BEFORE THE PUBLIC SERVICE COMMISSION OF UTAH

In the Matter of the Application of Rocky	)	
Mountain Power for Authority to Increase its	)	
Retail Electric Utility Service Rates in Utah	)	DOCKET NO. 13-035-184
and for Approval of its Proposed Electric	)	
Service Schedules and Electric Service	)	
Regulations	)	

COMMENTS OF THE UTAH PHYSICIANS FOR A HEALTHY ENVIRONMENT ON ROCKY MOUNTAIN POWER'S GENERAL RATE CASE–PHASE II

(May 22, 2014)

I. INTRODUCTION

The Utah Physicians for a Healthy Environment (UPHE) is a volunteer organization of over 300 physicians and consultants from other scientific fields including toxicology, biology, engineering, and ecology. We are aware of the accumulating body of scientific evidence that indicates that air pollution causes or exacerbates many of the illnesses that we, as physicians, are asked to treat. We offer our expertise to inform the public policy debate over the impact that continuing to rely of coal to meet society's power needs is having on our climate, the natural systems of which we depend, the quality of the air we breathe, and public health.

These comments focus on RMP's proposal in this docket to charge a $4.25 monthly fee for residential customers with net-metered solar PV installations. The fee is characterized as a “fairness” charge to cover the cost of network infrastructure. UPHE considers this fee to be arbitrary because it is unrelated to any demonstrated differential in infrastructure costs between solar panel owners and other RMP retail customers. It is unfair because it makes no attempt to credit producers of solar power with avoiding the enormous external costs that burning coal imposes on society in terms of climate disruption, air pollution, and impaired public health. This unbalanced approach to tariff design plainly violates S.B. 208.

Enacted this spring, S.B. 208 requires that tariffs for residential net-metered customers be structured to reflect the benefits as well as the costs of customer-generated renewable power. If approved, this surcharge on providers of solar-generated power will retard the conversion of energy production from an unsustainable form (coal-fired power plants) to a sustainable form (distributed solar) at great potential long-run cost to the environment and public health.

These comments take into account the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (AR5) and the National Climate Assessment (NCA), both of which were released within the past year, as well as the recent climate report issued by the Bureau of Reclamation required by the Secure Water Act. These reports are unanimous in concluding that greenhouse gas emissions are disrupting the planet’s climate, and doing so at an accelerating pace. Unless greenhouse gas emissions are curtailed, the effect on the health and wellbeing of Utah’s residents is likely to be severe, particularly in the long run.

CO_2 emitted by the burning of coal—which this proposed monthly charge would encourage--is particularly harmful to public health. In addition to forcing Utah’s climate toward greater heat, drought, and dust-borne pollution, emissions from the burning of coal are a major source of air-borne mercury and other toxic heavy metals.

For much of this past January, air pollution held the population of the Wasatch Front under siege. This caused almost 5,000 people to gather on the steps of the State capital building to demand that the legislature deal with the public health crisis that this pollution is causing. They demanded “Clean Energy, Clean Air, and a Clean Future" for

Utah. http://www.sltrib.com/sltrib/news/57447995-78/capitol-clean-industry-lake.html.csp. A poll taken this winter by the Salt Lake Tribune showed that Utah residents, by a 3 to 1 margin, want tighter regulation of industrial pollution. That same poll showed that 99% of Utah residents were willing to make personal sacrifices to reduce air pollution. http://www.sltrib.com/sltrib/politics/57395042-90/quality-pollution-utah-lake.html.csp. Another poll showed that reducing air pollution and improving education were tied as the top priorities of Utah voters. http://www.sltrib.com/sltrib/opinion/57467086-82/education-poll-state-utah.html.csp. A major part of the air pollution that is currently undermining the health of the people of Utah has its source in, or is increased by, the forcing of the climate out of its historic patterns by the rapid buildup of greenhouse gases in the atmosphere. The greenhouse gas whose growing concentration is responsible for the vast majority of climate damage is carbon dioxide. Therefore, it is inappropriate to propose surcharges on providers of clean sources of energy that avoid this damage to the environment and to public health.

II. IMPACTS OF RISING CO_2 ON THE PLANET

Although these comments focus primarily on the impact of climate change on human health at the regional (Western United States) or sub-regional level (the Great Basin and the Colorado Plateau), it is instructive to first consider likely impacts of climate change on human health at the global level, since it is futile to try and contain the effects of greenhouse gas buildup to any one portion of the earth.

A. IPCC Fifth Assessment Report

Considering the likely impacts of climate change on human health at the global level should begin with the recently released Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). This report synthesizes the results of hundreds of independently-conducted studies of the nature and causes of climate change. Five years have passed the IPCC published its Fourth Assessment Report. Over the past year, it has released its Fifth Assessment Report (IPCC AR5) in three parts. On September 27, 2013, it reported on the state of current science that estimates of the contribution of greenhouse gas buildup to the warming of global and regional climates (Working Group I Report). On March 31, 2014, it reported on the likely impact of that warming on ecosystems and human societies under four assumed trajectories of future greenhouse gas buildup (Working Group II Report). On April 13, 2014, it published a report on the choices that decision-makers face to mitigate greenhouse gas buildup or to accept the consequences and try to adapt to them (Working Group III Report).

The Working Group I Report states that it is unequivocal that the earth has warmed substantially since 1880 (the estimate is 1.5º F) and 95 percent certain that human activity is the dominant cause.[1] Taking a broader range of effects into account than the Fourth Assessment did, the Fifth Assessment estimates consequences associated with global warming that are generally more severe than those estimated by the Fourth Assessment Report. For example, the Fifth Assessment estimates that if greenhouse gas emissions continue to grow at current rates, global sea levels are likely to rise by 20-39 inches by 2100. This is more than double the sea level rise estimated in the Fourth Assessment Report for the same period. However, a few weeks after the issuance of the Fifth Assessment Report and the National Climate Assessment, two studies scheduled for publication later this month have independently concluded that sea level rise due to global warming will be much greater than the AR5 and NCA estimates, and is irreversible.[2]

[1] The Working Group I Report acknowledges that the period 1998—2012 appears to be a pause in the rise of global surface temperatures. It regards the pause as short-run temperature variation rather than evidence of a long-run trend. It observes that the beginning of the period reflects the end of a strong El Niño oscillation and that the balance of the period consists of successive La Niña events. It views the pause in surface warming as a redistribution of planetary heat within the ocean, rather than a pause in the increase in the earth's overall heat inventory. It notes that there has been no pause in the warming of the ocean as a whole, which is where nearly all of the earth's heat inventory resides.

[2] Studies sponsored by NASA and by the University of Washington conclude that a glacier system in West Antarctica will collapse into the sea in the next 200 to 1,000 years, raising sea levels by 10 feet. They characterize this now irreversible, although the timing will be influenced by future rates of global warming. http://news.nationalgeographic.com/news/2014/05/140512-thwaites-glacier-melting-collapse-

Perhaps the most important contribution of the Fifth Assessment Report to the public debate about what to do about climate change is its focus on acceptable limits to global warming endorsed by international agreement, and evaluating "carbon budgets" the world must live within if those limits are to be met. The most widely accepted limit to global warming above pre-industrial levels that is not viewed as dangerous to the welfare of the planet is 2ºC (3.6ºF). Above that level, the climate models agree that hundreds of millions of people will be at risk from extreme events such as heat waves, drought, floods, and storms, that coastal cities will be threatened by rising sea levels, that many ecosystems will be permanently impaired, and that a large percentage of plant and animal species will be driven to extinction.

The amount that the earth warms is almost directly proportional to the amount of CO_2 and other greenhouse gases that accumulate in the atmosphere. The Summary for Policy Makers accompanying the Working Group I Report estimates that the amount of carbon equivalent that mankind can burn before the 2ºC limit is exceeded is one trillion tons. Carbon can only make up 80% of that limit, because the components of other greenhouse gases will contribute 20% of any greenhouse effect. That leaves a carbon budget of 800 billion tons. Once that amount of carbon has been burned, the carbon reserves that remain (estimated at about 5 trillion tons) will have to stay in the ground if global temperatures are to be kept below the danger threshold.

The report estimates that since the beginning of the industrial revolution to 2011, 531 billion tons of carbon have been released into the atmosphere. This means that society has already spent two-thirds of its 800-billion-ton carbon budget. With about 270 billion tons left in the budget, and an annual burn of about 10 billion tons, the budget is on track to be spent by 2038.[3] According to the report, there is little leeway in

west-antarctica-ice-warming/. http://www.washington.edu/news/2014/05/12/west-antarctic-ice-sheet-collapse-is-under-way/.

[3] The 2ºC warming limit and associated carbon budget are simplifications. They do not adequately consider that greenhouse gases emitted decades ago have yet to have their full impact global temperatures. Nor do they account for the very real risk that temperature increases less than 2ºC may be enough to initiate a general melting of arctic permafrost. This would unleash prodigious amounts of methane into the atmosphere. Methane's radiative forcing is 25 to 75 times more powerful than carbon dioxide. The tipping point for initiating this ominous feedback loop may be less than 2ºC. See www.climatecodered.org/2013/10/confused-about-new-ipcc-carbon-budget.html. Broadening the analysis to take full account of these risks may lead to the conclusion that there is no carbon budget left to spend.

this budget. It estimates the odds that remaining within this carbon budget will limit global warming to 2ºC are about 66 percent. If the budget is exceeded by 5% (840 billion tons are burned), the odds drop to 50 percent. If the budget is exceeded by 10% (880 billion tons are burned), the odds of keeping global warming within 2ºC drop to 33 percent. It is important to note that the 2ºC limit can only be maintained if the burning of carbon falls to zero once the budget is spent.

The Working Group II Report estimates what the impacts will likely be if the climate is allowed to warm by the amount that this carbon "budget" would allow (2ºC by 2100). To remain within this carbon budget, it will be necessary to stabilize the concentration of greenhouse gases immediately, and to achieve a net reduction in greenhouse gas concentrations by mid-century. The Working Group II Report also estimates the impacts of allowing the climate to warm by various amounts up to twice that limit. Twice that limit would allow global temperature to rise above the 4ºC level by 2100). The latter scenario represents "business as usual" in which greenhouse gas concentrations continue to rise without major new mitigation programs.

The Summary for Policy Makers in the Working Group II Report, at 12, lists the key global risks that arise if the recommended carbon budget is exceeded. They include:

- Sickness, death, and loss of livelihood in coastal and island zones due to storm surges, coastal flooding, and sea-level rise that could affect hundreds of millions.
- Sickness, death, and loss of livelihood for large urban populations due to inland flooding.
- Breakdown of critical network services (water, power, health care and emergency services), due to extreme weather events.
- Death of urban and rural laborers during heat waves.
- Hunger from the breakdown of food production or distribution systems due to heat, drought, flooding, and erratic precipitation.

- Loss of rural livelihoods and income due to loss of drinking and irrigation water and reduced agricultural productivity, particularly for poor farmers and herders in semi-arid regions.

- Loss of ocean and freshwater fisheries and their ability to support the specialized communities that rely on them.

- Extensive damage to ecosystems, including forest dieback and species extinction, due to ocean acidification, heat, drought, and insect infestation.

All of these “key risks” impair human health, directly or indirectly. Staying within this carbon budget is clearly critical to preserving human health.

The Summary for Policy Makers, at 13, consolidates these “key risks” that global warming presents into five “reasons for concern.” These concerns are based on the severity of the consequences if the risks materialize, and how likely society will be able to avoid those consequences through adaptation. The five reasons for concern, and the amount of additional warming[4] that is likely to trigger them, are summarized below.

1) The number of unique ecosystems and human cultures at severe risk goes up with additional warming of around 1°C. Many are put at very high risk with additional warming of 2°C, particularly Arctic-sea-ice and coral-reef systems.

2) The increase in risk of heat waves, extreme precipitation, and coastal flooding is already moderate, and will become high with 1°C additional warming.

3) The risk that drying crop lands will hit some regions and economic classes harder than others is already moderate, and will become high for additional warming above 2°C.

4) Biodiversity and economic impairment will be moderate for additional warming between 1-2°C. Biodiversity loss and associated loss of ecosystem goods and

[4] The amount of additional warming is measured against a baseline of the global average temperature over 1986-2005.

services will become high with around 3°C additional warming. Above this level, there will be mounting aggregate economic damage.

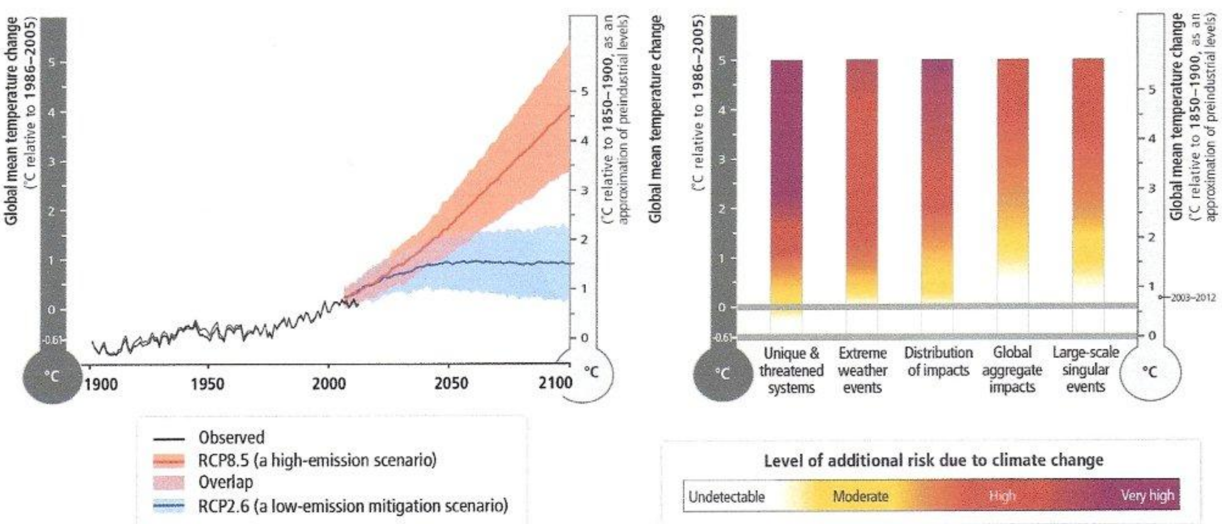
5) Some physical systems and ecosystems are already experiencing abrupt and irreversible changes (tipping points) or will reach them with additional warming of 0-1°C. These include warm-water coral reef and Arctic ecosystems. Risks increase disproportionately as temperature increases between 1-2°C. They become high above 3°C, due to the potential for a large and irreversible sea-level rise from ice sheet loss.

