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## **Between an Ocean and a Hard Place: Difficult Choices in Difficult Times**

### **INTRODUCTION**

One of the most serious effects of climate change is the danger of future sea level rise (SLR), which threatens to wipe out cities and nations and displace countless millions of people. Though the direct and indirect harms of SLR are incalculable in terms of human life and property, many nations have yet to undertake any comprehensive response measures.

The science of climate change and SLR is undeniable; the only questions left for policymakers to address are: *Should we let this happen? And what can we do to address climate change and sea level rise?*

### **CLIMATE CHANGE AND SEA LEVEL RISE (SLR)**

Since the beginning of the 20<sup>th</sup> century, the average temperature of the Earth has increased by approximately .7°C, much of which occurred in the last three decades alone. Furthermore, temperatures are projected to rise up to an additional 4°C (assuming we maintain our current “business as usual” or “do-nothing” policies) by the year 2100, depending upon which climate model (as developed by the Intergovernmental Panel on Climate Change, or IPCC) scenario is used.<sup>[1][2][3]</sup> These changes in climate are primarily attributed to man-made greenhouse gas (GHG) emissions caused by human industrial and economic activity.<sup>4</sup> One of the major results is that current sea levels will rise as glaciers, permafrost, and ice caps melt at an accelerated rate. In addition, thermal expansion of water (the tendency of all matter to increase in volume as its temperature increases) will also be a major contributing factor to sea level rise.<sup>5</sup>

The IPCC's Fourth Assessment (AR4) projected an increase of up to .59 meters by the end of the 21<sup>st</sup> century. However, more recent studies from Pfeffer *et al.* conclude that while a "2 meter [rise] by 2100 could occur under physically possible glaciological conditions....*more plausible but still accelerated conditions* lead to total sea-level rise by 2100 of about 0.8 meter."<sup>6</sup> Furthermore, Nicholls *et al.* predict that a 4°C rise in temperature [assuming a no-mitigation climate policy] will result in an impact of between ".5 meters and 2 meters."<sup>7</sup> Cazanave and Llovel are predicting a range of .2 to 1.2 meters, relative to 2000 sea levels.<sup>8</sup> The variation in the predicted range of SLR is primarily due to uncertainties about accelerated ice cap melting in the Greenland and Antarctic ice sheets, in contrast to more predictable thermal expansion effects.<sup>9</sup> In addition, the phenomenon of feedback (where changes in a system produce accelerated effects) also contributes to the variation in predicted SLR.<sup>10</sup> Nonetheless, the current scientific consensus is that there will be some significant measure of SLR which will impact coastal regions, even if the exact magnitude and probability are unknown.

The effects of SLR will not be uniform across all geographic areas; some regions will experience more deleterious effects than others. In addition to SLR, other predicted effects include greater intensity of tropical storms and hurricanes, increased salinization of delta regions, increased flooding, greater erosion, and various ecosystem changes, all of which will further impact coastal human habitation.<sup>11</sup> The risks of SLR to human populations are explored further in the next section.

### **CLIMATE REFUGEES**

The specter of sea level rise will have profound impacts on human settlements in coastal areas. Currently, a little more than half the world's population lives in cities and this

number is increasing.<sup>12</sup> Although the exact number of people living in coastal areas is difficult to estimate, approximately 634 million people (or about 10% of the current world population) live in low-elevation coastal areas (less than 30 feet above sea level), according to Balk.<sup>13</sup> Furthermore, Goudarzi (citing the Earth Institute at Columbia University) states that the number of people living within 100 kilometers of coasts will increase by 35% by 2050. Goudarzi further goes on to state that “this type of migration will expose 2.75 billion people to coastal threats from global warming such as sea level rise and stronger hurricanes in addition to other natural disasters like tsunamis.”<sup>14</sup>

The consequences of this migration pattern for nations dealing with the direct effects (such as homelessness and displacement) of climate change-induced SLR is dire. For example, a regional SLR in West Africa of “20 centimeters, would imply a displacement of 740,000 people in Nigeria” while “a rise of 1 meter, would lead to 3.7 million and 2m to 10 million homeless people in the country.”<sup>15</sup> The entire nation of the Maldives is exploring the possibility of relocating its entire population of 385,000 people, as SLR threatens the very sovereignty of the island nation as early as 2050.<sup>16</sup> Some inhabitants of Tuvalu and parts of Papua New Guinea have already been forced to relocate. In the Pacific area, there are 22 nations with 7 million people that will be adversely impacted by future SLR.<sup>17</sup> The nation of Bangladesh, with a population over 125 million, has already suffered significantly from SLR; 500,000 residents of Bhola Island were left homeless in 1995 after half of their island became permanently submerged and scientists are predicting a further 20 million homeless by 2030.<sup>18</sup> Furthermore, there are currently 35.1 million people living in Bangladesh’s low-lying coastal zone face the threat of homelessness from SLR.<sup>19</sup>

