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Applying Life Insurance Principles to Coastal Property Insurance to Incentivize Adaptation to Climate Change

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APPLYING LIFE INSURANCE PRINCIPLES TO COASTAL PROPERTY INSURANCE TO INCENTIVIZE ADAPTATION TO CLIMATE CHANGE

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Abstract: Current levels of greenhouse gases will result in significant sea level rise in the future, irrespective of the success of any future mitigation efforts. Paleoclimate and geologic data from past periods of rising sea level show that low lying areas, especially river deltas which are home to half a billion people, will be inundated. The best way to represent this risk through insurance is to apply the human-life insurance model to coastal property insurance. Human-life insurance is based on the assumption that every insured will die. Because the risk of death increases with age, the cost of insurance increases with age. Property-life insurance assumes that coastal properties will be lost at an unknown future date determined by the rate of sea level rise and patterns of catastrophic storms. As with human-life insurance, premiums would increase on a regular schedule through time. This predictable premium increase would create a powerful risk signal to incentivize adaptation.

INTRODUCTION

The earth is warming, the oceans are getting more acidic, and the climate is becoming more extreme.[1] The terms of the Paris Agreement on climate change aspire to limit global warming to 1.5 degrees Celsius, but the pledges in the agreement will only limit warming to 3.5 degrees Celsius.[2] Even if mitigation efforts limit the increase in temperature to the optimistic

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[1] Phil Plait, *Climate Change: It's Real, and It's Us*, SLATE (Sept. 30, 2013, 8:00 AM), http://www.slate.com/blogs/bad_astronomy/2013/09/30/climate_change_it_s_real_and_it_s_us.html [https://perma.cc/UN7P-KS34].

[2] Bec Crew, *Here's What You Need to Know About the New Paris Climate Deal*, SCI. ALERT (Dec. 14, 2015), http://www.sciencealert.com/here-s-what-you-need-to-know-about-the-climate-deal-from-paris [https://perma.cc/ZU6C-MSYP].

goal of two degrees Celsius, there will be significant harm to selected populations.[3] Most of this harm will be mediated through extreme weather events such as droughts, heat waves, and catastrophic storms.[4] Because insurance is a key strategy in managing extreme weather risk, it is logical to assume that insurance should play an important role in adapting to climate change.[5]

The role of insurance in driving adaptation is limited because most insured risks are short-term weather risks that are not tightly linked to climate change during the time period of the typical insurance policy.[6] The best fit is insurance for flooding of coastal communities that is exacerbated by baked-in sea level rise and climate change enhanced storms.[7] Such properties are currently insured by a combination of National Flood Insurance Program ("NFIP") policies, some private excess coverage for flooding, and federal disaster relief that is provided after specific events.[8] This bundle of resources is highly subsidized and encourages rebuilding in areas that are already at high risk and which will eventually be inundated.[9]

This Article argues that these high-risk coastal properties should be seen as having a life expectancy defined by future sea level rise. Similar to a person buying life insurance, the property owner and the insurer would not know when the property would flood, only that it is inevitable. As with life insurance, the cost of insurance would increase as the risk (sea level as opposed to age) increases with time. The predictable increasing cost of insurance would reduce the value of the property over time. Without an assurance of long-term value, there would be less political resistance to governmental programs that buy and tear down endangered properties to allow the coast to retreat inland. This would reduce catastrophic losses and deaths, and better preserve coastal ecology.

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[3] Jeff Tollefson, *Global-Warming Limit of 2°C Hangs in the Balance*, 520 NATURE 14, 14 (2015).

[4] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION 29 (2012).

[5] JOHN MCANENEY ET AL., MARKET-BASED MECHANISMS FOR CLIMATE CHANGE ADAPTATION: ASSESSING THE POTENTIAL FOR AND LIMITS TO INSURANCE AND MARKET-BASED MECHANISMS FOR ENCOURAGING CLIMATE CHANGE ADAPTATION 1 (2013).

[6] Kevin E. Trenberth et al., *Attribution of Climate Extreme Events*, 5 NATURE CLIMATE CHANGE 725, 726 (2015).

[7] Benjamin H. Strauss et al., *Carbon Choices Determine U.S. Cities Committed to Futures Below Sea Level*, 112 PNAS 13,508, 13,512 (2015).

[8] Omri Ben-Shahar & Kyle D. Logue, *The Perverse Effects of Subsidized Weather Insurance* 1, 3 (U. Mich. Law Sch., Law & Econ. Working Papers, Paper No. 111, 2015), http://repository.law.umich.edu/cgi/viewcontent.cgi?article=1221&context=law_econ_current [https://perma.cc/H7CE-6VRU].

[9] Jeffrey J. Pompe & James R. Rinehart, *Property Insurance for Coastal Residents: Governments' "Ill Wind,"* 13 INDEP. REV. 189, 203–04 (2008).

I. RETHINKING STEADY STATE EARTH

It is ironic that we think of geology as being static and humanity as being flexible and adaptable.[10] We see climate change/climate disruption as a potential existential threat to humanity, yet the history of the earth is one of an ever-changing climate that reshapes the face of the planet.[11] There have been five strong glacial cycles during the past 500,000 years.[12] The Holocene, the current geologic age, began 11,700 years ago, as the earth was warming after the end of the last ice age.[13] Human evolution occurred during this period of dramatically changing climate.[14] There is evidence that the changing climate influenced human evolution.[15]

Human civilization, however, evolved during a roughly 4,000-year period of stable climate.[16] Major world cities developed on coastal ports that in previous millennia had been under meters of water at one point and tens of miles inland at another.[17] Temperate agricultural belts have been stable for thousands of years in places that in past ages were under a mile of ice and then became tropical forests.[18] Although it is impossible to say how long the climate standstill might have lasted without the industrial revolution, the climate cycle is now turning again.[19]

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[10] JEFFERSON AIRPLANE, CROWN OF CREATION (RCA 1968).

[11] R. Bintanja & R.S.W. Van de Wal, *North American Ice-Sheet Dynamics and the Onset of 100,000-Year Glacial Cycles*, 454 NATURE 869, 869 (2008).

[12] *See* Laurent Augustin et al., *Eight Glacial Cycles from an Antarctic Ice Core*, 429 NATURE 623, 623 (2004).

[13] Mike Walker et al., *Formal Definition and Dating of the GSSP (Global Stratotype Section and Point) for the Base of the Holocene Using the Greenland NGRIP Ice Core, and Selected Auxiliary Records*, 24 J. QUATERNARY SCI. 3, 10 (2009).

[14] Stanley H. Ambrose, *Paleolithic Technology and Human Evolution*, 291 SCI. 1748, 1753 (2001).

[15] *See generally* Jonathan F. Donges et al., *Nonlinear Detection of Paleoclimate-Variability Transitions Possibly Related to Human Evolution*, 108 PNAS 20,422 (2011) (suggesting a correlation between changes in climate and rate of evolutionary change in humans).

[16] *See* Kent V. Flannery, *The Cultural Evolution of Civilizations*, 3 ANN. REV. ECOLOGY & SYSTEMATICS 399, 401 (1972).

[17] Most of the great ports and coastal cities are on river deltas that did not exist until sea level rise slowed about 6000 years ago. Daniel Jean Stanley & Andrew G. Warne, *Worldwide Initiation of Holocene Marine Deltas by Deceleration of Sea-Level Rise*, 265 SCI. 228, 229 (1994). Before then, they had been far inland. *Id.*

[18] JEFF ANDRESEN ET AL., U.S. GLOB. CHANGE RESEARCH PROGRAM, HISTORICAL CLIMATE AND CLIMATE TRENDS IN THE MIDWESTERN USA 3, 8 (2012).

[19] Eric McLamb, *The Ecological Impact of the Industrial Revolution*, ECOLOGY (Sept. 18, 2011) [https://perma.cc/6STN-HP4A] (original hyperlink no longer active); David Whitehouse, *2015: A Very Good Year for . . . Warm Weather*, GLOB. WARMING POLICY FORUM (Oct. 22, 2015), http://www.thegwpf.com/2015-a-very-good-year-for-warm-weather/ [https://perma.cc/MM4H-A6TW]. *See generally* John Cook et al., *Quantifying the Consensus on Anthropogenic Global Warming in the Scientific Literature*, 8 ENVTL. RES. LETTERS 1, 4–6 (2013) (analyzing recent historic trends of global warming opinions in the climate scientist community).

It is assumed that international agreements on greenhouse gas ("GHG") production and sequestration will not prevent a significant increase in the earth's temperature over the next hundred years.[20] The residence time of carbon dioxide ("CO2") in the atmosphere, and the thermal inertia of the oceans, assure that sea level rise caused by global warming will continue for centuries after the earth's temperature and GHG gas levels reach equilibrium.[21] Even with rapid and successful control of GHG production, mankind will need to adapt to rising temperatures for at least the next hundred years and to sea level rise for at least 500 years.[22] Despite these timeframes, many national environmental groups back coastal restoration plans that effectively deny climate change because they cannot succeed if the sea level is rising.[23] Such restoration mythologies depend on returning to a steady state earth.[24]

We must accept that climate change is the norm. The climate will not return to the late Holocene standstill for centuries, if ever. We should mitigate climate change to smooth the path for adaptation, but we must develop long-term environmental policy based on a changing climate. We cannot focus only on mitigation in hopes that the earth will return to a steady state.

II. IS THERE AN INSURABLE INTEREST IN CLIMATE CHANGE?

The purpose of insurance is to allow mitigation of future risks: the insured exchanges its risk of a large future loss for smaller periodic payments (premiums) paid to the insurance company.[25] Property-casualty insurance covers risks such as fire, theft, extreme weather damage, automobile accident injuries, property damage, being sued for liability by another person, and other risks of financial loss.[26] Life insurance pays for the losses caused by the insured's death and medical care insurance pays for medical care when the insured is sick or injured.[27] Actuarially sound insurance requires

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[20] *See* Justin Gillis & Somini Sengupta, *Limited Progress Seen Even as More Nations Step Up on Climate*, N.Y. TIMES (Sept. 28, 2015), http://www.nytimes.com/2015/09/28/world/limited-progress-seen-even-as-more-nations-step-up-on-climate.html.

[21] Michiel Schaeffer et al., *Long-Term Sea Level Rise Implied by 1.5°C and 2°C Warming Levels*, 2 NATURE CLIMATE CHANGE 867, 867 (2012).

[22] *Id.*

[23] D.M. Kennedy, *Tectonic and Geomorphic Evolution of Estuaries and Coasts*, *in* TREATISE ON ESTUARINE AND COASTAL SCIENCE 37, 38 (2011) (describing how the coast line advances and retreats tens to hundreds of miles with changes in sea level).

[24] *See id.*

[25] AM. INS. ASS'N, PROPERTY–CASUALTY INSURANCE BASICS 1 (n.d.) [hereinafter PROPERTY—CASUALTY].

[26] *Id.*

[27] G.C. Orros & J.M. Webber, *Medical Expenses Insurance—An Actuarial Review*, 115 J. INST. ACTUARIES 169, 169–269 (1988).

that the insured's risks be understood well enough that a premium can be set that will turn a profit for the insurer.[28] Risk is priced by looking at the data from a large number of parties with the same characteristics as those to be insured: the law of large numbers.[29] If the probability and severity are hard to determine, the premium will be higher or the insurer may not be willing to provide coverage.[30] Ironically, risks that are not anticipated by the insurer, popularly known as black swan risks, may be covered, even if they are potentially catastrophic.[31]

The core problem with using insurance to incentivize adaptation to climate change is the mismatch between the policy term for insurance and the timeframe that defines climate. Property-casualty insurance policies usually have a one-year term.[32] This allows premiums to be adjusted if the estimated probability of the insured risks change, or if market conditions change the other factors (capital investment returns, marketing goals, etc.) that influence premium pricing.[33] Climate is defined as the thirty-year average of metrological events (weather).[34] Once there was substantial evidence for climate change, the standard stayed a thirty-year average, but the average is recalculated every ten years.[35] Insurable events are the consequences of extreme weather such as hurricanes, tornados, droughts, and floods. A given extreme weather event cannot be attributed to climate change because the climate normal and climate models do not provide information that is fine

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[28] *See* PROPERTY—CASUALTY, *supra* note 25, at 5.

