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Climate Change and Integral Ecology

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Introduction

". . . the fragmentation of knowledge and the isolation of bits of information can actually become a form of ignorance, unless they are integrated into a broader vision of reality."

– *Pope Francis,* Laudato Si' (#138)

Everyday human activities—primarily burning fossil fuels—cause global warming by putting excess carbon dioxide and other greenhouse gases into the atmosphere. These gases trap heat and cause our planet to become gradually warmer. This simple picture is exacerbated by various feedback loops that accelerate the pace of warming. The Arctic, in particular, is warming twice as fast as the rest of the planet because bare ground and water exposed by melting ice absorb more heat from the Sun than does highly reflective white ice. Climate—that is, long-term weather patterns—is changing in response to global warming, bringing consequences such as changing weather patterns, sea level rise, severe storms, severe floods and droughts, spreading diseases, and disrupted ecosystems. Climate change is not the sole cause of such disasters; rather, it is the added impetus on top of a multiplicity of interrelated causes that makes things more devastating than they would be otherwise.

Pope Francis, in his landmark encyclical *Laudato Si',* promotes the concept of "integral ecology" in the context of the interplay between climate change and human behavior.[1] In commenting upon *Laudato Si',* Eoin O'Neill noted that Pope Francis "draws upon scientific research, although few lay-scholar texts are cited."[2] This seeming lack of citations is a result of the publication format of the encyclical, and it does an unfortunate disservice to the scholarly background that went into preparing the encyclical. As Bishop Marcelo Sánchez Sorondo has made clear, *Laudato Si'* is based in part upon findings from a joint workshop of the Pontifical Academies of Sciences and of Social Sciences, which came to the conclusion that "the resolution of major environmental problems facing society requires a fundamental

[1]Pope Francis, *Laudato Si': Care for Our Common Home* (Vatican City, VA: Libreria Editrice Vaticana, 24 May 2015), accessed 17 June 2015, http://w2.vatican.va/content/francesco/en/encyclicals/documents/papafrancesco_20150524_enciclica-laudato-si.html.

[2]Eoin O'Neill, "The Pope and the Environment: Towards an Integral Ecology?," *Environmental Politics* 25, no. 4 (2016): 749-754.

reorientation in our behavior and attitude toward nature and toward each other."[3] This is an emphatic foreshadowing of the major premise of *Laudato Si'*, and it is based upon the many detailed papers—each with copious references—published in the proceedings of the joint workshop.[4]

It is true, however, that much of the detailed scientific understanding of climate change has not been made readily accessible to scholars in fields outside of the sciences. In this paper, I hope to correct that omission by examining climate change in the context of integral ecology; that is to say, with careful attention to the many interrelationships between human activities and the various parts of the Earth's climatic systems. In particular, I will examine (1) how everyday human activities interact with various Earth systems to drive global warming and cause climate change, (2) how climate change in turn drives feedback loops and perturbs natural systems in ways that lead to accelerated warming and a myriad of disastrous consequences for human lives and livelihoods, and (3) how mitigating climate change requires blending technological solutions with significant changes in personal and societal attitudes. In short, human activities cause climate change, climate change causes human disasters, and changes in human attitudes are necessary in order to mitigate climate change. Climate change and integral ecology are intimately related.

Global Warming

The underlying driver of climate change is global warming which, within the scientific community, has been understood since the 19th century. In the 1820's physicist Joseph Fourier described a way in which the Earth's atmosphere might be trapping heat from the sun: visible light from the Sun penetrates through the atmosphere and heats the Earth's surface, but that same atmosphere blocks invisible heat rays (what we now call infrared radiation) from escaping back into space.[5] This was a very astute and accurate description of what we now call the greenhouse effect, in analogy to the way that the glass roof and walls of a greenhouse admit visible sunlight but prevent heat from escaping.

In 1859, physicist John Tyndall conducted experiments that validated the underlying physical principles of the atmospheric greenhouse effect. Through laboratory experiments, he showed that several of the gases in the Earth's atmosphere block the passage of infrared radiation; that is to say, they trap invisible heat waves. Finding that the gas with the greatest ability to trap heat waves is water vapor, he correctly concluded that the heat trapped by water vapor is what

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[3]Marcelo Sánchez Sorondo and Veerabhadran Ramanathan, "Pursuit of Integral Ecology," *Science* 352, no. 6287 (May 13, 2016): 747.

[4]*Sustainable Humanity Sustainable Nature Our Responsibility: Proceedings of the Joint Workshop 2-6 May 2014,* Partha S. Dasgupta, Veerabhadran Ramanathan, Marcelo Sánchez Sorondo, eds., (Vatican City: The Pontifical Academy of Sciences and The Pontifical Academy of Social Sciences, 2015).

[5]"The Carbon Dioxide Greenhouse Effect," in *The Discovery of Global Warming,* American Institute of Physics, (January 2017), accessed 10 June 2018 https://www.aip.org/history/climate/co2.htm.

prevents the Earth from permanently being locked in an Ice Age. He also showed that carbonic acid (what we now call carbon dioxide) and several other gases also trap heat, although not as effectively as does water vapor.[6]

Building on this work, the chemist and physicist Svante Arrhenius noted that the amounts of carbon dioxide in the atmosphere, changing over geological timescales, might regulate the ice ages. In 1896, he calculated that reducing the amount of carbon dioxide by half would lower the surface temperature of the earth by 4 to 5 degrees Celsius.[7] Geologist Arvid Högbom turned this idea around by pointing out that as human activities add more carbon dioxide to the atmosphere, the temperature of the Earth could *increase.* Indeed, he showed that the amounts of carbon dioxide being put into the atmosphere by burning coal at that time were comparable to the amounts by which carbon dioxide would have to be reduced to cause an ice age.[8] In response, Arrhenius did the reverse calculation and showed that doubling the amount of carbon dioxide in the atmosphere would increase the Earth's temperature by 5 to 6 degrees Celsius.[9] This stands as the first prediction of what we now call global warming.