### *International Insecurities*

According to the International Red Cross' 2001 World Disasters Report, there are more refugees caused by environmental disasters (not limited to climate change) than from war.<sup>20</sup> However, there is also the significant potential that a SLR-related refugee crises will be a potential *cause* of future conflicts within and between nations. Describing Bangladesh in particular, Barnett suggests millions of refugees will "pose potentially serious problems for state legitimacy and internal harmony" that will overwhelm that nation.<sup>21</sup> Furthermore, not only will Bangladesh's domestic capacity to deal with internal displacements be taxed, but so will the sovereignty of its neighbor's be challenged. Indeed, rising power India has taken measures to address their problems of cross-border illegal immigration by "building a fence along its porous 2,500-mile border with Bangladesh."<sup>22</sup> Although Barnett suggests that "most migration is not international but rather occurs within individual countries," it is difficult to see where climate refugees would migrate to other than across international borders, if a significant land area of their country was underwater or suffered some other climate-change related effects.<sup>23</sup>

According to Barnett, the most vulnerable nations are in Africa and are viewed "as being highly vulnerable to climate change, particularly due to decreased water availability, enhanced food insecurity, impacts on human health, and increased desertification."<sup>24</sup> Furthermore, Africa also appears "highly threatened owing to the low levels of development combined with expectations of rapid population growth in coastal areas: Egypt and Mozambique are two "hotspots" for potential impacts."<sup>25</sup> However, this author also sees the more worrying possibility of a populous nation with significant military resources unrestrained by democratic institutions using its economic and military might to seek "living space" for its citizens: China.

China faces significant risks from SLR; there are more than 80 million people living in the Yangtze River delta and trillions of dollars of investments in property and infrastructure.<sup>26</sup>In 1995, Chen of China's National Bureau of Surveying and Mapping states that "the coastline of China stretches for about 18,000 km. China's coastal areas concentrate 70% of big cities and 41% of the total population of the nation. Fifty-five percent of the gross national product and 65% of the national industrial output are made in these areas. Although the areas occupy less than 1/7 of the total territory of China, they create more than half of the national wealth."<sup>27</sup> Furthermore, more people continue to move to China's coastal cities as construction is booming and jobs are available.<sup>28</sup> In the event that China is unable to cope with SLR by redistributing its population internally, it is not out of the realm of possibility that China may seek to physically expand into Mongolia or Russia, either by military force (China has the largest land army in the world) or as a (relatively) more benign immigration outflow. In fact, Russian Siberia has been slowly transforming over the last 50 years as more and more Chinese become all the more attractive for greater settlement, especially as oil, gas, and other natural resources are discovered in economically-attractive quantities in the region.<sup>29</sup> Of course, nuclear-armed and still-capable Russia may not agree with any potential Chinese plans...

So what are the options for policymakers to avert these scenarios? The next section will describe further.

### **BURIDAN'S ASS: MITIGATION VS. ADAPTATION**

According to the tale of Buridan's Ass, an ass (donkey) is placed precisely midway between a stack of hay and a pail of water. Since the paradox assumes the ass will always go to whichever is closer and easier to reach, it will die of both hunger and thirst since it

cannot make any rational decision to choose one over the other. Placed into a more technical context, Lamport states this paradox as follows: “A discrete decision based upon an input having a continuous range of values cannot be made within a bounded length of time.”<sup>30</sup>

The decisions faced by the U.S. and other nations endangered by SLR involve one of two strategies: mitigation and adaptation. With limited time, political will, and economic resources available to nations, especially developing nations, leaders and policymakers will face their own Buridan’s Ass paradox in the future in choosing between mitigation and adaptation. Indeed, the longer time goes on without a comprehensive strategy, the more difficult and expensive it will become to adopt said strategy.