[29] *Id.* at 1.

[30] TRISTAN NGUYEN, U.N. OFFICE FOR DISASTER RISK REDUCTION (UNISDR), INSURABILITY OF CATASTROPHE RISKS AND GOVERNMENT PARTICIPATION IN INSURANCE SOLUTIONS 4 (2013) (noting that terrorism is an example of risk with a difficult to predict probability and severity).

[31] NASSIM NICHOLAS TALEB, THE BLACK SWAN: THE IMPACT OF THE HIGHLY IMPROBABLE 210–11 (2007) (explaining the "black swan" concept); *see, e.g.*, Scott Ross, *Risk Management and Insurance Industry Perspective on Cosmic Hazards*, *in* HANDBOOK OF COSMIC AND PLANETARY DEFENSE 1085, 1086 (2015) (noting that the risk of damage from comets, asteroids, and other bodies from space are currently covered under conventional property causality insurance; there are currently few claims worldwide from such events, so insurers do not worry about them, and anything that would increase the risk would likely cause them to require special (expensive) riders or be excluded altogether).

[32] *See* Dwight Jaffee et al., *Long-Term Property Insurance*, 29 J. INS. REG. 167, 171 (2010).

[33] *See id.* at 168.

[34] Anthony Arguez et al., *NOAA's 1981–2010 U.S. Climate Normals: An Overview*, 93 BULL. AM. METEOROLOGICAL SOC'Y 1687, 1687 (2012).

[35] Anthony Arguez & Russell S. Vose, *The Definition of the Standard WMO Climate Normal: The Key to Deriving Alternative Climate Normals*, 92 BULL. AM. METEOROLOGICAL SOC'Y 699, 699 (2011) (recognizing that although the climate normal is a historical reference, it is used for prospective purposes).

grained enough in time and space.[36] Although global warming will increase the probability and severity of extreme weather events over time, year-to-year property-casualty insurance only insures individual extreme weather events, not climate trends.[37]

Attributing specific extreme weather events to global warming is further complicated by the inherent variability of weather and even climate.[38] Extreme weather risk is discussed in terms of 100, 500, and 1000-year events, but reliable basic weather data extends back only to the late 1700s in places with long-term settlements.[39] In large parts of the world, including the United States, reliable data on large areas only goes back a hundred years or less, and weather radar and satellite data dates to the early 1960s.[40] Determining if an event is a 100-year event for a given location would require a good data record for several hundreds of years to see how often the event recurred. 500 and 1000-year events would take correspondingly longer.[41] In the face of this limited data, extreme events seem to be classified as less frequent than they appear in the historic record. For example, the Army Corps of Engineers (the "Corps") classified Hurricane Katrina as a 400-year storm.[42] Louisiana, however, is hit by a hurricane on average every 2.8 years, and Hurricane Katrina was not the most deadly storm to hit the state.[43] Within the last 2000 years, the west and the Great Plains have seen decades-long droughts that are much worse than the Dust Bowl in the 1930s and the recent drought in California.[44] Within this same period, the Mississippi River has had megafloods that greatly exceed what we assume is a 500-year flood.[45]

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[36] D.S. Shriner et al., *North America*, *in* REGIONAL IMPACTS OF CLIMATE CHANGE: AN ASSESSMENT OF VULNERABILITY 253, 264–65 (R.T. Watson et al. eds., 1998).

[37] Gerald A. Meehl et al., *Trends in Extreme Weather and Climate Events: Issues Related to Modeling Extremes in Projections of Future Climate Change*, 81 BULL. AM. METEOROLOGICAL SOC'Y 427, 433–34 (2000).

[38] *See* Michael E. Mann, *Climate Over the Past Two Millennia*, 35 ANN. REV. EARTH PLANET SCI. 111, 112 (2007).

[39] Petr Dobrovolný et al., *Monthly, Seasonal and Annual Temperature Reconstructions for Central Europe Derived from Documentary Evidence and Instrumental Records Since AD 1500*, 101 CLIMATIC CHANGE 69, 79 (2010).

[40] Gary Davis, *History of the NOAA Satellite Program*, J. APPLIED REMOTE SENSING, Jan. 25, 2007, at 4.

[41] D.R. Easterling et al., *Observed Variability and Trends in Extreme Climate Events: A Brief Review*, 81 BULL. AM. METEOROLOGICAL SOC'Y 417, 418 (2000).

[42] U.S. ARMY CORPS OF ENG'RS, LOUISIANA COASTAL PROTECTION AND RESTORATION FINAL TECHNICAL REPORT: STRUCTURAL PLAN COMPONENT APPENDIX 1–2 (2009).

[43] DAVID ROTH, NAT'L WEATHER SERV., LOUISIANA HURRICANE HISTORY 3, 7 (2010).

[44] Connie A. Woodhouse & Jonathan T. Overpeck, *2000 Years of Drought Variability in the Central United States*, 79 BULL. AM. METEOROLOGICAL SOC'Y 2693, 2710 (1998).

[45] *See* Paul Brown et al., *Marine Evidence for Episodic Holocene Megafloods in North America and the Northern Gulf of Mexico*, 14 PALEOCEANOGRAPHY 498, 508 (1999).

Thus, an ordinary property-casualty insurance policy only views weather through its one-year frame of reference because climate is defined as a thirty-year decadally-adjusted average. Even if extreme events are being exacerbated by climate change, the inherent variability in weather will mask that on a year-to-year basis. The property owner will see the year-to-year cost of the insurance, but that will not communicate increasing future risk, which would be necessary for the insurance to drive adaptation to climate change. What would be necessary is an insurable event with clear future risk signal. It must have effects that are routinely insured so the product will fit into the existing insurance market. If possible, it should be structured as an existing product so that the market can properly understand and rate it. The starting point is to analyze the currently understood risks posed by climate change to determine which, if any, fit within these criteria.

A. Ocean Acidification

There are two separate classes of risk from increased carbon dioxide ("CO2") in the atmosphere. The first is the direct chemical effect on water bodies.[46] As the concentration (partial pressure) of CO2 in the atmosphere increases, the amount of CO2 that will dissolve in water increases.[47] This increases the concentration of carbonate in the water and decreases the pH (makes the water more acidic).[48] The pH is directly linked to the partial pressure of CO2 in the atmosphere, so the pH at any given partial pressure of CO2 can be known precisely.[49] Thus, it is possible to know the pH with some accuracy for any projected level of CO2 in the atmosphere.[50] Although the pH can be accurately predicted, the effects of the pH change on natural systems are not well characterized.[51]

Decreasing pH affects the ability of organisms such as oysters and coral to build shells from calcium carbonate (CaCO3) and the metabolism of some non-shell building organisms.[52] It can change aquatic ecosystems in ways that are not well understood and which could impact species that are

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[46] Khan M.G. Mostofa et al., *Balancing of Ocean Acidification by Superoxide Redox Chemistry?*, 47 ENVTL. SCI. & TECH. 11,380, 11,380 (2013).

[47] *See* Frank J. Millero, *Thermodynamics of the Carbon Dioxide System in the Oceans*, 59 GEOCHIMICA ET COSMOCHIMICA ACTA 661, 661 (1995).

[48] *See id.* at 661–62.

[49] *See id.* at 662.

[50] *See id.*

[51] Kristy J. Kroeker et al., *Impacts of Ocean Acidification on Marine Organisms: Quantifying Sensitivities and Interaction with Warming*, 19 GLOBAL CHANGE BIOLOGY 1884, 1886 (2013).

[52] Frédéric Gazeau et al., *Impact of Elevated CO2 on Shellfish Calcification*, 34 GEOPHYSICAL RES. LETTERS 1, 3 (2007).

important for human nutrition.[53] These changes do not affect the climate, but the climate—through water temperature changes—will affect their severity.[54] The ecological effects could disrupt fisheries, destroy coral reefs, and have other effects, even positive effects, which we do not understand.[55] Of these, the only one with an insurable economic value would be effects on fisheries.[56] Although a coral reef may have many important ecological values, these are not traditional property values that fit into an insurance model.[57] It is also not subject to adaptation measures—you cannot move the Great Barrier Reef. Schemes to buffer anything but very small reefs from acidification are implausible. There is no clear insurable interest and no rationale for using insurance as risk communication for ocean acidification.

B. Heat, Drought, and Fire

California is a good example of the impact of increased temperatures on existing rain patterns. At the time this Article was written, California was in the fourth year of a profound drought.[58] Based on measurements of soil water and other indices of available water, 2014 was the driest year in the 1200 years of available California tree ring climate data.[59] Yet several years have had less rainfall than 2014.[60] The extreme drought is driven by the combination of very high temperatures and low rain.[61] Both the temperatures and the rainfall events have been seen in the climate record; this is the first time they have been seen together.[62] This does not prove that the tem-

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[53] *See* COMM. ON THE DEV. OF AN INTEGRATED SCI. STRATEGY FOR OCEAN ACIDIFICATION MONITORING, RESEARCH & IMPACTS ASSESSMENT, NAT'L RESEARCH COUNCIL, OCEAN ACIDIFICATION: A NATIONAL STRATEGY TO MEET THE CHALLENGES OF A CHANGING OCEAN 59–83 (2010) (discussing the impacts of ocean acidification generally, and how the ecological effects of ocean acidification are not totally understood).

[54] *See* Joan A. Kleypas et al., *The Impact of ENSO on Coral Heat Stress in the Western Equatorial Pacific*, 21 GLOBAL CHANGE BIOLOGY 2525, 2525 (2015) (discussing how coral bleaching—the loss of the symbiotic algae necessary for health coral—is exacerbated by higher ocean temperatures, further weakening coral already suffering from acidification).

[55] *See* CHRISTOPHER B. FIELD ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY 17 (2014).

[56] *See id.*

[57] *See* James Spurgeon, *The Economic Valuation of Coral Reefs*, 24 MARINE POLLUTION BULL. 529, 530 (1992).

[58] *See* Anne F. Van Loon et al., *Drought in the Anthropocene*, 9 NATURE GEOSCIENCE 89, 89 (2016).

[59] *See* Daniel L. Swain et al., *The Extraordinary California Drought of 2013/2014: Character, Context, and the Role of Climate Change*, 95 BULL. AM. METEOROLOGICAL SOC'Y S3, S3 (2014).

[60] Daniel Griffin & Kevin J. Anchukaitis, *How Unusual Is the 2012–2014 California Drought?*, 41 GEOPHYSICAL RES. LETTERS 9017, 9021 (2014).

[61] *Id.*

[62] *See id.* at 9022.

perature extremes were due to climate change but it is clear that the confluence of low rain and high temperatures will be more likely to happen with global warming.[63] Although 2014 may be the driest year, there have been longer droughts during the relatively recent past.[64]

The drought has lengthened the normal fire season and has exacerbated the fires that start.[65] Many trees are dying from the drought, which allows fires to burn mature trees that normally survive fires.[66] Rather than clearing the brush, these fires are leaving the land barren and increasing the risk of floods and landslides when rains return.[67] The muddy runoff will have severe impacts on the ecology of the streams that run through the fire zones.[68] Fires also destroy homes and communities, providing classic insurance risks.

The drought has hurt agriculture in California—the falling water tables have left some communities without running water.[69] Cities have been forced to impose restrictions on water use and San Diego has activated a desalination plant to provide supplemental drinking water.[70] Although the agricultural impact on the California economy has been projected at $2.7 billion for 2015, this is a small part of the state's economy.[71] This does not account for the human suffering caused by the fires or the loss of running water for some communities. If the drought continues, the cost may increase substantially as ground water levels fall below the reach of more communities. The impact of droughts in less wealthy countries is much more profound.

