## 1AC

### Plan

#### The United States federal government should fully fund the R&D and implementation of offshore small modular reactors

### Contention one- warming

#### Global Warming is happening – most recent and best evidence concludes that it is human induced

Muller 7-28-2012 [Richard, professor of physics at the University of California, Berkeley, and a former MacArthur Foundation fellow, “The Conversion of a Climate-Change Skeptic”, http://www.nytimes.com/2012/07/30/opinion/the-conversion-of-a-climate-change-skeptic.html?pagewanted=all]

CALL me a converted skeptic. Three years ago I identified problems in previous climate studies that, in my mind, threw doubt on the very existence of global warming. Last year, following an intensive research effort involving a dozen scientists, I concluded that global warming was real and that the prior estimates of the rate of warming were correct. I’m now going a step further: Humans are almost entirely the cause. My total turnaround, in such a short time, is the result of careful and objective analysis bythe Berkeley Earth Surface Temperature project, which I founded with my daughter Elizabeth. Our results show that the average temperature of the earth’s land has risen by two and a half degrees Fahrenheit over the past 250 years, including an increase of one and a half degrees over the most recent 50 years. Moreover, it appears likely that essentially all of this increase results from the human emission of greenhouse gases. These findings are stronger than those of the Intergovernmental Panel on Climate Change [IPCC], the United Nations group that defines the scientific and diplomatic consensus on global warming. In its 2007 report, the I.P.C.C. concluded only that most of the warming of the prior 50 years could be attributed to humans. It was possible, according to the I.P.C.C. consensus statement, that the warming before 1956 could be because of changes in solar activity, and that even a substantial part of the more recent warming could be natural. Our Berkeley Earth approach used sophisticated statistical methods developed largely by our lead scientist, Robert Rohde, which allowed us to determine earth land temperature much further back in time. We carefully studied issues raised by skeptics: biases from urban heating (we duplicated our results using rural data alone), from data selection (prior groups selected fewer than 20 percent of the available temperature stations; we used virtually 100 percent), from poor station quality (we separately analyzed good stations and poor ones) and from human intervention and data adjustment (our work is completely automated and hands-off). In our papers we demonstrate that none of these potentially troublesome effects unduly biased our conclusions. The historic temperature pattern we observed has abrupt dips that match the emissions of known explosive volcanic eruptions; the particulates from such events reflect sunlight, make for beautiful sunsets and cool the earth’s surface for a few years. There are small, rapid variations attributable to El Niño and other ocean currents such as the Gulf Stream; because of such oscillations, the “flattening” of the recent temperature rise that some people claim is not, in our view, statistically significant. What has caused the gradual but systematic rise of two and a half degrees? We tried fitting the shape to simple math functions (exponentials, polynomials), to solar activity and even to rising functions like world population. By far the best match was to the record of atmospheric carbon dioxide (CO2), measured from atmospheric samples and air trapped in polar ice.

#### CO2 is the primary driver of climate change – outweighs all alt causes

Vertessy and Clark 3-13-2012 [Rob, Acting Director of Australian Bureau of Meteorology, and Megan, Chief Executive Officer at the Commonwealth Scientific and Industrial Research Organisation, “State of the Climate 2012”, <http://theconversation.edu.au/state-of-the-climate-2012-5831>]

Carbon dioxide (CO2**)** emissions account for about 60% of the effect from anthropogenic greenhouse gases on the earth’s energy balance over the past 250 years. These global CO2 emissions are mostly from fossil fuels (more than 85%), land use change, mainly associated with tropical deforestation (less than 10%), and cement production and other industrial processes (about 4%). Australia contributes about 1.3% of the global CO2 emissions. Energy generation continues to climb and is dominated by fossil fuels – suggesting emissions will grow for some time yet. CO2 levels are rising in the atmosphere and ocean. About 50% of the amount of CO2 emitted from fossil fuels, industry, and changes in land-use, stays in the atmosphere. The remainder is taken up by the ocean and land vegetation, in roughly equal parts. The extra carbon dioxide absorbed by the oceans is estimated to have caused about a 30% increase in the level of ocean acidity since pre-industrial times. The sources of the CO2 increase in the atmosphere can be identified from studies of the isotopic composition of atmospheric CO2 and from oxygen (O2) concentration trends in the atmosphere. The observed trends in the isotopic (13C, 14C) composition of CO2 in the atmosphere and the decrease in the concentration of atmospheric O2 confirm that the dominant cause of the observed CO2 increase is the combustion of fossil fuels.

#### Positive feedbacks ensure runaway warming, causes extinction

Speth 2008 [James, dean of the Yale School of Forestry and Environmental Studies at Yale University, New Haven, Connecticut. Currently he serves the school as the Carl W. Knobloch, Jr. Dean and Sara Shallenberger Brown Professor in the Practice of Environmental Policy, The Bridge @ the Edge of the World, pg. 26]

The possibility of abrupt climate change is linked to what may be the most problematic possibility of all—"positive" feedback effects where the initial warming has effects that generate more warming. Several of these feedbacks are possible. First, the land's ability to store carbon could weaken. Soils and forests can dry out or burn and release carbon; less plant growth can occur, thus reducing nature's ability to remove carbon from the air. Second, carbon sinks in the oceans could also be reduced due to ocean warming and other factors. Third, the potent greenhouse gas methane could be released from peat bogs, wetlands, and thawing permafrost, and even from the methane hydrates in the oceans, as the planet warms and changes. Finally, the earth's albedo, the reflectivity of the earth's surface, is slated to be reduced as large areas now covered by ice and snow diminish or are covered by meltwater. All these effects would tend to make warming self-reinforcing, possibly leading to a greatly amplified greenhouse effect. The real possibility of these amplifying feedbacks has alarmed some of our top scientists. James Hansen, the courageous NASA climate scientist, is becoming increasingly outspoken as his investigations lead him to more and more disturbing conclusions. He offered the following assessment in 2007: "Our home planet is now dangerously near a 'tipping point.' Human-made greenhouse gases are near a level such that important climate changes may proceed mostly under the climate system's own momentum. Impacts would include extermination of a large fraction of species on the planet, shifting of climatic zones due to an intensified hydrologic cycle with effects on freshwater availability and human health, and repeated worldwide coastal tragedies associated with storms and a continuously rising sea level. .. . "Civilization developed during the Holocene, a period of relatively tranquil climate now almost 12,000 years in duration. The planet has been warm enough to keep ice sheets off North America and Europe, but cool enough for ice sheets on Greenland and Antarctica to be stable. Now, with rapid warming of o.6°C in the past 30 years, global temperature is at its warmest level in the Holocene. "This warming has brought us to the precipice of a great 'tipping point” If we go over the edge, it will be a transition to 'a different planet,' an environment far outside the range that has been experienced by humanity. There will be no return within the lifetime of any generation that can be imagined, and the trip will exterminate a large fraction of species on the planet.

#### Not too late – every reduction key

Nuccitelli 12 [Dana, is an environmental scientist at a private environmental consulting firm in the Sacramento, California area. He has a Bachelor's Degree in astrophysics from the University of California at Berkeley, and a Master's Degree in physics from the University of California at Davis. He has been researching climate science, economics, and solutions as a hobby since 2006, and has contributed to Skeptical Science since September, 2010, <http://www.skepticalscience.com/realistically-what-might-future-climate-look-like.html>, HM]

We're not yet committed to surpassing 2°C global warming, but as Watson noted, we are quickly running out of time to realistically give ourselves a chance to stay below that 'danger limit'. However, 2°C is not a do-or-die threshold. Every bit of CO2 emissions we can reduce means that much avoided future warming, which means that much avoided climate change impacts. As Lonnie Thompson noted, the more global warming we manage to mitigate, the less adaption and suffering we will be forced to cope with in the future. Realistically, based on the current political climate (which we will explore in another post next week), limiting global warming to 2°C is probably the best we can do. However, there is a big difference between 2°C and 3°C, between 3°C and 4°C, and anything greater than 4°C can probably accurately be described as catastrophic, since various tipping points are expected to be triggered at this level. Right now, we are on track for the catastrophic consequences (widespread coral mortality, mass extinctions, hundreds of millions of people adversely impacted by droughts, floods, heat waves, etc.). But we're not stuck on that track just yet, and we need to move ourselves as far off of it as possible by reducing our greenhouse gas emissions as soon and as much as possible. There are of course many people who believe that the planet will not warm as much, or that the impacts of the associated climate change will be as bad as the body of scientific evidence suggests. That is certainly a possiblity, and we very much hope that their optimistic view is correct. However, what we have presented here is the best summary of scientific evidence available, and it paints a very bleak picture if we fail to rapidly reduce our greenhouse gas emissions. If we continue forward on our current path, catastrophe is not just a possible outcome, it is the most probable outcome. And an intelligent risk management approach would involve taking steps to prevent a catastrophic scenario if it were a mere possibility, let alone the most probable outcome. This is especially true since the most important component of the solution - carbon pricing - can be implemented at a relatively low cost, and a far lower cost than trying to adapt to the climate change consequences we have discussed here (Figure 4).