### Mitigation

Mitigation involves the reduction of GHG emissions to prevent further carbon concentrations in the atmosphere. Current mitigation efforts appear to be aimed at preventing further GHG emissions and temperature increases instead of reversing existing concentrations.<sup>31</sup> According to Pacala and Socolow’s Stabilization Wedges model, there are several methods of stabilizing GHG emissions using currently available technology, including:<sup>32</sup>

- Energy conservation and efficiency improvements
  - Manufacturing and using more fuel-efficient vehicles
  - Reducing the use of vehicles
  - More efficient building construction
  - More efficient base-load coal-fueled power plants
- Shifting fuel source

- Shift to natural gas-powered power plants from coal generators
- Carbon Capture and Storage (CCS) Techniques
  - Capture CO<sub>2</sub> at existing power plants
  - Capture CO<sub>2</sub> at H<sub>2</sub> plant
  - Capture CO<sub>2</sub> at coal-to-synfuels plant
  - Geological storage of carbon
- Greater use of nuclear fission power
  - Replace all coal power plants with an additional 700GW of nuclear fission (which is twice the amount currently being used)
- Greater use of renewable energy
  - Replace all coal power plants with wind turbine
  - Replace all coal power plants with photovoltaic solar power
  - Substitute wind-based H<sub>2</sub> in fuel-cell cars for gasoline in hybrid cars
  - Substitute biomass fuel for fossil fuel
- Forests and agricultural soils improvements
  - Reduced deforestation, plus reforestation, afforestation, and new tree plantations
  - Employ conservation tillage techniques on all of world's cropland

According to this model, seven of the above fifteen 'wedges' are required to be adopted over the next 50 years in order to just stabilize GHG emissions. According to Pacala and Socolow, all of the wedges are "already implemented at an industrial scale and could be scaled up further over 50 years to provide at least one wedge."<sup>33</sup>

However, criticisms against such mitigation efforts cite political, economic, and technological limitations. Any one of these wedges will require international cooperation on an unprecedented scale; no one nation can bear the expense of pursuing a single wedge. Hoffert suggests that a massive mobilization of global resources will be necessary to mitigate using one of the wedges.<sup>34</sup> The prospects of international cooperation appear to be nil, absent a singular and shocking “Pearl-Harbor” event.

Due to the aforementioned risks of SLR, it is all the more urgent for nations to immediately prepare for the coming future. Although reducing GHGs is paramount for any environmental strategy, even if we are to assume a non-worst case scenario where GHG emissions were stabilized, SLR is still expected to occur to some degree. This is because there is a delay (Marshall estimates the “climate lag” at approximately 40 years) between GHG concentrations and atmospheric temperature increase.<sup>35</sup>

Nonetheless, it would appear that mitigation, while still necessary in the long-run for continued human survival on Earth, may not be nearly as feasible or urgent as adaptation. Indeed, almost two decades of climate change negotiations have yielded no fruitful or binding results, leading *The Economist* to recently conclude that “the fight to limit global warming to easily tolerated levels is over” and “analysts who have long worked on adaptation to climate change are starting to see their day in the uncomfortably hot sun.”<sup>36</sup>

### Adaptation

Adaptation is the employment of strategies to cope with the effects of climate change as they present themselves; in essence, adaptation seeks to reduce the negative effects of climate change on human civilization (rather than reducing or reversing GHG

emissions). In the case of SLR, adaptation would involve anything from construction of defenses against seas to even wholesale population relocation. More exotic (yet far-fetched) solutions may include underwater colonization or sealed arcologies. Furthermore, The Economist suggests that increasing urbanization may aid adaptation strategies by aggregating national economic activity into smaller geographic regions, increasing innovation (such as developing new business models), and reducing per-capita emissions (urban dwellers produce lower emissions), arguing that “protecting a single port city from floods is easier than protecting a similar population spread out along a coastline of fishing villages,” not unlike the military strategy of bastion defense, whereby cities and villages were fortified and the countryside was ceded to the enemy.<sup>37</sup>

According to the IPCC, a society’s ability to adapt is known as “adaptive capacity.” Adaptive capacity is largely determined by “wealth, technological expertise, strength of political institutions, equal distribution of power, and well-functioning social systems.”<sup>[38][39]</sup> Given the inherent tradeoffs between various adaptation strategies and even between adaptation and mitigation, certain considerations must be analyzed for effective policymaking. Titus identifies the following as key criteria for policymakers in assessing adaptation strategies and risks:<sup>40</sup>

- Economic Efficiency: Will the initiative yield benefits substantially greater than if the resources were applied elsewhere?
- Flexibility: Is the strategy reasonable for the entire range of possible changes in temperatures, precipitation, and sea level?
- Urgency: Would the strategy be successful if implementation were delayed ten or twenty years?