The Syrian refugee crisis is perhaps the first modern climate-driven large-scale population migration.[72] It should not be surprising that it has been

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[63] *See* Amir AghaKouchak et al., *Global Warming and Changes in Risk of Concurrent Climate Extremes: Insights from the 2014 California Drought*, 41 GEOPHYSICAL RES. LETTERS 8847, 8847 (2014); *see also* Noah S. Diffenbaugh et al., *Anthropogenic Warming Has Increased Drought Risk in California*, 112 PROC. NAT'L ACAD. SCI. 3931, 3931 (2015) (discussing that global warming is likely the proximate cause of California's current multiyear drought).

[64] Griffin & Anchukaitis, *supra* note 60, at 9021.

[65] Diffenbaugh et al., *supra* note 63, at 3931.

[66] Gregory P. Asner et al., *Progressive Forest Canopy Water Loss During the 2012–2015 California Drought*, 113 PROC. NAT'L ACAD. SCI. E249, E252 (2016).

[67] *See* Dennis L. Lynch, *What Do Forest Fires Really Cost?*, 102 J. FORESTRY 42, 42 (2004).

[68] *See id.* at 48.

[69] RICHARD HOWITT ET AL., U.C. DAVIS CTR. FOR WATERSHED SCI., ECONOMIC ANALYSIS OF THE 2015 DROUGHT FOR CALIFORNIA AGRICULTURE 1, 18 (2015).

[70] *Seawater Desalination*, SAN DIEGO CTY. WATER AUTH., http://www.sdcwa.org/seawater-desalination [https://perma.cc/BT3Y-UMNM].

[71] RICHARD HOWITT ET AL., *supra* note 69, at 10.

[72] Colin P. Kelley et al., *Climate Change in the Fertile Crescent and Implications of the Recent Syrian Drought*, 112 PROC. NAT'L ACAD. SCI. 3241, 3241 (2015) ("There is evidence that the 2007–2010 drought contributed to the conflict in Syria. It was the worst drought in the instrumen-

intermediated by the breakdown of civil society and civil war. This transforms the fleeing population from economic migrants with few rights under international law to political refugees, who are entitled to entry into other countries as well as support.[73] The destabilization of economies, especially in the belt from the Mediterranean across India to Bangladesh, is a major national security threat as climate destabilizes economies and the ensuing political refugees stream into nuclear-armed hostile neighboring countries.[74]

Drought and its consequences will likely be more common in the future as the climate warms, but their occurrence will continue to be difficult to predict with sufficient certainty over adequate time to properly incorporate them into insurance.[75] Catastrophic effects, such as civil war and massive migration, are in the nature of gray swans—novel and beyond our experience, but foreseeable. Being foreseeable is not the same as being subject to statistical characterization as to both occurrence and severity, which is necessary for insurance.[76]

C. Inland and River Flooding

Some scholars prefer to use the term climate disruption rather than climate change.[77] The intent is to emphasize that global warming increases the variability of climate.[78] Because climate is the thirty-year running average of

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tal record, causing widespread crop failure and a mass migration of farming families to urban centers. Century-long observed trends in precipitation, temperature, and sea-level pressure, supported by climate model results, strongly suggest that anthropogenic forcing has increased the probability of severe and persistent droughts in this region, and made the occurrence of a 3-year drought as severe as that of 2007–2010 2 to 3 times more likely than by natural variability alone. We conclude that human influences on the climate system are implicated in the current Syrian conflict.").

[73] *See* Bonnie Docherty & Tyler Giannini, *Confronting a Rising Tide: A Proposal for a Convention on Climate Change Refugees*, 33 HARV. ENVT'L L. REV. 349, 376 (2009).

[74] *See* Terrence M. O'Sullivan, *Environmental Security Is Homeland Security: Climate Disruption as the Ultimate Disaster Risk Multiplier*, 6 RISK HAZARDS & CRISIS IN PUB. POL'Y 183, 198 (2015).

[75] *See, e.g.*, *Initial Perspectives of Crop Insurance Underwriting Losses Due to the 2012 Drought*, FARMDOC DAILY (Aug. 7, 2012), http://farmdocdaily.illinois.edu/2012/08/initial_perspectives_of_crop_i.html [https://perma.cc/H9D5-8EWR] (discussing the difficulty of predicting drought in the context of crop insurance).

[76] *See* Jerome Stein & Seth Stein, *Gray Swans: Comparison of Natural and Financial Hazard Assessment and Mitigation*, 72 NAT. HAZARDS 1279, 1292–95 (2014) (discussing risk mitigation and calculating expected loss).

[77] *See* William R. Freudenburg & Violetta Muselli, *Reexamining Climate Change Debates: Scientific Disagreement or Scientific Certainty Argumentation Methods (SCAMs)?*, 57 AM. BEHAV. SCIENTIST 777, 777 (2013).

[78] JOHN P. HOLDREN, EXEC. OFFICE OF THE PRESIDENT OF THE U.S., CLIMATE-CHANGE SCIENCE AND POLICY: WHAT DO WE KNOW? WHAT SHOULD WE DO 3 (2010).

weather, it is not variable at the level of individual extreme weather events.[79] It is weather that is disrupted, in the sense that its short-term variability is increased.[80] Thus 100-year floods might become 20-year floods, and 1000-year events might become 100-year events. There are many drivers of the increased variability. The simplest is that warmer air holds more water than cooler air.[81] The warmer the air, the greater potential rainfall as the moisture condenses from the air.[82] The paleoclimate record for megafloods also indicates that small shifts in climate during the Holocene have had profound impacts on flooding.[83] Paleoclimate data can also help establish that a recent event is outside of the long-term record, strengthening the argument that it has been influenced by recent climate change.[84] Although river flooding will likely become more frequent, so will droughts that reduce river flow.[85] Until these patterns are better established, it is hard to characterize the long-term risk profile that would be necessary for insurance.

D. Sea Level Rise

Before climate disruption and climate change there was global warming. Although global warming as terminology has been displaced to stress that the impact is much broader than just an increase in temperature, the core process is the atmosphere retaining more heat due to the accumulation of CO2, along with methane and several other industrial gases.[86] The increased heat in the lower atmosphere is transferred to the land and the ocean.[87] The ocean is the primary heat sink. It has a much larger heat capacity than the atmosphere so that it heats and cools slowly, damping out variations in atmospheric temperature.[88] The deep ocean is approximately the

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[79] Arguez et al., *supra* note 34, at 1687.

[80] John M. Wallace et al., *Global Warming and Winter Weather*, 343 SCI. 729, 729 (2014).

[81] *Id.*

[82] *See* A.M. Fowler & K.J. Hennessy, *Potential Impacts of Global Warming on the Frequency and Magnitude of Heavy Precipitation*, 11 NAT. HAZARDS 283, 285 (1995).

[83] Paul Brown et al., *supra* note 45, at 508.

[84] *See* Daniel R.H. O'Connell et al., *Bayesian Flood Frequency Analysis with Paleohydrologic Bound Data*, 38 WATER RESOURCES RES. 16-1, 16-1, 16-8 (2002).

[85] VIRGINIA R. BURKETT, POTENTIAL IMPACTS OF CLIMATE CHANGE AND VARIABILITY ON TRANSPORTATION IN THE GULF COAST/MISSISSIPPI DELTA REGION 8–9 (n.d.), http://climate.dot.gov/documents/workshop1002/burkett.pdf [https://perma.cc/EBF4-ZNJA].

[86] *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: SYNTHESIS REPORT 1, 4 (Rajendra K. Pachauri et al. eds., 2014).

[87] Josh K. Willis et al., *Interannual Variability in Upper Ocean Heat Content, Temperature, and Thermosteric Expansion on Global Scales*, 109 J. GEOPHYSICAL RES., Dec. 30, 2004, at 1.

[88] Syukuro Manabe et al., *Transient Response of a Global Ocean—Atmosphere Model to a Doubling of Atmospheric Carbon Dioxide*, 20 J. PHYSICAL OCEANOGRAPHY 722, 722–23 (1990).

temperature of freezing seawater, -1.90°C.[89] Winds and currents change the mixing rate between the warm surface waters and the deep, freezing water, which reduces the surface temperature and can cool the atmosphere.[90] The net thermal energy in the ocean continues to increase because the surface heat is transferred to deep water.[91]

Sea level is determined by the volume of the ocean basin, the temperature of the water (water increases in volume as it warms), and the amount of water in the ocean.[92] Although the volume of the ocean basin changes with crustal plate movement, this is a very slow process and has been effectively stable for several million years.[93] In the early solar system, asteroids brought water to the earth.[94] This process still continues at a low rate, but not enough to affect ocean volume over human timeframes.[95] The only significant source of additional water in the ocean is ice on land, primarily in Antarctica, Greenland, and mountain glaciers.[96] Warmer air and warmer water cause the ice to melt faster than it accumulates and raises sea level.[97] Thus, sea level is a thermometer for the earth, rising as the temperature rises.[98] Sea level has been rising for more than a hundred years, and the rate of rise has been increasing.[99] Although the future rate of increase in sea level rise is uncertain, even the most conservative estimates show significant im-

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[89] Jess F. Adkins et al., *The Salinity, Temperature, and $\delta^{18}O$ of the Glacial Deep Ocean*, 298 SCI. 1769, 1771 (2002).

[90] Andrew B.G. Bush & S. George H. Philander, *The Role of Ocean-Atmosphere Interactions in Tropical Cooling During the Last Glacial Maximum*, 279 SCI. 1341, 1342 (1998).

[91] *See* Yu Kosaka & Shang-Ping Xie, *Recent Global-Warming Hiatus Tied to Equatorial Pacific Surface Cooling*, 501 NATURE 403, 406 (2013).

[92] *See* Eric W. Leuliette & Josh K. Willis, *Balancing the Sea Level Budget*, 24 OCEANOGRAPHY 122, 123–24 (2011).

[93] Kenneth G. Miller, *Sea Level Change, Last 250 Million Years*, *in* ENCYCLOPEDIA OF PALEOCLIMATOLOGY & ANCIENT ENVIRONMENTS 879, 884 (2009).

[94] Adam R. Sarafian et al., *Early Accretion of Water in the Inner Solar System from a Carbonaceous Chondrite-Like Source*, 346 SCI. 623, 625 (2014).

[95] *See generally* A. Morbidelli et al., *Source Regions and Timescales for the Delivery of Water to the Earth*, 35 METEORITICS & PLANETARY SCI. 1309 (2000) (discussing the controversial history of asteroids bringing water to earth and noting that this process still likely continues but at a rate that does not affect earth's present surface).

[96] *See* Andrew Shepherd et al., *Recent Loss of Floating Ice and the Consequent Sea Level Contribution*, 37 GEOPHYSICAL RES. LETTERS 1, 1 (2010). Melting sea ice, primarily in the Artic, does not contribute significantly to sea level rise because it is already displacing its weight in water. *Id.*

[97] *See generally* J. Bamber & R. Riva, *The Sea Level Fingerprint of Recent Ice Mass Fluxes*, 4 CRYOSPHERE 621 (2010) (discussing the impact that glacial sources have had in accelerating the rise in sea levels).

[98] Susan Solomon et al., *Irreversible Climate Change Due to Carbon Dioxide Emissions*, 106 PROC. NAT'L ACAD. SCI. 1704, 1705 (2009).