At the time, Arrhenius and Högbom were not particularly concerned about global warming. Arrhenius estimated that at the rate at which coal was then being burned, it would take some three thousand years to double the amount of carbon dioxide in the atmosphere. Högbom showed that much of the added carbon dioxide would be absorbed by the oceans, thus reducing the amount of expected warming.[10] On both of these counts, they were much too conservative. We now use enough coal and other fossil fuels to double the amount of carbon dioxide in the atmosphere in this century,[11] and the rate at which we are generating carbon

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[6]Steve Graham, "John Tyndall (1820-1893)," *On the Shoulders of Giants,* NASA Earth Observatory, (8, October 1999), accessed 10 June 2018, http://earthobservatory.nasa.gov/Features/Tyndall/; "The Carbon Dioxide Greenhouse Effect," in *The Discovery of Global Warming,* American Institute of Physics, (January 2017), accessed 10 June 2018 https://www.aip.org/history/climate/co2.htm; John Tyndall, "On the Absorption and Radiation of Heat by Gases and Vapours," *Philosophical Magazine* 22, ser. 4 (1861): 169-94, 273-85; John Tyndall, "On Radiation Through the Earth's Atmosphere," *Philosophical Magazine* 25, ser. 4 (1863): 200-206.

[7]Svante Arrhenius, "On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground," *Philosophical Magazine* 41, ser. 5 (1896): 237-76.

[8]"The Carbon Dioxide Greenhouse Effect," in *The Discovery of Global Warming,* American Institute of Physics, (January 2017), accessed 10 June 2018 https://www.aip.org/history/climate/co2.htm.

[9]Svante Arrhenius, "On the Influence of Carbonic Acid in the Air Upon Temperature of the Earth," *Astronomical Society of the Pacific* 9, no. 54 (1897): 14.

[10]"The Carbon Dioxide Greenhouse Effect," in *The Discovery of Global Warming,* American Institute of Physics, (January 2017), accessed 10 June 2018 https://www.aip.org/history/climate/co2.htm.

[11]National Oceanic and Atmospheric Administration Earth System Research Laboratory, "Trends in Atmospheric Carbon Dioxide," Global Greenhouse Gas Reference Network, accessed 15 June 2018, http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html; Intergovernmental Panel on Climate Change, "Carbon Dioxide: Projected Emissions and Concentrations," (April 2014), accessed 8 June 2017, http://www.ipcc-data.org/observ/ddc_co2.html.

dioxide is too rapid for the ocean to absorb nearly as much as Högbom expected.[12] Nevertheless, the sum of this 19th century work clearly laid out the interrelated chain of events that cause global warming: (1) Water vapor in the atmosphere traps heat, creating a natural "greenhouse effect" that prevents the Earth from freezing; (2) Carbon dioxide in the atmosphere also traps heat; (3) Human activities—primarily burning coal and other fossil fuels—add additional carbon dioxide to the atmosphere and thus causes the Earth to get warmer.

The then nascent idea that human activities could at least in principle cause substantial changes in the Earth's climate set the stage for the more detailed understanding that we have today. The true extent of global warming can only be understood by looking at the complex interrelationships that are causing the warming to accelerate.

Feedback Loops

A myriad of interrelationships between various aspects of the Earth's systems create feedback loops that drive the warming to proceed much faster than would otherwise be predicted. These feedback mechanisms might be roughly classified as those that involve the responses of the polar regions, of the oceans, and of biota. This article will unfold the resultant feedback mechanisms.

The first feedback mechanism is "Arctic amplification." "Arctic amplification" is the term commonly used to describe processes that speed the rate of warming in the polar regions of the planet. The most basic process is that once ice begins to melt, it exposes bare ground or open water. The ground and water, being darker than the white ice, absorbs more heat from the Sun than the ice did. Thus, the ground and water warm more quickly than white ice, which causes the remaining ice to melt more quickly, which in turn exposes more bare ground and open water, which leads to even greater warming, and so forth. The warming is amplified.[13] A secondary amplification comes from black carbon, more commonly known as soot. Soot is produced from burning fossil fuels (e.g., the exhaust from a diesel engine or burning wood in cook fires). This soot is taken up into the air and deposited on ice fields in areas such as Greenland and the Himalayas. Once there, it darkens the ice, which causes the ice to absorb more heat from the Sun than it would absorb if it had remained white. That causes the ice to

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[12] "NOAA, Partners: Earth's Oceans and Ecosystems Still Absorbing About Half the Greenhouse Gases Emitted by People," National Oceanic and Atmospheric Administration, (August 1, 2012), https://research.noaa.gov/article/ArtMID/587/ArticleID/1412/NOAA-partners-Earth%E2%80%99s-oceans-and-ecosystems-still-absorbing-about-half-the-greenhouse-gases-emitted-by-people; A.P. Ballantyne, et. al., "Increase in Observed Net Carbon Dioxide Uptake by Land and Oceans During the Past 50 years," *Nature* 488, no. 7409 (2 August 2012): 70–72; C.L. Sabine, et. al., "The Oceanic Sink for Anthropogenic CO2," *Science* 305, no. 5682 (16 July 2004): 367-371.

[13] "Arctic Amplification," NASA Earth Observatory, (May 26, 2013), accessed 10 June 2017, http://earthobservatory.nasa.gov/IOTD/view.php?id=81214; M. Serreze and R. Barry "Processes and Impacts of Arctic Amplification," *Global and Planetary Change* 77, no. 1-2 (2011): 85-96.

melt, leading to further rounds of Arctic amplification. In addition, the melt water carries the soot into the ocean where it dissolves. Sunlight then releases it as carbon dioxide that enters the atmosphere where it causes additional greenhouse warming.[14]

The second feedback mechanism comes from the warming of the oceans. Högbom's simple calculations had predicted that the oceans would absorb more than 80 percent of the excess carbon dioxide produced by human activities. In fact, we are now generating carbon dioxide faster than the ocean can absorb it. As a result, the oceans are absorbing only about 50 percent of the excess carbon dioxide.[15] In addition, more than 90 percent of the excess heat trapped by human contributions to the greenhouse effect is taken up by the ocean.[16] On the one hand, these are good things: without the ocean absorbing the excess heat and carbon dioxide, global warming would be impossibly rapid and devastating. However, the ocean is only giving us a temporary reprieve. As the oceans gets warmer, they release carbon dioxide back into the atmosphere, thus enhancing the greenhouse effect. Warmer conditions also cause more water to evaporate, which puts more water vapor into the air and again enhances the greenhouse effect. In short, as global temperatures rise, the ocean will become less and less effective at slowing the pace of global warming.