- Low Cost: Does the strategy require minimal resources?
- Equity: Does the strategy unfairly benefit some at the expense of other regions, generations, or economic classes?
- Institutional feasibility: Is the strategy acceptable to the public? Can it be implemented with existing institutions under existing laws?
- Unique or Critical Resources: Would the strategy decrease the risk of losing unique environmental or cultural resources?
- Health and Safety: Would the proposed strategy increase or decrease the risk of disease or injury?
- Consistency: Does the policy support other national state, community, or private goals?
- Private v. Public Sector: Does the strategy minimize governmental interference with decisions best made by the private sector?

In the absence of international frameworks, it is likely that individual nations will undertake independent (or regionally-coordinated) ad hoc actions to adapt. For developing nations, the costs of adaptation will be high; the World Bank estimates that the costs of adaptation require investments of somewhere between \$75 and \$100 Billion per year between 2010 and 2050 (assuming a projected temperature change of 2°C).<sup>41</sup> In light of the current global economic crisis, such projections are highly optimistic.

Adaptation may be driven by public policy or undertaken as private initiatives, although public-private partnerships are more likely to be the trend, a position supported by the UN Framework Convention on Climate Change (UNFCCC).<sup>42</sup> Some mechanisms (such as flood control barriers) are “clearly public goods, best supplied through collective

action.”<sup>43</sup> Other adaptation measures can readily be taken without government involvement, such as purchasing homes and relocating businesses away from flood-prone areas or insurance companies refusing to insure property in high-risk zones.

#### *Current and Proposed Adaptation Measures in Selected Countries*

There are several adaptation projects that are underway or on the drawing board. Much of the adaptation proposals are being spearheaded by private groups and municipal governments. This highlights a trend in the U.S. of local and state governments crafting their own environmental policies in the absence of federal action.<sup>44</sup>

In the United States, the U.S. EPA and several other federal agencies have jointly released a report in 2009 detailing the effects of SLR on coastal communities. Indeed, the EPA has been compiling such reports for the last 25 years.<sup>45</sup> However, no comprehensive federal policy addressing SLR is yet in place.

On the municipal front, the non-profit San Francisco Planning and Urban Research Association (SPUR) is advocating sea barriers for the Golden Gate Bridge to manage tidal flows and combat storm surges, which are expected to worsen as sea levels rise. Other options include coastal armoring (an ancient strategy of coastal protection involving seawalls and levees), floating structures, land reclamation projects, floodable development (structures and urban designs meant to withstand flooding), living shorelines (natural wetlands incorporated into urban planning to serve as natural ‘sponges’), and managed retreat (comprehensive evacuation plans to relocate populations further inland and abandon non-salvageable areas).<sup>46</sup> The San Francisco Bay Conservation and Development Commission has developed flood maps of flooding scenarios.<sup>47</sup> The City itself is in the process of developing legislation to establish an “inter-agency task force to establish a Sea

Level Rise Adaptation Policy” and to explore “potential future flood risks associated with a range of sea level rise over the next century, including engineered and non-engineered adaptive strategies.”<sup>48</sup>

The City of New York, location of some of the most expensive real estate in the world, has established an advisory New York City Panel on Climate Change (NPCC) to explore the effects of SLR, using IPCC data. The NPCC is “charged with investigating current and future climate hazards, including sea level rise, outlines an overall adaptation strategy for urban infrastructure, and describes an iterative risk-management process incorporating damages, benefits, and equity. Legal and insurance issues are also examined.”<sup>49</sup>The threat to New York City is particularly dire as recent climate models indicate the city’s sea level will rise twice as much as the rest of the U.S. and much of the city’s infrastructure (subways, power, and water lines) are underground and vulnerable to flooding.<sup>50</sup> Architects and civil engineers are exploring seawalls while the city has recently installed \$400 million dollars of water pumps to prevent flooding in the subway system. One proposal is that construction of massive sea barriers at designated “choke points.” Jacob estimates “the cost of such a project “up to \$100 billion”, which is ten percent of the “\$1 trillion gross regional product of the New York metropolitan area, embracing three states and 22 million people.”However, Jacob also suggests that the only true defense is to “retreat from low-lying areas.”<sup>51</sup>