[99] *See* Thomas Gouriou et al., *Reconstruction of a Two-Century Long Sea Level Record for the Pertuis d'Antioche (France)*, 61–62 CONTINENTAL SHELF RES., Apr. 24, 2013, at 38.

pact on low lying coastal areas by 2100.[100] This lower bound of sea level rise is the most certain and clear risk associated with climate change.[101]

1. Sea Level Rise Driven Coastal Retreat

The location of beaches, barrier islands, and coastal wetlands is defined by sea level; as sea level rises, they migrate inland.[102] In the case of beaches and barrier islands, if there is inadequate sand available, they will disappear as sea level rises.[103] Sand can be lost naturally as shore currents change with sea level rise. On many beaches in the United States, sand was mined for use in construction, leaving inadequate sand to sustain the beach in the face of sea level rise.[104] The Outer Banks of North Carolina are an example of high value real estate that is already being lost to sea level rise.[105] Although coastal wetlands tend to retreat differently than beaches do, wetlands, including those that define river deltas such as the Mississippi River Delta and the delta that forms Bangladesh, also retreat inland with sea level rise.[106]

River deltas are at special risk from sea level rise.[107] They are the location of many of the world's great cities and some of the most productive farmland.[108] What is popularly called the delta starts at the open water at the edge and extends inland and upland.[109] Moving inland on a natural delta, at the edges there are coastal wetlands of salt marsh, which give way to fresh water marshes, which transition to wet forests such as cypress, and then to

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[100] *See generally* THOMAS W. DOYLE ET AL., U.S. GEOLOGICAL SURVEY, SEA-LEVEL RISE MODELING HANDBOOK: RESOURCE GUIDE FOR COASTAL LAND MANAGERS, ENGINEERS, AND SCIENTISTS 2–3, 15 (2015), http://pubs.usgs.gov/pp/1815/pp1815.pdf [https://perma.cc/J6AU-F8JE] (describing how even at the lowest projection of 0.66 feet by 2100, there would be considerable flooding in low lying cities such as Miami and many east coast port cities because the sea level rise magnifies the impact of surge generated by weather systems such as winter storms).

[101] *See id.* (discussing the certainty of sea level rise).

[102] *See* JAMES G. TITUS ET AL., U.S. CLIMATE CHANGE SCI. PROGRAM & SUBCOMM. ON GLOB. CHANGE RESEARCH, COASTAL SENSITIVITY TO SEA LEVEL RISE: A FOCUS ON THE MID-ATLANTIC REGION 44 (2009).

[103] *See id.*

[104] Edward B. Thornton et al., *Sand Mining Impacts on Long-Term Dune Erosion in Southern Monterey Bay*, 229 MARINE GEOLOGY 45, 45–47 (2006) (discussing the impacts of mining on beaches).

[105] ROBERT DOLAN & HARRY LINS, U.S. GEOLOGICAL SURVEY, THE OUTER BANKS OF NORTH CAROLINA 2 (2000), http://pubs.usgs.gov/pp/1177b/report.pdf [https://perma.cc/P9SU-4GEZ].

[106] *See* Thomas Spencer et al., *Global Coastal Wetland Change Under Sea-Level Rise and Related Stresses: The DIVA Wetland Change Model*, 139 GLOBAL & PLANETARY CHANGE 15, 24 (2016).

[107] IRINA OVEREEM ET AL., LAND-OCEAN INTERACTIONS IN THE COASTAL ZONE (LOICZ), DYNAMICS AND VULNERABILITY OF DELTA SYSTEMS 9–10 (2009).

[108] *Id.*

[109] *Id.*

upland forests.[110] This green zone extending to the water sits on the geologic delta, which is an upside down mountain of sediment that has been accumulating for tens to hundreds of millions of years.[111] In the case of the Mississippi Delta, it was the weakness of the crust that allowed the delta to form by accommodating the ever-increasing load of sediment by subsiding.[112] The subsidence is driven by the existing load of sediment so that any parts of the delta that are not being actively supplied with sediment rapidly sink below sea level.[113]

The location of the coastal edge of the delta is determined by the level of the ocean—all the major river deltas across the world date back to between 8500 and 6500 years ago, when sea level from the melting of the last ice age stabilized.[114] The deltas were far offshore during the glacial maximum—the point of maximum ice coverage during a glacial cycle—when the ocean was more than a hundred meters lower.[115] They retreated inland as sea level rose, and what we see as the current river deltas built when sea level stopped rising.[116] The coastal edge of deltas has been following sea level for millions of years as sea level rises and falls with the formation and melting of the ice pack.[117] Deltas' coastal edges will recede as sea level rises with global warming.[118] Because many are very flat, the rate of land loss will be high as the coast retreats inland to keep pace with sea level.[119] Despite a long history of engineering efforts to hold back the retreat of the shoreline and to restore lost land, none of these efforts can be successful in the face of sea level rise.[120]

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[110] *Id.*

[111] *See* William E. Galloway, *Depositional Evolution of the Gulf of Mexico Sedimentary Basin*, *in* SEDIMENTARY BASINS OF THE UNITED STATES AND CANADA 505, 513 (Andrew D. Miall ed., 2008) (noting that the Mississippi River delta is 65,000 feet thick).

[112] *See id.* at 509.

[113] *See* James M. Coleman & Sherwood M. Gagliano, *Cyclic Sedimentation in the Mississippi River Deltaic Plain*, 14 GULF COAST ASS'N GEOLOGICAL SOCIETIES TRANSACTIONS 67, 71 (1964).

[114] Stanley & Warne, *supra* note 17, at 229.

[115] William E. Galloway, *Gulf of Mexico Basin Depositional Record of Cenozoic North American Drainage Basin Evolution*, *in* FLUVIAL SEDIMENTOLOGY VII: SPECIAL PUBLICATION NUMBER 35 OF THE INTERNATIONAL ASSOCIATION OF SEDIMENTOLOGISTS 409, 418 (Michael D. Blum et al. eds., 2005).

[116] *See* Stanley & Warne, *supra* note 17, at 229.

[117] *See* Kennedy, supra note 23, at 38.

[118] *See* OVEREEM ET AL., *supra* note 107, at 9–10.

[119] *See id.*

[120] Orrin H. Pilkey & J. Andrew G. Cooper, *"Alternative" Shoreline Erosion Control Devices: A Review*, *in* PITFALLS OF SHORELINE STABILIZATION: SELECTED CASE STUDIES 187, 187 (J. Andrew G. Cooper & Orrin H. Pilkey eds., 2012).

Coastal retreat is a long-term and predictable process, to the extent that sea level rise can be anticipated, but the bigger threat to communities is how the baseline increase in sea level increases the reach of storm-driven coastal flooding.[121] As sea level rises, the impact of any given storm is increased.[122] The worst storms are tropical cyclonic storms because they build the highest surge.[123] These affect the Atlantic and Gulf Coasts of the United States, and the coasts of most Asian countries (they are called typhoons in the western Pacific and hurricanes in the Atlantic and eastern Pacific).[124] As they drift farther north they lose their tropical designation because of the loss of energy from warm waters.[125] Although Hurricane Sandy had become an extratropical storm by the time it hit the northeast, it demonstrated the damage that a tropical storm can do even when far from tropical waters.[126]

As a consequence of sea level rise, flooding during storms will necessarily increase. This will extend flooding farther inland and deeper in areas that have flooded in the past.[127] If there are areas protected by barriers such as sea walls or levees, it will increase the chance that the barriers will be overtopped or breached.[128] This catastrophic increase in risk is called the levee or escalator effect, because the existence of the levees escalates the risk of flooding by leading people to discount the risk they face.[129] Although warming the ocean may increase the frequency and strength of hurricanes, it will clearly allow them to maintain strength farther into cooler wa-

[121] Gordon McGranahan et al., *The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zone*s, 19 ENV'T & URBANIZATION 17, 17–20 (2007).

[122] *Id.*

[123] *See* Donald T. Resio & Jennifer L. Irish, *Tropical Cyclone Storm Surge Risk*, 1 CURRENT CLIMATE CHANGE REP. 74, 74–75 (2015).

[124] *See Frequently Asked Questions*, NAT'L OCEANIC & ATMOSPHERIC ADMIN. (July 15, 2011), http://www.aoml.noaa.gov/hrd/tcfaq/A1.html [https://perma.cc/9NTZ-WLWR].

[125] *See id.*

[126] *See generally* ERIC S. BLAKE ET AL., NAT'L HURRICANE CTR., TROPICAL CYCLONE REPORT: HURRICANE SANDY (2013) (noting that the designation "Super Storm" was an attempt to give a scary name to a storm that was no longer properly a hurricane, but needed to be treated as a major threat).

[127] *See* Angela Fritz, *Mid-Atlantic Coastline Flooded by Blizzard's Storm Surge. 'This Is Worse Than Sandy,'* WASH. POST (Jan. 24, 2016), https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/01/24/mid-atlantic-coastline-flooded-by-blizzards-storm-surge-this-is-worse-than-sandy/?hpid=hp_hp-top-table-main_eastcoast_pn_110pm [https://perma.cc/6F6J-A2TZ]. The January 2016 snow storm on the northeast coast of the United States produced worse flooding in some areas than Superstorm Sandy, showing the worsening flooding risk as relative sea level rises. *Id*.

[128] *See* Jeffrey Mount & Robert Twiss, *Subsidence, Sea Level Rise, and Seismicity in the Sacramento-San Joaquin Delta*, 3 S.F. ESTUARY & WATERSHED SCI., Mar. 2005, at 1, 3.

[129] Byron Newberry, *Katrina, Macro-Ethical Issues for Engineers*, 16 SCI. & ENGINEERING ETHICS 535, 557 (2010).

ters. This will increase the risk to more northern areas and might extend the length of the hurricane season. Most areas of the U.S. Gulf and Atlantic coasts are already at excessive risk for hurricane damage, complicating attributing the additional risk to climate change.[130]

Many major cities are on bays where navigable rivers enter the ocean, or are relatively close to the coast, up a navigable river. Sea level rise will deepen and expand the bays, and will reduce the head (slope) of the river. This will make it harder for the river to drain. For any given river-flooding event, an increase in sea level will increase the flooding at the bay and upriver. Sea level rise, combined with larger climate change driven rain events, will potentiate the flooding beyond historical norms. Thus, flooding risk on rivers near the coast can increase dramatically with climate change. This will make the risk profile and insurance issues on properties on those rivers look more like the risk profile on coastal properties.

2. The Insurable Interest in Sea Level Rise

These coastal and riverine effects of sea level rise are the best understood effects of climate change.[131] They are already well established by the past hundred years of sea level rise, and there is extensive geologic and paleoclimate information about migration of the coast during periods of changing sea level in the past.[132] There is uncertainty regarding how much the rate of sea level rise will increase over the next hundred years, but that is a question of timing more than of the ultimate level the ocean will reach as its temperature equilibrates with the increased level of heat retention by the atmosphere.[133] Coastal properties are at risk from current sea level rise and storms, and this risk will rise with sea level and ocean temperature. As the consequence of climate change with the most predictable risks that fit within the existing property casualty insurance framework, it is the best candidate for insurance products that encourage adaptation to climate change.[134]

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[130] Jeffrey Pompe & Jennifer Haluska, *Estimating the Vulnerability of U.S. Coastal Areas to Hurricane Damage*, *in* RECENT HURRICANE RESEARCH: CLIMATE, DYNAMICS, AND SOCIETAL IMPACTS 407, 407 (Anthony R. Lupo ed., 2011), http://www.intechopen.com/books/recent-hurricane-research-climate-dynamics-and-societal-impacts/estimating-the-vulnerability-of-u-s-coastal-areas-to-hurricane-damage.

[131] *See* Yosuke Adachi, *Human Lives at Risk Because of Eustatic Sea Level Rise and Extreme Coastal Flooding in the Twenty-First Century*, 7 WEATHER CLIMATE & SOC'Y 118, 118, 124–30 (2015).

[132] *See* Stanley & Warne, *supra* note 17, at 229.

[133] *See* Schaeffer et al., *supra* note 21, at 867.

[134] *Coastal Flooding*, FLOODSMART.GOV, https://www.floodsmart.gov/floodsmart/pages/coastal_flooding/cf_overview.jsp [https://perma.cc/6MWM-T6FH] ("[O]wning coastal property comes with a serious risk of flooding."); *Home*, FLOODSMART.GOV, https://www.floodsmart.gov/floodsmart/ [https://

It is also one of the highest risks as measured by the value of property and the number of lives at risk.[135]

Using population numbers from 2000, there are 600,000,000 people worldwide living in the low elevation coastal zone ("LECZ").[136] A majority of those people live on river deltas and flat lands that are subject to the most dangerous storm risk—tropical cyclones (hurricanes and typhoons).[137] Through natural geology and bad land use practices, especially ground water withdrawal, most of these areas are also subsiding faster than sea level is rising.[138] They are already subject to catastrophic flooding, a risk that subsidence exacerbates every year.[139] Even in a steady state earth, we would be facing large disasters each year because of the concentration of risk and economic development in these areas.[140] As sea level rises, it may make economic sense to defend some LECZ areas with favorable geology and high value real estate, but much of the property in the LECZ will have to be abandoned.