The final feedback mechanism discussed in this article comes from the interactions of global warming on certain biological systems. Whether on land or in the ocean, most plant life undergoes daytime photosynthesis in which it takes in carbon dioxide and releases oxygen. At night the opposite process, respiration, occurs in which the plants take in oxygen and release carbon dioxide. Under normal conditions, photosynthesis is stronger than respiration so, on average, more carbon dioxide is taken in than is released. This is good because removing carbon dioxide from the atmosphere reduces greenhouse warming. However, there is growing evidence that, as temperatures rise, respiration cycles are getting stronger,[17] thus reducing the

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[14] University of Georgia, "Climate Change Likely to Increase Black Carbon Input to the Arctic Ocean," *ScienceDaily,* (30 November 2015), accessed 8 June 2017, http://www.sciencedaily.com/releases/2015/11/151130182247.htm; Aron Stubbins, et.al., "Utilizing Colored Dissolved Organic Matter to Derive Dissolved Black Carbon Export by Arctic Rivers," *Frontiers in Earth Science* 63, no.3 (2015).

[15] "NOAA, Partners: Earth's Oceans and Ecosystems Still Absorbing About Half the Greenhouse Gases Emitted by People," National Oceanic and Atmospheric Administration, (August 1, 2012), https://research.noaa.gov/article/ArtMID/587/ArticleID/1412/NOAA-partners-Earth%E2%80%99s-oceans-and-ecosystems-still-absorbing-about-half-the-greenhouse-gases-emitted-by-people; A.P. Ballantyne, et. al., "Increase in Observed Net Carbon Dioxide Uptake by Land and Oceans During the Past 50 years," *Nature* 488, no. 7409 (2 August 2012): 70–72; C.L. Sabine, et. al., "The Oceanic Sink for Anthropogenic CO2," *Science* 305, no. 5682 (16 July 2004): 367-371.

[16] "Climate Change: Ocean Heat Content," National Oceanic and Atmospheric Administration, (14 July 2015), accessed 10 June 2017, https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content; N.L. Bindoff, et. al. "Observations: Oceanic Climate Change and Sea Level," in *Climate Change 2007: The Physical Science Basis,* ed. S. Solomon, et. al. (Cambridge, UK and New York, NY: Cambridge University Press, 2007).

[17] Umeå University, "Increased CO2 Concentrations in the Atmosphere have Altered Photosynthesis of Plants Over the 20th Century," *ScienceDaily*, (2015), accessed 17 June 2017, http://www.sciencedaily.com/releases/

net amount of carbon dioxide being removed from the atmosphere and, consequently, increasing greenhouse warming on the planetary level. This also means that the amount of oxygen being produced is declining. This phenomenon leads to a sobering prediction involving phytoplankton in the ocean. Currently, phytoplankton produce about 70 percent of the Earth's oxygen. Mathematical projections predict that if the temperature rise exceeds approximately 6 degrees Celsius, the net production of oxygen by phytoplankton will cease altogether.[18] This clearly would be disastrous for higher order species (like us) that rely on having oxygen to breathe.

In fresh water lakes, temperatures are warming even faster than they are in the oceans and the atmosphere. One consequence is algal blooms, which rob the lakes of oxygen and lead to emissions of methane.[19] As a greenhouse gas, methane is approximately thirty times more effective at trapping heat than is carbon dioxide (over a 100-year period). Additional methane is produced in response to the warming in the Arctic. Melting tundra leaves pools of meltwater in which the formerly growing tundra vegetation is left to decompose, and decomposition underwater produces methane.[20] In the more temperate regions, microbial activity in soils thankfully does not produce methane; however, it still produces carbon dioxide. As temperatures warm, the rate of carbon dioxide release from soils is increasing.[21] The net impact

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2015/12/151207164333.htm; Ina Ehlers, et. al., "Detecting Long-term Metabolic Shifts using Isotopomers," *Proceedings of the National Academy of Sciences of the United States of America* 112, no. 51 (December 2015): 15585–15590; Princeton University, "Warm Nights Could Flood the Atmosphere with Carbon Under Climate Change," *Science Daily*, (December 7, 2015) accessed 17 June 2018, http://www.sciencedaily.com/releases/2015/12/151207165741.htm; William R. L. Anderegg, et. al., "Tropical Nighttime Warming as a Dominant Driver of Variability in the Terrestrial Carbon Sink," *Proceedings of the National Academy of Sciences of the United States of America* 12, no. 51 (December 2015): 15591–15596.

[18]University of Leicester, "Failing Phytoplankton, Failing Oxygen," *ScienceDaily*, (December 1, 2015), accessed 17 June 2017, http://www.sciencedaily.com/releases/2015/12/151201094120.htm; Yadigar Sekerci and Sergei Petrovskii, "Mathematical Modelling of Plankton–Oxygen Dynamics Under the Climate Change," *Bulletin of Mathematical Biology* 77, no. 12 (2015): 2325–2353.

[19]Washington State University, "Climate Change Rapidly Warming World's Lakes: More than Half World's Freshwater Supplies Measured," *ScienceDaily,* (16 December 2015) accessed 12 July 2018, http://www.sciencedaily.com/releases/2015/12/151216174555.htm; C.M. O'Reilly, et al., "Rapid and Highly Variable Warming of Lake Surface Waters Around the Globe," *Geophysical Research Letters* 42, no. 24 (2015): 10,773–10,781.

[20]University of Colorado at Boulder, "Ancient Permafrost Quickly Transforms to Carbon Dioxide Upon Thaw," *ScienceDaily,* (26 October 2015), accessed 12 June 2018, http://www.sciencedaily.com/releases/2015/10/151026171407.htm; Travis W. Drake, et. al. "Ancient Low–molecular-weight Organic Acids in Permafrost Fuel Rapid Carbon Dioxide Production Upon Thaw," *Proceedings of the National Academy of Science of the United States of America* 112, no. 45 (November 2015): 13946–13951; "Methane and Frozen Ground," *All About Frozen Ground,* National Snow and Ice Data Center, https://nsidc.org/cryosphere/frozenground/methane.html; Princeton University.

[21]"Dirty Pool: Soil's Large Carbon Stores Could be Freed by Increased CO_2, Plant Growth," *ScienceDaily*, (23 December 2014), accessed 12 June 2018, http://www.sciencedaily.com/releases/2014/12/141223114233.htm; Benjamin N. Sulman, et. al., "Microbe-driven Turnover Offsets Mineral-mediated Storage of Soil Carbon Under Elevated CO_2," *Nature Climate Change* 4, no. 12 (10 November 2014): 1099.

of these and other biological activities invariably feeds back into the atmosphere in ways that accelerate the pace of global warming.