The report summarizes these five reasons for concern and the additional warming that is estimated to trigger them in Figure 1, taken from the WGII Summary for Policy Makers at 39. On the left of Figure 1 is a graph of global average temperatures that have actually been experienced in the 20th and 21st centuries (black line) and projected increases in global average temperatures under two scenarios of greenhouse gas buildup through the end of the 21st century.

The blue line estimates the amount of warming projected under the scenario in which greenhouse gas concentrations are quickly stabilized and a net reduction is achieved by mid-century (the carbon budget is honored). The pink line estimates the amount of warming projected under a scenario in which rates of emissions growth continue without major new mitigation programs through the end of the century.[5] It can be seen that adhering to the carbon budget limits global warming to about 2ºC (3.6ºF) by the end of this century. Under the unrestrained emissions scenario, the warming of the earth is over 4ºC (7.2ºF).

[5] The additional warming of the globe depicted in Figure 1 is measured from two alternative base periods: a recent one (1986-2005, shown on the black thermometers) and a more distant one that roughly corresponds to the beginning of the industrial revolution (1850-1900, shown on the grey thermometers). The projected impacts associated with the amount of additional warming shown are almost equally grave, regardless of the base period from which the warming is measured.

Figure 1



In Figure 1, the bar chart on the right shows how much warming is expected to trigger each of the five reasons for concern described above. The color coding ranges from warming that entails no additional risk (white) to warming that entails very high additional risk (purple) for each concern. With Figure 1, the WGII Summary for Policy Makers illustrates that if additional warming of the earth is limited to 2ºC, the risk that the five listed concerns will materialize ranges from moderate to high, depending on the concern. However, if the earth warms by more than an additional 4ºC, all of the listed concerns are virtually certain to materialize, and to be so severe as to exceed society's ability to avoid the consequences by adaptation.

The main report from Working Group II includes an evaluation of the impact on North America that additional warming within the 2ºC limit is likely to have. It estimates with a 90% level of confidence that there will be more heat waves and floods over most of North America. The western United States and Canada will experience more frequent low snow years, and shifts towards earlier snowmelt runoff. Increased precipitation variability and more intense droughts are projected to impair water supplies, agricultural productivity, economic productivity, and the livability of urban and rural settlements. Human health will suffer from increased water-, food-, and vector-borne infectious diseases, pollens and air pollutants. The WGII Report warns, however, that if there are no major new carbon mitigation programs, and the earth is allowed to warm more than 4°C (7.8º F), the impacts will be so severe that it is unlikely that the countries of North America would be able to effectively adapt to them.

The Working Group III Report's Summary for Policy Makers addresses the mitigation/adaptation choices that decision makers must make. It observes that current greenhouse gas concentration trends are highly unfavorable for staying within the carbon budget that would keep global warming under 2ºC. It notes that while annual increases in greenhouse gas concentrations were 1.3% during the period 1970-2000, they nearly doubled in the period 2000-2010 (2.2%), despite significant efforts to mitigate them. It notes that earlier progress in decarbonizing the energy supply was reversed in the 2000-2010 period by a shift back toward reliance on coal. AR5/WWGIII/SPM at 5.

According to the report, the concentration of CO_2-equivalent greenhouse gases in the atmosphere in 2011 was 430 part per million. It estimates that to keep additional warming of the globe to 2ºC, the concentration of CO_{2eq} must be kept below 450 ppm. Id. at 9. Accomplishing this, it concludes, will require huge reductions in greenhouse gas emissions by Mid-Century from both the burning of fossil fuels, and changes in how forests and croplands are managed. It will require a tripling to quadrupling of the share of energy produced by renewables coupled with aggressive energy efficiency initiatives. It will also require the widespread implementation of carbon capture technologies, even though the feasibility of commercial-scale carbon capture technologies has yet to be shown. Id. at 15. It estimates that to remain within the 2ºC warming limit, renewable sources of energy in the power supply must rise from their current share of 30% to 80% by 2050, and that the burning of fossil fuels for any purpose must end by 2100. Id. at 23.

The report notes that if current trends continue, emissions from the energy supply sector will double or triple by 2050. For that reason, most of the computermodeled scenarios that succeed in limiting global warming to 2ºC require large reductions in emissions from the energy supply sector through the switch to low-carbon fuels. Id. at 22. The report notes that if society waits until after 2030 to bring greenhouse gas emissions below current levels, it will become very difficult to keep additional warming of the earth below 2ºC, and very few options will remain for achieving that goal.

On an optimistic note, the report finds that the economic sacrifice required to achieve the reductions in greenhouse gas emissions needed to stay within the 2ºC limit would be relatively trivial, particularly in relation to the reduction in risk to the planet's ecology and economy that such reductions would yield. According to the report, the direct cost of many forms of renewable energy are reaching parity with fossil fuels, and will have an increasing cost advantage going forward. If the co-benefits of renewable energy (energy security, cleaner air, etc.) were factored into investment decisions, it concludes, low-carbon fuels would be recognized as especially profitable investments. Id. at 23.

The report estimates that if all available carbon emissions mitigation technologies were deployed in conjunction with a carbon tax that reflects its social costs, the concentration of greenhouse gases could be kept under 450 ppm by 2100. It estimates that the cost to the global economy would be a slowing of the global economy by only 0.06% per year through 2100. This estimate errors on the high side, because it ignores the value of the co-benefits of switching to low-carbon fuels. It also ignores the value of the climate damage avoided by making the switch. It notes that the loss of economic growth from making the switch to a low-carbon economy will only increase the longer aggressive mitigation policies are delayed. Id., at 17.

The message of the Working Group III report is that the cost of mitigation now is far smaller than the cost of adaptation to the impacts of global warming once those impacts become irreversible. But, it warns, the conversion to a low-carbon economy is progressing much too slowly to succeed in limiting global warming to 2ºC. It notes that there are obstacles to making the switch to low-carbon energy supplies in the form of capital-intensive investments in carbon-based assets (wells, mines, pipelines, refineries, etc.), in carbon-intensive equipment (low-mileage cars, trucks, etc.), in energy inefficient buildings, and in housing built in sprawled urban patterns.

The report recommends that the economic inertia that exists due to the sunk costs in carbon-intensive assets be overcome by government measures such as a carbon tax reflecting the climate and health costs caused by burning carbon, feed-in tariffs for power networks, incentives to adopt state-of-the-art technologies, such as Natural Gas Combined Cycle power generation, investments in mass transit, and financial incentives for solar, wind, and hydro power that reflect the climate/health damage that they prevent. Id. at 24. The surcharge on providers of solar power proposed in this docket by Rocky Mountain Power would serve as a perverse disincentive to shifting to sustainable sources of power.

III. IMPACTS OF RISING CO_2 ON THE WESTERN UNITED STATES

Four major geographic features converge in Utah— the Rocky Mountains, the Colorado Plateau, the Great Basin, and the Bonneville Salt Flats. The Colorado Plateau occupies most of its eastern half, the Great Basin most of its western half. Climate change caused by the buildup of greenhouse gases is having major impacts on all four. Of the four, the ecosystem of the sparsely populated Great Basin is the least familiar to Utahn's, but is probably the most threatened by climate change. Disruption of the climate and ecosystem of the Great Basin will have a number of major impacts on the health and well-being of Utah's more populated Wasatch Front.

A. Great Basin Climate Change in the Fossil Record

The Great Basin is North America's largest desert, encompassing 135 million acres of land between the Rocky and Sierra Nevada Mountains. As Figure 2 shows, it includes parts of Nevada, Utah, Idaho, Oregon, and California.

Figure 2

Its climate is arid. To appreciate how arid, consider that it receives less than 10 inches of annual precipitation, but has evapotranspiration rates ranging from 30 to 50 inches. If its ecosystems are to remain viable, there is no room for further drying. According to the available science, further drying of these valleys is what climate change has in store.

The climate of the Great Basin has fluctuated widely both on a relatively short and long time frame. It can experience extremes in precipitation in which an occasional wet year can be followed by several years of drought and high temperatures. National Forest Service scientists maintain that to understand what abrupt climate change is currently doing to the Great Basin's ecosystems, it is necessary to understand what impacts much more gradual climate change has had in the past. They describe that history in the Humboldt-Toiyabe National Forest Climate Change Vulnerability Report. This report is available at http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5294901.pdf./

At the end of the Pleistocene epoch (11,000 years ago) the Great Basin was emerging from the most recent ice age. Its climate was cool and moist. Lakes, marshes, and rivers were abundant in valley bottoms. Sagebrush, perennial grasses and forbs (such as clover) were the dominant vegetation. Biodiversity was relatively high. Juniper and pinyon pine were relatively rare. Fir, spruce, and pine were more abundant than now, growing at elevations 3,000 to 6,000 lower than at present.

During the Holocene Drought (2,500 to 550 years ago), the temperature rose. Winters became mild and short. What precipitation there was fell mostly in the spring and summer. Wildfires increased. The increased heat, drought, and fire, removed much of the sagebrush/perennial grass vegetative cover. As a result, soils were stripped from the hillsides and deposited on valley floors and on side-valley alluvial fans. Streams became heavily sedimented, giving streambeds a natural tendency to incise and erode, rather than recharge groundwater. This caused a lowering of water tables.

The Holocene Drought ended with the Holocene Little Ice Age (550 to 160 years ago) when a cooler, wetter climate allowed the sagebrush/perenial grass ecosystem to recover, and the Great Basin ecosystem to heal. This process lasted until 160 years ago, when it was interrupted by two severe disturbances--man started intense grazing, mining, and logging activity, and the climate began a rapid warming trend. Now, due to the climate forcing of concentrating greenhouse gases, the pattern of soil erosion and stream incision observed during the Holocene Drought has resumed, but is unfolding much more rapidly.

B. Evidence That Current Climate Change is Abrupt

In the last 100 years, the Great Basin has warmed by 1 to 3°F and is projected to warm another 3.6 to 9°F by the end of the century. (Chambers and Pellant, 2008, pp. 29-33.) Since about 1980, winter temperatures in the western U.S. have been consistently above the historical average, and winter snow packs have declined. Periods of slightly higher-than-average precipitation have not offset the effects of declining snow packs. (McCabe and Wolock, 2009.)

This pattern is consistent with general climate trends. Across the globe, winter temperatures are rising more rapidly than summer temperatures, particularly in the Northern Hemisphere, and there has been an increase in the length of the frost-free period in mid- and high-latitude regions of both hemispheres. (Loehman, R., 2010.)

Eighty-five percent of the water available in the Great Basin for human use comes from snowmelt. (Loehman, R., 2010). The onset of snow runoff in the Great Basin is currently 10–15 days earlier than 50 years ago, with significant impacts on the downstream utilization of this water. (Ryan, M., et al., 2008, p. 362). Annual precipitation increased slightly. (Chambers and Pellant, Id.). Future precipitation cannot be predicted with certainty with existing Global Circulation Models. However, higher temperatures are predicted with great certainty, which will increase evapotranspiration. The Palmer Drought Index (which measures the deficit of water compared to the needs of natural systems) is expected to increase as the Great Basin becomes more arid. (Chambers, J., 2011).

Since 1986, the length of the active wildfire season in the Great Basin has increased by an alarming 78 days, and the average duration of large fires has increased from 7.5 days to 37.1 days. Forest wildfire frequency is nearly four times higher and the total area burned by these fires is more than six and a half times its previous levels. (Westerling, A., 2008). In 1999, a consortium of organizations led by The Nature

Conservancy identified the Great Basin as the third most endangered ecosystem in the United States. It described native sagebrush and perennial grasses, weakened by heat, drought, and overgrazing, giving way to juniper, pinyon pine, and exotic annuals and weeds. These replacement plant communities are more fire-prone, shallow-rooted, and less able to hold soil in place in the face of floods, winds, and drought.

These effects are expected to accelerate as global warming accelerates. Compared with other ecosystems, the impact of climate change on Great Basin ecosystems is magnified because its environment is more arid and its ecosystems are more fragile than most. Rangelands in the Great Basin already exist at the margin of viability, given the uncertain timing and quantity of precipitation, the pressure from invasive species, intensified fire regimes, and increasing human population pressures. (Humboldt-Toiyabe Report, 2011). As these comments explain in a subsequent section, the impacts of climate change in the Great Basin, coupled with the planned dewatering of much of the Great Basin that lies upwind from the Wasatch Front, has the potential to repeat the ecological and public health tragedies of the Dust Bowl of the Great Plains in the 1930s, the dust bowl of that is now the Owens Valley, and the dust bowl that surrounds the Aral Sea.