The core policy question for LECZ properties subject to tropical cyclones is whether they will end through punctuated catastrophe (periodic catastrophic storm flooding punctuated with cycles of rebuilding until a given storm is sufficiently catastrophic that the body politic is no longer willing to finance rebuilding). At least in the United States, where the commercial interests will see even greater insurance costs, it is likely that there will also be a long-term economic decline during this period as major employers move out of the high risk zone.

New Orleans is an example of the punctuated catastrophe cycle. In the author's opinion, the process of retreat should have started in 1965 with Hurricane Betsy, and certainly after Hurricane Katrina in 2005.[141] Despite the city's rebirth myth, jobs data has shown a continuing shift to low wage

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perma.cc/CQ32-35D4] (showing that there are well established flood insurance products provided through the Federal Emergency Management Agency).

[135] Toon Haer et al., *Relative Sea-Level Rise and the Conterminous United States: Consequences of Potential Land Inundation in Terms of Population at Risk and GDP Loss*, 23 GLOBAL ENVTL. CHANGE 1627, 1627–28 (2013)

[136] *See* McGranahan et al., *supra* note 121, at 22.

[137] *See id.*

[138] James P. M. Syvitski et al., *Sinking Deltas Due to Human Activities*, 2 NATURE GEOSCIENCE 681, 685 (2009).

[139] Charles W. Schmidt, *Delta Subsidence: An Imminent Threat to Coastal Populations*, 123 ENVTL. HEALTH PERSP., at A204, A205–206 (2015).

[140] *Id.*

[141] *See 1965-Hurricane Betsy*, HURRICANES: SCI. & SOC'Y, http://www.hurricanescience.org/history/storms/1960s/betsy/ [https://perma.cc/FM8L-4BKG] (describing the damage inflicted by Hurricane Betsy).

service jobs throughout the Katrina recovery.[142] This shows the ongoing loss of major commercial activity due to increased insurance pressure and the risks of doing business in a high-risk zone. The city's economy will continue to decline, as it has since the 1950s, as it awaits the next catastrophic storm.[143] A properly constructed climate change insurance product could create incentives to break the punctuated catastrophe cycle.

III. BUILDING A NEW MODEL FOR INSURING COASTAL RISKS

In an ideal world, everyone would be wealthy enough to make an informed choice between buying insurance and bearing the risk of loss for given risks. The state would be indifferent as to whether individuals purchase insurance because the individual would be able to bear the risk of loss and not become a burden to the state or others. Few families in the United States are so wealthy, so the government has become involved in insurance and insurance regulation.[144] The government may require the purchase of insurance when an individual's inability to bear the risk of loss will be a burden on society.[145] The government may do this through its *parens patriae* interest in the welfare of the insured or those the insured might injure.[146] The government also has an interest in its own finances when individuals require medical care, social services, or other benefits that they cannot afford.[147] The states require liability insurance for automobile drivers; and the

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[142] *See* MARLA NELSON ET AL., DATA CTR., PERSISTENT LOW WAGES IN NEW ORLEANS' ECONOMIC RESURGENCE: POLICIES FOR IMPROVING EARNINGS FOR THE WORKING POOR 2 (2015).

[143] *See 2000 Census: US Municipalities over 50,000: Ranked by 2000 Population*, DEMOGRAPHIA, http://www.demographia.com/db-uscity98.htm (noting that by year 2000, New Orleans was the thirty-first largest city in the United States); *Population of the 100 Largest Cities and Other Urban Places in the United States: 1790 to 1990*, U.S. CENSUS BUREAU (1998), https://www.census.gov/library/working-papers/1998/demo/POP-twps0027.html [https://perma.cc/T2Q5-9HAP] (describing how in 1860, New Orleans was the sixth largest city in the United States; in 1950, it was the sixteenth largest; and in 1990, it was the twenty-fourth largest).

[144] *See generally* Lisa Dubay et al., *The Uninsured and the Affordability of Health Insurance Coverage*, 26 HEALTH AFF., Jan. 2007, at w22–25 (discussing that the phenomena has been most studied with health insurance—Medicare was passed because the elderly could not afford medical insurance or medical care, Medicaid was for indigent persons, and even with these programs a large number of Americans could not afford medical care and remained uninsured before the Affordable Care Act).

[145] *See generally* Steven Shavell, *Minimum Asset Requirements and Compulsory Liability Insurance as Solutions to the Judgment-Proof Problem*, 36 RAND J. ECON. 63, 64–65 (2005) (discussing that insurance tends to incentivize to reduce risk).

[146] Edward P. Richards, *The Historical Background for Mandatory Reporting Laws in Public Health*, *in* MANDATORY REPORTING LAWS AND THE IDENTIFICATION OF SEVERE CHILD ABUSE AND NEGLECT 105, 110 (2015).

[147] Jack Hadley & John Holahan, *How Much Medical Care Do the Uninsured Use, and Who Pays for It?*, HEALTH AFF., Feb. 2, 2003, at W3-66, W3-69. A 2003 study showed that the unin-

federal mortgage insurance system requires property-casualty insurance on all mortgaged homes and flood insurance on those that are in the Federal Emergency Management Agency ("FEMA") designated floodplains.[148] The Affordable Care Act requires that most individuals carry medical insurance.[149]

When the government requires insurance, politics and fairness demand that it try to make the insurance affordable for the less wealthy. This can be done in three ways. First, the government can maintain the insurance as a private market product, but limit individualized rating decisions so that the risk is spread over a larger population. This forces insureds at lower risk to subsidize those at higher risk, thus reducing their insurance costs. Second, it can subsidize the cost of insurance with public funds to directly lower the cost below actuarially sound levels. Third, it can provide a pure public benefit without using the insurance model. The government uses all three of these approaches in its current approach to coastal properties.[150]

A. The Existing Coastal Insurance and Compensation System

1. Wind Damage Insurance

In the pure private insurance states, which are mostly not subject to hurricanes, insurance regulators may force companies to spread the coastal risk over a larger pool of insureds to keep the coastal policies more affordable.[151] In the major states subject to hurricanes—including Florida, Texas, and Louisiana—the states have set up captive carriers to provide subsidized wind coverage for coastal areas.[152] These citizens plans are intended to keep

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sured received $98.9 billion in medical care, which had to be paid by the government or by cost-shifting by medical care providers to private insurance or their own assets. *Id.*

[148] *See* RICHARD J. TOBIN & CORINNE CALFEE, AM. INST. FOR RESEARCH, THE NATIONAL FLOOD INSURANCE PROGRAM'S MANDATORY PURCHASE REQUIREMENT: POLICIES, PROCESSES, AND STAKEHOLDER, at iv (2005).

[149] *See* Tom Baker, *Health Insurance, Risk, and Responsibility After the Patient Protection and Affordable Care Act*, 159 U. PA. L. REV. 1577, 1617 (2011) (discussing that there is no constitutional right that requires subsidized insurance yet the Affordable Care Act provides subsidies for low income individuals in states that do not take the Medicaid expansion, and penalizes for non-compliance).

[150] *See* National Flood Insurance Act of 1968, 42 U.S.C. §§ 4000–4129 (2012). Although hurricanes and other coastal storms cause both wind and flood damage, the federal government took over the residential and small business flood insurance business in 1968. *See id.*

[151] *See generally* Carolyn Kousky, *Managing Natural Catastrophe Risk: State Insurance Programs in the United States*, 5 REV. ENVTL. ECON. & POL'Y 153, 163 (2011) (discussing that insurance programs spread risk of loss amongst all policyholders to cover costs related to natural catastrophe).

[152] *See id.* at 167.

coverage affordable, to protect real estate values, and to allow existing homeowners to continue affording coverage.[153] The subsidy is funded by statutory provisions, which allow a surcharge against all insurance plans in the state.[154] This is effectively a contingent tax to pay off the bonds that would be issued to pay claims after a major storm. The number of insureds in these plans exploded after Hurricane Katrina, but their economic viability has not yet been tested by a major storm.[155] This subsidy also externalizes the cost of the risk and mitigates the risk communication effect of the insurance.[156] In states where the rates for citizen's policies are still high, there is some incentive to adapt, either through reinforcing the house if that will earn a discount on the premium or by moving out of the flood zone.

2. The National Flood Insurance Program

The National Flood Insurance Program ("NFIP") provides residential coverage up to $250,000 for the structure and $100,000 for contents, and up to $500,000 for business structures and $500,000 for business contents.[157] Because flood losses are seldom complete losses, $250,000 is adequate for most residential property covered by the NFIP.[158] Larger business will supplement this coverage through the private insurance and reinsurance markers.[159] This supports a private insurance market for flood insurance that could be drawn on as an alternative to the NFIP.[160] The NFIP has been widely criticized for subsidizing flood insurance rates and for subsidizing

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[153] *See id.* at 156–57.

[154] *See id.* at 158.

[155] *See* RACHEL CLEETUS, UNION OF CONCERNED SCIENTISTS, OVERWHELMING RISK: RETHINKING FLOOD INSURANCE IN A WORLD OF RISING SEAS 5 (2013). Florida is the largest of these state plans and has very little capital to pay claims and depends on the ability to sell $100–200 billion in bonds on short notice to pay claims after a storm, which could be complicated if the bond market is unstable at the time. *Id.*

[156] *See* Ben-Shahar & Logue, *supra* note 8, at 2, 14–15.

[157] *See* NAT'L FLOOD INS. PROGRAM, PREFERRED RISK POLICY: LOW-COST FLOOD INSURANCE FOR BUSINESSES (2016), https://www.floodsmart.gov/toolkits/flood/downloads/CommercialPRP.pdf [https://perma.cc/7AC5-JQ36]; NAT'L FLOOD INS. PROGRAM, PREFERRED RISK POLICY: LOW-COST FLOOD INSURANCE FOR HOMEOWNERS AND RENTERS (2016), https://www.floodsmart.gov/toolkits/flood/downloads/ResidentialPRP.pdf [https://perma.cc/RZT5-ZN6Y].

[158] U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-13-568, FLOOD INSURANCE: IMPLICATIONS OF CHANGING COVERAGE LIMITS AND EXPANDING COVERAGE 14 (2013), http://www.gao.gov/assets/660/655719.pdf [https://perma.cc/HRE3-QUQG].

[159] *Id.*

[160] *See* Erwann Michel-Kerjan et al., *Could Flood Insurance Be Privatised in the United States? A Primer*, 40 GENEVA PAPERS ON RISK & INS. 179, 198 (2015).

the rebuilding of flooded properties in high risk areas.[161] It has also been found that the program shifts money from less affluent taxpayers to more affluent coastal landowners.[162]

In addition to the economic problems with the NFIP, there is a fundamental risk assessment flaw. As discussed previously, the 100-year flood standard tends to underestimate the actual risk of flooding.[163] (This is distinct from the misperception that every major flood is a 100 year flood.)[164] The main problem with the 100-year standard, however, is that it ignores all risk beyond the 100-year flood.[165] Properties outside the 100-year flood zone are not subject to floodplain building restrictions and property owners are not required to purchase flood insurance as a condition for mortgages.[166] If the property is behind a levee that the Army Corps of Engineers (the "Corps") certifies as providing 100-year flood protection, then insurance is rated as if there is no flood risk from hurricanes or river flooding.[167] This 100-year standard, which is meant to be a risk communication tool, is now a design criterion: the Corps designs levees, such as those built in New Orleans after Hurricane Katrina, to withstand the 100-year flood.[168]

There is no consideration of the 101-year risk, the 200-year risk, or the 500-year risk. It is also assumed that certified levees are never breached. Thus, houses ten feet below sea level in New Orleans, which were flooded to the rafters in 1965 and in 2005, are underwritten as having no hurricane flood risk.[169] An objective risk analysis would include all the risks beyond the 100-year storm, including the probability that the levees would fail dur-

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[161] *See* Jennifer Wriggins, *Flood Money: The Challenge of U.S. Flood Insurance Reform in a Warming World*, 119 PENN. ST. L. REV. 361, 414 (2014); Ben-Shahar & Logue, *supra* note 8, at 14–15.