The lesson here is the various Earth systems of air, water, and biota cannot be considered in isolation. It is the interrelationships between them that cause the pace of warming to accelerate. Underlying all this is another interrelationship: the fact that human activities that put excess carbon dioxide and other greenhouse gases into the atmosphere drive the warming in the first place.

Human Activities

Virtually every aspect of everyday life in the developed world contributes to the atmospheric carbon budget. The largest source of carbon dioxide is the burning of fossil fuels—coal, natural gas, and petroleum products—for electricity, heating, industrial processes, and transportation. Other notable sources of carbon dioxide include agriculture (including through powering farm equipment and manufacturing industrial fertilizers), the burning of forests, and making concrete.[22] Of these fossil fuels, coal is the largest source of carbon emissions. Oil is slightly less of a greenhouse gas source, releasing roughly 25 percent less carbon dioxide to produce a given amount of energy than does coal.[23] Natural gas is often touted as a "clean" alternative to coal, as in the combustion process it releases only half as much carbon dioxide to produce a given amount of energy than does coal. However, leakage of natural gas must be taken into account. Natural gas is primarily methane, so any leaks put methane directly into the atmosphere. If, over a 20-year timeframe, leakages of natural gas exceed 3.2 percent of the amount of gas used, then the lifecycle greenhouse gas emissions for electricity generation from natural gas exceed that of coal. Currently available data from monitoring natural gas leakages, although sparse, indicates that leakages in the range of 1 to 9 percent may be routine. This makes natural gas potentially as large or larger a source of greenhouse gas emissions than is coal.[24]

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[22]United States Environmental Protection Agency, "Overview of Greenhouse Gases," *Greenhouse Gas Emissions,* accessed 12 June 2018, http://www3.epa.gov/climatechange/ghgemissions/gases.html; National Research Council, *Advancing the Science of Climate Change* (Washington, DC: The National Academies Press, 2010); United States Department of State, *Fourth Climate Action Report to the UN Framework Convention on Climate Change: Projected Greenhouse Gas Emissions* (Washington, DC: US Department of State, 2007); United States Environmental Protection Agency, "Global Greenhouse Gas Emissions Data" *Greenhouse Gas Emissions,* http://www3.epa.gov/climatechange/ghgemissions/global.html; Intergovernmental Panel on Climate Change, "Summary for Policymakers," in *Climate Change 2014: Mitigation of Climate Change*, ed. O. Edenhofer, et. al. (Cambridge, UK and New York, NY: Cambridge University Press, 2014).

[23]United States Energy Information Administration, "How Much Carbon Dioxide is Produced when Different Fuels are Burned?" (2017), accessed 8 June 2017, https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11.

[24]R. A. Alvarez, et.al., "Greater Focus Needed on Methane Leakage from Natural Gas Infrastructure," *Proceedings of the National Academy of Science of the United States of America* 109, no. 17 (April 2012): 6435–6440); J. Tollefson, "Methane Leaks Erode Green Credentials of Natural Gas," *Nature* 493, no. 7430 (January 2013): 12; L.M., Cathles, et.al., "A Commentary on 'The Greenhouse Gas Footprint of Natural Gas in Shale Formations' by R.W. Howarth, R. Santoro, and A. Ingraffea," *Climatic Change* 113, no. 2 (July 2012): 525–535; R.W. Howarth, et. al.,

The concentration of carbon dioxide in our atmosphere is rising rapidly. Before the industrial age, the carbon dioxide concentration varied with the Ice Ages between about 200 and 300 parts per million (ppm).[25] Since the industrial age began, human activities have caused the carbon dioxide concentration to rise to over 400 ppm—a 50 percent increase.[26] If our current pace of carbon emissions continues unabated, by mid-century the concentration will exceed 600 ppm.[27] We will have achieved in less than two centuries the doubling of carbon dioxide that Arrhenius thought would take thousands of years to reach.

Climate Change

Climate—that is, long-term weather patterns—is changing in response to global warming. The consequences include changing weather patterns, sea levels rising, increasingly severe storms, floods, droughts, spreading diseases, and disrupted ecosystems. As we analyze these phenomena, it is important to avoid asking questions that seek single causes (e.g., does global warming cause severe storms?). These are complex phenomena that are driven by a multiplicity of interrelated causes, so it is not possible or useful to attempt to isolate single causes. Instead, the more salient question is to ask what is the impact of global warming on the phenomena being studied (e.g., what impact does global warming have on the severity of storms?). This approach is more likely to reveal the role of global warming in driving climate change, and it is more consistent with the themes of the interrelationships that define integral ecology.

Weather patterns are clearly changing. The most basic effect is that it really is getting warmer. Including projections for 2017, 17 of the 18 warmest years on record (since global weather stations were established) have occurred since 2001.[28] In 2015, the total increase in global average surface temperature since the pre-industrial era passed the one degree Celsius mark,[29]

"Methane Emissions from Natural Gas Systems," Background paper prepared for the National Climate Assessment, reference number 2011-0003 (2012); G. Petron, et.al., "Hydrocarbon Emissions Characterization in the Colorado Front Range: A Pilot Study," *J. Geophys. Res. Atmospheres* 117, no. (February 2012); T. Skone, "Role of Alternative Energy Sources: Natural Gas Power Technology Assessment," National Energy Technology Laboratory, DOE/NETL-2011/1536 (2012).

[25]Luthi Dieter, et. al., "High-resolution carbon dioxide concentration record 650,000-800,000 years before present," *Nature* 453, no. 7193 (2008): 379-82.

[26]National Oceanic and Atmospheric Administration Earth System Research Laboratory, "Trends in Atmospheric Carbon Dioxide," Global Greenhouse Gas Reference Network, accessed 15 June 2018, http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html.

[27]Intergovernmental Panel on Climate Change, "Carbon Dioxide: Projected Emissions and Concentrations," (April 2014), accessed 8 June 2017, http://www.ipcc-data.org/observ/ddc_co2.html.

[28]NASA Global Climate Change, "Global Temperature," (2018), https://climate.nasa.gov/vital-signs/global-temperature; National Centers for Environmental Information, "NOAA Global Climate Report", (2017) , accessed 1 July 2018, https://www.ncdc.noaa.gov/sotc/global/201711.