C. Causes of Climate Trends in the Great Basin.

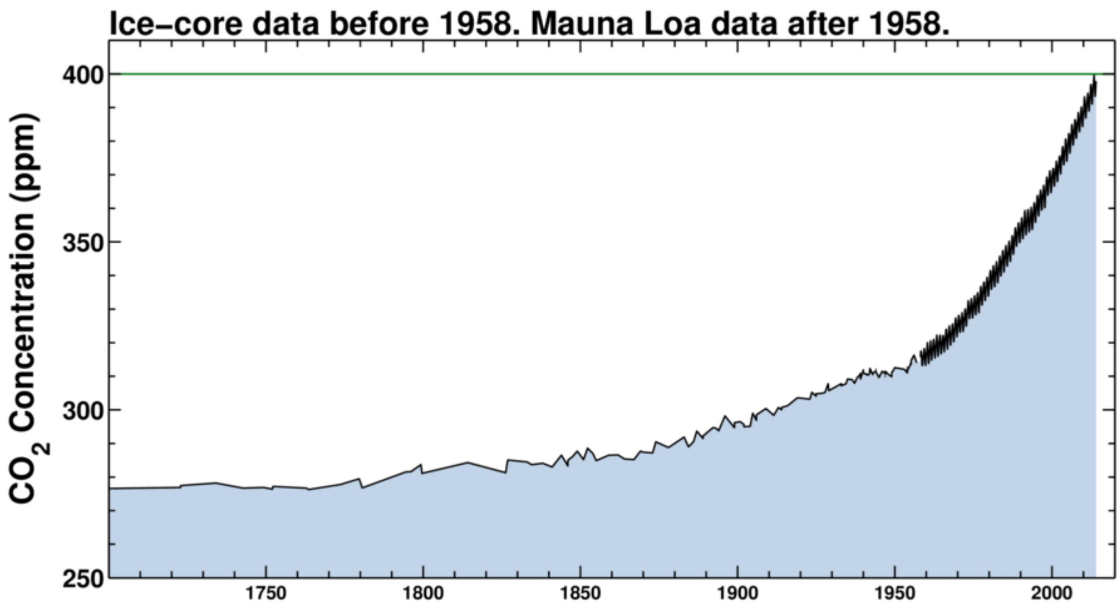
Among earth scientists there is nearly complete consensus that accumulating greenhouse gas emissions have the planet on a long-run path to an ever hotter atmosphere and ocean, and ever greater climate disruption. The debate about this survives only at the political level. It is kept alive primarily by commercial interests who are aware of the implications of climate science, but would be disadvantaged if this country were to deal with them seriously. As rangeland scientist Dr. Thad Box observes, the controversy between scientists and climate change critics over whether human-induced changes drive the major changes in climate now being observed, or simply intensify “natural” climatic variation is irrelevant. The countermeasures required in either case are the same, and it diverts society from making the responses that it must in order to survive.

The basic mechanism by which greenhouse gases warm the earth's climate is straightforward. Greenhouse gases in the upper atmosphere warm the earth by allowing high-frequency radiation from the sun (which includes visible light) to pass through the atmosphere to the earth. This is no different from the sun passing through the glass covering of a greenhouse. When solar radiation reflects back off the earth's surface, it becomes low-frequency (infrared) radiation. Greenhouse gases trap the infrared radiation and recycle it as heat. This is no different from infrared heat being trapped by the glass covering of a greenhouse.

If it weren't for this property of greenhouse gases, the average temperature on the earth's surface would be below freezing, and the earth would be far less hospitable to life. To keep the earth hospitable to life, it is necessary to keep its climate in balance. A simple truth is that to keep the earth's climate in balance, it is necessary to keep its greenhouse gases in balance. A large and sudden buildup of greenhouse gases is having huge adverse impacts on the Great Basin's native species which are not accustomed to short winters, early snowmelt, higher evapotranspiration, and frequent, intense fires. (Humboldt- Toiyabe Report, 2011, p. 4.)

Since the industrial revolution began in the early 1800s, the atmospheric concentration of CO_2 has increased from 280 parts per million (ppm) to 400 ppm—an increase of over 40%. See Figure 3. Today's CO_2 concentrations are higher than any that have been observed in the past 800,000 years, when CO_2 varied between about 180 and 300 ppm. The concentration of methane, a more potent greenhouse gas, is now 2.5 times as high as at any time in the past 800,000 years. (National Academies of Science Brochure, p. 7, available at http://nas-sites.org/americasclimatechoices/more-resources-on-climate-change/.)

Figure 3



This is a radical change in the chemical composition of the earth's atmosphere. The large and sudden rise in greenhouse gases has knocked the earth's climate out of balance. Various lines of evidence point strongly to human activity being the main reason for the recent increase. The main factor is the burning of fossil fuels (coal, oil, gas) with smaller contributions from land-use changes and cement manufacture. Evidence that the global warming now underway is caused primarily by burning fossil fuels includes the consistency between the amount of total CO_2 emitted and the percent that climate models predicted would not be absorbed by natural carbon sinks, but, instead, would build up in the atmosphere (45%). The proportions of CO_2 isotopes in the atmosphere provide a chemical "fingerprint" revealing how much CO_2 comes from natural sources, and how much from the burning of fossil fuels.[6] Finally, the depletion of atmospheric oxygen is the amount that models predicted would result from the amount of fossil fuel that is now being burned. (Id., p. 8)

Since the injection of fossil carbon into the atmosphere began on a large scale in the late 19th Century, only 55% has been absorbed by oceans, forests, and other natural carbon sinks. Forty-five percent has remained in the atmosphere. An appropriate metaphor is to view the earth as a bathtub with carbon constantly coming out of the tap. Forty-five percent of the carbon entering the tub now spills over the rim. With no legitimate place to go, the excess carbon is flooding humanity's "house," undermining its foundation. Ultimately, excess carbon will destroy humanity's house if the spigot is not turned off.

Since 1750, the infrared energy that falls on each square meter of the earth's surface every second has gone up by 1.6 Watts. Over the entire earth's surface, this extra energy amounts to 800 trillion Watts per second. In any given second, the extra heat is 50 times the amount of power produced by all of the power plants in the world combined. (National Academies of Science Brochure, p. 8.) Scientist's ask what physical mechanism could account for this huge increment of energy now being absorbed by the earth's surface. They know that over this period, the amount of solar radiation reaching the earth's atmosphere has been virtually unchanged. (Id.) Volcanic aerosols over this period, if anything, should have slightly reduced the radiation reaching the earth. There is no physical mechanism that can plausibly account for the added infrared energy that now strikes the earth's surface, other than greenhouse gases, whose concentration has gone up more than 40 percent over the same period. This is the "smoking gun" that should put an end to any skepticism that might remain among the scientifically literate about the central role that greenhouse gases are playing in warming the globe.

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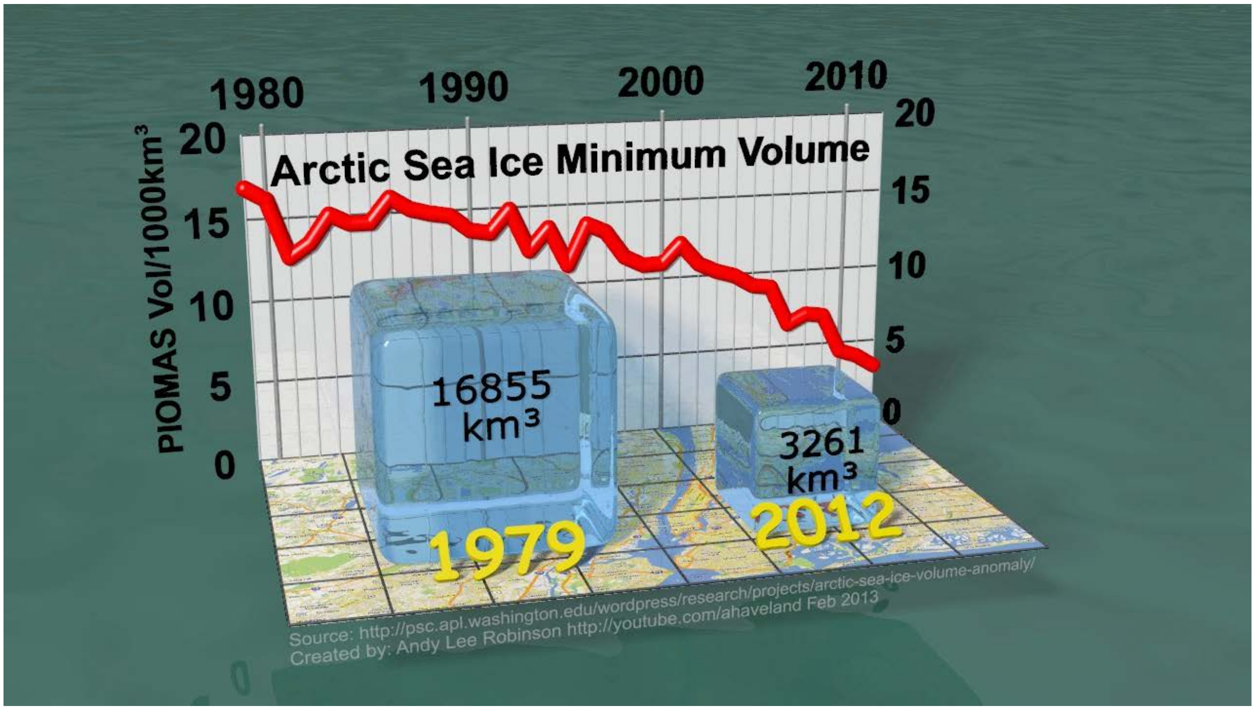
[6] The carbon stored in plants, and therefore the carbon released when fossil plants are burned, contains a smaller percentage of Carbon 13 and 14 to total carbon than naturally occurring atmospheric carbon. Since the onset of the industrial revolution and its massive release of fossilized carbon, the ratio of Carbon 13 and 14 to total atmospheric carbon has been falling at the rates predicted.

D. The Social Cost of Relying on Carbon.

The most recent twelve years account for 12 of the 14 hottest years the earth has experienced since recording of global temperatures began in 1880. As reported in March, 2013, in the journal Science, global temperatures now are warmer than at any time in at least 4,000 years. One of the most dramatic effects of this warming is the loss of sea ice in the Arctic. As seen in Figure 4, an astounding 80 percent of the volume of Arctic sea ice has been lost over the last three decades. Injections of heat onto the earth's surface are first absorbed by sea ice. In this way, sea ice serves as a balance wheel moderating swings in the earth's surface temperature.

Figure 4



Source: https://www.skepticalscience.com/2013-arctic-sea-ice-prediction.html.

If the earth continues to warm at current rates, global temperatures in the coming decades will exceed levels not experienced since before the last ice age, which ended roughly 12,000 years ago.[7] The result for the Western United states, generally, and for Utah, in particular, will be an economic and public health catastrophe.

Putting the most directly relevant climate science in a nutshell: Global warming has already drastically warmed the Artic, which has dramatically melted its ice cover. By September, 2012, the Arctic lost 1.3 million square miles of sea ice relative to the September average for the 1979-2000 base period. This has cut the extent (as opposed to the volume) of Arctic sea ice roughly in half. To put this in lay terms, the Arctic sea ice lost in the just three decades is five times the area of Texas. http://www.epa.gov/climatechange/science/indicators/snow-ice/sea-ice.html.

Not surprisingly, this has had a major impact on the weather of the Northern Hemisphere. Eighty percent of the solar radiation that strikes sea ice is reflected back into space, while 20 percent is absorbed as heat. When bright, reflective sea ice is replaced by dark sea water, however, only 10 percent of the solar radiation that strikes it is reflected into space and 90 percent is absorbed as heat. http://science.howstuffworks.com/environmental/earth/geophysics/arctic-ice.htm. It is estimated that converting Arctic ice to sea water accounts for one fourth of the climate warming that has occurred over the last three decades. http://thinkprogress.org/climate/2014/02/18/3302341/arctic-sea-ice-melt-ocean-absorbs-heat/.

One might ask if those who live in Utah should care that Arctic ice is disappearing with breathtaking speed. The answer is that they should care very much. The rapid warming of the Arctic has reduced the temperature gradient between polar and tropical air. This has weakened the force of the giant convection cells (the Polar,

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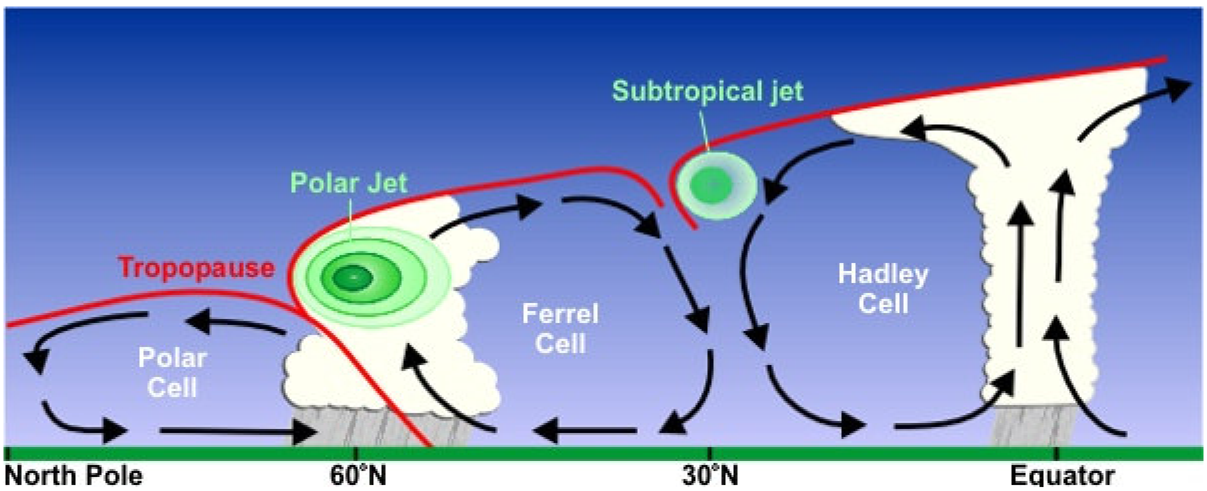
[7] See news article "Global Temperature Highest in 4,000 Years," by Justin Gillis, New York Times, March 7, 2013, summarizing research published in the journal Science. [DOI: 10.1126/science.1228026, Science 339, 1198 (2013); Shaun A. Marcott et al. A Reconstruction of Regional and Global Temperature for the Past 11,300 Years.] This study reconstructed global temperatures over virtually the entire Holocene period (the period since most recent ice age). It used such proxies as the distribution of fossils of microscopic, temperature-sensitive ocean creatures to determine past climate. It suggests that changes in the amount and distribution of incoming sunlight, caused by wobbles in the earth's orbit, contributed to a sharp temperature rise in the early Holocene. Dr. Michael Mann of Penn State University points out that the early Holocene temperature increase was almost certainly slow, giving plants and creatures time to adjust. But, he said, the modern temperature spike is so sudden that it threatens the survival of many species, in addition to putting severe stresses on human civilization.