[162] Chad McGuire et al., *Subsidizing Risk: The Regressive and Counterproductive Nature of National Flood Insurance Rate Setting in Massachusetts* 1, 13 (U. Mass. Dartmouth Pub. Policy Ctr. Working Paper Series, Working Paper No. ENV-2015-01, 2015).

[163] *See* Robert E. Criss, *Statistics of Evolving Populations and Their Relevance to Flood Risk*. 27 J. EARTH SCI. 2, 3 (2016); *supra notes* 38–46 and accompanying text.

[164] *See* FED. EMERGENCY MGMT. AGENCY, THE 100 YEAR FLOOD MYTH 2 (n.d)

[165] GERALD E GALLOWAY ET AL., WATER POLICY COLLABORATIVE, UNIV. OF MD., ASSESSING THE ADEQUACY OF THE NATIONAL FLOOD INSURANCE PROGRAM'S 1 PERCENT FLOOD STANDARD, at xiv (2006).

[166] *Id.*

[167] *See id.* at 88

[168] *See* S.N. Jonkman et al., *Risk-Based Design of Flood Defence Systems: A Preliminary Analysis of the Optimal Protection Level for the New Orleans Metropolitan Area,* 2 J. FLOOD RISK MGMT. 170, 170 (2009).

[169] NAT. RESEARCH COUNCIL, LEVEES AND THE NATIONAL FLOOD INSURANCE PROGRAM: IMPROVING POLICIES AND PRACTICES 43 (2013) ("Under current NFIP policies, lands behind accredited levee systems are not designated as being in a Special Flood Hazard Area (SFHA) and are not required to manage flood risk, even though the risk can be significant.").

ing a 100-year or smaller event.[170] For the purposes of this Article, the NFIP systematically underestimates the risk of flooding, to the point of denying flood risk in situations where the risk is obvious and catastrophic.[171] For the flood risks that are recognized, the policies are underpriced and rates are not adjusted after flooding if the property was grandfathered into the NFIP.[172] This prevents adjusting rates as sea level rise increases the risk of flooding.[173] Rather than encourage adaptation, the NFIP encourages high-risk development.[174]

3. FEMA and the Stafford Act

When individual home or business owners have an underinsured or uninsured event, they generally bear the risk of the loss. They may get access to low interest loans for rebuilding, but there is no systematic federal program to shelter them from the consequences of being under or uninsured.[175] When a community suffers a major disaster, the federal government will often come in and protect homeowners who have voluntarily chosen to forgo insurance coverage, along with those who could not afford insurance coverage.[176] In flooding events, the government will even provide funding to allow the inadequately insured to rebuild in the same place where they were flooded.[177] This defeats even the limited provisions of the NFIP on rebuilding in high-risk areas.[178]

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[170] *Id.* at 27 (stating that the National Academic of Sciences study panel recommended that rates be based on risk analysis unless an urban area is protected by a 500-year levee, rather than a 100-year levee).

[171] *Id*. at 43 ("The current approach to flood risk analysis does not address certain components that are critical to a modern flood risk analysis. These include the uncertainties in the hydrology, the probabilities that a protection structure might fail at less than the design elevation, the consequences that will result from the actual flooding, and the probabilities of the success of actions such as, for example, evacuation of the elderly and disabled.").

[172] *Id.* at 93–94.

[173] *Id.*

[174] Kenneth J. Bagstad et al. *Taxes, Subsidies, and Insurance as Drivers of United States Coastal Development*, 63 ECOLOGICAL ECON. 285, 286 (2007).

[175] *See Is Disaster Insurance a Good Thing?*, SAFE & SOUND (Dec. 28, 2014), http://www.safe-and-sound.net/disasterinsurance/ [https://perma.cc/2DVP-S9YN] (describing Small Business Administration ("SBA") loans).

[176] *See id.* (describing how FEMA and SBA may step in to help in the event of a major disaster).

[177] John A. Lovett, *Property and Radically Changed Circumstances*, 74 TENN. L. REV. 463, 547–48 (2007).

[178] CONG. BUDGET OFFICE (CBO), THE NATIONAL FLOOD INSURANCE PROGRAM: FACTORS AFFECTING ACTUARIAL SOUNDNESS 26 (2009), https://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/106xx/doc10620/11-04-floodinsurance.pdf [https://perma.cc/KSJ3-C4PB].

The most extensive example of direct aid to underinsured homeowners after a coastal flooding event at the time of this Article is the Louisiana Road Home Program instituted after Hurricane Katrina.[179] This program was intended to help persons whose homes were destroyed by Hurricane Katrina find new housing.[180] Although the State of Louisiana tried to require that the money only be used for rebuilding in the same high-risk place, the federal government allowed homeowners to also use the money to relocate.[181] The vast majority of homeowners in New Orleans and many others in high-risk areas choose to use the money to rebuild in the same place.[182] Rather than seeing this as a disaster, most commentators saw rebuilding in these high-risk areas as evidence of community resilience.[183]

From the perspective of short-term human suffering, disaster relief that tries to reestablish the status quo is politically irresistible. Calls for relocation will draw scorn from local politicians who worry that their constituencies will shrink.[184] Social justice advocates will argue, correctly, that the poor will suffer disproportionately from relocation schemes.[185] The homeowners themselves will resist efforts at relocation as they believe that they will not flood again—however naïve that belief.[186]

4. Insurance as Risk Communication

The existing coastal risk insurance and compensation system is intended to shield property owners and communities from the full costs of living in a high-risk zone.[187] This eliminates the critical role insurance can play in communicating and managing risks.[188] Property casualty insurance has a long history of combining insurance and risk management to reduce and

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[179] *See* Davida Finger, *Stranded and Squandered: Lost on the Road Home*, 7 SEATTLE J. SOC. JUST. 59, 61–62 (2008) (discussing the Louisiana Road Home Program following Katrina).

[180] *See id.*

[181] *Id.* at 61.

[182] *See* Christina Finch et al., *Disaster Disparities and Differential Recovery in New Orleans*, 31 POPULATION & ENV'T 179, 195 (2010).

[183] *See* Lovett, *supra* note 177, at 487.

[184] William P. Quigley, *Katrina Voting Wrongs: Aftermath of Hurricane and Weak Enforcement Dilute African American Voting Rights in New Orleans*, 14 WASH. & LEE J. CIV. RTS. & SOC. JUST. 49, 50 (2007).

[185] Jeanette Schade et al., *Climate Change and Climate Policy Induced Relocations: A Challenge for Social Justice: Recommendations of the Bielefeld Consultation*, 1 MIGRATION ENV'T & CLIMATE CHANGE, Dec. 2015, at, 1–9.

[186] *See* Emily Chamlee-Wright & Virgil Henry Storr, *Expectations of Government's Response to Disaster,* 144 PUB. CHOICE 253, 259 (2010). Research has shown a profound faith in the ability and willingness of the government to fix things after disasters. *Id.*

[187] *See supra* notes 190–202 and accompanying text.

[188] *See supra* notes 190–202 and accompanying text.

control risks.[189] An early example was the work of the Hartford Steam Boiler Insurance & Inspection Co. with the steam boiler engineering community in setting standards for steam boilers, which were a major risk for fire and explosions in buildings in the 1800s.[190] The insurer provided insurance, which was contingent on meeting boiler safety standards.[191] This reduced the risk of property damage and injury to the insured, as well as the cost of the insurance.

More generally, actuarially sound insurance is a direct economic indicator of the risk of an activity or the probability of damage to property. If an insured is buying coverage from a market that has not been distorted by regulation intended to create social benefits, the cost of insurance is a powerful communicator of risk.[192] For example, the cost and availability of products liability insurance affects the decision to market and design products. The design and location of buildings are affected by the cost of insuring them. Rather than saving money on the initial construction by designing to a minimum wind load, the owner may build a more expensive but stronger building to gain a discount in the yearly insurance bill.

Risk communication is distorted when the insurer prices risk below its real cost.[193] Insurers may do this for short periods to gain market share.[194] Part of the instability in the medical malpractice insurance markets in the 1970s was driven by insurers entering the market with low rates to attract policy holders, then dramatically raising the rates in later policy years when it was difficult to switch carriers.[195] Much more commonly, the rate structure is distorted by legislative and regulatory decisions intended to use the insurance system for other social welfare purposes.[196] Citizen's wind insurance programs spread the risk of coastal wind damage over the entire state

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[189] *See* Omri Ben-Shahar & Kyle D. Logue, *Outsourcing Regulation: How Insurance Reduces Moral Hazard*, 111 TENN. L. REV. 197, 205 (2012).

[190] *See id.*

[191] *See id.*

[192] *See* STRATEGIC FORESIGHT INITIATIVE, RISK MANAGEMENT AND INSURANCE: ISSUES AFFECTING EMERGENCY MANAGEMENT 1 (2013), http://www.fema.gov/media-library-data/1402675808237-9a0e29469813017ce9f990ecd751e265/Risk+Management+and+Insurance+17+Jan+13_508.pdf [https://perma.cc/NHZ7-E82P] (describing insurance prices as a tool for risk communications).

[193] Howard Kunreuther et al., *Making America More Resilient Toward Natural Disasters: A Call for Action*, 55 ENV'T, July/Aug. 2013, at 15–23.

[194] Scott E. Harrington & Patricia M. Danzon, *Price Cutting in Liability Insurance Markets*, 67 J. BUS. 511, 519 (1994).

[195] *See* Tom Baker, *Medical Malpractice and the Insurance Underwriting Cycle*, 54 DEPAUL L. REV. 393, 414–15 (2005); William M. Sage, *The Forgotten Third: Liability Insurance and the Medical Malpractice Crisis*, 23 HEALTH AFF. 10, 12 (2004).

[196] David Barker, *Terrorism Insurance Subsidies and Social Welfare*, 54 J. URBAN ECON. 328, 330–33 (2003).

to make the insurance more affordable, which reduces the risk signal to coastal property owners.[197] The NFIP reduces the risk signal by having the government subsidize premium costs with general tax revenue.[198] These programs, combined with disaster relief through the Stafford Act, FEMA, and direct appropriations effectively remove the risk signal that could incentivize adaptation to sea level rise.[199]

B. The Structure of Human Life Insurance

An insurance system for incentivizing adaption to rising sea level must communicate the increasing future risk while still functioning as a conventional property-casualty insurance policy. Although it is impossible to know precisely when low lying properties will be lost to flooding or catastrophic storms, it is clear that at some point in the future they will be gone. Traditional property-casualty insurance is written on the assumption that the property will continue in existence for an indefinite period and will face the same risks during this period. The best-known insurance product that explicitly deals with the lifetime problem is term life insurance.

Life insurance is a simple bet: the insured bets the insurance company that he will die sooner than the insurance company thinks he will.[200] If the insured dies during the term of the policy, the total amount of the policy is paid out.[201] The insurer wins—makes a profit on the policy—if the insured lives longer than the term of the policy if it is a fixed term, or lives longer than the predicted age of death that the premiums are based on if the policy is still in force at death. The insured wins—collects more money than the discounted net present day value of the policy—by dying early.[202]

1. Pricing Life Insurance

The premium for a given amount of life insurance—the terms of the bet—is based on actuarial analysis of the life tables developed by govern-

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[197] Ben-Shahar & Logue, *supra* note 8, at 17.

[198] *See* BARBARA MULLER VOGT & JOHN H. SORENSEN, OAK RIDGE NAT'L LAB., RISK COMMUNICATIONS AND THE CHEMICAL STOCKPILE EMERGENCY-PREPAREDNESS PROGRAM 45 (1994), http://emc.ornl.gov/publications/PDF/RiskDoc.pdf [https://perma.cc/6WTV-6ZN9].