[29]"NASA, NOAA Analyses Reveal Record-Shattering Global Warm Temperatures in 2015," NASA Press Release 16-

leading to a 2300 percent increase in global heat-related deaths in the last decade as compared to previous decades.[30]

Further consequences occur because the warming is not uniform over the globe. As seen above, Arctic amplification is causing the polar regions to warm at a rate that is twice as fast as that of the rest of the planet. This reduces the temperature difference between the poles and the equator which, in turn, reduces the amount of energy available to drive the jet stream. Consequently, the jet stream is weakening. This, coupled with significant changes in the heat balance of the oceans, is disrupting the normal west-to-east flow of weather patterns. The jet stream now commonly becomes very serpentine, at times allowing severely cold air from the Arctic to flow south into the Midwestern and Eastern United States and allowing warm air from the tropics to flow north into Alaska and Western Canada.[31]

The general warming, greatly bolstered by Arctic amplification and by the deposition of soot on glaciers, is causing alarmingly rapid ice melt. As the meltwater from landlocked ice in Antarctica, Greenland, and other areas of the world flow into the ocean, the sea level is rising. This is in addition to the sea level rise that occurs from expansion of the water in response to warming sea temperatures. The average sea level has already risen about 0.20 meters since 1880, and the United Nations Intergovernmental Panel on Climate Change predicts a rise of between 0.26 and 0.82 meters by the end of this century.[32] However, more recent comprehensive studies predict a sea level rise of as much as 5 meters by the end of this century. This much higher prediction comes from including in the calculations a wide range of new data and analyses including paleoclimatic data, the effects of changes in ocean surface temperature and salinity due to the injection of meltwater, changes in deep ocean energetics and currents, and new data on the topography under the ice sheets. [33] A sea level rise of 5

008, (20 January 2016), http://www.nasa.gov/press-release/nasa-noaa-analyses-reveal-record-shattering-global-warm-temperatures-in-2015.

[30]University of Hawaii at Manoa “Brace Yourself for Coming Heatwaves, There are at Least 27 Ways They Can Kill You,” *ScienceDaily*, (9 November 2017), http://www.sciencedaily.com/releases/2017/11/171109093248.htm; Camilo Mora, e. al., “Twenty-Seven Ways a Heat Wave Can Kill You: Deadly Heat in the Era of Climate Change,” *Circulation: Cardiovascular Quality and Outcomes* 10, no. 11, (9 November 2017).

[31]Eli Kintisch, **“**Into the Maelstrom,” *Science*, no. 6181 (18 April 2014): 250-253; Carolyn Gramling, “Arctic Impact,” *Science*, no. 347 (2015): 818-821; University of Sheffield, “Extreme Cold Winters Fueled by Jet Stream and Climate Change.” *Science Daily,* (26 October 2016), accessed 7 June 2018, http://www.sciencedaily.com/releases/2016/10/161026081551.htm; James E. Overland, et. al., “Nonlinear Response of Mid-latitude Weather to the Changing Arctic,” *Nature Climate Change* 6 (26 October 2016): 992-999; University of Lincoln, “Is Arctic Warming Influencing the UK's Extreme Weather?” *ScienceDaily*, (4 January 2018), accessed 5 March 2018, http://www.sciencedaily.com/releases/2018/01/180104120311.htm; Edward Hanna, Richard J. Hall, James E. Overland, “Can Arctic Warming Influence UK Extreme Weather?” *Weather* 72, no. 11, (November 2017): 346.

[32]Intergovernmental Panel on Climate Change, *Climate Change 2014: Synthesis Report,* ed. R.K. Pachauri and L.A. Meyer (Geneva, Switzerland, 2014).

[33]Sasha Wright, “All Eyes on the Oceans—James Hansen and Sea Level Rise,” Physics.org, (1 September 2015), accessed 2 July 2018, http://phys.org/news/2015-09-eyes-oceansjames-hansen-sea.html; J. Hansen, et.al. “Ice

meters would obviously be devastating to coastal communities around the globe,[34] but damaging impacts are happening already. Saltwater intrusion into fresh water aquifers and coastal destruction from higher storm surges are being felt along coastlines in the United States[35] and, especially, on highly vulnerable islands such as Kiribati[36] and the Solomon Islands.[37]

Global warming does not cause storms, however, it does increase the severity of storms. The energy driving a tropical storm or hurricane comes from the sea surface: the warmer the sea surface, the stronger the storm. As sea surface temperatures increase, what would have been ordinary storms become superstorms. Increased evaporation and the fact that warm air holds more moisture than cool air does means that there is more moisture available for storms to collect and drop as torrential rainfall. When this occurs over land, catastrophic flooding results. In general, wet regions are getting wetter and experiencing catastrophic (100-year or greater) flooding. Dry regions, on the other hand, are getting drier and thus becoming more susceptible to extreme droughts. Lightning strikes are becoming more frequent, which, coupled with conditions caused by drought, leads to more incidences of uncontrollable wildfires. [38]

Climate change also affects public health in a myriad of interrelated ways. Excessive heat alone

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Melt, Sea Level Rise and Superstorms," *Atmospheric Chemistry and Physics Discussion* 15 (2015): 20059-20179.

[34]Intergovernmental Panel on Climate Change, "Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects," *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. C. Field, et. al. (Cambridge, UK, and New York, NY: Cambridge University Press, 2014).

[35]C. Tebaldi, B.H. Strauss, and C.E. Zervas, "Modelling Sea Level Rise Impacts on Storm Surges Along US Coasts," *Environmental Research Letters* 7, no. 1 (March 2012): 014032; R.A. Pielke Jr., et. al., "Normalized Hurricane Damage in the United States: 1900-2005," *Natural Hazards Review* 9 (February 2008): 29-42.

[36]Office of the President, Republic of Kiribati, *Kiribati Climate Change*, http://www.climate.gov.ki/category/effects.

[37]Simon Albert, et. al., "Interactions Between Sea-level Rise and Wave Exposure on Reef Island Dynamics in the Solomon Islands," *Environmental Research Letters*11, no. 5 (6 May 2016): 054011.