Ferrel, and Hadley Cells) that circulate air from the tropics to the North Pole and back. See Figure 5. These convection flows are the engines that distribute the heat received from the sun around the planet. The boundaries between these convention cells form a path of least resistance where air rushes in to equalize the pressure between cells. The produces a pair of high-altitude jet streams.

Figure 5



As the earth spins, it converts these north-south jet streams into east-west flows. These east-west flows are the familiar subtropical jet stream that determines storm tracks in the Northern Hemisphere (centered around 30° North latitude), and the less familiar polar jet (centered around 60° North latitude), that typically determines storm tracks in the Arctic. By steering storms across the Northern Hemisphere, these jet streams determine what regions of the Northern Hemisphere will receive rain.

The buildup of greenhouse gases has transformed the Arctic from the Northern Hemisphere's ice box to a major heat sink in just three decades. This has weakened the force of the Northern Hemisphere's convection cells. This, in turn, has weakened the subtropical jet stream that brings winter snows and spring rains into the parched Western states. The subtropical jet stream has been weakening and retreating northward since the mid-1900s, as predicted by climate models. (Garfin, G., et al., eds. 2013, at 114-15). The result has been increasingly severe drought expanding from the Southwest through Nevada, Utah, and Colorado.

Even more damaging to the climate of the Western United States, the warming of the Arctic caused by the buildup of greenhouse gases is causing the disintegration of the polar jet stream. Once a strong, coherent, and relatively predictable east-west flow, the weakened polar jet has begun to wobble erratically. It has lost so much force that the basic storm track that had traditionally moved storms from east to west across North America, has, in the past several years, entered long periods in which it meandered for thousands of miles in a north-south direction. For graphic demonstrations of this phenomenon, see, e.g., http://robertscribbler.wordpress.com/2013/07/16/dr-jennifer-francis-top-climatologists-explain-how-global-warming-wrecks-the-jet-stream-and-amps-up-hydrological-cycle-to-cause-dangerous-weather/;

http://www.sciencedaily.com/releases/2008/04/080416153558.htm.

The weakening of the polar jet allows it to "kink," or bend in on itself (much like a cowboy's lariat when it rotates too slowly to maintain its circular shape). This has allowed high-pressure areas of unprecedented strength and duration to camp over North America, producing historic weather extremes. Persistent blocking highs made possible by the disintegrating polar jet were responsible for both the historic drought that gripped the Mid-West in 2012 and for Superstorm Sandy. The bizarre weather patterns that it has caused across the Northern Hemisphere in the most recent 12 months, were predicted by climate change models.
See http://e360.yale.edu/slideshow/loss_of_arctic_sea_ice_already_influencing_weather/74/4/.

The most recent example of the impact that these persistent blocking highs can have is the one that was responsible for the unprecedented drought that is now destroying California's agriculture. This past winter, the polar jet transported tropical air from the Hawaiian Islands all the way to Alaska. This caused Alaska to have a higher average winter temperature than the continental United States—an upside down

weather pattern that persisted for almost a year. While Alaska basked in tropical air in the dead of winter, barely a flake of snow fell in the mountains of the West. This same blocking high formed by the polar jet caused Arctic air to spill down the eastern United States, freezing the Great Lakes solid. The polar jet plunged all the way to Florida, where it merged with the subtropical jet. The merging of the two produced an unprecedented temperature gradient that supercharged the polar jet and sent moisture-laden tropical air slamming into Great Britain, producing wind, rain and floods greater than any Great Britain has experienced in 100 winters.
See http://e360.yale.edu/feature/is_weird_winter_weather_related_to_climate_change/2742/.; and http://robertscribbler.wordpress.com/2014/01/23/arctic-heat-wave-to-rip-polar-vortex-in-half-shatter-alaskas-all-time-record-high-for-january/.

The most devastating consequence of this winter's disintegrating polar jet was its effect on California. It caused California's twelve-year drought to reach a severity not seen in centuries. California's Central Valley serves as a breadbasket, not just to the United States, but to the world. It is about 450 miles long, from Bakersfield up to Redding, and is 60 miles at its widest, between the Sierra Nevada to the east and the Coast Ranges to the west. It is the world's largest patch of Class 1 soil--the best there is. The 25-degree (or so) temperature swing from day to night is an ideal growing range for plants. The sun shines nearly 300 days a year. The eastern half of the valley (and the western, to some extent) historically uses snow melt from the Sierra as its water source. In the past, this meant that it was often spared the chronic cycle of drought and flood that plague the Midwest. Cool mild winters that never see snow offer a whole different growing season for plants that cannot take the summer heat.

Because of this convergence of desirable qualities, the valley yields a third of all the produce grown in the United States. Unlike the Midwest, which concentrates (at great risk) on corn and soybeans, more than 230 crops are grown in the valley, including those indigenous to South Asia, Southeast Asia and Mexico. Among other things, it provides the Nation with the bulk of its lettuce, carrots, tomatoes, asparagus, cabbage, artichokes, broccoli, chard, collards, pomegranates, almonds, raisins, pistachios, and grapes.

This May, the snowpack in the Sierra Nevada, on which California relies to keep functioning during the dry season, is 18% of normal. This reflects the total absence of rain or snow in December and January. An article in the February 1, 2014, New York Times reports that this summer there won't be enough water for many of California's inhabitants to drink, let alone to keep its orchards, vineyards, and livestock alive. That article quotes B. Lynn Ingram, professor of earth and planetary sciences at the University of California, Berkeley, concluding that "We are on track for having the worst drought in 500 years."

Larry Bernstein, in an article published in the February 9. 2014, Washington Post, describes grocery and hardware stores in small towns across California's central valley going out of business due to the drought. By some estimates, half a million acres of San Joaquin Valley farmland will lie fallow during the upcoming growing season. Radiative forcing by greenhouse gases has turned the most fertile and productive valley on earth into a dustbowl before our eyes. The damage to California's agricultural industry is expected to run into the tens of billions of dollars. Unemployment in the Central Valley is expected to exceed 30 percent.

The water outlook for Nevada, Arizona, New Mexico, and Southern Utah is bleak as well. See http://droughtmonitor.unl.edu/. Herds are being sold off because parched rangelands will produce no feed. In normally fertile valleys, soil moisture is so low that there is no point in planting crops.

The drought that is currently destroying the productivity of America's breadbasket is just one of a multitude of ways in which the buildup of greenhouse gases in the earth's atmosphere has thrown the earth climate out of balance. It is an example of what economists call the "external cost," or "social cost," of continuing to rely on carbon to power our nation. It is a "social cost" because those who mine coal and those who burn it do not pay it. The cost is borne by society at large. Anyone doubting the reality of the social costs of relying on carbon to power our nation should pay close attention to the price of tomatoes, asparagus, raisins and almonds in the coming year.

A study by the faculty of Harvard Medical School published in 2011 quantified the social costs incurred in the United States annually by using coal to generate electric power. The study noted that each stage in the life cycle of coal—extraction, transport, processing, and combustion—generates a waste stream and carries multiple hazards for health and the environment. It notes that those who profit from mining and burning coal do so by not having to pay its social costs. The study estimates that the life-cycle effects of coal and the waste stream it generates are costing the American public from one-third to over one-half of a trillion dollars annually.[8] The cost of complying with the EPA's proposed CO_2 standard for new power plants is trivial in comparison.

The Harvard study monetized damages due to climate change that include public health damages from NOx, SO_2, PM2.5, and mercury emissions; fatalities of members of the public due to rail accidents during coal transport; the public health burden in Appalachia associated with coal mining; government subsidies; and the lost productivity of mined land after it has been abandoned. The estimate is conservative in that it does not account for damages outside of Appalachia, nor does it account for unquantifiable costs, such as the cost to a family of losing a wage earner due to black lung disease. It notes that many of these "external" costs are cumulative.

The Harvard study conservatively estimates that if all of the external costs of coal were accounted for, they would double or triple the price of coal. This would raise the price of coal-generated electricity by 9—27 cents per kilowatt hour.

The average price of electricity in the United States is about 10 cents per kilowatt hour. http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6

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[8] The "external" costs of coal burned worldwide each year from pollution, climate warming, health effects and contaminated water and sterilized forest, range, and farmland is estimated to be $4.7 trillion. Trucost PLC, "Natural Capital at Risk: the Top 100 Externalities of Business." *TEEB for Business Coalition,* April, 2013. These indirect costs of burning coal are borne by taxpayers, health care systems, and insurers.

_a. In some regions, low-carbon electricity has already reached grid parity. For example, utility-scale solar power can now be delivered in California at prices well below 10 cents per kilowatt hour--less than most other peak generators, including those that use natural gas. See Arno Harris (31 August 2011). "A Silver Lining in Declining Solar Prices". Renewable Energy World.

If energy were priced in an economically rational manner that reflected both the direct and the indirect costs that various sources of energy impose on society, a spread would be maintained that would keep coal-generated electricity from two-to-three times as expensive as carbon-free renewables. Rather than move toward that economically rational price relationship, the solar surcharge proposed by Rocky Mountain Power in this docket would do the opposite—narrowing the already inadequate gap between the price of coal-generated electricity and the price of carbon-free electricity.

Dr. Zhengrong Shi is the CEO of Suntech, China's leading solar manufacturer. In a 2012 interview published in Fortune Magazine, he says that the cost of solar-generated power will fall to about 11.8c/kWh by 2015, and 8.8c/kWh by 2020. By then, solar PV will not need subsidies, and its competitive advantage will only accelerate thereafter.
See www.reneweconomy.com.au/2012/euro-utilities-declare-war-on-solar-pv-57935.

Given the rapid movement of low-carbon energy toward grid parity, doubling or tripling the price of coal-generated electricity by including its social costs would give wind, solar, and numerous other forms of non-fossil-fuel power a decisive advantage over coal in the market place. Adding the social costs of burning coal to its price would also make investments in efficiency and electricity conservation far more profitable than expenditures in additional electric power generating capacity from coal. (Epstein, et al., 2011). The path forward to weaning the world from carbon would be clear, and entirely feasible, if the price of coal could be adjusted to reflect its total economic cost.

The growing cost advantage that renewable distributed forms of energy will have going forward is a challenge to Rocky Mountain Power's business model of centralized power generation and distribution relying on stagnant technology. The solution is not--as Rocky Mountain Power proposes here--to obstruct the inevitable shift to renewable forms of energy, which will be the only economically and environmentally sustainable forms in the future. The solution is to adapt Rocky Mountain Power's business model to facilitate that shift.

The Public Service Commission should investigate ways to reward Rocky Mountain Power for facilitating the inevitable shift to renewable energy. For example, rather than adopting a surcharge for just one of the many groups of customers who benefit from the network, and whose effect would be to lock in an unsustainable reliance on coal, the Public Service Commission should consider a truly equitable surcharge on all customers to fund reductions in electricity demand of all kinds.

The uses of such a fund would be rebates for buying energy-efficient light bulbs, appliances, and building retrofits, and rebates for investing in customer-supplied renewable power. Such a rebate program would pay for itself, because it would reduce Rocky Mountain Power's need to add power generating and transmission capacity to accommodate Utah rapidly growing population and economy.

In fact, it would be justified if such a rebate program were to single out customer-supplied solar as a particularly advantageous way to reduce demand for electrical power and the infrastructure needed to provide that power. This is because the power from solar PV is typically fed into the network at the time it is needed most—in the afternoon, and in summer--while the credits earned are typically redeemed off peak, in the evening. If a substantial share of total power fed into the network were solar, the effect would be to avoid the need to expand power generating and transmission capacity to accommodate peaks as the overall demand for energy in Utah grows.[9]

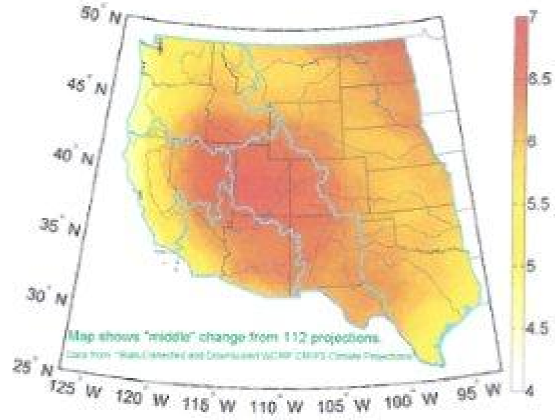
IV. IMPACT ON UTAH'S ECOLOGY IF CO_2 CONCENTRATIONS CONTINUE TO RISE

As noted earlier, the subtropical jet stream that brings storms into Utah in the winter and spring, is being weakened, and pulled north, away from Utah, by global warming. Studies of precipitation and runoff over the past several centuries and climate model projections for the next century indicate that ongoing greenhouse gas emissions at or above current levels will likely result in a long-run decline in Utah's mountain snowpack and an increased threat of severe and prolonged episodic drought in Utah, even though the possibility of occasional extreme precipitation and periodic flooding will remain.
See http://www.deq.utah.gov/BRAC_Climate/docs/Final_Report/Sec1_SCIENCE_REPORT.pdf; http://robertscribbler.wordpress.com/tag/dr-jennifer-francis.

In 2011, the Bureau of Reclamation prepared a report to Congress required by the Secure Water Act. It assesses the risks that climate change poses for water operations, hydropower, flood control, and fish and wildlife in the western United States. (Alexander, P., et al., Secure Water Act Report, 2011). Averaging projections from 112 peer-reviewed climate models, the Bureau estimates that the western United States will warm from 5º to 7º F during 2070-2099, relative to a base period of 1950-1979. The most severe warming is projected to be centered of Utah. See Figure 6(a).