[199] Scott Gabriel Knowles & Howard C. Kunreuther, *Troubled Waters: The National Flood Insurance Program in Historical Perspective*, 26 J. POL'Y HIST. 327, 329, 340 (2014). When Congress attempted to reform a few problems in the NFIP in 2012, the political firestorm was so intense that the reforms were quickly rescinded. *Id.*

[200] *All You Need to Know About Life Insurance*, EVERPLANS, https://www.everplans.com/articles/all-you-need-to-know-about-life-insurance [https://perma.cc/3EWR-3F8T].

[201] *See id.*

[202] *See id.*

mental and private interests.[203] Life tables are based on death certificates and provide an average life expectancy at each age.[204] In 2013, a person born in the United States could expect to live to be 78.8 years old.[205] If you live to be sixty, you can expect to live 21.44 more years, and an eighty-year-old can expect to live an additional 8.13 years while at a hundred, it is 2.09 additional years.[206] The simplest underwriting model looks only at the insured's age at the inception of a given policy year and the expected years of life for the individual's birth cohort. For an annually renewing policy, the premium for a given amount of coverage increases with the insured's age.[207] At advanced ages, the cost of insurance approaches the value of the policy and buying insurance no longer makes economic sense.

Underwriting can be refined by incorporating additional risk factors. For example, the basic life expectancy table includes both smokers and non-smokers. The insurer can include smoking into the underwriting. This will increase the expected years of life for non-smokers and reduce it for smokers, so that smokers will pay more for life insurance at any given age. Additional information about the individual insured's health or risk taking profile allows a more accurate estimate of the insured's life expectancy than simply using the life tables.[208] For example, from birth, a woman has an 81.0-year life expectancy and a man has a 76.2-year life expectancy.[209] Black men, on average, have a 4.7-year lower life expectancy than white men.[210] In a pure market insurance system, blacks would pay more for life insurance than whites and men would pay more than women. From an actuarial perspective, these are both neutral rating criteria.

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[203] Susanne Gschlössl et al., *Risk Classification in Life Insurance: Methodology and Case Study*, 1 EUR. ACTUARIAL J. 23, 23–24 (2011).

[204] *See* KENNETH D. KOCHANEK ET AL., NAT'L CTR. FOR HEALTH STATISTICS, MORTALITY IN THE UNITED STATES, 2013, at 5 (2014).

[205] *See Actuarial Life Table*, SOC. SEC. ADMIN., https://www.ssa.gov/oact/STATS/table4c6.html [https://perma.cc/57X4-DDF9].

[206] *Id.*

[207] *See Term Life Insurance*, THISMATTER.COM, http://thismatter.com/money/insurance/types/life/term-insurance.htm [https://perma.cc/5FL6-BWDC].

[208] Susan T. Stewart et al. *Forecasting the Effects of Obesity and Smoking on U.S. Life Expectancy*, 361 NEW ENG. J. MED. 2252, 2252–59 (2009).

[209] Elizabeth Arias, *United States Life Tables, 2010*, 63 NAT'L VITAL STAT. REP., Nov. 6, 2014, at 3.

[210] KENNETH D. KOCHANEK ET AL., NAT'L CTR. FOR HEALTH STATISTICS, HOW DID CAUSE OF DEATH CONTRIBUTE TO RACIAL DIFFERENCES IN LIFE EXPECTANCY IN THE UNITED STATES IN 2010? 4 (2013).

2. Social Justice and Life Insurance

As social policy, these racial and sexual criteria are problematic. The most sustained controversy over individual ratings for insurance has been over race-based ratings for life insurance.[211] Stretching back more than a hundred years, the insurance industry conflated discriminatory rates and rates that reflected different life expectancy risks for blacks.[212] This has been largely resolved in favor of requiring that life insurance rates for blacks be priced the same for whites.[213] On average, this creates a subsidy (social benefit) for black insureds as long as there is a discrepancy between white and black death rates.[214] While this distorts the market, it supports a social policy against race-based classifications. In contrast, women were originally lumped with men and thus paid premiums based on a higher average life expectancy rather than on a life expectancy based on gender stratified rates.[215] Eventually, social policy was changed so that women and men are rated separately so that women pay the real cost of their risk of dying.[216]

Persons with certain genetic diseases can have considerably shortened life expectancies.[217] If the person already manifests the disease when he or she applies for individual insurance, the insurer is allowed to take this into consideration and charge more for the policy or deny coverage.[218] But what if there is no manifestation of the disease, only a genetic test that shows the potentiality for developing the disease?[219] Should the insurer be allowed to test for possible future illnesses? This would increase the accuracy of the rating process, and thus reduce the cost for those who are not potentially afflicted. On the other hand, it would burden those with genetic diseases—

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[211] *See* Mary L. Heen, *Ending Jim Crow Life Insurance Rates*, 4 NW. J. L. & SOC. POL'Y 360, 362 (2009).

[212] *See id.*

[213] *See id.* at 375, 383.

[214] *See id.* at 366–69.

[215] *Id.* at 398.

[216] Bruce Kennedy, *How Men Get Socked on Life Insurance Premiums*, CBS MONEY WATCH (July 25, 2014), http://www.cbsnews.com/news/how-men-get-socked-on-life-insurance-premiums/ [https://perma.cc/ZRD4-7GTY].

[217] Robert J. Pokorski, *Insurance Underwriting in the Genetic Era*, 60 AM. J. HUMAN GENETICS 205, 207 (1997).

[218] *See id.* at 208–09.

[219] *See, e.g.*, Krupa Subramanian et al., *Estimating Adverse Selection Costs from Genetic Testing for Breast and Ovarian Cancer: The Case of Life Insurance*, 66 J. RISK & INS. 531, 534 (1999) (demonstrating the impact that decisions based on HIV positive test results can have on insurance provisions).

something they have no control over—with increased, potentially unaffordable costs. Public policy is still developing in this area.[220]

3. Is There Moral Hazard in Life Insurance?

The insurance programs for coastal risk create moral hazard by shifting the risks of living on the coast to other insureds and tax payers, thus incentivizing risky behavior. These public policy modifications to the pure market model for life insurance are adverse characteristics that cannot be modified by the individual; this means that they should not create moral hazard while supporting social policy beyond the availability of purely market priced insurance.[221] It is also assumed that generally individuals will not try to die early to collect insurance and that having health insurance does encourage people to get sick.[222]

C. Structuring Life Insurance for Coastal Properties

Sea level rise creates a limited life expectancy for low-lying coastal property. As with life insurance for people, death is certain but the timing is uncertain. Unlike with human life insurance, there are no life tables for coastal property. Coastal property life insurance would need to be priced by determining the probability of inundation for a given location and property at a sequence of future times. Climate models would provide the basic projections for global sea level rise in the future. As human life insurance ratings are refined with factors such as whether the insured is a smoker, the impact of sea level would need to be modified by specific information about the location and the property.

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[220] *See* Eric A. Feldman, *The Genetic Information Nondiscrimination Act (GINA): Public Policy and Medical Practice in the Age of Personalized Medicine*, 27 J. GEN. INTERNAL MED. 743, 743–44 (2012). The Genetic Information Nondiscrimination Act (GINA) limits how medical insurance companies can use genetic information about potential future illnesses to justify higher premiums. *Id.*; *see also* Alicia A. Parkman et al., *Public Awareness of Genetic Nondiscrimination Laws in Four States and Perceived Importance of Life Insurance Protections*, 24 J. GENETIC COUNSELING 512, 518 (2014) (illustrating how some states prevent the use of genetic information in rating life insurance policies).

[221] *See* Mark V. Pauly et al., *Price Elasticity of Demand for Term Life Insurance and Adverse Selection* 1, 5 (Nat'l Bureau of Econ. Research, Working Paper No. 9925, 2003).

[222] *See* George L. Priest, *Insurability and Punitive Damages*, 40 ALA. L. REV. 1009, 1024 (1989) (describing how life insurance policies include limitations on paying claims in cases of suicide).

1. Rating Factors

The starting point would be to determine local relative sea level rise. This is the average global sea level rise plus local factors that affect the elevation of the land and whether local sea level rise deviates from global sea level rise. Some coastal areas are still undergoing glacial isostatic adjustment ("GIA"), which is the rebound of the land after being depressed by the weight of the ice during the last ice age.[223] Long-term tide gauge data from sites undergoing GIA shows falling sea levels.[224] GIA is a deep (crustal) process and is generally six millimeters a year or less.[225] In North America, the highest rates for GIA are in the Hudson Bay area where the ice was thickest and melted most recently.[226]

Coastal subsidence is more common than GIA and makes tidal gauges register a higher rate of sea level rise than the global average.[227] Subsidence is a major problem on river deltas, where more than half a billion people live.[228] River deltas naturally experience subsidence from shallow processes such as the compaction of recent sediments, deep processes such as the crustal deformation that creates the accommodation space for the delta, and localized hot spots of subsidence associated with faulting on the delta.[229] The crustal deformation and shallow compaction can result in up to twelve millimeters of subsidence a year, while faulting can result in subsidence rates of up to thirty millimeters a year.[230]

Ground water pumping causes the most serious widespread subsidence on river deltas.[231] Jakarta, Indonesia is on a deltaic plane fed by thirteen rivers.[232] Jakarta is subsiding at up to ten centimeters a year, which may result in as much as six meters of subsidence by 2100.[233] Most of this is

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[223] *See* Mark E. Tamisiea & Jerry X. Mitrovica, *The Moving Boundaries of Sea Level Change: Understanding the Origins of Geographic Variability*, 24 OCEANOGRAPHY, June 2011, at 24, 26. While it may have been 10,000 years since the ice melted, the depression caused by a mile to a two-mile-thick sheet of ice will still be resolving. *Id.*

[224] *See id.* at 27.

[225] Joshua David Kent & Roy K. Dokka, *Potential Impacts of Long-Term Subsidence on the Wetlands and Evacuation Routes in Coastal Louisiana*, 78 GEOJOURNAL 641, 642 (2013).

[226] *See* Giovanni F. Sella et al., *Observation of Glacial Isostatic Adjustment in "Stable" North America with GPS*, 34 GEOPHYSICAL RES. LETTERS 1, 2 (2007).

[227] R. Eugene Turner, *Tide Gauge Records, Water Level Rise, and Subsidence in the Northern Gulf of Mexico*, 14 ESTUARIES 139, 139–147 (1991).

[228] *See* Syvitski et al., *supra* note 138, at 681.

[229] *See* Kent & Dokka, *supra* note 225, at 642.

[230] *See id.*

[231] *See* H.Z. Abidin et al., *Study on the Risk and Impacts of Land Subsidence in Jakarta*, 372 PROC. INT'L ASS'N HYDROLOGICAL SCI. 115, 117 (2015).

[232] *Id.*

[233] *See id.* at 115.

driven by ground water extraction.[234] Jakarta is now sitting in a depression that traps flood waters. In 2007, more than 200,000 people were displaced by flooding, and 1400 were hospitalized for waterborne diarrheal diseases and Dengue Fever, spread by mosquitoes that breed in the pooled flood waters.[235] In New Orleans, ground water pumping may have lowered critical flood control structures by 0.8 meters before Hurricane Katrina.[236]

The second is the correction for local sea level rise.[237] For example, local hydrologic geologic factors appear to cause Cape Hatteras off the east coast of North Carolina to see more than three to four times the global average sea level rise.[238] A related issue is how the local geographic features affect storm surge. Research on the Mississippi River Delta shows that the submerged, abandoned delta lobes, which create large areas of shallow water with a flat bottom, significantly increase storm surge.[239] Property on an estuary can also see increased surge, depending on the direction that the storm takes across the estuary.[240] The distance from the shore and the elevation of the property will also affect the probability of flooding.

2. Policy Term

Life insurance can be purchased as a year-to-year renewable contract, with the cost of coverage increasing each year, based on the life tables and individual rating factors. This allows the insurer to rerate the policy each year, based on changes in the insured's health, or cancel the policy if the insurer is worried about the insured dying too early. Unlike property insurance, an insured may also buy a multi-year contract of insurance.[241] This may be a variable rate contract, with the premium increasing on a known schedule each year, or a fixed price contract where the insured pays the same premium each year for the term of the policy.[242]

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[234] *See id.* at 117.