[38]Adam Volland, "In a Warming World, Storms may Be Fewer but Stronger," *NASA Earth Observatory* (5 March 2013), accessed 8 June 2018, http://earthobservatory.nasa.gov/Features/ClimateStorms; K. Emanuel, "Factors Affecting Tropical Cyclone Power Dissipation," *Journal of Climate* 20 (2007): 5497-5509; Anthony Del Genio, "Will a Warmer World Be Stormier?" *Earthzine* (2011), accessed 12 July 2018, http://earthzine.org/2011/04/16/will-a-warmer-world-be-stormier; University of Toronto, "Global Warming Won't Mean More Storms," *ScienceDaily* (29 January 2015), accessed 12 June 2018, http://www.sciencedaily.com/releases/2015/01/150129143040.htm; Seung-Ki Min, Xuebin Zhang, Francis W. Zwiers, and Gabriele C. Hegerl, "Human Contribution to More-intense Precipitation Extremes," *Nature* 470, no. 7334 (2011): 378–381; Yukiko Hirabayashi, et. al "Global Flood Risk Under Climate Change," *Nature Climate Change* 3 (2013): 816–821.; O. Pechony and D. Shindell, "Driving Forces of Global Wildfires Over the Past Millennium and the Forthcoming Century," *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 45 (9 November 2010): 19167-19170; R. Seager, et al., "Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America," *Science* 316, no. 5828 (27 May 2007): 1181-1184.

causes premature deaths, as was witnessed during the European heat wave of 2003 that caused an estimated 30,000 to 70,000 deaths. Additional deaths can occur from malnutrition (resulting, for example, from crop failures) and from insect- and water-borne diseases such as malaria and cholera. The World Health Organization projects approximately 250,000 additional deaths from such causes over the period from 2030 to 2050. In addition, deteriorating living conditions and civil conflicts driven by climate change are projected to lead to some 200 million climate migrants worldwide by 2050, the majority of whom will be children and the poor.[39]

Even greater impacts of climate change may come from disruptions of oceanic ecosystems. As the oceans absorb excess heat and carbon dioxide they become warmer and more acidic. Under these conditions, coral and shellfish are declining precipitously because they have difficulties forming shells and skeletons in a warmer and more acidic ocean.[40] More sobering are laboratory experiments predicting that Trichodesmium, a type of cyanobacteria, may undergo a sudden catastrophic die-off as ocean temperatures rise.[41] Trichodesmium is one of the few key species that fix nitrogen and thus form a substantial part of the base of the oceanic food chain.[42]

Climate change, then, is a result of a multitude of interactions between human beings, the sun and earth's atmospheres, oceans, land masses, and biota. The overused question, "do human activities cause climate change?" is ill-phrased. It over-simplifies the complexity of the Earth system. The more salient questions are: Can we adopt an integral ecology point of view when it

[39] U.S. Global Change Research Program, "USGCRP, 2016: *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment,"* A. Crimmins, et. al., eds., (2016) https://health2016.globalchange.gov; World Health Organization, "Climate Change and Health," http://www.who.int/mediacentre/factsheets/fs266/en; Centers for Disease Control and Prevention, "Climate Effects on Health," http://www.cdc.gov/climateandhealth/effects; Princeton University, "As Global Temperatures Rise, Children Must be Central Climate Change Debates," *ScienceDaily* (4 May 2016), accessed 12 June 2018, https://www.sciencedaily.com/releases/2016/05/160504121330.htm.

[40] R.A. Feely, et al., "Impact of Anthropogenic CO_2 on the $CaCO_3$ System in the Oceans," *Science* 305, no. 5682 (16 July 2004): 362-366; James C. Orr, et al., "Anthropogenic Ocean Acidification Over the Twenty-first Century and its Impact on Calcifying Organisms," *Nature* 437, no. 7059 (2005): 681-686; University of Hawaii at Manoa, "Rapidly Acidifying Waters Pose Major Threat for Southern Ocean Ecosystem," *ScienceDaily* (2015), accessed 12 June 2018, http://www.sciencedaily.com/releases/2015/11/151102125452.htm; Claudine Hauri, Tobias Friedrich, and Axel Timmermann, "Abrupt Onset and Prolongation of Aragonite Undersaturation Events in the Southern Ocean," *Nature Climate Change* 6 (2015): 172–176.

[41] University of Southern California, "Climate Change will Irreversibly Force Key Ocean Bacteria into Overdrive," *ScienceDaily* (1 September 2015), accessed 12 June 2018, http://www.sciencedaily.com/releases/2015/09/150901140204.htm; David A. Hutchins, et. al, "Irreversibly Increased Nitrogen Fixation in Trichodesmium Experimentally Adapted to Elevated Carbon Dioxide," *Nature Communications* 6 (1 September, 2015): 8155.

[42] Richard A. Feely, Christopher L. Sabine, and Victoria J. Fabry, "Carbon Dioxide and Our Ocean Legacy," NOAA Pacific Marine Environmental Laboratory (April 2006), http://www.pmel.noaa.gov/pubs/PDF/feel2899/feel2899.pdf.

comes to climate change? Can we take to heart the idea that our everyday actions trigger an intertwined set of events that harm Earth and, even more importantly, harm the lives of people all over the globe? Can we offer an act of contrition; that is, take responsibility for the consequences of our actions? And, most important of all, can we as an act of penance take concrete steps to prevent our future actions from contributing to further harm? That is, can we reduce our emissions of greenhouse gases?

Mitigating Climate Change

To slow the pace of climate change, we must substantially reduce our emissions of greenhouse gases. We have the technological ability to do so; the U.S. Department of Energy's National Renewable Energy Laboratory has shown that the United States could provide 80 percent of its electricity needs from renewable sources by 2050 using only technologies that are currently commercially available.[43] But there are sociological, political, and infrastructure barriers to doing so. Basically, people have to want to make the change, the political system has to encourage it, and improvements in electricity storage and delivery have to be made. In short, an integral ecological approach to solutions is necessary.

Progress begins at home, and most people are aware of the simple things that we can and should do to reduce our contributions to global warming. We conserve energy by changing our light bulbs to LED's and adjusting our thermostats. We reduce the energy burden of manufacturing by recycling our cans and bottles and, slowly but surely, we convert from using disposable water bottles to using refillable ones. We take shorter showers, reduce the amount we drive, and think about getting a higher mileage car. These acts are indeed helpful, but they are not enough.[44]

If we are to make more substantial progress, we have to think more comprehensively about our everyday actions. For example, we might be tempted to actually buy an electric car. But, in so doing, we have to think about how we will acquire the electricity to charge it up. If that electricity comes from our own solar panels or from a local electric utility that uses renewable energy sources, then driving the electric car will clearly reduce our carbon emissions. But, if the

[43] M.M. Hand, et. al. (eds.), *Renewable Electricity Futures Study* (Golden, CO: National Renewable Energy Laboratory, 2012).