#### Absent cuts in emissions, warming causes extinction

Mazo 10 (Jeffrey Mazo – PhD in Paleoclimatology from UCLA, Managing Editor, Survival and Research Fellow for Environmental Security and Science Policy at the International Institute for Strategic Studies in London, 3-2010, “Climate Conflict: How global warming threatens security and what to do about it,” pg. 122)

The best estimates for global warming to the end of the century range from 2.5-4.~C above pre-industrial levels, depending on the scenario. Even in the best-case scenario, the low end of the likely range is 1.goC, and in the worst 'business as usual' projections, which actual emissions have been matching, the range of likely warming runs from 3.1--7.1°C. Even keeping emissions at constant 2000 levels (which have already been exceeded), global temperature would still be expected to reach 1.2°C (O'9""1.5°C)above pre-industrial levels by the end of the century." Without early and severe reductions in emissions, the effects of climate change in the second half of the twenty-first century are likely to be catastrophic for the stability and security of countries in the developing world - not to mention the associated human tragedy. Climate change could even undermine the strength and stability of emerging and advanced economies, beyond the knock-on effects on security of widespread state failure and collapse in developing countries.' And although they have been condemned as melodramatic and alarmist, many informed observers believe that unmitigated climate change beyond the end of the century could pose an existential threat to civilisation." What is certain is that there is no precedent in human experience for such rapid change or such climatic conditions, and even in the best case adaptation to these extremes would mean profound social, cultural and political changes

#### Largest risk of extinction

Deibel ‘7 (Terry L. Deibel, professor of IR at National War College, Foreign Affairs Strategy, “Conclusion: American Foreign Affairs Strategy Today Anthropogenic – caused by CO2”)

Finally, **there is one major existential threat** to American security (as well as prosperity) of a nonviolent nature, which, though far in the future, demands urgent action. **It is the threat of global warming to the stability of the climate upon which all earthly life depends. Scientists worldwide have been observing the gathering of this threat for three decades now, and what was once a mere possibility has passed through probability to near certainty. Indeed not one of more than 900 articles on climate change published in refereed scientific journals from 1993 to 2003 doubted that anthropogenic warming is occurring**. “In legitimate scientific circles,” writes Elizabeth Kolbert, “**it is virtually impossible to find evidence of disagreement over the fundamentals of global warming.” Evidence from a vast international scientific monitoring effort accumulates almost weekly, as this sample of newspaper reports shows: an international panel predicts “brutal droughts, floods and violent storms across the planet over the next century”; climate change could “literally alter ocean currents, wipe away huge portions of Alpine Snowcaps and aid the spread of cholera and malaria”; “**glaciers in the Antarctic and in Greenland are melting much faster than expected, and…worldwide, plants are blooming several days earlier than a decade ago”; “rising sea temperatures have been accompanied by a significant global increase in the most destructive hurricanes”; “NASA scientists have concluded from direct temperature measurements that 2005 was the hottest year on record, with 1998 a close second”; “Earth’s warming climate is estimated to contribute to more than 150,000 deaths and 5 million illnesses each year” as disease spreads; “widespread bleaching from Texas to Trinidad…killed broad swaths of corals” due to a 2-degree rise in sea temperatures. “The world is slowly disintegrating,” concluded Inuit hunter Noah Metuq, who lives 30 miles from the Arctic Circle. “They call it climate change…but we just call it breaking up.” From the founding of the first cities some 6,000 years ago until the beginning of the industrial revolution, carbon dioxide levels in the atmosphere remained relatively constant at about 280 parts per million (ppm). At present they are accelerating toward 400 ppm, and by 2050 they will reach 500 ppm, about double pre-industrial levels. Unfortunately, atmospheric CO2 lasts about a century, so there is no way immediately to reduce levels, only to slow their increase, we are thus in for significant global warming; the only debate is how much and how serous the effects will be. As the newspaper stories quoted above show, **we are already experiencing the effects of 1-2 degree warming in more violent storms, spread of disease, mass die offs of plants and animals, species extinction, and threatened inundation of low-lying** countries like the Pacific nation of Kiribati and the Netherlands at a warming of 5 degrees or less the Greenland and West Antarctic ice sheets could disintegrate, **leading to a sea level of rise of 20 feet that would cover North Carolina’s outer banks, swamp the southern third of Florida,** and inundate Manhattan up to the middle of Greenwich Village. **Another catastrophic effect would be the collapse of the Atlantic thermohaline circulation** that keeps the winter weather in Europe far warmer than its latitude would otherwise allow. Economist William Cline once estimated the damage to the United States alone from moderate levels of warming at 1-6 percent of GDP annually; severe warming could cost 13-26 percent of GDP. But **the most frightening scenario is runaway greenhouse warming, based on positive feedback from the buildup of water vapor in the atmosphere that is both caused by and causes hotter surface temperatures**. Past ice age transitions, associated with only 5-10 degree changes in average global temperatures, took place in just decades, even though no one was then pouring ever-increasing amounts of carbon into the atmosphere. Faced with this specter, the best one can conclude is that “humankind’s continuing enhancement of the natural greenhouse effect is akin to playing Russian roulette with the earth’s climate and humanity’s life support system. At worst, says physics professor Marty Hoffert of New York University, “**we’re just going to burn everything up;** we’re going to het the atmosphere to the temperature it was in the Cretaceous when there were crocodiles at the poles, and then **everything will collapse.”** During the Cold War, astronomer Carl Sagan popularized a theory of nuclear winter to describe how a thermonuclear war between the Untied States and the Soviet Union would not only destroy both countries but possible end life on this planet. **Global** warming is the **post-Cold War era’s** equivalent of nuclear winter **at least as serious and considerably better supported scientifically. Over the long run** it puts **dangers form** terrorism andtraditional military challenges to shame. It is a threat **not only to the security and prosperity to the United States, but potentially** to the continued existence oflife on this planet.

#### Multiple internal links to extinction:

#### Agriculture

#### Global warming makes global agricultural production impossible – resulting in mass starvation

Potsdam Institute, 2012 (Potsdam Institute for Climate Impact Research and Climate Analytics, “Turn Down the Heat: Why a 4°C Warmer World Must be Avoided”, A report for the World Bank, November, http://climatechange.worldbank.org/sites/default/files/Turn\_Down\_the\_heat\_Why\_a\_4\_degree\_centrigrade\_warmer\_world\_must\_be\_avoided.pdf)

**The overall conclusions** of IPCC AR4 **concerning** food production and **agriculture included** the following: • Crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1 to 3°C depending on the crop, and then decrease beyond that in some regions (medium confidence) {WGII 5.4, SPM}. • At lower latitudes, especially in seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1 to 2°C) which would increase the risk of hunger (medium confidence) {WGII 5.4, SPM}. • **Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1 to 3°C,** but above this it is projected to decrease (medium confidence) {WGII 5.4, 5.5, SPM}. These findings clearly indicate a growing risk for low-latitude regions at quite low levels of temperature increase and a growing risk for systemic global problems above a warming of a few degrees Celsius. While a comprehensive review of literature is forthcoming in the IPCC AR5, the snapshot overview of recent scientific literature provided here illustrates that **the concerns identified in the AR4 are confirmed by recent literature and in important cases extended**. In particular, impacts of extreme heat waves deserve mention here for observed agricultural impacts (see also Chapter 2). This chapter will focus on the latest findings regarding possible limits and risks to large-scale agriculture production because of climate change, summarizing recent studies relevant to this risk assessment, including at high levels of global warming approaching 4°C. In particular, it will deliberately highlight important findings that point to the risks of assuming a forward projection of historical trends. **Projections for food and agriculture over the 21st century indicate substantial challenges irrespective of climate change**. As early as 2050, the world’s population is expected to reach about 9 billion people (Lutz and Samir 2010) and demand for food is expected to increase accordingly. Based on the observed relationship between per capita GDP and per capita demand for crop calories (human consumption, feed crops, fish production and losses during food production), Tilman et al. (2011) project a global increase in the demand for crops by about 100 percent from 2005 to 2050. Other estimates for the same period project a 70 percent increase of demand (Alexandratos 2009). Several projections suggest that global cereal and livestock production may need to increase by between 60 and 100 percent to 2050, depending on the warming scenario (Thornton et al. 2011). **The historical context can on the one hand provide reassurance that despite growing population, food production has been able to increase to keep pace with demand** and that despite occasional fluctuations, food prices generally stabilize or decrease in real terms (Godfray, Crute, et al. 2010). **Increases in food production have mainly been driven by more efficient use of land, rather than by the extension of arable land,** with the former more widespread in rich countries and the latter tending to be practiced in poor countries (Tilman et al. 2011). While grain production has more than doubled, the area of land used for arable agriculture has only increased by approximately 9 percent (Godfray, Beddington, et al. 2010). However, **although the expansion of agricultural production has proved possible through technological innovation and improved water-use efficiency, observation and** analysis point to a significant level of vulnerability of food production and prices to the consequences of climate change**, extreme weather, and underlying social and economic development trends**. There are some indications that **climate change may reduce arable land** in low-latitude regions, with reductions most pronounced in Africa, Latin America, and India (Zhang and Cai 2011). For example, **flooding of agricultural land is also expected to severely impact crop yields in the future**: 10.7 percent of South Asia´s agricultural land is projected to be exposed to inundation, accompanied by a 10 percent intensification of storm surges, with 1 m sea-level rise (Lange et al. 2010). Given the competition for land that may be used for other human activities (for example, urbanization and biofuel production), which can be expected to increase as climate change places pressure on scarce resources, it is likely that the main increase in production will have to be managed by an intensification of agriculture on the same—or possibly even reduced—amount of land (Godfray, Beddington et al. 2010; Smith et al. 2010). **Declines in nutrient availability** (for example, phosphorus), **as well as the spread in pests and weeds, could further limit the increase of agricultural productivity.** **Geographical shifts in production patterns resulting from the effects of global warming could further escalate distributional issues in the future**. While this will not be taken into consideration here, it illustrates the plethora of factors to take into account when thinking of challenges to promoting food security in a warming world. New results published since 2007 point to a more rapidly escalating risk of crop yield reductions associated with warming than previously predicted (Schlenker and Lobell 2010; Schlenker and Roberts 2009). In the period since 1980, patterns of global crop production have presented significant indications of an adverse effect resulting from climate trends and variability, with maize declining by 3.8 percent and wheat production by 5.5 percent compared to a case without climate trends. A significant portion of increases in crop yields from technology, CO2 fertilization, and other changes may have been offset by climate trends in some countries (Lobell et al. 2011**). This indication alone casts some doubt on future projections based on earlier crop models**. In relation to the projected effects of climate change three interrelated factors are important: temperature-induced effect, precipitation-induced effect, and the CO2 -fertilization effect. The following discussion will focus only on these biophysical factors. Other factors that can damage crops, for example, the elevated levels of tropospheric ozone (van Groenigen et al. 2012), fall outside the scope of this report and will not be addressed. Largely beyond the scope of this report are the far-reaching and uneven adverse implications for poverty in many regions arising from the macroeconomic consequences of shocks to global agricultural production from climate change. It is necessary to stress here that even where overall food production is not reduced or is even increased with low levels of warming, distributional issues mean that food security will remain a precarious matter or worsen as different regions are impacted differently and food security is further challenged by a multitude of nonclimatic factors.

