity, livestock health, and the economic vitality of rural communities. While some regions (such as the Northern Great Plains) may see conditions conducive to expanded or alternative crop productivity over the next few decades, overall, yields from major U.S. crops are expected to decline as a consequence of increases in temperatures and possibly changes in water availability, soil erosion, and disease and pest outbreaks. Increases in temperatures during the growing season in the Midwest are projected to be the largest contributing factor to declines in the productivity of U.S. agriculture. Projected increases in extreme heat conditions are expected to lead to further heat stress for livestock, which can result in large economic losses for producers. Climate change is also expected to lead to large-scale shifts in the availability and prices of many agricultural products across the world, with corresponding impacts on U.S. agricultural producers and the U.S. economy. These changes threaten future gains in commodity crop production and put rural livelihoods at risk. Numerous adaptation strategies are available to cope with adverse impacts of climate variability and change on agricultural production. These include altering

what is produced, modifying the inputs used for production, adopting new technologies, and adjusting management strategies. However, these strategies have limits under severe climate change impacts and would require sufficient long- and short-term investment in changing practices.”

Recommendations:

- **In short, climate change means that food will become more expensive, in several senses of the word, including water use (which is problematic because of the already noted increasing stresses to the water supply), fuel use (for pumping water and increased refrigeration), and financial (which will affect producers and consumers).**

- **To the degree possible, food sources and production should be developed locally. Currently, the average item of food in your refrigerator travels 1500 miles to get there. Some come from much further away. This consumes a huge amount of fuel for transportation and refrigeration, creating a large carbon footprint.**

10. “Climate change and extreme weather events are expected to increasingly disrupt our Nation’s energy and transportation systems, threatening more frequent and longer-lasting power outages, fuel shortages, and service disruptions, with cascading impacts on other critical sectors. Infrastructure currently designed for historical climate conditions is more vulnerable to future weather extremes and climate change. The continued increase in the frequency and extent of high-tide flooding due to sea level rise threatens America’s trillion-dollar coastal property market and public infrastructure, with cascading impacts to the larger economy. In Alaska, rising temperatures and erosion are causing damage to buildings and coastal infrastructure that will be costly to repair or replace, particularly in rural areas; these impacts are expected to grow without adaptation. Expected increases in the severity and frequency of heavy precipitation events will affect inland infrastructure in every region, including access to roads, the viability of bridges, and the safety of pipelines. Flooding from heavy rainfall, storm surge, and rising high tides is expected to compound existing issues with aging infrastructure in the Northeast. Increased drought risk will threaten oil and gas drilling and refining, as well as electricity generation from power plants that rely on surface water for cooling. Forward-looking infrastructure design, planning, and operational measures and standards can reduce exposure and vulnerability to the impacts of climate change and reduce energy use while providing additional near-term benefits, including reductions in greenhouse gas emissions.”

Recommendation:

- **State resources, with the assistance of private industry, should be directed to hardening all aspects of our infrastructure: Roads, water, power generation and transmission, communications, health care, law enforcement, fire control, education, etc.**

- **Individual households should prepare for extended power outages by investing in low-power methods for food storage, heating, cooling, communication, and water pumping, as well as grid-connected back-up power supplies (which implies stepping up the transition to *net metering*).**

- **Power companies, directed by the PUC, should improve responses to outages by (a) investing in more emergency response resources to be kept in stand-by, and (b) improving our cooperative agreements with neighboring regions for mutual aid in the event of disasters.**

11. "Rising water temperatures, ocean acidification, retreating arctic sea ice, sea level rise, high-tide flooding, coastal erosion, higher storm surge, and heavier precipitation events threaten our oceans and coasts. These effects are projected to continue, putting ocean and marine species at risk, decreasing the productivity of certain fisheries, and threatening communities that rely on marine ecosystems for livelihoods and recreation, with particular impacts on fishing communities in Hawaiʻi and the U.S.-Affiliated Pacific Islands, the U.S. Caribbean, and the Gulf of Mexico. Lasting damage to coastal property and infrastructure driven by sea level rise and storm surge is expected to lead to financial losses for individuals, businesses, and communities, with the Atlantic and Gulf Coasts facing above-average risks. Impacts on coastal energy and transportation infrastructure driven by sea level rise and storm surge have the potential for cascading costs and disruptions across the country. Even if significant emissions reductions occur, many of the effects from sea level rise over this century—and particularly through mid-century—are already locked in due to historical emissions, and many communities are already dealing with the consequences. Actions to plan for and adapt to more frequent, widespread, and severe coastal flooding, such as shoreline protection and conservation of coastal ecosystems, would decrease direct losses and cascading impacts on other sectors and parts of the country. More than half of the damages to coastal property are estimated to be avoidable through well-timed adaptation measures. Substantial and sustained reductions in global greenhouse gas emissions would also significantly reduce projected risks to fisheries and communities that rely on them."

- **See comments in response to all previous points.**