[44] These everyday actions are not insignificant. For example, if, over the next 3 decades, everyone recycled their household waste it would reduce atmospheric carbon dioxide by 2.77 GT CO2-eq (gigatons of atmospheric carbon dioxide or its equivalent). Changing all household lighting to LEDs would entail a reduction 7.81 GT CO2-eq. Installing smart thermostats in all households generate a reduction of 2.62 GT CO2-eq. These are significant reductions, although they are still small compared to the 1,00 to 2,000 GT CO2 (even without including other greenhouse gases) that we are expected to add to the atmosphere from 2020 to 2050. For further information see Paul Hawkins (ed.), Drawdown (New York, NY: Penguin Books, 2017) or the online summary at https://www.drawdown.org/solutions, and N. Bowerman, et. al., "Cumulative carbon emissions, emissions floors and short-term rates of warming: implications for policy," *Phil. Trans. R. Soc. A* (2011) 369, 45–66 doi:10.1098/rsta.2010.0288.

electricity comes from a coal-fired power plant, then driving that electric car may actually increase our carbon emissions over what they would be from a high mileage gasoline-powered car.[45]

We might think about installing solar panels on our house or business but be dissuaded by the cost of doing so. Here, we have to think long term. If we can find a way to cover the initial cost, as for example through a loan, then we can recover those costs through the savings we gain from having a reduced or zero electricity bill, typically in as little as 7 years.[46] After that, we save money each month from the electricity savings. In the long run, installing solar panels is an investment with a guaranteed lifetime payoff. We can make the payoff even higher by taking additional steps to reduce our in-home electricity use and by using any excess electricity we generate to charge an electric car or two. Now we have not only reduced or eliminated our electric bills, but we have also eliminated our gasoline bills. In this scenario, as in most carbon reducing scenarios, we actually save money in the long term.

Is it possible to adopt a totally zero carbon emissions lifestyle without reducing our so-called standard of living? Demonstration projects in the U.S.[47] and existing buildings in Europe[48] show that it is entirely possible. It requires taking an integrated look at all of the energy-related systems in the house—a mini integral ecology, if you will. In order to prevent heat loss, the house must be entirely airtight and outfitted with extremely high-efficiency insulation. Fresh outside air is brought in through a mechanical ventilation system that exchanges heat with outgoing air so that no heat is lost through the ventilation system. Large south-facing windows provide passive heating from sunlight in the winter, and, with proper shading, prevent direct sunlight from entering in the summer. Solar panels, supplemented by heat pump systems, provide the energy for all household needs; no exotic or costly technology is involved. In fact, the cost of such zero-carbon construction can be as low as only two percent more than standard construction would have cost. This marginal extra cost can be recovered—and extra savings generated—through energy savings over the lifetime of the house. Unfortunately, such zero-carbon construction is exceedingly rare in the United States. Many of the necessary components are not available in the U.S. (they have to be imported from Europe), and the vast majority of builders do not or will not engage in zero-carbon construction.

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[45]Union of Concerned Scientists, “Cleaner Cars from Cradle to Grave,” (2015) accessed 12 June 2018, https://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions#.Wk_nPVQ-dp8.

[46]Energy Sage, “How to calculate solar panel payback period (ROI), accessed February 26, 2019, https://news.energysage.com/understanding-your-solar-panel-payback-period/.

[47]Nora Knox, “Green Building Costs and Savings,” *US Green Building Council* (25 March 2015), http://www.usgbc.org/articles/green-building-costs-and-savings; U.S. Department of Energy, “To Create a Zero Energy Building…,” https://energy.gov/eere/buildings/zero-energy-buildings; Jonathan Lane, *Energy-efficient Housing Design: A CombinedAapproach*. (New York: Van Nostrand Reinhold, 1986); Zero Energy, “Home Plans,” http://zero-energyplans.com.

[48]HM Government, *Strategy for Sustainable Construction* (Great Britain: Department for Business Enterprise & Regulatory Reform, 2008).

In contrast, some other sectors of the business world are learning that engaging in sustainable business practices is good for business. For example, Siemens recently committed to spending $110 million on emissions reductions, with an expected return of $20 million to $30 million per year in energy cost savings—a return on investment time of only 4 or 5 years.[49] Microsoft has introduced an internal carbon tax which holds each business group financially accountable for the carbon emissions associated with their operations. This has resulted in an energy cost savings of over $10 million per year.[50] Statistically, companies that actively manage and plan for climate mitigation techniques secure an 18 percent higher return on investment than companies that do not. As an added bonus, publicizing sustainable business practices or selling sustainably-produced products attracts new customers and therefore generates more business.[51]

Further progress unavoidably requires government actions to cause major changes in consumer habits and business practices among all entities, not just the early adopters. However, to be effective, it is important for governments to take a comprehensive approach to such actions. For example:

- Measures taken to encourage consumers and businesses to purchase electric cars should be initiated in concert with measures taken to provide easy access to charging stations powered by renewable energy sources.
- Measures taken to encourage consumers and businesses to install solar panels should be initiated in concert with measures taken to simplify the process of connecting to the utility grid—or possibly with national support for establishing a smart grid that can easily handle significant numbers of small solar installations.
- Measures taken to encourage consumers and businesses to invest in zero-carbon homes and commercial buildings should be initiated in concert with programs to train consumers and builders in the "how-to" of zero-carbon construction, and with trade provisions to make it easier to acquire the necessary equipment from overseas.
- Programs to rebuild housing and businesses destroyed in fires, floods, or hurricanes should require safe and sustainable construction: moving if necessary to a safer

[49] Katie Fehrenbacher, "How Big Companies are Reducing Emissions—and Making Money," *Fortune* (28 September 2015), accessed 12 June 2018, http://fortune.com/2015/09/28/carbon-emissions-seimens-dell.

[50] Microsoft, "Addressing Our Carbon Footprint" and "Corporate Social Responsibility," https://www.microsoft.com/about/csr/environment/carbon and https://www.microsoft.com/about/csr/ transparencyhub/ citizenship-reporting.

[51] Dara O'Rourke and Abraham Ringer, "The Impact of Sustainability Information on Consumer Decision Making," *Journal of Industrial Ecology* 20, no. 4 (August 2016): 882-892; ClimateCare, "CDP Research," https://climatecare.org/carbon-reduction.

location and rebuilding as zero-carbon structures. This will help prevent disasters from repeating themselves.

- Municipalities, as well as states/provinces and nations, can make a formal commitment to reducing and/or eliminating greenhouse gas emissions on a rapid timescale, as has been done in Eugene, Oregon, and in several communities in Indiana in response to lobbying by youths in those communities.[52] This type of comprehensive action is in keeping with the most fundamental point of integral ecology*:* everything is interrelated. Solutions therefore must be interrelated as well.