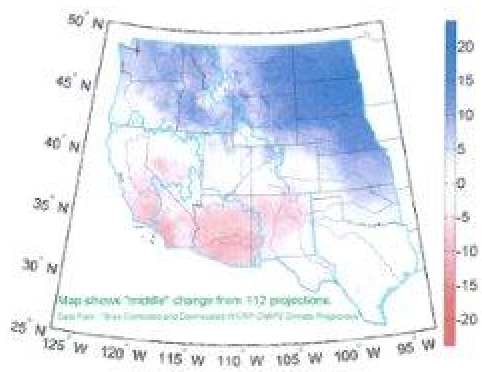
[9] The significance of this savings is verified by the recent experience of Germany and Italy. Thanks to a generous feed-in tariff, Germany now has 25 Gigawatts of installed solar capacity. In just four years (2008 to 2010), this altered Germany's time-of-day demand profile from one of a sustained 11-hour peak from morning to early evening, to two very brief smaller peaks at the breakfast and dinner hours, as the contribution from solar ramped up in the morning and then down in the evening. This resulted in cost reductions of 40% for German electricity customers. www.crickey.com.au/2012/03/27/why-generators-are-terriried-of-solar/.

Figure 6(a)



Projected median temperature change in degrees Fahrenheit (°F)(of 112 climate projections) over the Western United States, 2070–2099 relative to 1950–1979.

Figure 6(b)



Projected median percentage precipitation change (of 112 climate projections) over the Western United States, 2070–2099 relative to 1950–1979.

Precipitation is projected to decline in the southern two-thirds of the State. See Figure 6(b). The precipitation declines that the Bureau of Reclamation projects are modest in percentage terms. However, the projected increases in temperature are large, and will cause much higher evapotranspiration rates. Much higher evapotranspiration rates in the presence of unchanged or modestly less precipitation will have a powerful drying effect on Utah's climate.[10] Much less of the precipitation that is received will fall as snow. Summers will come earlier, last longer, and be much dryer. Summer drought will increase in the Great Basin and the Colorado Plateau. This will increase the frequency and intensity of dust storms, and of forest and range fires, and will encourage pollen, pathogens, and insect pests, such as locusts and bark beetles, to thrive.

The models from which the Fifth Assessment of the Intergovernmental Panel on Climate Change report summarized earlier are compiled use sufficiently detailed data[11] to model climate effects at the regional level. The report produced maps showing expected future effects of climate change on the western United States and the Great Basin. Those maps agree with the findings of the Bureau of Reclamation's Secure Water Study that the warming and drying effects of climate change on North America will be felt most intensely in Utah and its bordering states to the South and the West. AR5/WGII/Chapter 26, at 88.

What follows is a discussion of some of the ways in which the long-run increase in heat and drought expected from climate change is likely to damage Utah's ecology, economy, and the health of its citizens.

A. Impact on Sagebrush Ecosystems.

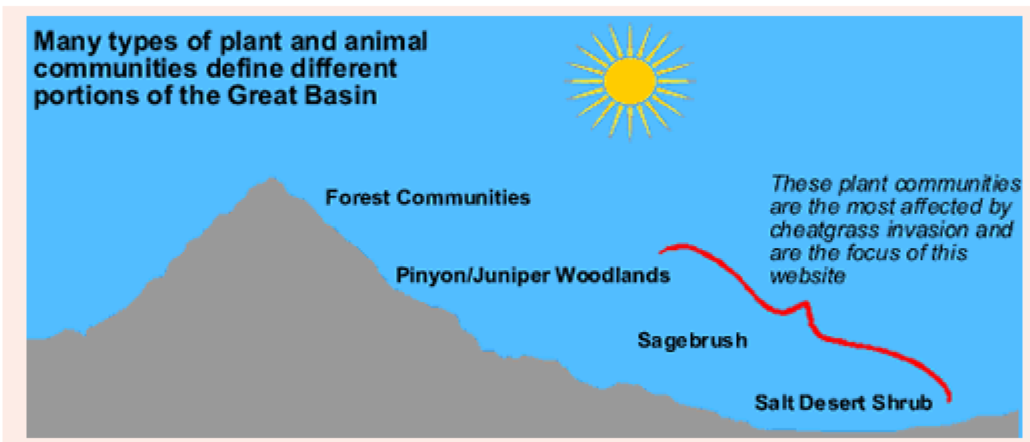
Referring back to Figure 2, the Great Basin takes in portions of the states of Utah, Idaho, Nevada, Oregon, and California. The author Stephen Trimble memorialized the Great Basin as "the sagebrush ocean." In 1845, explorer John

[10] Higher evapotranspiration associated with higher temperatures will cause large effects on ground water recharge and run off. For example, it is estimated that each degree increase in temperature (Celsius) reduces run off entering the Colorado River by 2-9%. (Hoerling, et al. 2009).
[11] Most of the datasets are at 0.5 degree spatial resolution.

C. Fremont first recognized the uniqueness of the Great Basin's internal drainage and coined its name. The Great Basin covers 75 million acres. It is a series of dry, windswept valleys whose few rivers and streams never reach the sea. Instead, they flow inland to terminal lakes, marshes, and salt flats.

As Figure 7 shows, plant communities define different portions of the Great Basin. Forest communities occur at high elevations. Lower in elevation are the pinyon/juniper woodlands.

Figure 7



As elevation decreases further, the ecosystem is dominated by sagebrush, and several varieties of perennial grasses, and forbs (such as clover). The lowest elevations are at the bottoms of valley basins. These areas often have salty soils. The only plants that can tolerate these conditions grow in salt-desert shrub communities.

Most of the native plants found in the Great Basin are relatively long-lived perennials that are slow to replace themselves when disturbed. Because of this, Great Basin rangelands have gone through cyclical vegetation changes. In sagebrush steppe communities, perennial grasses and forbs are faster growing and dominate first. Eventually, these herbaceous species give way to the longer-lived shrubs. The longer-lived shrubs persist until there is a disturbance (usually fire) which returns the rangeland to perennial grasses and forbs.

Since 1970, temperatures in the Great Basin have increased by 2ºF, which is nearly twice the average global temperature rise. The disruptive effect that climate warming is having on this cycle is summarized by the Bureau of Land Management and the National Forest Service. Rising temperatures have already altered the characteristics of a broad range of plant and animal species (80% of species from 143 studies). These changes include reduced species density, northward range shifts, altered timing of organism growth and reproduction, and reductions in the diversity of species' gene pools.

Most notably, there has been a rapid expansion of invasive species. This can be attributed primarily to the direct and indirect effects of climate change, including elevated CO_2 and Nitrogen deposition. Changes in past and present land uses, such as intense grazing, have also contributed. Consequently, approximately 20% of the sagebrush ecosystem's native flora and fauna are considered imperiled, and the remaining components of the sagebrush-based ecosystem are in decline. (Miller and Tausch, 2000, pp. 15–30).

Prior to the 1860s, the Great Basin was dominated by a sagebrush ecosystem featuring an understory of perennial grasses (bunchgrasses). This ecosystem was resilient to drought and flood, and effective in holding the soil in place. Since 1860, much of the sagebrush ecosystem has been displaced by pinyon and juniper woodland or by invasive annual grasses and a wide variety of thistles and other noxious weeds. (Id.)

This takeover is being carried out primarily by the ecologically deadly combination fire and cheatgrass.[12] In the last half of the 19th Century, after the completion of the transcontinental railroad, the Great Basin saw a rapid influx of farmers and ranchers. They brought with them alfalfa seed from Europe that was

[12] Overgrazing of perennial grasses by cattle and sheep is also an important contributor.

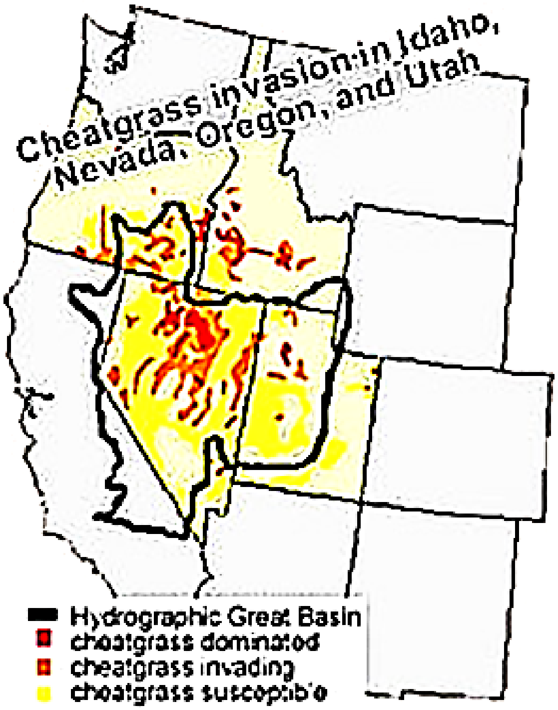
contaminated with cheatgrass seed. Foreign cheatgrass thrived in the Great Basin climate and had no natural enemies to keep it in check.

Cheatgrass is a short-rooted annual that moves in to a plant community when perennial grasses are destroyed by fire or overgrazing. Its success is based on its ability to respond with rapid growth to the brief spring wet period in the Great Basin. Once established, cheatgrass grows densely, pushing aside all competitors for moisture and nutrients. This produces large, unbroken swaths of short-rooted grass that dry out in mid-summer. They provide a continuous expanse of fuel to feed fires once they start. When fire comes, cheatgrass transforms what would have been intermittent patchy burns into large-scale infernos. Due to the recent warming of the Great Basin, these infernos are now more frequent and start earlier in the season.

Frequent, intense fires reduce the ability of many perennial plants to re-establish, furthering the dominance of cheatgrass. In this way, cheatgrass and fire feed on each other, and the problem magnifies itself with every reoccurring blaze. http://www.usu.edu/weeds/great_basin/ecology.html. Given the synergy between fire and cheatgrass, anything that promotes fire, including global warming, hastens the demise of the native sagebrush-dominant ecosystem of the Great Basin.

As Figure 8 shows, cheatgrass has taken over many landscapes once occupied by perennial shrubs, grasses, and forbs. The increased heat and episodes of drought associated with global warming also encourage the replacement of sagebrush ecosystems with stands of juniper and pinyon pine.

Figure 8



Because the juniper and pinyon ecosystem lacks perennial grasses, it is less able to protect the soil from erosion by wind and water. The juniper/pinyon ecosystem is also more fire prone, especially where the stands are dense and their crowns merge. (Miller and Tausch, 2000, pp.15–30).

As discussed in more detail below, global warming is dramatically increasing the frequency and intensity of fire in the Great Basin. Fire is so frequent in former shrub lands that have been converted to cheatgrass that rangelands that were carbon sinks are now carbon emitters on a large scale (Bradley et al., 2006). The combined effects of increased burn area and overgrazing mean that, by the end of the century, almost 59% of sagebrush-bunchgrass communities throughout the western U.S. could be taken over either by communities of annual grasses and noxious weeds, or communities of juniper and pinyon pine.

The consequences of this transformation will be devastating for mule deer, pronghorn and other species that depend on the sagebrush ecosystem. (Glick, 2006). The consequences for the Great Basin's soils will be equally harmful. Juniper, pinyon, annual grasses, and noxious weeds are ineffective in preventing fluvial erosion, and do not facilitate infiltration of moisture into soil and ground water recharge. The decline in the sagebrush-bunchgrass ecosystem in the Great Basin will expose those soils to erosion by wind, rain, and flood. While overgrazing, road building, and urban construction contribute to demise of the sagebrush ecosystem, global warming is the main forcing mechanism, largely through its facilitation of fire. (Humboldt-Toiyabe Report, p. 9).

Global warming threatens the integrity of the soils of the American West in another important way. At the lower elevations of the Great Basin, as well as the lower elevations of the Colorado Plateau in eastern and southern Utah, vegetation is sparse or absent. The open ground, however, is not bare. It is covered with a thin layer of biological soil crusts.

Biological soil crusts are formed by interactions between soil particles and cyanobacteria, algae, microfungi, lichens, and bryophytes (in different proportions) which live within the uppermost millimeters of soil. The presence and activity of this biota knit the soil particles together. The living crusts that result cover the surface of the ground as a coherent, protective layer.

Their niche is in the hottest and driest portions of the Plateau and the Basin, where there is little vegetation to defend the soil against wind and rain. In such places, soil is primarily held in place by the thin, dark crust formed on the surface by cyanobacteria. These tiny organisms, along with soil particles held together by materials they produce, provide the foundation for many biological processes. In addition to protecting the soil from erosion, they fix nitrogen and carbon to the soil, facilitating seed germination and plant growth. (Belnap and Lange, 2003, p. 503.)

Biological crusts are a vital part of the Colorado Plateau and of the Great Basin, but they are fragile and easily damaged. Because of their harsh environment, biological crusts can take centuries to form. When it is crushed by cattle hoofs, road grading, recreational off-road vehicle traffic, traffic associated with mining and oil and gas exploration, or urban construction, biological crusts can take centuries to re-form.[13] Biological crusts are also vulnerable to the higher air temperatures and more frequent droughts associated with global warming. Heat and drought shorten the time that these crusts can remain biologically active before they dry out. When dry, they are unable to produce or repair chlorophyll and/or pigments that would provide protection from solar radiation. (Belnap, et al., 2004, pp. 306-316.)

The damage to these crusts caused by changes to the climate, combined with the mechanical damage from human activity, has increased erosion of Utah's desert soils. One ominous impact of this increased erosion is a substantial increase in the amount of dust that coats the snowpack of the Rocky Mountains. Dust on snow causes it to absorb rather than reflect solar radiation. It is estimated that the flow of the Colorado River has already been reduced an average of 6% by the increased dust that now coats the mountain snowpack. http://www.colorado.edu/news/releases/2013/11/14/new-study-dust-warming-portend-dry-future-colorado-river. Since the population centers of Arizona, Southern Nevada, and Southern California are utterly dependent on the Colorado River, this long-term reduction in the flow of the Colorado caused by the conversion of once-stable soil to dust is imposing major hardships on those desert cities.