In Europe, the Netherlands has taken affirmative steps in combating SLR, given the fact that almost 20 percent of the country lies below sea level (an area inhabited by 9 million people) and the nation possesses a system of interlocking dikes and levees (DeltaWorks). A national flood risk management program (the Delta Commission) has

recommended upgrading DeltaWorks at a projected cost of \$144 billion through the year 2100 to combat an assumed SLR of 1.3 meters.<sup>52</sup> The Dutch have also signed an agreement with Vietnam to develop a master plan for the Mekong Delta region in light of SLR concerns.<sup>53</sup>

On the Asian side, China has begun to undertake scientific research and policy development and has created a national strategic response to climate change: “the National Development Reform Commission (the central economic planning and coordination ministry) has taken responsibility for coordinating national climate responses, and has assembled a multi-sectoral advisory National Leading Group on Climate Change (NLGCC), with representatives from 10 national ministries.”<sup>54</sup> Chinese coastal provinces, such as Zhejiang, are building or improving seawall protection. The Zhejiang seawall is 2,132 kilometers long but has been deemed inadequate by the NLGCC in meeting future SLR dangers. In addition, the Chinese province of Ningxia has relocated poorly-situated villages and demolished farmers’ homes and fields to prevent reoccupation.<sup>55</sup> Official adaptation policies also incorporate mitigation measures, including the development of alternative energy systems and promoting mass transit.<sup>56</sup>

In Nigeria, the Lagos State government has partnered with the Canada-based Building Nigeria's Response to Climate Change to develop a climate change adaptation policy.<sup>57</sup> Meanwhile, the Bangladesh Government has implemented the Mangrove Greenbelt Project, as of 2003, to reforest low-lying areas to combat SLR and flooding. Other projects include floating gardens (where vegetables are grown in floating nets) and improving natural surface water flows. However, harder measures such as seawalls are slowly-progressing due to insufficient financing and significant construction times.<sup>58</sup> The

lack of funding will continue be a persistent issue for the Bangladeshi government to develop effective climate change adaptations.

### *The Precautionary Principle*

To paraphrase former U.S. Secretary of Defense Donald Rumsfeld: “There are known knowns. These are things we know that we know. There are also known unknowns. That is to say, there are things that we know we don't know.” As related to the threat of climate change, the world's coastlines are facing a serious short-/mid-term challenge but it is also an anticipated threat. Forward-looking policymakers and other actors have a strong incentive to address this “known unknown” due to human self-interest and to seek out strategies and tactics to cope with these issues.

Therefore, adoption of the Precautionary Principle is a key measure that policymakers must consider. Indeed, the principle has been enshrined within 1992 Earth Summit and Rio Declaration on Environment and Development, which notes: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."<sup>59</sup> Despite the uncertainties revolving around responses to climate change and SLR, immediate action is necessary because the risks of doing-nothing are far greater than the risks of doing-something.

### **CONCLUSION**

Despite what the media, political pundits (i.e., Rush Limbaugh), and others may lead one to believe, the fact that human-caused climate change is no longer up for scientific debate. According to Naomi Oreskes, “politicians, economists, journalists, and others may

have the impression of confusion, disagreement, or discord among climate scientists, but that impression is incorrect."<sup>60</sup>

Nonetheless, there is still the *myth* of scientific uncertainty that pervades the American polity when it comes to understanding climate change and its consequences. Combined with a new generation of politicians who are either ignorant of climate change or all-too-willing to appeal to their “global warming is a hoax” political base, it appears that a solid, comprehensive, and international policy to address climate change is on the backburner for the foreseeable future.

However, the time for policymakers, scientists, and the general public to plan adequately for difficult decisions to be made is becoming shorter and shorter. Given the risks and scenarios described herein associated with climate change and SLR, science and fact can no longer be ignored; the ostrich cannot continue to bury its head in the ground...for the ground may soon be submerged.

### **Writer's Comments**

This paper is meant to underscore the urgency with which policymakers must act to address climate change and some the options available to them. The ‘alarmist’ tone of this paper (adequately supported by the research) is designed to achieve this effect.

However, if this author truly believed in the futility of government and leaders to address this grave challenge, then(to paraphrase Len Berman regarding ‘catastrophic budget failure’) he would be stocking up on guns, gold, and food in a remote cabin in upstate New York (far, far away from the oceans). Humanity has survived predictions of Malthusian catastrophe and Mutually Assured Destruction; this author is optimistic that we’ll survive this one too.

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