The Cost of Delay

In December 2015, the nations of the world[53] reached an international agreement aimed at holding global warming to no more than 2 degrees Celsius above the pre-industrial average.[54] While the resultant *Paris Agreement* is a wonderful statement of international cooperation and progress, it is far too little and too slow to significantly stem the tide of climate change.

The 2-degree Celsius target is, in truth, a rather arbitrary number. We have already passed the 1 degree mark, and the impacts of climate change are already devastating. In the United States alone in 2017 estimated damages from hurricanes exceeded $200 billion and property damages from wildfires approached another $200 billion—and these monetary figures do not even begin to encompass the human tragedies involved.[55] Clearly the present 1 degree rise in temperature is already "too much;" and even 1.5 degrees is far too dangerous. Since the last ice age, global temperatures have never risen to more than 1.5 degrees Celsius above pre-industrial levels. Simple logic thus says that all species on Earth—including human beings—have evolved to expect temperatures within that 1.5-degree limit. Going beyond that limit pushes all life on

[52] Our Children's Trust, https://www.ourchildrenstrust.org; Youth Power Indiana, http://www.youthpowerindiana.com.

[53] All of the 197 nations have signed the Paris Agreement. Two nations failed to sign initially—Syria (because of war) and Nicaragua (because they thought the agreement was too weak)—but they both signed on later. One nation—the United States—has announced that it is leaving the agreement.

[54] United Nations Climate Change, *COP21,* https://unfccc.int/process/conferences/past-conferences/paris-climate-change-conference-november-2015/cop-21.

[55] CNN, "2017 Hurricanes Could Cost Over $200 billion," http://www.cnn.com/videos/cnnmoney/2017/09/26/cost-of-hurricanes.cnnmoney; National Geographic, "2017 Hurricane Season Was the Most Expensive in U.S. History," (2017), https://news.nationalgeographic.com/2017/11/2017-hurricane-season-most-expensive-us-history-spd; AccuWeather, "AccuWeather Predicts 2017 California Wildfire Season Cost to Rise to $180 billion," (2017), https://www.accuweather.com/en/weather-news/accuweather-predicts-2017-california-wildfire-season-cost-to-rise-to-180-billion/70003495.

Earth into a temperature regime that has never before been experienced.[56] Adopting arbitrary targets like the 2-degree limit give the false impression that 2 degrees is really acceptable when, in truth, it is not.

The importance of acting rapidly is highlighted in recent studies showing that every ten years of delay in implementing mitigation measures translates into an additional 0.5 degree rise in the ultimate peak temperature. In other words, if there is a ten-year delay in actually implementing the policies laid out in 2015, the actual temperature rise will be 2.5 degrees rather than the hoped for 2 degrees.[57] There is an even more serious hidden caveat in the climate accords signed at Paris. A significant portion of the reduction in carbon dioxide emissions is expected to come through carbon capture and sequestration. Very unfortunately, such technologies have yet to be developed on any large scale, and there is no confidence that they ever will be. The simple energetics of carbon capture imply that such technologies may be too expensive and too energy-intensive to ever be widely deployed. Without those technologies, the peak warming will be 4 degrees rather than 2 degrees—a level that will be unspeakably devastating.[58]

Finally, it is important to understand that, although we can slow down global warming, we cannot actually stop it. The greenhouse gases that we have already put in the atmosphere are there to stay for thousands of years or more.[59] Thus, even if we stopped all greenhouse gas emissions today, the warming will continue until it reaches a peak of roughly 1.5 degrees Celsius several decades from now.[60] For this reason, policies that seek to gradually reduce the amounts of greenhouse gases emitted to merely some arbitrary "safe" level are deceiving: there is no "safe" level.

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[56] Elizabeth A. Fulton, "A Stitch in Time Saves Nine . . . Billion," *Science* 354, no. 6319 (December 2016): 1530-1531; Joel Guiot and Wolfgang Cramer, "Climate Change: The 2015 Paris Agreement Thresholds and Mediterranean Basin Ecosystems," *Science* 354, no. 6311 (October 2016): 465-468; Will Steffen, et. al., "Planetary Boundaries: Guiding Human Development on a Changing Planet," *Science* 347, no. 6223 (February 2015): 736.

[57] University of Bern, "Timely Action Needed to Meet Climate Targets," *ScienceDaily* (21 January 2016), http://www.sciencedaily.com/releases/2016/01/160121093151.htm; Patrik L Pfister and Thomas F Stocker, "Earth System Commitments Due to Delayed Mitigation," *Environmental Research Letters* 11, no. 1 (January 2016): 014010.

[58] Kevin Anderson and Glen Peters, "The Trouble with Negative Emissions," *Science* 354, no. 6309 (October 2016):182-183.

[59] David Archer, et. al. "Atmospheric Lifetime of Fossil Fuel Carbon Dioxide," *Annual Review of Earth and Planetary Sciences* 37 (May 2009): 117-134.

[60] NASA Earth Observatory, "Q &A, July 2, 2007," (2007), https://earthobservatory.nasa.gov/blogs/climateqa/would-gw-stop-with-greenhouse-gases; J. Hansen, et. al., "Dangerous Human-made Interference with Climate: A GISS ModelE Study," *Atmospheric Chemistry and Physics* 7, (May 2007): 2287-2312; J. Hansen, et. al., "Earth's Energy Imbalance: Confirmation and Implications," *Science* 308 (June 2005): 1431-1435.

Towards a Livable Future

Worldwide many governments (at all levels), businesses, and consumers are taking steps to reduce their greenhouse gas emissions on what is perceived as a "reasonable" time scale—typically a commitment to reduce greenhouse gas emissions by a certain percentage over a period of time measured in decades. While this is very encouraging, it is much too slow. It guarantees that the global warming will exceed 1.5 degrees Celsius, putting the planet in a regime that current life forms have never before experienced. We have to instead make a global commitment to reducing greenhouse gas emissions to zero on the most rapid time scale possible, and we can do that in ways that improve our lifestyles and provide economic benefits.

The key is to make integral ecology a way of thinking for people, churches, and governments everywhere. Can we all take to heart the idea that our seemingly innocent everyday actions lead to warming our climate and consequently drive the major disasters that our now becoming commonplace? Can we learn to think of greenhouse gas reduction measures as investments rather than burdens—investments that will pay off in long-term savings, economic growth, and healthier lifestyles? Can we learn to think comprehensively about solutions, so that real progress can be made? All of the necessary tools are at our disposal; we just have to make a firm commitment to using them.