1. **Biodiversity**

#### 4 degrees of warming make sustaining biodiversity impossible – the impact is extinction

Potsdam Institute, 2012 (Potsdam Institute for Climate Impact Research and Climate Analytics, “Turn Down the Heat: Why a 4°C Warmer World Must be Avoided”, A report for the World Bank, November, http://climatechange.worldbank.org/sites/default/files/Turn\_Down\_the\_heat\_Why\_a\_4\_degree\_centrigrade\_warmer\_world\_must\_be\_avoided.pdf)

Ecosystems and their species provide a range of important goods and services for human society. These include water, food, cultural and other values. In the AR4 an assessment of climate change effects on ecosystems and their services found the following: • **If greenhouse gas emissions and other stresses continue at or above current rates, the resilience of many ecosystems is likely to be exceeded** by an unprecedented combination of change in climate, associated disturbances (for example, flooding, drought, wildfire, insects, and ocean acidification) and other stressors (global change drivers) including land use change, pollution and over-exploitation of resources. • **Approximately 20 to 30 percent of plant and animal species assessed so far are likely to be at increased risk of extinction, if increases in global average temperature exceed** of 2–**3° above preindustrial levels.** • For increases in global average temperature exceeding 2 to 3° above preindustrial levels and in concomitant atmospheric CO2 concentrations, **major changes are projected in ecosystem structure and function, species’ ecological interactions and shifts in species’ geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services**, such as water and food supply. It is known that **past large-scale losses of global ecosystems and species extinctions have been associated with rapid climate change combined with other ecological stressors**. Loss and/or degradation of ecosystems, and **rates of extinction because of human pressures over the last century or more**, which **have intensified in recent decades**, have contributed to a very high rate of extinction by geological standards. It is well established that loss or degradation of ecosystem services occurs as a consequence of species extinctions**, declining species abundance, or widespread shifts in species and biome distributions** (Leadley et al. 2010). Climate change is projected to exacerbate the situation. This section outlines the likely consequences for some key ecosystems and for biodiversity. The literature tends to confirm the conclusions from the AR4 outlined above. Despite the existence of detailed and highly informative case studies, upon which this section will draw, it is also important to recall that there remain many uncertainties (Bellard, Bertelsmeier, Leadley, Thuiller, and Courchamp, 2012). However, **threshold behavior is known to occur in biological systems** (Barnosky et al. 2012) **and most model projections agree on major adverse consequences for biodiversity in a 4°C world** (Bellard et al., 2012). With high levels of warming, coalescing human induced stresses on ecosystems have the potential to trigger large-scale ecosystem collapse (Barnosky et al. 2012). Furthermore, while uncertainty remains in the projections, **there is a risk not only of major loss of valuable ecosystem services, particularly to the poor and the most vulnerable who depend on them, but also of feedbacks being initiated** that would result in ever higher CO2 emissions and thus rates of global warming. Significant effects of climate change are already expected for warming well below 4°C. In a scenario of 2.5°C warming, severe ecosystem change, based on absolute and relative changes in carbon and water fluxes and stores, cannot be ruled out on any continent (Heyder, Schaphoff, Gerten, & Lucht, 2011). If warming is limited to less than 2°C, with constant or slightly declining precipitation, small biome shifts are projected, and then only in temperate and tropical regions. Considerable change is projected for cold and tropical climates already at 3°C of warming. **At greater than 4°C of warming, biomes in temperate zones will also be substantially affected. These changes would impact** not only the **human and animal communities that directly rely on the ecosystems**, but would also exact a cost (economic and otherwise) on society as a whole, ranging from extensive loss of biodiversity and diminished land cover, through to loss of ecosystems services such as fisheries and forestry (de Groot et al., 2012; Farley et al., 2012). Ecosystems have been found to be particularly sensitive to geographical patterns of climate change (Gonzalez, Neilson, Lenihan, and Drapek, 2010). Moreover, ecosystems are affected not only by local changes in the mean temperature and precipitation, along with changes in the variability of these quantities and changes by the occurrence of extreme events. These **climatic variables are thus decisive factors in determining plant structure and ecosystem composition** (Reu et al., 2011). **Increasing vulnerability to heat and drought stress will likely lead to increased mortality and species extinction**. For example, temperature extremes have already been held responsible for mortality in Australian flying-fox species (Welbergen, Klose, Markus, and Eby 2008), and interactions between phenological changes driven by gradual climate changes and extreme events can lead to reduced fecundity (Campbell et al. 2009; Inouye, 2008). **Climate change also has the potential to facilitate the spread and establishment of invasive species** (pests and weeds) (Hellmann, Byers, Bierwagen, & Dukes, 2008; Rahel & Olden, 2008) **with often detrimental implications for ecosystem services and biodiversity**. Human land-use changes are expected to further exacerbate climate change driven ecosystem changes, particularly in the tropics, where rising temperatures and reduced precipitation are expected to have major impacts (Campbell et al., 2009; Lee & Jetz, 2008**). Ecosystems will be affected by the increased occurrence of extremes such as forest loss resulting from droughts and wildfire exacerbated by land use and agricultural expansion** (Fischlin et al., 2007). **Climate change also has the potential to catalyze rapid shifts in ecosystems such as sudden forest loss or regional loss of agricultural productivity resulting from desertification** (Barnosky et al., 2012). The predicted increase in extreme climate events would also drive dramatic ecosystem changes (Thibault and Brown 2008; Wernberg, Smale, and Thomsen 2012). One such extreme event that is expected to have immediate impacts on ecosystems is the increased rate of wildfire occurrence. Climate change induced shifts in the fire regime are therefore in turn powerful drivers of biome shifts, potentially resulting in considerable changes in carbon fluxes over large areas (Heyder et al., 2011; Lavorel et al., 2006) It is anticipated that global warming will lead to global biome shifts (Barnosky et al. 2012). Based on 20th century observations and 21st century projections, **poleward latitudinal biome shifts of up to 400 km** are possible in a 4° C world (Gonzalez et al., 2010). **In the case of mountaintop ecosystems,** for example, **such a shift is not necessarily possible, putting them at particular risk of extinction** (La Sorte and Jetz, 2010). **Species that dwell at the upper edge of continents or on islands would face a similar impediment to adaptation, since migration into adjacent ecosystems is not possible** (Campbell, et al. 2009; Hof, Levinsky, Araújo, and Rahbek 2011). The consequences of such geographical shifts, driven by climatic changes as well as rising CO2 concentrations, would be found in both reduced species richness and species turnover (for example, Phillips et al., 2008; White and Beissinger 2008). A study by (Midgley and Thuiller, 2011) found that, of 5,197 African plant species studied, 25–42 percent could lose all suitable range by 2085. **It should be emphasized that competition for space with human agriculture over the coming century is likely to prevent vegetation expansion in most cases** (Zelazowski et al., 2011) Species composition changes can lead to structural changes of the entire ecosystem, such as the increase in lianas in tropical and temperate forests (Phillips et al., 2008), and the encroachment of woody plants in temperate grasslands (Bloor et al., 2008, Ratajczak et al., 2012), putting grass-eating herbivores at risk of extinction because of a lack of food available—this is just one example of the sensitive intricacies of ecosystem responses to external perturbations**. There is also an increased risk of extinction for herbivores in regions of drought-induced tree dieback, owing to their inability to digest the newly resident C4 grasses** (Morgan et al., 2008). The following provides some examples of ecosystems that have been identified as particularly vulnerable to climate change. The discussion is restricted to ecosystems themselves, rather than the important and often extensive impacts on ecosystems services. Boreal-temperate ecosystems are particularly vulnerable to climate change, although there are large differences in projections, depending on the future climate model and emission pathway studied. Nevertheless there is a clear risk of large-scale forest dieback in the boreal-temperate system because of heat and drought (Heyder et al., 2011). Heat and drought related die-back has already been observed in substantial areas of North American boreal forests (Allen et al., 2010), characteristic of vulnerability to heat and drought stress leading to increased mortality at the trailing edge of boreal forests. The vulnerability of transition zones between boreal and temperate forests, as well as between boreal forests and polar/tundra biomes, is corroborated by studies of changes in plant functional richness with climate change (Reu et al., 2011), as well as analyses using multiple dynamic global vegetation models (Gonzalez et al., 2010). Subtle changes within forest types also pose a great risk to biodiversity as different plant types gain dominance (Scholze et al., 2006). Humid tropical forests also show increasing risk of major climate induced losses. At 4°C warming above pre-industrial levels, the land extent of humid tropical forest, characterized by tree species diversity and biomass density, is expected to contract to approximately 25 percent of its original size [see Figure 3 in (Zelazowski et al., 2011)], while at 2°C warming, more than 75 percent of the original land can likely be preserved. For these ecosystems, water availability is the dominant determinant of climate suitability (Zelazowski et al., 2011). In general, Asia is substantially less at risk of forest loss than the tropical Americas. However, even at 2°C, the forest in the Indochina peninsula will be at risk of die-back. At 4°C, the area of concern grows to include central Sumatra, Sulawesi, India and the Philippines, where up to 30 percent of the total humid tropical forest niche could be threatened by forest retreat (Zelazowski et al., 2011). There has been substantial scientific debate over the risk of a rapid and abrupt change to a much drier savanna or grassland ecosystem under global warming. This risk has been identified as a possible planetary tipping point at around a warming of 3.5–4.5°C, which, if crossed, would result in a major loss of biodiversity, ecosystem services and the loss of a major terrestrial carbon sink, increasing atmospheric CO2 concentrations (Lenton et al., 2008)(Cox, et al., 2004) (Kriegler, Hall, Held, Dawson, and Schellnhuber, 2009). Substantial uncertainty remains around the likelihood, timing and onset of such risk due to a range of factors including uncertainty in precipitation changes, effects of CO2 concentration increase on water use efficiency and the CO2 fertilization effect, land-use feedbacks and interactions with fire frequency and intensity, and effects of higher temperature on tropical tree species and on important ecosystem services such as pollinators. While climate model projections for the Amazon, and in particular precipitation, remain quite uncertain recent analyses using IPCC AR4 generation climate indicates a reduced risk of a major basin wide loss of precipitation compared to some earlier work. If drying occurs then the likelihood of an abrupt shift to a