A. Impact on Forests.

[13] In southern Utah one can find places where the tracks of a lone wagon cut into bioactive crusts in the mid-19th Century and the cuts remain as crisp as if they had been laid down yesterday.

Changes in temperature and precipitation associated with climate change are causing widespread deforestation across the globe. (Bonan, et al., 2008.) Deforestation, in turn, is responsible for 20% of the "greenhouse effect."

In the Great Basin, climate change is expected to continue to produce hotter, drier conditions at high elevations, drought-weakened trees, broader insect infestations, more frequent and more intense wildfires, and impaired forest ecosystems. The weakened stands of White Pine and aspen that remain are in special peril. http://www.deq.utah.gov/BRAC_Climate/docs/Final_Report/Sec-A-1_SCIENCE_REPORT.pdf.

Of particular concern is the greatly expanded burn acreage caused by a warming climate and the effects of extreme wildfire events on ecosystems. It is estimated that increases in temperature will cause annual mean area burned in the western United States to increase by 54% by the 2050s relative to the present-day. The forests of the Pacific Northwest and Rocky Mountains will experience the greatest increases--78% and 175% respectively. The increase in the area burned is expected to cause a near doubling of wildfire carbonaceous aerosol emissions by mid-century. (Spraklen et al., DOI:10.1029.) In 2004, researchers at the U.S. Forest Service's Pacific Wildland Fire Lab looked at past fires in the West to create a statistical model of how future climate change may affect wildfires. They found that by the year 2100, the area burned annually in Washington, Montana, Utah, and New Mexico could be five times greater than at present. (McKenzie, et al., 2004, pp. 890-902.)

Although wildfire activity in the forests of the western United States has increased in recent decades, neither the extent of recent changes, nor the degree to which climate may be driving regional changes in wildfire, has been systematically documented. Much of the earlier research has laid the majority of the blame on the effects of 19th- and 20th-century land-use history.

A study published in *Science* magazine in 2006 corrects this misassumption. It compiled a comprehensive database of large wildfires in western United States forests since 1970 and compared it with hydroclimatic and land-surface data. It found that large wildfire activity increased suddenly and markedly in the mid-1980s, with higher large-wildfire frequency, longer wildfire durations, and longer wildfire seasons. It found that the greatest increases occurred in the mid-elevation forests of the Northern Rockies, where burned area increased 650% between 1970 and 2003. It noted that land-use histories have had relatively little effect on fire risks in these zones. Instead, it demonstrates, those risks are driven by the higher spring and summer temperatures and the earlier spring snowmelts associated with climate change. (Westerling, et al., 2006, pp. 940-943.)

Global warming gives the various species of bark beetle an overwhelming advantage in their assaults on their host spruce and pine trees. In 2009, bark beetle infestations destroyed 9 million acres of forest in the western United States. http://www.scientificamerican.com/article/mountain-pine-beetle-damage-declines/.

Higher temperatures benefit every aspect of the bark beetle's life cycle, from the number of eggs laid by a single female beetle, to the beetles' ability to disperse to new host trees, to individuals' over-winter survival. Higher temperatures associated with climate change speed up reproductive cycles, particularly when there are consecutive warm years. Warmer winters make it easy for spruce and pine bark beetles to survive even at the highest elevations. Drought-weakened trees have few defenses against the newly robust beetle populations. www.fs.fed.us/ccrc/topics/bark-beetles.shtml. They have virtually eradicated particularly vulnerable species such as lodgepole pine from the western United States in the last few decades.

In the Western U.S., as noted above, the forest fire season is 79 days longer than 25 years ago. The severity of these fires is greatly enhanced by the unrestrained depredations of bark beetles. The dead tree litter caused by bark beetle infestations creates ideal conditions for catastrophic forest fires. Northern latitude forests on other continents have been similarly affected.

The climate impact of the loss of forests to bark beetle infestations is magnified by the fact that dead trees not only cease to absorb carbon from the atmosphere, they return it to the atmosphere as they decay.

E. Impact on Species Extinction

Current trends suggest that the fastest and most wide-spread mass extinction of species in the Earth's history is very likely underway. In the tropics alone, we may now be losing 27,000 species per year to extinction. http://www.pbs.org/wgbh/evolution/library/03/2/l_032_04.html. By the year 2050, it is estimated that 15–37% of land plants and animals will become extinct as a result of climate change. (Thomas, C. et al., 2004.) Many species will die because they will not be able to migrate to places where the climate remains suitable. Others will die because suitable habitat will no longer exist. http://www.nature.com/nature/links/040108/040108-1.html.

When viewed on an evolutionary time scale, the current pace of climate change is essentially instantaneous. For example, studies of the fossil record indicate that for tree species to adapt to the current pace of climate change, they would have to migrate to suitable habitats ten times faster than most species were able to respond to climates shifts in the past two million years. Few, if any, tree species have this ability. (Davis and Shaw, 2001.)

Species mortality has serious consequences. In plant communities, reduced diversity leads to lower productivity, less nutrient retention in ecosystems and ecosystem instability. An average plot containing one plant species is less than half as productive as an average plot containing 24–32 species. As plant diversity is lost, leaching of nutrients from the soil increases, reducing its fertility. (Tilman, D., 2000).

It is helpful to consider that the species presently inhabiting the earth are the result of over 3 billion years of natural selection that fostered efficiency, productivity, and specialization. These organisms are the agents that capture and transform energy and materials, producing, among other things, food, fuel, fiber, and medicines. These species also recycle wastes, create pure drinking water, drive global biogeochemical cycles that created and maintain an aerobic atmosphere, regulate global climate by absorbing greenhouse gases, regulate local climate through plant evapotranspiration, make soils fertile, and provide other natural “goods and services.”

In addition, the Earth's biodiversity is the source of all crops and all pollinators of crops, of all livestock, and of many pharmaceuticals and pesticides. Just three crops--corn, rice and wheat--provide about 60% of the human food supply. To remain viable, these crops must remain genetically diverse. Among other things, genetic diversity ensures that strains are available that are resistant to emerging and evolving diseases and pests. In the long term, food stability will require development of new crops from what are now wild plants, because disease or pesticide-resistant pests will eventually decimate the mono-cultured crops on which we currently rely, just as disease has eliminated chestnuts, elms, and other tree species from North American forests.

Ours is a society that is accustomed to the availability of the services of natural systems. We think of the services they provide (breathable air, drinkable water, livable temperatures), as opposed to the resources extracted from them, as free. We take the health and abundance of natural systems for granted.

The most recent attempt to estimate the total value of the services provided by earth’s natural systems of which we are aware was conducted in 1997. It conservatively estimated that the annual value of the services provided by “natural capital” at $33 trillion. Adjusted for inflation, the value of natural services would have been $47 trillion in 2012, two-thirds as large as the world’s Gross Domestic Product in that year ($72 trillion).[14] If a capitalized book value

[14] See “A Road Map for Natural Capitalism,” Harvard Business Review, May-June 1999, reprint # 99309. Applying the 1997-2012 inflation rate of 43% to $33 trillion rounds to $47 trillion.

approach is applied to valuing the earth's natural systems, $47 trillion would have a capitalized value of well over $500 trillion.[15]

The purpose of this attempt to place a price tag on the value of natural systems is to put in perspective the enormous harm to the welfare of society going forward if the world continues to take a "business as usual" approach to burning carbon for energy. For most of natural services, there is no known substitute at any price, and we can't live without them. These natural systems cannot continue to provide these services unless they are healthy, functioning ecosystems. The value of nearly all of the earth's $500 trillion worth of natural systems are threatened by climate disruption.

Focusing on the value of Utah's natural systems, it is noteworthy that this this State is where four major, unique ecosystems intersect—the Rocky Mountains, the Colorado Plateau, the Basin and Range, and the Bonneville Salt Flats. As a result, despite being a predominantly desert state, Utah is ranked fifth in the nation for biodiversity. The diversity of Utah's ecosystems can be expected to suffer more than the diversity of ecosystems generally as a result of climate change because its water-constrained ecological systems already exist at the margin of viability. For example, a large portion of the State is covered by the Great Salt Lake. The Great Salt Lake is an indispensable waypoint for internationally migrating waterfowl. Yet, of all the wetlands in the United States, the Great Salt Lake may be one of the most at risk from climate change because it is so shallow and its evaporation rate is so high.

V. IMPACT OF RISING CO_2 ON PUBLIC HEALTH IN UTAH.

Climate change can be expected to impact the health of Utah residents in the following ways.

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[15] See "A Road Map to Natural Capitalism," Harvard Business Review, July, 2007, www:hbr.org/2007/07/a-road-map-natural capitalism/ar/1.

A. Impaired Respiratory Function from Increased Ground-Level Ozone.

The chemical reaction that forms ozone combines nitrous oxides and Volatile Organic Compounds (VOCs) in the presence of sunlight. This reaction is, in part, heat driven. A warming climate caused by the burning of carbon promotes the formation of ozone. Plants emit more VOCs at higher temperatures, which can increase ozone formation if mixed with pollutants from human sources. Methane, which is increasing in the atmosphere, contributes to increased ozone globally and enhances baseline levels of surface ozone across the United States. These gases come from human activities such as the burning of coal and oil as well as natural sources such as emissions from plants.

Research by the National Center for Atmospheric Research (NCAR) shows that Americans face the risk of a 70 percent increase in unhealthy summertime ozone levels by 2050 if global warming increases at its current rate. The study models two climate change scenarios in great detail, using the new Yellowstone supercomputer to assist with the geophysical modeling. In one scenario, emissions of nitrogen oxides and volatile organic compounds from human activities would continue at current levels through 2050. In the other, emissions would be cut by 60-70 percent. Both scenarios assume continued greenhouse gas emissions with significant warming.

The researchers found that, if emissions continue at present-day rates, the number of eight-hour periods in which ozone would exceed 75 parts per billion (ppb) would jump by 70 percent on average across the United States by 2050. The 75 ppb level over eight hours is the threshold that is considered unhealthy by the Environmental Protection Agency.[16] Other studies established that higher ozone concentrations lead to higher death rates. See European Lung Foundation. "Climate change set to increase ozone-related deaths over next 60

[16] Pfister, G., et al., 2014. The nitrous oxides and VOCs produced by burning fossil fuels promote the formation of ozone, not the CO_2. Under the study's second scenario, temperatures continued to warm, but pollution controls on fossil fuel burning were assumed to achieve sharp reductions in nitrogen oxides and volatile organic compounds. Under this scenario, 90 percent of the time, ozone levels would range from 27 to 55 ppb. The number of instances when ozone pollution would exceed the 75 ppb level dropped to less than 1 percent of current cases.

years, scientists warn." ScienceDaily, 27 September 2011. <www.sciencedaily.com/releases/2011/09/110927073159.htm>.

The incidence of forest fires is also heat driven. Forest fires are a major source of ground-level ozone. As forest fires become more frequent and intense, exposures to ground-level ozone will increase. The significance of forest fires as sources of ozone can be appreciated by considering that smoke plumes from forest fires in Alaska have been shown to significantly increase ground-level ozone concentrations as far away as Europe. (Real E., et al., 2007).

Ozone creates a positive feedback mechanism for global warming because ozone itself is a greenhouse gas. In yet another positive feedback mechanism, higher ozone concentrations retard the growth of trees, which reduces the ability of forests to absorb CO_2.

The American Lung Association estimates that at least one-third of Utah is vulnerable to the impacts of air pollution. Of a population of 2.8 million, more than 1 million are under 19 or over 64. About 230,000 have asthma, and nearly 494,000 have cardiovascular disease. The effect of ground-level ozone pollution on the delicate lining of the lungs is analogous to the effects of sunburn on the skin. It aggravates respiratory diseases like asthma, and impairs lung function in both the vulnerable and the healthy segments of Utah's population.

Until recently, high concentrations of ground-level ozone in the Mountain West were observed only in the summer in population centers, as auto and industrial emissions reacted in the presence of sunlight and heat. High concentrations of ground-level ozone are now appearing in the Mountain West's remote areas as well, especially in areas where oil and gas producers have recently drilled thousands of wells. Oil and gas drilling, as presently practiced, releases large quantities of ozone precursors, such as nitrogen oxide (NOx), volatile organic compounds (VOCs), and formaldehyde. http://rd.usu.edu/files/uploads/ubos_2011-12_final_report.pdf. Recently, for the first time, concentrated ground-level ozone has appeared in the winter in the remote energy development areas of Wyoming, Colorado, and Utah's Uinta Basin.

The Uinta Basin covers nearly 6 million acres. In winter, emissions from energy production collect in its lower atmosphere where they are transformed into ozone by interacting with sunlight and snow. Air pollution monitors installed in the Uintah Basin measured ozone concentrations exceeding federal health standards more than 68 times in the first three months of 2010. http://www.nytimes.com/gwire/2010/10/01/01greenwire-air-quality-concerns-may-dictate-uintah-basins-30342.html?pagewanted=all. Maximum 8-hour average ozone concentrations at the Ouray air monitoring station during 2013 reached 142 ppb. This exceeds federal air quality standards by 89%. http://www.deq.utah.gov/envrpt/Planning/s12.htm. For long periods of time, ground-level ozone concentrations in the Uinta Basin now exceed those of Los Angeles County, where the nation's highest ozone concentrations traditionally occur.[17]

Atmospheric currents are capable of transporting ozone and particulate matter thousands of miles away from their original sources. For example, ozone is showing up now in high concentrations in the air over the middle of the Atlantic Ocean. This raises the prospect that the rapidly growing supply of ozone precursors in the Uinta Basin will combine with the higher temperatures that global warming will bring to increase ground-level ozone in the Uintah Basin and allow it to bleed into adjacent regions, including the mountain valleys of the heavily populated Wasatch Front.