[235] Schmidt, *supra note* 139, at A205.

[236] Roy K. Dokka, *The Role of Deep Processes in Late 20th Century Subsidence of New Orleans and Coastal Areas of Southern Louisiana and Mississippi*, 116 J. GEOPHYSICAL RES., June 2011, at 1.

[237] *See* Asbury H. Sallenger, Jr. et al., *Hotspot of Accelerated Sea-Level Rise on the Atlantic Coast of North America*, 2 NATURE CLIMATE CHANGE 884, 884 (2012).

[238] *Id.*

[239] Qin Chen et al., *Hydrodynamic Response of Northeastern Gulf of Mexico to Hurricanes*, 31 ESTUARIES & COASTS 1098, 1115 (2008).

[240] *Id.* at 1114.

[241] *See* Jaffee et al., *supra* note 32, at 177.

[242] *See id.* (noting that a fixed price contract is more attractive to the insurer because the early premiums will be higher than in a variable rate policy and thus, if the policy holder terminates the policy early, as often happens, the insurance company makes more profit because it does not bear the risk in the later years when death is more likely).

There have been proposals to sell flood insurance as a multi-year product, with a fixed premium for the term.[243] The insurance would run with the property, not the owner, so the policy could be transferred if the property was sold.[244] This would help property owners by assuring the availability of affordable flood insurance and it would assure that coverage would be maintained by tying the long-term contract into the mortgage on the property.[245] The author recognizes that such insurance would only incentivize adaptation if the rates were risk-based, rather than being subsidized, and if there was a discount for taking measures that reduce risk.[246]

The problem with this version of long-term property insurance is that it is intended to create stability for the property owner to insure that property owners maintain their insurance.[247] My proposal is to fully embrace the life insurance model and require insurers to provide a schedule of premium increases based on the average sea level rise projections, adjusted for the risk factors of the insured's property. This would be a life table for coastal risk for the property. The insured would pay an increasing premium if the policy was an annual policy. The insured could also buy a term policy for the term of the mortgage, which would have a set premium rate for the term of the policy.

3. Shifting Incentives

Forcing insurers to assume the risk of sea level rise by guaranteeing the rate for twenty to thirty years should give them an incentive to be realistic in projecting the future risk of sea level rise. The insured would also be told that the policy would be significantly more expensive at renewal, and that it might not be renewable at all, depending on the rate of sea level rise. Rather than providing steady state earth insurance stability, it would force the property owner to internalize the risk of sea level rise. This could be offset by selling the property and moving inland, or by elevating or hardening the property, if feasible.

Research has shown that property values rapidly recover in the year after major hurricane damage.[248] This may be due to reduction in the housing market, which drives up prices, the impact of disaster aid, or other factors

[243] *See id.* at 181.
[244] *Id.*
[245] *See id.* at 182.
[246] *Id.* at 179.
[247] *See id.* at 182.
[248] *See* Eli Beracha & Robert S. Prati, *How Major Hurricanes Impact Housing Prices and Transaction Volume*, 33 REAL ESTATE ISSUES 45, 56 (2008).

that have not been characterized.[249] Longer-term studies confirm this effect.[250] In New Orleans, the U.S. city hardest hit by a hurricane in modern times and a delta city subject to rapidly escalating sea level rise risk, there has been a housing bubble post-Katrina.[251] Rising property values make it much harder to institute land use restrictions and they encourage new development in high-risk areas. Risk-based insurance with an escalating premium that would effectively communicate the climate change risk for the property could eliminate this post-disaster property value bump and would ideally reduce the value of the property through time. As the property loses value because of the increasing cost of the insurance or at the expiration of the policy if insurance is no longer available at an affordable price, there should be less resistance to the restrictions on development.

D. Transitioning to a Life Insurance Model

Changing the NFIP is a daunting challenge. As of the end of 2011, the NFIP had 5.6 million policies in force nationwide covering approximately $1.3 trillion in property.[252] By June 30, 2012, the NFIP was $17,750,000,000 in debt.[253] The debt was entirely due to catastrophic losses from Hurricanes Katrina and Rita—in all other years, premium income offset payouts.[254] This debt and the perverse incentives arising from subsidized flood insurance led Congress to pass a major reform of the NFIP, the Biggert-Waters Flood Insurance Reform Act of 2012.[255] This was a major reform that eliminated subsidies for second homes and repetitive loss properties and phased subsidies out for properties that were added to the program recently.[256] The annual cap on premium increases was raised from ten to twenty percent.[257]

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[249] *See id.*

[250] *See generally* Anthony Murphy & Eric Strobl, *The Impact of Hurricanes on Housing Prices: Evidence from US Coastal Cities* 1 (Fed. Reserve Bank of Dall., Working Paper No. 1009, 2010) (exploring the effect of hurricane strikes on housing prices in coastal cities).

[251] *See* Katherine Sayre, *New Orleans Home Prices Up 46 Percent Since Hurricane Katrina; Suburbs More Modest*, NOLA.COM (Aug. 11, 2015), http://www.nola.com/business/index.ssf/2015/08/new_orleans_home_prices_up_46.html [https://perma.cc/P7LM-ZRN5].

[252] RAWLE O. KING, CONG. RESEARCH SERVS., THE NATIONAL FLOOD INSURANCE PROGRAM: STATUS AND REMAINING ISSUES FOR CONGRESS 1, 15 (2013).

[253] *Id.* at 18.

[254] *Id.* at 17 (It is important to note that this data does not include losses from Hurricane Sandy.).

[255] Moving Ahead for Progress in the 21st Century Act, Pub. L. No. 112-141, 126 Stat 405 (2012).

[256] *See* KING, *supra* note 252, at 35.

[257] *See id.*

This bold reform lasted less than two years before Congress rolled back most of the reforms in face of massive opposition from high-risk communities and interest groups.[258] One of the most powerful arguments was that the NFIP provides insurance to the poor and working class, who would not be able to afford their homes under the reforms.[259] In reality, the NFIP primarily benefits wealthy individuals and wealthy communities.[260] While poor counties do get substantial benefits, a fine-grained study shows that it is often a small, wealthy part of the county that gets the benefits.[261] For example, in a typical beach community, the property at or close to the water's edge will be very valuable, but the property values fall off quickly as you move inland where permanent residents of the community live.[262] More than fifty percent of the policies are in the wealthy states of Texas and Florida.[263] The NFIP has a wealthy and powerful constituency that has shown its ability to thwart reform.

Two trends could create a window for meaningful reform and help move coastal property insurance toward a life insurance model. First is the increasing reluctance of Congress to provide blank check disaster relief as it did for Katrina, as evidenced by the opposition to relief after Hurricane Sandy.[264] Secondly, big businesses and large employers with extensive capital facilities in coastal areas are effectively outside of the NFIP because its commercial coverage is limited to $500,000 for buildings and $500,000 for contents.[265] These business properties are outside of the NFIP and they must buy unsubsidized commercial insurance. Sellers of commercial insurance for high risk properties depend on the reinsurance industry to take on some of the risk and to spread this risk to capital markets through securitization.[266] Without this global risk sharing, insurance will not be available.[267]

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[258] *See* Ben-Shahar & Logue, *supra* note 189, at 15–16.

[259] *See id.*

[260] *See* J. SCOTT HOLLADAY & JASON A. SCHWARTZ, INST. FOR POLICY INTEGRITY, FLOODING THE MARKET: THE DISTRIBUTIONAL CONSEQUENCES OF THE NFIP 1, 5 (2010).

[261] *See id.*

[262] *See* CHRISTOPHER MAJOR, THE BEACH STUDY: AN EMPIRICAL ANALYSIS OF THE DISTRIBUTION OF COASTAL PROPERTY VALUES 165, 170 (n.d.).

[263] HOLLADAY & SCHWARTZ, *supra* note 260, at 6.

[264] *See* Theodoric Meyer, *Why 58 Representatives Who Voted for Hurricane Katrina Aid Voted Against Aid for Sandy*, PROPUBLICA (Jan. 18, 2013), http://www.propublica.org/article/the-58-representatives-who-voted-for-katrina-aid-and-against-sandy-aid [https://perma.cc/Q3QH-7Q6B].

[265] *See* FEMA, NATIONAL FLOOD INSURANCE PROGRAM SUMMARY OF COVERAGE FOR COMMERCIAL PROPERTY 1 (n.d.), http://www.fema.gov/media-library-data/6a2ad0291e8d6a5452aa891a6c037039/fema_Summary_508C.pdf [https://perma.cc/Q4NG-LPDN].

[266] *See* Arthur Charpentier, *Insurability of Climate Risks*, 33 GENEVA PAPERS ON RISK & INS. 91, 99 (2008).

[267] *See id.*

Swiss Re is the largest international reinsurance company and it is including climate change risk in its products.[268] The rest of the reinsurance industry is also concerned about climate change.[269] Incorporating climate risk will increase the cost of insurance because it is uncertain and the reinsurance and capital markets are reluctant to take on uncertain risks.[270] In the worst case, insurance may become unavailable in high-risk areas, which would drive businesses to relocate or be forced to self-insure.[271] In the long-term, businesses will face progressive increases in coverage for coastal properties subject to sea level rise risk. They will be priced off the coast. While there is no reason for the private insurers to explicitly define a lifetime for coastal property, they will effectively do that by creating a point where it will not make financial sense to be on the coast. The only missing piece would be to require private insurers to project a future rate schedule based on sea level rise for commercial coastal risk insurance.

Coastal economies will be hollowed out by the loss of non-tourism employers to lower cost areas and the remaining tourist-based business will face increasing disruptions by low level flooding. Some deep-water ports will prosper, but many rivers and estuary ports, such as New Orleans, will have increasing difficulties keeping channels open for shipping.[272] The states and the federal government will eventually have to confront the fact that coastal communities are not economically viable and will need to be relocated. Cutting off the NFIP will not be politically possible and would cause terrible hardships. The NFIP, however, could be transformed into a life insurance model by instituting a set fee increase schedule. The government could also offer a buy-out schedule if the property owner wants to abandon the property and thus eliminate the government's insurance risk.

CONCLUSION

It is unlikely that legislatures will dismantle the National Flood Insurance Program and citizens' insurance plans and prohibit disaster aid in the near term. What is more likely is that as disaster losses increase, less and

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[268] SWISS RE, WEATHERING CLIMATE CHANGE: INSURANCE SOLUTIONS FOR MORE RESILIENT COMMUNITIES 16 (2010), http://europa.eu/epc/pdf/workshop/2-3_pub_climate_adaption_en.pdf [https://perma.cc/JQ85-S5XN].

[269] *See* Jonathan Gould, *Reinsurers Call for Action at Climate Change Summit*, REUTERS (Sept. 16, 2015), http://www.reuters.com/article/us-reinsurers-climatechange-idUSKCN0RG2FA20150916 [https://perma.cc/74PQ-G4WW].

[270] *See* Charpentier, *supra* note 266, 105–07.

[271] *See id.* at 107 (discussing that it may be difficult to find an insurer willing to pay for potentially extremely large losses).

[272] Michael D. Blum & Harry H. Roberts, *Drowning of the Mississippi Delta Due to Insufficient Sediment Supply and Global Sea-Level Rise*, 2 NATURE GEOSCIENCE 488, 488–90 (2009).

less money will be appropriated for coastal protection in any given community and disaster relief will be less generous. Through time, as the core businesses are priced off the coast and the infrastructure degrades due to increased tidal and storm flooding, local economies will fail. In coastal communities that are not destroyed by hurricanes, the end game is a failed city or town, bankrupt and hollowed out as it falls into the sea. It would be much better policy to accept that these communities have a limited lifetime. This would allow a real discussion about retreat over a timeframe of decades that might allow better preservation of the local culture and relationships. This discussion will not happen, however, until we admit that climate change matters and has consequences. Accepting that coastal properties have a limited lifetime is the first step.