drier, less biodiverse ecosystem would increase. Current projections indicate that fire occurrence in the Amazon could double by 2050, based on the A2 SRES scenario that involves warming of approximately 1.5°C above pre-industrial levels (Silvestrini et al., 2011), and can therefore be expected to be even higher in a 4°C world. Interactions of climate change, land use and agricultural expansion increase the incidence of fire (Aragão et al., 2008), which plays a major role in the (re)structuring of vegetation (Gonzalez et al., 2010; Scholze et al., 2006). A decrease in precipitation over the Amazon forests may therefore result in forest retreat or transition into a low biomass forest (Malhi et al., 2009). Moderating this risk is a possible increase in ecosystem water use efficiency with increasing CO2 concentrations is accounted for, more than 90 percent of the original humid tropical forest niche in Amazonia is likely to be preserved in the 2°C case, compared to just under half in the 4°C warming case (see Figure 5 in Zelazowski et al., 2011) (Cook, Zeng, and Yoon, 2012; Salazar & Nobre, 2010). Recent work has analyzed a number of these factors and their uncertainties and finds that the risk of major loss of forest due to climate is more likely to be regional than Amazon basin-wide, with the eastern and southeastern Amazon being most at risk (Zelazowski et al., 2011). Salazar and Nobre (2010) estimates a transition from tropical forests to seasonal forest or savanna in the eastern Amazon could occur at warming at warming of 2.5–3.5°C when CO2 fertilization is not considered and 4.5–5.5°C when it is considered. It is important to note, as Salazar and Nobre (2010) point out, that the effects of deforestation and increased fire risk interact with the climate change and are likely to accelerate a transition from tropical forests to drier ecosystems. Increased CO2 concentration may also lead to increased plant water efficiency (Ainsworth and Long, 2005), lowering the risk of plant die-back, and resulting in vegetation expansion in many regions, such as the Congo basin, West Africa and Madagascar (Zelazowski et al., 2011), in addition to some dry-land ecosystems (Heyder et al., 2011). The impact of CO2 induced ‘greening’ would, however, negatively affect biodiversity in many ecosystems. In particular encroachment of woody plants into grasslands and savannahs in North American grassland and savanna communities could lead to a decline of up to 45 percent in species richness ((Ratajczak and Nippert, 2012) and loss of specialist savanna plant species in southern Africa (Parr, Gray, and Bond, 2012). Mangroves are an important ecosystem and are particularly vulnerable to the multiple impacts of climate change, such as: rise in sea levels, increases in atmospheric CO2 concentration, air and water temperature, and changes in precipitation patterns. Sea-level rise can cause a loss of mangroves by cutting off the flow of fresh water and nutrients and drowning the roots (Dasgupta, Laplante et al. 2010). By the end of the 21st century, global mangrove cover is projected to experience a significant decline because of heat stress and sea-level rise (Alongi, 2008; Beaumont et al., 2011). In fact, it has been estimated that under the A1B emissions scenario (3.5°C relative to pre-industrial levels) mangroves would need to geographically move on average about 1 km/year to remain in suitable climate zones (Loarie et al., 2009). The most vulnerable mangrove forests are those occupying low-relief islands such as small islands in the Pacific where sea-level rise is a dominant factor. Where rivers are lacking and/ or land is subsiding, vulnerability is also high. With mangrove losses resulting from deforestation presently at 1 to 2 percent per annum (Beaumont et al., 2011), climate change may not be the biggest immediate threat to the future of mangroves. However if conservation efforts are successful in the longer term climate change may become a determining issue (Beaumont et al., 2011). Coral reefs are acutely sensitive to changes in water temperatures, ocean pH and intensity and frequency of tropical cyclones. Mass coral bleaching is caused by ocean warming and ocean acidification, which results from absorption of CO2 (for example, Frieler et al., 2012a). Increased sea-surface temperatures and a reduction of available carbonates are also understood to be driving causes of decreased rates of calcification, a critical reef-building process (De’ath, Lough, and Fabricius, 2009). The effects of climate change on coral reefs are already apparent. The Great Barrier Reef, for example, has been estimated to have lost 50 percent of live coral cover since 1985, which is attributed in part to coral bleaching because of increasing water temperatures (De’ath et al., 2012). Under atmospheric CO2 concentrations that correspond to a warming of 4°C by 2100, reef erosion will likely exceed rates of calcification, leaving coral reefs as “crumbling frameworks with few calcareous corals” (Hoegh-Guldberg et al., 2007). In fact, frequency of bleaching events under global warming in even a 2°C world has been projected to exceed the ability of coral reefs to recover. The extinction of coral reefs would be catastrophic for entire coral reef ecosystems and the people who depend on them for food, income and shoreline. Reefs provide coastal protection against coastal floods and rising sea levels, nursery grounds and habitat for a variety of currently fished species, as well as an invaluable tourism asset. These valuable services to often subsistence-dependent coastal and island societies will most likely be lost well before a 4°C world is reached. The preceding discussion reviewed the implications of a 4°C world for just a few examples of important ecosystems. The section below examines the effects of climate on biological diversity **Ecosystems are composed ultimately of the species and interactions between them and their physical environment. Biologically rich ecosystems are usually diverse and it is broadly agreed that there exists a strong link between this biological diversity and ecosystem productivity**, stability and functioning (McGrady-Steed, Harris, and Morin, 1997; David Tilman, Wedin, and Knops, 1996)(Hector, 1999; D Tilman et al., 2001). Loss of species within ecosystems will hence have profound negative effects on the functioning and stability of ecosystems and on the ability of ecosystems to provide goods and services to human societies. It is the overall diversity of species that ultimately characterizes the biodiversity and evolutionary legacy of life on Earth. As was noted at the outset of this discussion, **species extinction rates are now at very high levels compared to the geological record. Loss of those species presently classified as ‘critically endangered’ would lead to mass extinction on a scale that has happened only five times before in the last 540 million years. The loss of those species classified as ‘endangered’ and ‘vulnerable’ would confirm this loss as the sixth mass extinction episode** (Barnosky 2011). Loss of biodiversity will challenge those reliant on ecosystems services. Fisheries (Dale, Tharp, Lannom, and Hodges, 2010), and agronomy (Howden et al., 2007) and forestry industries (Stram & Evans, 2009), among others, will need to match species choices to the changing climate conditions, while devising new strategies to tackle invasive pests (Bellard, Bertelsmeier, Leadley, Thuiller, and Courchamp, 2012). These challenges would have to be met in the face of increasing competition between natural and agricultural ecosystems over water resources. **Over the 21st-century climate change is likely to result in some bio-climates disappearing,** notably in the mountainous tropics and in the poleward regions of continents, **with new**, or novel, **climates** **developing** in the tropics and subtropics (Williams, Jackson, and Kutzbach, 2007). In this study **novel climates are those where 21st century projected climates do not overlap with their 20th century analogues, and disappearing climates are those 20th century climates that do not overlap with 21st century projected climates**. The projections of Williams et al (2007) indicate that in a 4°C world (SRES A2), 12–39 percent of the Earth’s land surface may experience a novel climate compared to 20th century analogues. Predictions of species response to novel climates are difficult because researchers have no current analogue to rely upon. However, at least such climates would give rise to disruptions, with many current species associations being broken up or disappearing entirely. Under the same scenario an estimated 10–48 percent of the Earth’s surface including highly biodiverse regions such as the Himalayas, Mesoamerica, eastern and southern Africa, the Philippines and the region around Indonesia known as Wallacaea would lose their climate space. With limitations on how fast species can disperse, or move, this indicates that many species may find themselves without a suitable climate space and thus face a high risk of extinction. Globally, as in other studies, there is a strong association apparent in these projections between regions where the climate disappears and biodiversity hotspots. Limiting warming to lower levels in this study showed substantially reduced effects, with the magnitude of novel and disappearing climates scaling linearly with global mean warming. More recent work by Beaumont and colleagues using a different approach confirms the scale of this risk (Beaumont et al., 2011, Figure 36). Analysis of the exposure of 185 eco-regions of exceptional biodiversity (a subset of the so-called Global 200) to extreme monthly temperature and precipitation conditions in the 21st century compared to 1961–1990 conditions shows that within 60 years almost all of the regions that are already exposed to substantial environmental and social pressure, will experience extreme temperature conditions based on the A2 emission scenario (4.1°C global mean temperature rise by 2100) (Beaumont et al., 2011). Tropical and sub-tropical eco-regions in Africa and South America are particularly vulnerable. Vulnerability to such extremes is particularly acute for high latitude and small island biota, which are very limited in their ability to respond to range shifts, and to those biota, such as flooded grassland, mangroves and desert biomes, that would require large geographical displacements to find comparable climates in a warmer world. The overall sense of recent literature confirms the findings of the AR4 summarized at the beginning of the section, with a number of risks such as those to coral reefs occurring at significantly lower temperatures than estimated in that report. **Although non-climate related human pressures are likely to remain a major and defining driver of loss of ecosystems and biodiversity in the coming decades, it is also clear that as warming rises so will the predominance of climate change as a determinant of ecosystem and biodiversity survival. While the factors of human stresses on ecosystems are manifold,** in a 4°C world, climate change is likely to become a determining driver of ecosystem shifts and large-scale biodiversity loss (Bellard et al., 2012; New et al., 2011). Recent research suggests that large-scale loss of biodiversity is likely to occur in a 4°C world, with climate change and high CO2 concentration driving a transition of the Earth´s ecosystems into a state unknown in human experience. Such damages to ecosystems would be expected to dramatically reduce the provision of ecosystem services on which society depends (e.g., hydrology—quantity flow rates, quality; fisheries (corals), protection of coastline (loss of mangroves). Barnosky has described the present situation facing the biodiversity of the planet as “the perfect storm” with multiple high intensity ecological stresses because of habitat modification and degradation, pollution and other factors, unusually rapid climate change and unusually high and elevated atmospheric CO2 concentrations. In the past, as noted above, **this combination of circumstances has led to major, mass extinctions with planetary consequences. Thus, there is a growing risk that climate change, combined with other human activities, will cause the irreversible transition of the Earth´s ecosystems into a state unknown in human experience** (Barnosky et al., 2012).