Another source of ozone adjacent to the Wasatch Front is the ultraviolet light that reflects off of the surface of the Great Salt Lake and interacts with the chemical soup produced by the refinery emissions and the vehicle exhaust

[17] The Uinta Basin's average ozone concentration for 2010-2011 was 116.5 ppb (based on the NAAQS-created measurement of the fourth-highest value averaged over the two years). In comparison, Los Angeles County averaged 108 ppb over the same two years. http://www.blm.gov/pgdata/etc/medialib/blm/ut/lands_and_minerals/oil_and_gas/november_2011.Par.75557.File.dat/Email%20July%2015%202011%20Garbett%20-%20SUWA%20Comments%20Nov%202011.

emitted near the eastern and southern shores of the lake. This intensifies the concentration of ozone along the Wasatch Front, and makes the Wasatch Front all the more vulnerable to the ozone-promoting effects of global warming.

A recent study of ozone by Utah's Division of Air Quality reports annual concentrations of ozone in metropolitan Salt Lake City of 0.079 ppb. This violates the National Ambient Air Quality Standard of 0.075 ppb (based on the 4th highest annual 8-hour maximum). The study shows that ozone is expanding far beyond the areas traditionally affected by photochemical reaction. It reports ozone levels virtually as high in the parks of Southern Utah as in the urbanized North. http://www.airquality.utah.gov/Public-Interest/Current-Issues/Ozone/2012_Utah_Ozone_Study.pdf. This is evidence that Utah's air quality is affected by events and policies in other parts of the world, and this trend is growing.

A recent, landmark study led by Brigham Young University's Arden Pope has enhanced our understanding of the impact of ozone on public health. It clearly demonstrates that ozone exposure increases rates of respiratory death. Along the Wasatch Front, the study concludes, exposure to ground-level ozone increases the rate of respiratory death by about 25%. Other studies establish that ground-level ozone negatively impacts lung function across all segments of the population, including young, healthy adults, even at levels below current national air quality standards.

B. Impaired respiratory and cardiac function due to excessive heat events.

Models from climate researchers indicate that climate change will not just warm the climate on average, but will also increase extreme climate events, such as heat waves. Studies show a correlation between temperature and hospital admissions for respiratory failure and for cardiac death. For example, a study published in The American Journal of Respiratory and Critical Care Medicine examined populations in 12 different European cities. For each city they found a temperature/humidity threshold beyond which each degree of increase resulted in a 4% increase in respiratory admissions for all ages, but especially those over 75.

In the summer of 2003, a heat wave in Europe killed 70,000 people within a few weeks. A similar heat wave struck Russia in 2010. In the Russian event, monthly temperatures were more than 5º Celsius above average, and daily temperatures peaked at up to 12º above average, reaching over 40º Celsius (104ºF). These conditions caused an estimated 55,000 deaths, a 25% drop in annual crop production, and a total economic loss of more than $15 billion.

An Oxford University study published in 2012 estimates that the risk of a heat wave of the magnitude of the Russian event has approximately tripled due to the warming of the globe that has occurred since the 1960s, caused mostly by increases in greenhouse gas emissions. The study concluded that this kind of extreme weather event can be "mostly natural" in terms of magnitude, but "mostly human-induced" in terms of the probability of occurrence. By modeling these distinct aspects of this event, the study was able to calculate how much human-induced climate change cost the Russian economy in the summer of 2010. http://phys.org/news/2012-02-russian-manmade-natural.html#jCp.

A study published in the Proceedings of the National Academy of Science in 2012 concluded that the global distribution of temperature anomalies has shifted toward higher temperatures, and that the range of such anomalies has increased. This has created a category of extreme summertime outliers, more than three standard deviations (3σ) warmer than the climate in the 1951–1980 base period. The distribution of such heat extremes covered much less than 1% of Earth's surface during the base period. Now, such heat extremes typically cover about 10% of the land area. The study concludes that it is extremely unlikely that the heat waves that struck Moscow in 2010, and those that struck Texas and Oklahoma in 2011, would have occurred absent global warming. http://www.pnas.org/content/early/2012/07/30/1205276109.

Global warming also increases the severity of heat waves indirectly. Using broad measurements taken in southeastern Europe, a study demonstrates that the moisture contained in soils acts as a heat sink, absorbing heat until the moisture in the soil is exhausted. The study concludes that compared to wet summers, the frequency of very hot days increases tenfold in summers with dry soils. Soils dried out by heat and drought associated with global warming cannot function as a heat sink to moderate regional heat waves once they occur. http://www.ethlife.ethz.ch/archive_articles/101213_hitzewellen_paper_ga/index_EN.

The likely cause of the recent heat waves in Europe, Russia, Texas, and Oklahoma is the breakdown of the polar jet stream described earlier. Because this phenomenon will only grow as the earth warms, the Mountain West can expect to experience a similar extreme heat event at some point in the future. As a desert state, moist soils are unlikely to be available to soften the impact.

C. Hazardous substances distributed by dust pollution.

As described earlier, hotter temperatures and reduced precipitation expected in the Great Basin as a result of climate change are likely to result in widespread loss of native vegetation in the already water-stressed Great Basin. This can be expected to expand the sources of dust, or particulate matter pollution, to which Utah residents are exposed.

Particulates that are likely to increase as a result of global warming, and the additional threats that they pose to the health of Utah's residents, are discussed below.

Erionite exposure

Erionite is a mineral that forms long fibers that have an effect on the lungs similar to asbestos fibers. Like asbestos, inhaling erionite produces Malignant Mesothelioma (MM).

MM is a rare and unusually deadly form of cancer that develops from cells of the mesothelium, the protective lining that covers many of the internal organs of the body. Most often MM develops in the pleura (the outer lining of the lungs and internal chest wall), but it can also develop in the peritoneum (the lining of the abdominal cavity), the pericardium (the sac that surrounds the heart), or the tunica vaginalis (a sac that surrounds the testis). MM has a long latency period--30 to 60 years. This tends to obscure both its sources, and its prevalence. Despite the various forms of treatment available (chemotherapy, radiation therapy, sometimes surgery), MM carries a poor prognosis once contracted.

Inhaling erionite fibers is 300 to 800 times as likely to cause MM as exposure to asbestos. (Wagner, et al.,1985, pp. 727-730). It is the most toxic naturally occurring fibrous mineral known. (Pass, et al., 2005). It was first recognized as a potent carcinogen in the 1980s when a cluster of villages located in a part of Turkey were found to have astonishingly high rates of MM. In those villages, the rate of cancer is about 1000 times the normal rate, and causes 40 percent to 50 percent of all deaths. (Baris, et al.,1978, pp. 181-192). Epidemiological studies linked these high concentrations of MM to exposure to erionite released into the air from the soil and decaying rock formed from the local volcanic tuff. (Int. J. Cancer 39, 1987, pp.10-17); Proceedings of the National Academy of Sciences, (June, 2011) www.pnas.org/cgi/goi/10.1073/pnas.1105887108.

Very low ambient fiber concentrations were associated with this extraordinarily high incidence of MM. This, together with the prevalence of erionite in other parts of the world, notably the western United States, indicated an urgent need to develop animal models to investigate the relationship between erionite and MM.

Erionite is a silicate found in volcanic ash that has been altered by weathering or exposure to alkaline ground water. The Great Basin is uniquely suited to the formation of erionite because a great deal of volcanic ash has accumulated in its valleys. The permanent saline, alkaline lakes and playas provide ideal circumstances for the volcanic ash to transform into erionte. Figure 9 shows that Utah lies in the center of an arc of erionite that sweeps from Arizona through Nevada and Oregon to Montana and North Dakota. The deposits are most prevalent in central Nevada, upwind of the Wasatch Front.

Figure 9

When eronite is disturbed, it can release fibers that cause MM into the air. The source of the erionite fibers in the “cancer villages” of Turkey was poorly consolidated, incompletely formed zeolite rock. (Wagner, J. et al., pp. 727-730). A systematic survey of the characteristics of the many erionite deposits in Nevada, California, and Oregon that are generally upwind of Utah has yet to be made. Therefore, it is not known how many of them consist of poorly consolidated zeolite similar to the erionite outcroppings in Turkey. Therefore, it is not known how prone erionite beds in the Western United States are to weathering and release into the air.

The extreme toxicity of even small amounts of erionite is established. The risk that Utah's residents are being exposed to erionite-laden dust from the numerous desposits that lie upwind of the State is potentially large. It is quite possible that erionite occurs in loose, weathered outcrops that are susceptible to natural dispersion by dust storms, similar to the deposits that contaminate the air in the "cancer villages" of Turkey. In addition, roads, mines, pipelines, power lines, wind and solar farms, and recreation sites, are proliferating in those areas, making it likely that such activity is unwittingly disturbing erionite and releasing it into the air.

Because exposure to erionite is not regulated, there are no applicable Federal standards to enforce. Federal agencies have failed to notify land-use officials, developers, or residents of affected areas to look for erionite outcrops or to avoid disturbing them by their development activity. What is needed now is a systematic study of levels of exposure in the western United States and any correlation between levels of exposure and the incidence of MM. Such studies, however, have yet to be funded outside of North Dakota.

Dr. William N. Rom, currently director of the pulmonary division at the New York University School of Medicine, and Dr. Kenneth R. Casey, now at the University of the Cincinnati College of Medicine, recognized the risks that erionite deposits pose to the population of the western United States. They requested a grant from NIH to conduct the needed studies. Unfortunately, their proposal was not accepted.

The people of Utah are at risk from the failure to conduct the studies proposed by Drs. Rom and Casey. There is a compelling need to inventory erionite deposits and assess their susceptibility to both man-made and natural dispersion. As noted, erionite deposits are prevalent in the parts of the Great Basin that are upwind of Utah. If there are weathered erionite outcrops or artificially disturbed erionite beds upwind of Utah, they place Utahns at risk of inhaling erionite fibers and contracting MM. By damaging the shrubs, perennial grasses, and biological crusts that now hold the soil of these regions in place, global warming can be expected to increase Utahn's exposure to dust-borne erionite. As will be explained later in these comments, the risk that dust containing erionite (and a wide range of other hazardous substances that contaminate Nevada's soil) will be carried to Utah's population centers will be greatly amplified if Las Vegas carries out its plans to dewater central Nevada and Western Utah.

Radionuclide exposure

In 2006, the Federal government announced plans to simulate the destruction of a nuclear warhead by detonating a non-nuclear bomb. The test was dubbed "Divine Strake" and was scheduled to take place at the nuclear testing facility in Nevada. Utahns sent ten thousand letters to the Federal government opposing "Divine Strake," most of them citing the risk that dust contaminated with radionuclides would be blown aloft and drift into Utah.

Divine Strake was cancelled due to public opposition and pressure from Utah's Governor Jon Huntsman. Now there is the worrisome prospect that desertification intensified by global warming, and accelerated by Las Vegas's plan to drain nearby acquirers, is the next pathway by which radionuclides could be dispersed downwind to Utah from Nevada's nuclear test sites.

Over 900 above-ground nuclear bomb tests have been conducted at the Nevada test site in the mid-20th century. The Department of Energy (DOE) also conducted numerous non-nuclear "safety tests" in which it blew up mock nuclear war heads in contaminated soil. While not nuclear explosions, safety tests caused significant contamination of the surface with plutonium. Nuclear "rocket tests" caused additional radioactive contamination.

The contamination from above-ground testing, along with the safety shots, and cratering events, left an estimated 27,000 acres (42 square miles) of surface soils contaminated at levels in excess of 40 pico curies per gram (20). (Walker, et al., 1998). Underground tests, which continued until 1992, also released significant radioactivity into the atmosphere.

The Department of Energy has stated that it is not possible to fully define the level of residual contamination that remains from the atmospheric testing program. It admits that radioactive isotopes that are still in Great Basin soil in largely unknown concentrations include americium, plutonium, uranium, cobalt, cesium, strontium, and europium. (Id.)

Some of these isotopes are alpha-emitters--the most carcinogenic substances known. Nuclear weapons brainstorming during World War II illustrates how toxic alpha emitters are. Since 1943, the military has been aware of the extreme toxicity of uranium as a gas. In a document dated October 30, 1943 and declassified June 5, 1974, three major scientists from the Manhattan Project, Drs. James Conant, A. H. Compton, and H. C. Urey wrote to Brigadier General Leslie R. Groves, who was the head of the atom bomb project, concerning "Radioactive Materials as a Military Weapon." In that document they stated:

> As a gas warfare instrument the material (uranium) would be ground into particles of microscopic size to form dust and smoke and distributed by a ground-fired projectile, land vehicles, or aerial bombs. In this form it would be inhaled by personnel. The amount necessary to cause death to a person inhaling the material is extremely small. It has been estimated that one millionth of a gram accumulating in a person's body would be fatal. There are no known methods of treatment for such a casualty.

Uranium was also recommended as a permanent terrain contaminant which could be used to destroy populations by contaminating water supplies and agricultural land with radioactive dust. http://www.mindfully.org/Nucs/Groves-Memo Manhattan30oct43.htm.