1. **Carbon Dioxide**

#### Current Carbon emissions guarantee ocean acidification – only reversing these trends ensures ocean resiliency – the alternative collapses marine life

Potsdam Institute, 2012 (Potsdam Institute for Climate Impact Research and Climate Analytics, “Turn Down the Heat: Why a 4°C Warmer World Must be Avoided”, A report for the World Bank, November, http://climatechange.worldbank.org/sites/default/files/Turn\_Down\_the\_heat\_Why\_a\_4\_degree\_centrigrade\_warmer\_world\_must\_be\_avoided.pdf)

The high emission scenarios would also result in very high carbon dioxide concentrations and ocean acidification, as can be seen in Figure 25 and Figure 26. **The increase of carbon dioxide** concentration to the present-day value of 390 ppm **has caused the pH to drop by 0.1 since** **preindustrial conditions.** **This has increased ocean acidity**, which because of the logarithmic scale of pH is equivalent to a **30 percent** increase in ocean acidity (concentration of hydrogen ions). **The scenarios of 4°C warming** or more by 2100 **correspond to a carbon dioxide concentration of above 800 ppm and lead to a further decrease of pH by another 0.3**, equivalent to a 150 percent acidity increase since preindustrial levels. **Ongoing ocean acidification is likely to have very severe consequences for coral reefs**, various species of **marine** calcifying **organisms**, **and ocean ecosystems** generally (for example, Vézina & Hoegh-Guldberg 2008; Hofmann and Schellnhuber 2009). **A recent review shows that the degree and timescale of ocean acidification resulting from anthropogenic CO2 emissions appears to be greater than during any of the ocean acidification events identified so far over the geological past**, **dating back millions of years and including several mass extinction** events (Zeebe 2012). If atmospheric CO2 reaches 450 ppm, coral reef growth around the world is expected to slow down considerably and at 550 ppm reefs are expected to start to dissolve (Cao and Caldeira 2008; Silverman et al. 2009). Reduced growth, coral skeleton weakening, and increased temperature dependence would start to affect coral reefs already below 450 ppm. Thus, a CO2 level of below 350 ppm appears to be required for the long-term survival of coral reefs, if multiple stressors, such as high ocean surface-water temperature events, sea-level rise, and deterioration in water quality, are included (Veron et al. 2009). Based on an estimate of the relationship between atmospheric carbon dioxide concentration and surface ocean acidity (Bernie, Lowe, Tyrrell, and Legge 2010), only very low emission scenarios are able to halt and ultimately reverse ocean acidification (Figure 26). An important caveat on these results is that the approach used here is likely to be valid only for relatively short timescales. **If mitigation measures are not implemented soon to reduce carbon dioxide emissions, then** ocean acidification can be expected to extend into the deep ocean. **The calculations shown refer only to the response of the ocean surface layers, and once ocean acidification has spread more thoroughly, slowing and reversing this will be much more difficult.** This would further add significant stress to marine ecosystems already under pressure from human influences, such as overfishing and pollution.

#### Extinction

Kristof 6 (NICHOLAS D. KRISTOF, American journalist, author, op-ed columnist, and a winner of two Pulitzer Prizes, “Scandal Below the Surface”, Oct 31, 2006, http://select.nytimes.com/2006/10/31/opinion/31kristof.html?\_r=1, CMR)

If you think of the earth’s surface as a great beaker, then it’s filled mostly with ocean water. It is slightly alkaline, and that’s what creates a hospitable home for fish, coral reefs and plankton — and indirectly, higher up the food chain, for us. But scientists have discovered that the carbon dioxide (**CO2) we’re spewing** into the air doesn’t just heat up the atmosphere and lead to rising seas. Much of that carbon is absorbed by the oceans, and there it produces carbonic acid — the same stuff found in soda pop. That **makes oceans** a bit **more acidic**, impairing the ability of certain shellfish to produce shells, which, like coral reefs, are made of calcium carbonate. A recent article in Scientific American explained the indignity of being a dissolving mollusk in an acidic ocean: “Drop a piece of chalk (calcium carbonate) into a glass of vinegar (a mild acid) if you need a demonstration of the general worry: the chalk will begin dissolving immediately.” The more acidic waters may spell the end, at least in higher latitudes, of some of the tiniest variations of shellfish — certain plankton and tiny snails called pteropods. **This would** disrupt the food chain, possibly killing off many whales and fish, and **rippling up all the way to humans**. We stand, so to speak, on the shoulders of plankton. “There have been a couple of very big events in geological history where the carbon cycle changed dramatically,” said Scott Doney, senior scientist at the Woods Hole Oceanographic Institution in Massachusetts. One was an abrupt warming that took place 55 million years ago in conjunction with acidification of the oceans and **mass extinctions**. Most scientists don’t believe we’re headed toward a man-made variant on that episode — not **yet**, at any rate. But many worry that **we’re hurtling into unknown dangers.** “Whether in 20 years or 100 years, I think **marine ecosystems are going to be dramatically different** by the end of this century, **and that’ll lead to** extinction events,” Mr. Doney added. “This is the only habitable planet we have,” he said. “The **damage** we do **is going to be felt by all the** generations to come.” So that should be one of the great political issues for this century — the vandalism we’re committing to our planet because of our refusal to curb greenhouse gases. Yet the subject is barely debated in this campaign. Changes in ocean chemistry are only one among many damaging consequences of carbon emissions. Evidence is also growing about the more familiar dangers: melting glaciers, changing rainfall patterns, rising seas and more powerful hurricanes. Last year, the World Health Organization released a study indicating that climate change results in an extra 150,000 deaths and five million sicknesses each year, by causing the spread of malaria, diarrhea, malnutrition and other ailments. A report prepared for the British government and published yesterday, the Stern Review on the Economics of Climate Change, warned that inaction “could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century.” If emissions are not curbed, climate change will cut 5 percent to 20 percent of global G.D.P. each year, declared the mammoth report. “In contrast,” it said, “the costs of action — reducing greenhouse gas emissions to avoid the worst impacts of climate change — can be limited to around 1 percent of global G.D.P. each year.” Some analysts put the costs of action higher, but most agree that it makes sense to invest far more in alternative energy sources, both to wean ourselves of oil and to reduce the strain on our planet. We know what is needed: a carbon tax or cap-and-trade system, a post-Kyoto accord on emissions cutbacks, and major research on alternative energy sources. But as The Times’s Andrew Revkin noted yesterday, spending on energy research and development has fallen by more than half, after inflation, since 1979.

#### Nuclear power is critical to reducing emissions and preventing catastrophic global warming

Deutch et. al, 2009 (John, Professor of Chemistry MIT; Dr. Charles Forsberg, Executive Director of the MIT Nuclear Fuel Cycle Study – Dept. of Nuclear Science and Engineering; Andrew Kadak, Professor of Dept of Nuclear Science and Engineering; Mujid Kazimi, TEPCO professor of nuclear engineering and mechanical engineering; Ernest Moniz, Cecil and Ida Green Professor of Physics and Engineering Systems; John E. Parsons, Executive Director of MIT Center for Energy and Environmental Policy Research; “Update of the MIT 2003 Future of Nuclear Power”, MIT Energy Initiative, http://web.mit.edu/nuclearpower/pdf/nuclearpower-update2009.pdf)

Concern with avoiding the adverse consequences of climate change has increased significantly in the past five years 2 . The United States has not adopted a comprehensive climate change policy, although President Obama is pledged to do so. Nor has an agreement been reached with the emerging rapidly-growing economies such as China, India, Indonesia, and Mexico, about when and how they will adopt greenhouse gas emission constraints. With global greenhouse gas emissions projected to continue to increase, there is added urgency both to achieve greater energy efficiency and to pursue all measures to develop and deploy carbon free energy sources. Nuclear power, fossil fuel use accompanied by carbon dioxide capture and sequestration, and renewable energy technologies (wind, biomass, geothermal, hydro and solar) are important options for achieving electricity production with small carbon footprints. Since the 2003 report, interest in using electricity for plug-in hybrids and electric cars to replace motor gasoline has increased, thus placing an even greater importance on exploiting the use of carbon-free electricity generating technologies. At the same time, as discussed in the MIT report The Future of Coal 3 , little progress has been made in the United States in demonstrating the viability of fossil fuel use with carbon capture and sequestration—a major “carbon-free” alternative to nuclear energy for base-load electricity. With regard to nuclear power, while there has been some progress since 2003, increased deployment of nuclear power has been slow both in the United States and globally, in relation to the illustrative scenario examined in the 2003 report. While the intent to build new plants has been made public in several countries, there are only few firm commitments outside of Asia, in particular China, India, and Korea, to construction projects at this time. Even if all the announced plans for new nuclear power plant construction are realized, the total will be well behind that needed for reaching a thousand gigawatts of new capacity worldwide by 2050. In the U.S., only one shutdown reactor has been refurbished and restarted and one previously ordered, but never completed reactor, is now being completed. No new nuclear units have started construction. In sum, compared to 2003, the motivation to make more use of nuclear power is greater, and more rapid progress is needed in enabling the option of nuclear power expansion to play a role in meeting the global warming challenge. The sober warning is that if more is not done, nuclear power will diminish as a practical and timely option for deployment at a scale that would constitute a material contribution to climate change risk mitigation.

### Contention two – nuclear leadership

#### US Nuclear leadership is decline

Michael Wallace & George David Banks, June 14, 2013 (Wallace - Director and Senior Adviser, Nuclear Energy Program/ Banks - Senior Fellow and Deputy Director, Nuclear Energy Program) “A National Security Imperative”, (<http://csis.org/publication/restoring-us-leadership-nuclear-energy>) DA: 8/28/14

The United States' nuclear energy industry is in decline. Low natural gas prices, financing hurdles, failure to find a permanent repository for high-level nuclear waste, reactions to the Fukushima accident in Japan, and other factors are hastening the day when existing U.S. reactors become uneconomic. The decline of the U.S. nuclear energy industry could be much more rapid than policymakers and stakeholders anticipate. China, India, Russia, and others plan on adding nuclear technology to their mix, furthering the spread of nuclear materials around the globe. U.S. companies must meet a significant share of this demand for nuclear technology, but U.S. firms are currently at a competitive disadvantage due to restrictive and otherwise unsupportive export policies. Without a strong commercial presence in new markets, the United States' ability to influence nonproliferation policies and nuclear safety behaviors worldwide is bound to diminish. The United States cannot afford to become irrelevant in a new nuclear age.

#### Key to stop proliferation

Pete. V. Domenici & Dr. Warren F. Miller, September 2012 Pietro Vichi "Pete" Domenici (born May 7, 1932) is an American Republican politician, who served six terms as a United States Senator from New Mexico, from 1973 to 2009, the longest tenure in the state's history. Warren F. Miller, Jr., PhD, is an assistant secretary for nuclear energy at the U.S. Department of Energy “Maintaining US leadership in Global Nuclear Energy Markets” (<http://bipartisanpolicy.org/sites/default/files/Nuclear%20Report.PDF> Page 8) DA: August 28, 2014

Another critical factor for the nuclear energy industry—one that affects both existing reactors and the prospects for building new reactors—is the need to execute an effective strategy for storing and disposing spent nuclear fuel. While the current practice of storing this material on-site at operating and at shut-down reactors is sate, it is not an acceptable long-term strategy. The federal government is legally obligated to take title to the spent fuel and its failure to do so has made American taxpayers liable for billions of dollars in damages. With the world's largest commercial nuclear fleet, the United States was once the world's leader in nuclear technology development and operations. In recent years, other countries, notably France and South Korea, have risen in international prominence; these countries will continue to develop technologies (or domestic markets as well as to export. It will be increasingly difficult for the United States to maintain its technological leadership without some near\* term domestic demand for new construction. Diminished U.S. leadership will make U.S. drums less competitive in nuclear export markets while also reducing U.S. influence over nuclear developments abroad. As more countries seek to develop nuclear capacity, the United States must work with the international community to minimize the risk of nuclear weapons proliferation. Our event series explored several of these challenges and sought to identify areas where federal policy can most effectively address barriers to maintaining a viable domestic nuclear industry. We also believe that federal policy can help support U.S. leadership in international nuclear issues. The next section reviews near-term prospects for nuclear power domestically and internationally by highlighting the importance of continued U.S. leadership.

#### Prolif causes conflict escalation and nuclear war – deterrence doesn’t check

Muller 2008 [Harald, Executive Director, Head of Research Department (RD) Peace Research Institute of Frankfurt, “The Future of Nuclear Weapons in an Interdependent World” The Washington Quarterly, Spring, http://www.twq.com/08spring/docs/08spring\_muller.pdf]

**A world populated by many nuclear-weapon states poses grave dangers. Regional conflicts could escalate to the nuclear level. The optimistic expectation of a universal law according to which nuclear deterrence prevents all wars** **rests on scant historical evidence and is dangerously naive. Nuclear uses in one part of the world could trigger “catalytic war” between greater powers, drawing them into smaller regional conflicts**, particularly if tensions are high. This was always a fear during the Cold War, and it motivated nonproliferation policy in the first place. Moreover, **the more states that possess nuclear weapons and related facilities, the more points of access are available to terrorists**.

#### Snowball effect ensures extinction

National Journal 9-14-2K2 (“Invading Iraq Wouldn't Necessarily Make Us Safer”) (<http://www.nationaljournal.com/magazine/column-invading-iraq-wouldn-39-t-necessarily-make-us-safer-20020914>)

That risk dwarfs anything that Saddam Hussein could do with chemical or biological weapons. And even if he drops dead tomorrow, **it is** quite **probable** that **we will experience** such a **catastrophe within 20 years-if not 20 months**-unless we do two things that are barely on the national radar screen and that go against the grain of Republican unilateralism. The first is to spend whatever it takes to secure the vast Russian nuclear stockpile and other nuclear installations around the world. They are far more dangerous than Saddam because there is no doubt that Al Qaeda (and perhaps other terrorists) will use any unsecured weapons or fissile (bomb-making) materials against us if they can get ahold of them. The second is to get much, much more serious about stopping the proliferation of nuclear weapons, which is a huge threat to civilization itself. A push to end nuclear proliferation could work only if enforced by the threat or use of pre-emptive military action-not only in Iraq but also in Iran, North Korea, Libya, and perhaps others of the more than 60 nations capable of building nuclear weapons-either on our own or through an international coalition. Doing this on our own, as Bush administration hawks prefer, could mean launching bloody invasion after invasion, at enormous cost in lives, treasure, and international standing, if rogue states call our bluff. Rallying a potent and determined coalition seems possible only if we stop thumbing our nose at world opinion, offer to scrap the bulk of our own arsenal, and renounce first use of nuclear weapons in exchange for similar concessions by others. The truth is, no matter what we do about Iraq, **if we don't stop proliferation, another five or 10** potentially **unstable nations may go nuclear** before long, **making it** ever more **likely that** one or more **bombs will be set off** anonymously on our soil by terrorists or a terrorist government. **Even an airtight missile defense would be useless against a nuke hidden** in a truck, a shipping container, or a boat. As to Iraq, unless we can get U.N. Security Council support for whatever we decide to do (on which, more below), either a go-it-alone U.S.-British invasion or a Bush backdown from the beating of war drums would carry incalculable risks. An invasion would, of course, end Saddam's quest for nuclear weapons and probably Saddam himself. So far, so good. But some hawks greatly underestimate the costs and risks, claiming that an easy victory in Iraq will lead to a flowering of democracy that will inspire the rest of the Arab world to follow suit, destroy the appeal of militant Islam, pave the way for Israeli-Palestinian peace, and make us all safer. This is a fantasy. Unless Saddam is overthrown from within, we would have to take Baghdad in house-to-house fighting, with many thousands of casualties. The task of pacifying and democratizing a nation that has never known freedom and hates our ally Israel would be at least as difficult as bringing peace and democracy to Afghanistan. And the administration has not made a very credible beginning there. The effects of a unilateral invasion on our national security would extend far beyond Iraq. Viewed optimistically, it might also-if accompanied by a credible threat to launch a succession of pre-emptive wars-convince Iran, Libya, North Korea, and other potential threats that we would do the same to them if they persist in developing nuclear weapons. But then again, rogue nations might react by hiding, rather than ending, their bomb- building programs. And as the cost of a policy of pre-emptive wars without end becomes apparent, American voters might balk. A U.S.-British invasion would also divert resources from the war against Al Qaeda, especially in Afghanistan, where Al Qaeda is already regrouping. It would alienate Russia and others whose cooperation we need in the vital project of securing fissile materials. It would thereby increase the danger of a nuclear attack by Al Qaeda or others. By enraging hundreds of millions of Muslims worldwide, it would swell the ranks of terrorist groups-perhaps making it easier for them to recruit nuclear engineers as well as suicide bombers-and risk a militant Islamist takeover of nuclear-armed Pakistan. Years or even decades of sometimes-bloody occupation could keep the hate- America pot boiling. With Kurds in the north and Shiites in the south demanding independence, we would have to choose between crushing those movements and alienating Turkey, a vital ally with a region of restive Kurds bordering Iraq. Many in Europe and elsewhere would see the Bush administration as less interested in democratizing Iraq than in controlling the region's oil and in achieving world domination. All of this international ill will could doom any hope for support in fighting nuclear proliferation. Does all of this mean that a unilateral invasion should be ruled out as complete folly? Not necessarily. The dangers of backing down are also grave. It is foolish for doves to scoff at the risk that a nuclear-armed Saddam could or would launch what they say would be a "suicidal" attack on the United States. He seems entirely capable of smuggling a bomb into one of our cities, perhaps in league with Al Qaeda, and setting it off anonymously in the hope of escaping retaliation. If we stand aside while Saddam builds or buys nuclear weapons, and if at some point thereafter a bomb takes out Washington or New York, how could we be sure that Saddam was involved? The culprits might be terrorists connected, not to Iraq, but perhaps to Pakistan, North Korea, Iran, or Libya. Against whom would we retaliate? Doves also seem disingenuous in ruling out an invasion unless and until we can produce irrefutable evidence that Saddam presents an imminent nuclear threat. Most would be no less dovish after seeing such proof than they are now. After all, once Iraq has nuclear arms, an invasion would be far more perilous. So a decision not to invade now is a decision not to invade ever-not, at least, until Saddam has actually used nuclear or biological weapons or repeated his use of chemical weapons. And a Bush backdown now would surely embolden other rogue states to accelerate their nuclear programs. In short, the future will be extremely dangerous no matter what we do about Iraq. The best way out would be to use the threat of a unilateral invasion to push the U.N. Security Council to demand that Iraq submit to unconditional, unrestricted arms inspections, as proposed by President Chirac of France, followed by military action if Saddam balks or cheats or it becomes clear that inspections cannot be effective. France and Russia might go along, suggests a former Clinton administration official, if that were the only way to get a piece of the post- invasion protectorate over the world's second-largest oil supply. We should not become so fixated on Iraq that we ignore the greater dangers: Al Qaeda, loose nuclear materials in Russia and elsewhere, and nuclear proliferation. House Republicans have idiotically refused to provide adequate funding to secure nuclear stockpiles abroad. They and the Bush administration have greatly damaged the effectiveness of the Nuclear Nonproliferation Treaty by spurning the closely related Comprehensive Test Ban Treaty, without which more and more nations will be tempted to seek nuclear weapons. **Unless we get serious about stopping proliferation, we are headed for "a world filled with nuclear-weapons states, where every crisis threatens to go nuclear," where "the survival of civilization truly is in question** from day to day," **and where "it would be impossible to keep these weapons out of the hands of** terrorists, **religious cults, and criminal organizations**." So writes Ambassador Thomas Graham Jr., a moderate Republican who served as a career arms-controller under six presidents and led the successful Clinton administration effort to extend the Nuclear Nonproliferation Treaty. The only way to avoid such a grim future, he suggests in his memoir, Disarmament Sketches, is for the United States to lead an international coalition against proliferation by showing an unprecedented willingness to give up the vast majority of our own nuclear weapons, excepting only those necessary to deter nuclear attack by others.

#### Your statistical authors concede the consequence of failed proliferation is high enough to outweigh potential pacifying effects

Asal, Professor of Political Science at State U of New York, and Beardsley**,** Professor of Political Science at Emory University, ‘7 (Victor and Kyle, “Proliferation and International Crisis Behavior” Journal of Peace Research, Vol 44 No 2, p 139-155, SagePub)

Our findings shed light only on the general impact that increasing the number of nuclear participants in a crisis has on the outcome of that crisis. **We do not address other potential perils that proliferation might bring, such as greater risks of accident or the higher risks of use by terrorist networks. The pacification effect of nuclear states in crises is only one of many important factors to consider when states adopt their proliferation stances. And it should not be lost that the pacification effect is only so strong, as some serious violent conflicts have occurred between nuclear-weapon states**. Zagare & Kilgour (2000) demonstrate that **deterrence can fail in any number of situations. The costs of failed deterrence are so great when there are nuclear weapons involved that policymakers must seriously weigh the benefits of decreasing the likelihood of deterrence failure with increasing the costs of each failure instance**.

#### SMR’s are key – alternative financing ensures stable global modeling

Mandel 9 – Writer for Scientific American(Jenny, “Less Is More for Designers of "Right-Sized" Nuclear Reactors”, Sep 9, 2009, <http://www.scientificamerican.com/article/small-nuclear-power-plant-station-mini-reactor/>, Daehyun)

Tom Sanders, president of the American Nuclear Society and manager of Sandia National Laboratories' Global Nuclear Futures Initiative, has been stumping for small rectors for more than a decade. American-made small reactors, Sanders insists, can play a central role in global nonproliferation efforts. "Our role at Sandia is the national security-driven notion that it's in the interests of the U.S. to be one of the dominant nuclear suppliers," Sanders said. While U.S. companies have been exiting the industry over the past decades as government and popular support for new construction has waned, Sanders maintains that strong U.S. participation in the nuclear energy marketplace would give diplomats a new tool to use with would-be nuclear powers. "It's hard to tell Iran what to do if you don't have anything Iran wants," he explained. Sanders said mini-reactors are ideal to sell to developing countries that want to boost their manufacturing might and that would otherwise look to other countries for nuclear technologies. If the United States is not participating in that market, he said, it becomes hard to steer buyers away from technologies that pose greater proliferation risks. Sanders been promoting this view since the 1990s, he said, when he realized "we were no longer selling nuclear goods and services, so we could no longer write the rules." The domestic nuclear industry had basically shut down, with no new construction in decades and a flight of talent and ideas overseas. There is a silver lining in that brain drain, though, he believes, in that U.S. companies getting back into the game now are less tied to the traditional, giant plants and are freer to innovate. A feature that several of the new product designs share is that the power plants could be mass-produced in a factory to minimize cost, using robots to ensure consistency. Also, with less design work for each installation, the time to complete an order would be shortened and some of the capital and other costs associated with long lead times avoided, Sanders said. Another feature he favors is building the plants with a lifetime supply of fuel sealed inside. Shipped loaded with fuel, such reactors could power a small city for 20 years without the host country ever handling it. Once depleted, the entire plant would be packed back up and shipped back to the United States, he said, with the sensitive spent fuel still sealed away inside. Sanders is working on a reactor design hatched by the lab with an undisclosed private partner. He believes it is feasible to build a prototype modular reactor -- including demonstration factory components and a mockup of the reactor itself -- as early as 2014, for less than a billion dollars. A mini-reactor could ring up at less than $200 million, he said, or at $300 million to $400 million with 20 years of fuel. At $3,000 to $4,000 per kilowatt, he said, that would amount to significant savings over estimates of $4,000 to $6,000 per kilowatt for construction alone with traditional plant designs. To get a design ready to build, Sanders is urging a partnership between the government and the private sector. "If it's totally a government research program, labs can take 20 to 30 years" to finish such projects, he said. "If it becomes a research science project, it could go on forever." New approach, old debates So far, there is no sign that the government's nuclear gatekeeper, NRC, is wowed by the small-reactor designs. NRC's Office of New Reactors warned Babcock & Wilcox in June that the agency "will need to limit interactions with the designers of small power reactors to occasional meetings or other nonresource-intensive activities" over the next two years because of a crowded schedule of work on other proposals. Meanwhile, opponents of nuclear technologies are not convinced that small reactors are an improvement over traditional designs. Arjun Makhijani, who heads the Institute for Energy and Environmental Research, a think tank that advocates against nuclear power, sees disseminating the technology as incompatible with controlling it. "A lot of the proliferation issue is not linked to having or not having plutonium or highly enriched uranium, but who has the expertise to have or make bombs," Makhijani said. "In order to spread nuclear technologies, you have to have the people who have the expertise in nuclear engineering, who know about nuclear materials and chain reactions and things like that -- the same expertise for nuclear bombs. That doesn't suffice for you to make a bomb, but then if you clandestinely acquire the materials, then you can make a bomb." Peter Wilk, acting program director for safe energy with Physicians for Social Responsibility, an anti-nuclear group, argues that expanding nuclear power use runs counter to the goal of nonproliferation. "The whole proposition presupposes an ... international economy in which more and more fuel is produced and more and more waste must be dealt with, which only makes those problems that are still unsolved larger," he said. "It may or may not do a better job of preventing the host country from literally getting their hands on it, but it doesn't reduce the amount of fuel in the world or the amount of waste in the world," Wilk added. And then there is the issue of public opinion. "Imagine that Americans would agree to take the waste that is generated in other countries and deal with it here," Makhijani said. "At the present moment, it should be confined to the level of the fantastic, or even the surreal. If [the technology's backers] could come up with a plan for the waste, then we could talk about export." Makhijani pointed to a widely touted French process for recycling nuclear waste as a red herring (ClimateWire, May 18). "It's a mythology that it ameliorates the waste problem," he said. According to Makhijani's calculations, the French recycling process generates far more radioactive waste than it cleans up. One category of highly radioactive material, which ends up stored in glass "logs" for burial, is reduced, he said. But in processing the waste, about six times the original volume of waste is produced, he said. Much of that must be buried deep underground, and the discharge of contaminated wastewater used in recycling has angered neighboring countries, he said. Operational risk, of course, is another major concern. "One has reduced the amount of unnecessary risk," Wilke said, "but it's still unnecessary risk." He added, "I get the theory that smaller, newer, ought to be safer. The question is: Why pursue this when there are so many better alternatives?" To Sandia's Sanders, Wilke is asking the wrong question. With the governments of major economies like China, Russia and Japan putting support and cash into nuclear technologies, the power plants are here to stay, he believes. "There's going to be a thousand reactors built over the next 50 years," he said. "The question is: Are we building them, or are we just importing them?"

### Contention three - solvency

#### Nuclear is inevitable globally but won’t solve warming until the US develops SMR’s

Lovering et al 2012 – et al and Ted Nordhaus—co-founders of American Environics and the Breakthrough Institute a think tank that works on energy and climate change – AND – Jesse Jenkins-Director of Energy and Climate Policy, the Breakthrough Institute (Michael, Why We Need Radical Innovation to Make New Nuclear Energy Cheap, 9/11, thebreakthrough.org/index.php/programs/energy-and-climate/new-nukes/)

Arguably, the biggest impact of Fukushima on the nuclear debate, ironically, has been to force a growing number of pro-nuclear environmentalists out of the closet, including us. The reaction to the accident by anti-nuclear campaigners and many Western publics put a fine point on the gross misperception of risk that informs so much anti-nuclear fear. Nuclear remains the only proven technology capable of reliably generating zero-carbon energy at a scale that can have any impact on global warming. Climate change -- and, for that matter, the enormous present-day health risks associated with burning coal, oil, and gas -- simply dwarf any legitimate risk associated with the operation of nuclear power plants. About 100,000 people die every year due to exposure to air pollutants from the burning of coal. By contrast, about 4,000 people have died from nuclear energy -- ever -- almost entirely due to Chernobyl.¶ But rather than simply lecturing our fellow environmentalists about their misplaced priorities, and how profoundly inadequate present-day renewables are as substitutes for fossil energy, we would do better to take seriously the real obstacles standing in the way of a serious nuclear renaissance. Many of these obstacles have nothing to do with the fear-mongering of the anti-nuclear movement or, for that matter, the regulatory hurdles imposed by the U.S. Nuclear Regulatory Commission and similar agencies around the world.¶ As long as nuclear technology is characterized by enormous upfront capital costs, it is likely to remain just a hedge against overdependence on lower-cost coal and gas, not the wholesale replacement it needs to be to make a serious dent in climate change. Developing countries need large plants capable of bringing large amounts of new power to their fast-growing economies. But they also need power to be cheap. So long as coal remains the cheapest source of electricity in the developing world, it is likely to remain king.¶ The most worrying threat to the future of nuclear isn't the political fallout from Fukushima -- it's economic reality. Even as new nuclear plants are built in the developing world, old plants are being retired in the developed world. For example, Germany's plan to phase-out nuclear simply relies on allowing existing plants to be shut down when they reach the ends of their lifetime. Given the size and cost of new conventional plants today, those plants are unlikely to be replaced with new ones. As such, the combined political and economic constraints associated with current nuclear energy technologies mean that nuclear energy's share of global energy generation is unlikely to grow in the coming decades, as global energy demand is likely to increase faster than new plants can be deployed.¶ To move the needle on nuclear energy to the point that it might actually be capable of displacing fossil fuels, we'll need new nuclear technologies that are cheaper and smaller. Today, there are a range of nascent, smaller nuclear power plant designs, some of them modifications of the current light-water reactor technologies used on submarines, and others, like thorium fuel and fast breeder reactors, which are based on entirely different nuclear fission technologies. Smaller, modular reactors can be built much faster and cheaper than traditional large-scale nuclear power plants. Next-generation nuclear reactors are designed to be incapable of melting down, produce drastically less radioactive waste, make it very difficult or impossible to produce weapons grade material, useless water, and require less maintenance.¶ Most of these designs still face substantial technical hurdles before they will be ready for commercial demonstration. That means a great deal of research and innovation will be necessary to make these next generation plants viable and capable of displacing coal and gas. The United States could be a leader on developing these technologies, but unfortunately U.S. nuclear policy remains mostly stuck in the past. Rather than creating new solutions, efforts to restart the U.S. nuclear industry have mostly focused on encouraging utilities to build the next generation of large, light-water reactors with loan guarantees and various other subsidies and regulatory fixes. With a few exceptions, this is largely true elsewhere around the world as well.¶ Nuclear has enjoyed bipartisan support in Congress for more than 60 years, but the enthusiasm is running out. The Obama administration deserves credit for authorizing funding for two small modular reactors, which will be built at the Savannah River site in South Carolina. But a much more sweeping reform of U.S. nuclear energy policy is required. At present, the Nuclear Regulatory Commission has little institutional knowledge of anything other than light-water reactors and virtually no capability to review or regulate alternative designs. This affects nuclear innovation in other countries as well, since the NRC remains, despite its many critics, the global gold standard for thorough regulation of nuclear energy. Most other countries follow the NRC's lead when it comes to establishing new technical and operational standards for the design, construction, and operation of nuclear plants.¶ What's needed now is a new national commitment to the development, testing, demonstration, and early stage commercialization of a broad range of new nuclear technologies -- from much smaller light-water reactors to next generation ones -- in search of a few designs that can be mass produced and deployed at a significantly lower cost than current designs. This will require both greater public support for nuclear innovation and an entirely different regulatory framework to review and approve new commercial designs.¶ In the meantime, developing countries will continue to build traditional, large nuclear power plants. But time is of the essence. With the lion's share of future carbon emissions coming from those emerging economic powerhouses, the need to develop smaller and cheaper designs that can scale faster is all the more important.¶ A true nuclear renaissance can't happen overnight. And it won't happen so long as large and expensive light-water reactors remain our only option. But in the end, there is no credible path to mitigating climate change without a massive global expansion of nuclear energy. If you care about climate change, nothing is more important than developing the nuclear technologies we will need to get that job done.

#### Use of pre-existing technology from offshore drilling and nuclear submarines mean fast development

Chandler ’14 (David L. Chandler, MIT News Office, The paper was co-authored by NSE students Angelo Briccetti, Jake Jurewicz, and Vincent Kindfuller; Michael Corradini of the University of Wisconsin; and Daniel Fadel, Ganesh Srinivasan, Ryan Hannink, and Alan Crowle of Chicago Bridge and Iron, based in Canton, Mass, The MIT Energy Initiative (MITei) is MIT's hub for research, education, campus energy management and outreach programs that cover all areas of energy supply and demand, security, and environmental impact, “Floating Nuclear Plants Could Ride Out Tsunamis”, <http://theenergycollective.com/energyatmit/369266/floating-nuclear-plants-could-ride-out-tsunamis>, April 17, 2014)

When an earthquake and tsunami struck the Fukushima Daiichi nuclear plant complex in 2011, neither the quake nor the inundation caused the ensuing contamination. Rather, it was the aftereffects — specifically, the lack of cooling for the reactor cores, due to a shutdown of all power at the station — that caused most of the harm. A new design for nuclear plants built on floating platforms, modeled after those used for offshore oil drilling, could help avoid such consequences in the future. Such floating plants would be designed to be automatically cooled by the surrounding seawater in a worst-case scenario, which would indefinitely prevent any melting of fuel rods, or escape of radioactive material. Floating Nuclear Plants Cutaway view of the proposed plant shows that the reactor vessel itself is located deep underwater, with its containment vessel surrounded by a compartment flooded with seawater, allowing for passive cooling even in the event of an accident. Illustration courtesy of Jake Jurewicz/MIT-NSE The concept is being presented this week at the Small Modular Reactors Symposium, hosted by the American Society of Mechanical Engineers, by MIT professors Jacopo Buongiorno, Michael Golay, and Neil Todreas, along with others from MIT, the University of Wisconsin, and Chicago Bridge and Iron, a major nuclear plant and offshore platform construction company. Such plants, Buongiorno explains, could be built in a shipyard, then towed to their destinations five to seven miles offshore, where they would be moored to the seafloor and connected to land by an underwater electric transmission line. The concept takes advantage of two mature technologies: light-water nuclear reactors and offshore oil and gas drilling platforms. Using established designs minimizes technological risks, says Buongiorno, an associate professor of nuclear science and engineering (NSE) at MIT. Although the concept of a floating nuclear plant is not unique — Russia is in the process of building one now, on a barge moored at the shore — none have been located far enough offshore to be able to ride out a tsunami, Buongiorno says. For this new design, he says, “the biggest selling point is the enhanced safety.” A floating platform several miles offshore, moored in about 100 meters of water, would be unaffected by the motions of a tsunami; earthquakes would have no direct effect at all. Meanwhile, the biggest issue that faces most nuclear plants under emergency conditions — overheating and potential meltdown, as happened at Fukushima, Chernobyl, and Three Mile Island — would be virtually impossible at sea, Buongiorno says: “It’s very close to the ocean, which is essentially an infinite heat sink, so it’s possible to do cooling passively, with no intervention. The reactor containment itself is essentially underwater.” Buongiorno lists several other advantages. For one thing, it is increasingly difficult and expensive to find suitable sites for new nuclear plants: They usually need to be next to an ocean, lake, or river to provide cooling water, but shorefront properties are highly desirable. By contrast, sites offshore, but out of sight of land, could be located adjacent to the population centers they would serve. “The ocean is inexpensive real estate,” Buongiorno says. In addition, at the end of a plant’s lifetime, “decommissioning” could be accomplished by simply towing it away to a central facility, as is done now for the Navy’s carrier and submarine reactors. That would rapidly restore the site to pristine conditions. This design could also help to address practical construction issues that have tended to make new nuclear plants uneconomical: Shipyard construction allows for better standardization, and the all-steel design eliminates the use of concrete, which Buongiorno says is often responsible for construction delays and cost overruns. There are no particular limits to the size of such plants, he says: They could be anywhere from small, 50-megawatt plants to 1,000-megawatt plants matching today’s largest facilities. “It’s a flexible concept,” Buongiorno says. Most operations would be similar to those of onshore plants, and the plant would be designed to meet all regulatory security requirements for terrestrial plants. “Project work has confirmed the feasibility of achieving this goal, including satisfaction of the extra concern of protection against underwater attack,” says Todreas, the KEPCO Professor of Nuclear Science and Engineering and Mechanical Engineering. Buongiorno sees a market for such plants in Asia, which has a combination of high tsunami risks and a rapidly growing need for new power sources. “It would make a lot of sense for Japan,” he says, as well as places such as Indonesia, Chile, and Africa. This is a “very attractive and promising proposal,” says Toru Obara, a professor at the Research Laboratory for Nuclear Reactors at the Tokyo Institute of Technology who was not involved in this research. “I think this is technically very feasible. ... Of course, further study is needed to realize the concept, but the authors have the answers to each question and the answers are realistic.”

#### No risk of natural disasters

Verge, April 16, 2014 (“Floating nuclear power plants could avoid disasters like Fukushima”, [**http://www.theverge.com/2014/4/16/5620916/mit-floating-power-plant-concept-could-avoid-disasters**](http://www.theverge.com/2014/4/16/5620916/mit-floating-power-plant-concept-could-avoid-disasters))

Researchers have an idea for how future nuclear reactors can avoid the trauma that led to the 2011 disaster at Fukushima: by building new plants five to seven miles out into the ocean. "This affords some absolutely crucial advantages," Jacopo Buongiorno, a professor of nuclear science and engineering at MIT, which led the research, explains in a video presenting the idea. In particular, Buongiorno says that this distance into the ocean will remove the risk of tsunamis, which won't throw big waves in such deep water, and of earthquakes, the seismic waves of which will be damped by the ocean. But the plan also offers one far more critical advantage: the ability to avoid potential meltdowns by using the ocean's water as a coolant. "The ocean itself can be used as an infinite heat sink," Buongiorno says. "The decay heat, which is generated by the nuclear fuel even after the reactor is shutdown, can be removed indefinitely." Under the team's plans, nuclear plants would be floating on platforms similar to what's used for offshore oil drilling, and they'd be designed so that they would automatically be cooled by ocean water should the plant's systems fail by keeping the reactor deep underwater. They don't say how this might impact surrounding sea life. Those advantages would theoretically allow nuclear plants to avoid what happened at Fukushima, which was unable to cool its reactors after being struck by an earthquake and tsunami. MIT believes that the design could be expanded to any size of nuclear plant, and that it's a logical location since these plants are frequently placed beside large bodies of water anyway. These plants would be constructed at a shipyard and then towed to their location offshore. They would be moored to the seafloor, and an underwater cable would transmit electricity back to land. A living quarters for employees would even be placed on the top floor of the plant. Though Russia is already at work building a floating nuclear plant, it's being placed right beside the shore — not miles out, which would give it the big advantages that MIT is proposing here. It's not clear how long it might take before someone puts this design to use, but MIT argues that it should even be cost effective than other designs by cutting down on elements like concrete that can lead to delays and inflated costs. The work is being presented this week at the Small Modular Reactors Symposium, hosted by the American Society of Mechanical Engineers.