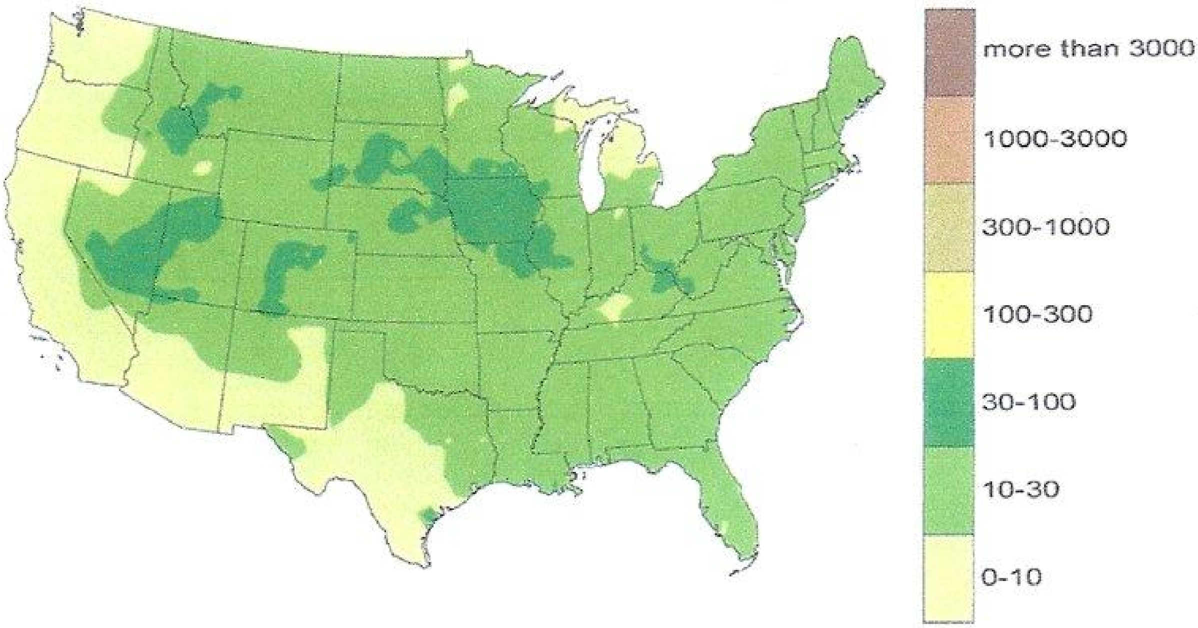
To provide some perspective on the toxicity of alpha emitters, consider that one millionth of a gram of uranium yields 1,000 alpha particles per day, and that each alpha particle carries over 4 million electron volts. It takes only 6-10 electron volts to break a strand of DNA.

The longer-lived radioactive elements, including plutonium, Cesium 137, and Strontium 90, bioconcentrate as they rise up the food chain. They reach concentrations that are thousands of times higher when they accumulate in meat and milk, including human breast milk. Humans reside at the top of the food chain, especially human embryos.

Once ingested, these radioactive elements continue to bioconcentrate, accounting for their distinctive carcinogenic patterns and enhancing the toxicity of low-dose exposures. Strontium concentrates in bone, bone marrow and teeth, resulting in bone cancers and leukemia. Cesium resembles potassium, which is ubiquitous in every cell. It concentrates in brain, muscle, ovary and testicles. This leads to brain cancer, muscle cancers (rhabdomyosarcomas), ovarian and testicular cancer. Most importantly, Cesium 137 can mutate genes in eggs and sperm, causing genetic diseases in future generations.

The Nevada Test Site and other nuclear test areas in Nevada were previously identified in Figure 2. Figure 10 is reproduced from a 1997 National Cancer Institute study. It shows the pattern of deposition of all of the Plutonium dust released from those sites.

Figure 10



Plutonium (239+240) deposition density (Bq/m^2) due to all NTS tests.

The six test main series which took place in 1951, 1952, 1953, 1955, 1957, and 1962, deposited different amounts of fallout within the United States. For example, the 1957 Plumbbob series deposited 35% of the total cesium followed by the 1953 Upshot-Knothole series that contributed 23%.

Of all the alpha emitters, Plutonium is the most deadly. If inhaled, it is transported from the lung to thoracic lymph nodes where it can induce Hodgkins disease or lymphoma. Because it is an iron analogue, it combines with the iron transporting protein. It concentrates in the liver, causing liver cancer, and the bone marrow causing bone cancer, leukemia, or multiple myeloma. It also concentrates in the testicles and ovaries where it can induce testicular or ovarian cancer, and/or mutate genes to induce genetic disease in future generations.

Plutonium can cross the placental barrier which protects the embryo. Once lodged within the embryo, just one alpha particle could be enough to kill the cell that would eventually have formed the left side of the brain, or the right arm, as thalidomide did years ago. The half-life of plutonium is 24,400 years, so it can cause harm for 500,000 years--inducing cancers, congenital deformities, and genetic diseases for the rest of time, not only in humans, but in all life forms.

The Nevada Test Site has a “Soils Program” to determine the extent of surface contamination and develop mitigation plans for these areas, which may involve soil removal. Prior to 2006, there was an estimated 20-25 million cubic feet of plutonium-contaminated soil at the NTS and the adjacent Tonopah Test Range. How much of that remains is unclear.

It is estimated by the National Nuclear Security Administration that about 3,000 acres are contaminated with plutonium at levels in excess of 40 pCi/g (with some areas in excess of 12,000 pCi/g) left by the “safety tests.” In a 2003 document, all of the safety test areas were to have been cleaned up by 2006 to a “target level” of 200 picograms of plutonium per gram of soil (a picogram is one-trillionth of a gram).[18] Over time some of the longer-lived radioactive particles have been taken up by plants in the area or concentrated in drainage gullies. The Site Wide Draft Environmental Impact statement for the NTS does not say whether these sites have been cleaned up. It does say that there is a target date of 2022 for all the soils sites to be “closed.” Unfortunately, DOE does not say what level of clean-up will be achieved at a “closed site” in its public documents. Nevada Test Site Public Information Brief - March 2012. http://www.h-o-m-e.org/nts-vision-project/nts-briefing-paper.html.

An article published in 1979 in the Washington Post quoted Utah scientists stating that in the 1950s, plutonium was spread across the most densely populated part of Utah (the Salt Lake City area) that produced levels of plutonium as much as 3.8 times higher than concentrations elsewhere. These scientists

[18] While this level seems very small it is still 4 times dirtier than the clean-up level for Rocky Flats.

were surprised that plutonium was found in such large quantities. The scientists attributed it to the safety tests in which mock warheads were blown up. A study conducted in the 1990s by a Nevada graduate student found plutonium dust in the attics of homes in Las Vegas and other towns in Nevada and Utah. He, also, attributed this contamination to the safety tests.

The dirtiest of all the safety tests was 'Project 57.' The plume cloud from Project 57 went north-northeast and deposited just over 200 Curies of plutonium over a large area extending towards Ely, Nevada, and into Utah, and possibly Salt Lake City. Project 57 contaminated Nevada Test Site's Area 13 with four times more Curies of radioactivity than the average at nine other safety test sites. At Area 13, hundreds of acres of soils are contaminated at the level of 46 Curies – a level immensely higher than that which would provide a fatal dose to humans.

Since plutonium concentrations greater than 10 picoCuries (10 trillionths of a Curie) per gram are fatal for humans, there are a lot of 'hot' areas at Area 13, and downwind of that area in Nevada and Utah, that still contain dangerous levels of plutonium.[19] The danger will remain for the next 240,000 years. Ninety-nine percent of the plutonium particulates at Area 13 (and possibly elsewhere) are small enough to be picked up by wind. Area 13 has yet to cleaned up and the plutonium there keeps on getting resuspended into other areas that don't have radiation monitoring equipment. Although the DOE has a monitoring network in place, it provides little comfort concerning the prevalence of Plutonium contamination, since it is not capable of detecting alpha or beta radiation (e.g., plutonium 239). (Wilshire, et al., 2008, pp. 395-398).

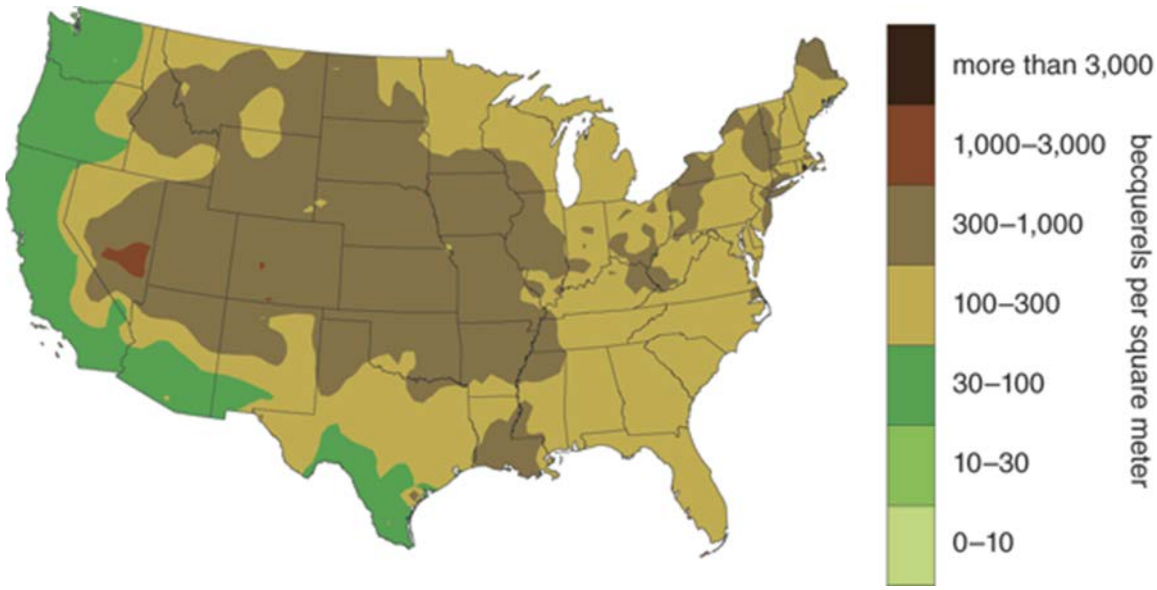
Utahns, both in the southern and the more heavily-populated northern end of the State, were, and still are, "downwinders" of the Nevada tests. Many residents of the St. George and the Salt Lake City areas were heavily exposed at

[19] Figure 10 shows that the region of highest Plutonium soil deposition coincides with the region that Las Vegas plans to dewater with its groundwater pumping project. With the die off of vegetative cover of this region that would follow dewatering, its Plutonium-contaminated soils can be expected to become airborne during periods of high wind.

the time and some are still dying from that exposure. The lack of data and availability of fallout maps regarding these safety tests has prevented the public from appreciating the seriousness of ongoing risks of radiation-induced illness that lingers from the atomic tests that were conducted upwind of the State. The Department of Energy has yet to provide comprehensive data that would allow the risk to be quantified. The DOE's environmental analysis of Area 13 remains incomplete and its environmental cleanup of the area has stalled. The DOE should complete a new, full-blown EIS for the Nevada test sites to address these lingering radiation hotspots, the dangers of resuspension, and the lack of adequate airborne radiation monitoring in and around downwind communities.

Figure 11, taken from a 1997 National Cancer Institute study, shows the pattern of soil deposition of cesium-137, a radionuclide traditionally used for reference, resulting from all NTS tests in the entire United States.

Figure 11

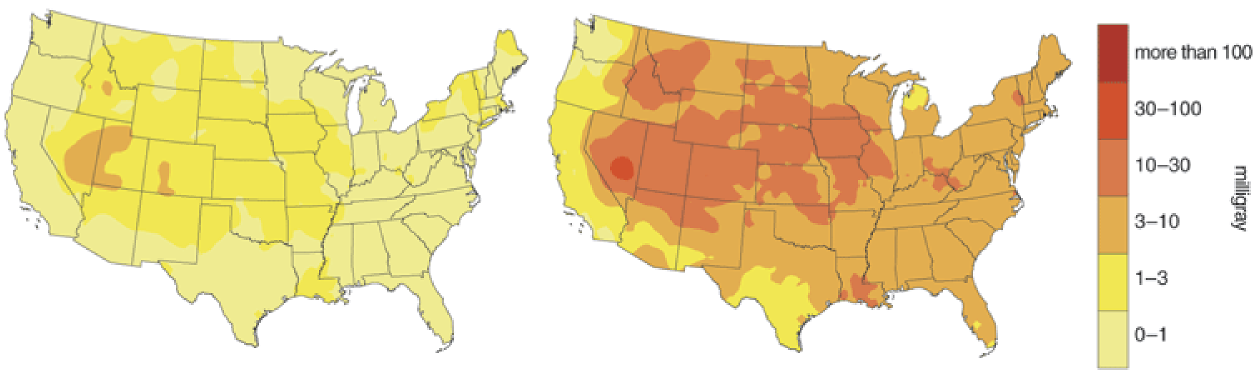


Cesium-137 deposition density resulting from the cumulative effect of the Nevada tests. Data from 1997 National Cancer Institute study.

Fallout decreased with distance from the NTS along the prevailing wind direction, which was from west to east. Utah was first in line to receive this contaminant after it left the test area. Very little fallout was observed along the Pacific coast, which was usually upwind from the NTS. The soil deposition pattern for Strontium 90, another long-lived radionuclide, was virtually identical to that of Cesium 137, with Utah first in line for exposure to the contaminant. (Dept. of Health and Human Services, 2005).

Estimated internal doses of Cesium 137 absorbed by bone-marrow and thyroid glands are illustrated in Figure 12 on the left, while external doses are illustrated on the right. The internal doses present the greatest health risk. The fact that both external and internal doses were roughly proportional to the deposition density is reflected in similarities between the two figures. Again, it is significant that after the immediate test area, Utah is positioned to be exposed to the next most concentrated internal dosage of Cesium 137.

Figure 12



Total external and internal dose to the red bone marrow of persons born on January 1, 1951, from all Nevada tests is shown at left. Data from NCI 1997.

In a 2009 masters thesis, a study was conducted using soil samples from Utah's Washington County to determine how much Cesium 137 still exists there. Over a hundred soil samples were collected and analyzed. Only one did not have detectable amounts of Cesium 137. The author noted that several of the samples contained levels substantially higher than earlier estimates would have predicted, which led him to conclude that doses to the public from the testing could also have been higher than had previously been estimated. http://ir.library.oregonstate.edu/xmlui/handle/1957/9293.

If Cesium 137 is still ubiquitous in soil in Washington County, Utah, one can assume that it, and other long-lived radioactive isotopes, would be all the more prevalent in soil in the part of Nevada where state officials are planning to drain aquifers, parts of which are closer to Nevada's Nuclear Testing Site. The combined effects of global warming and aquifer draining could well destroy the vegetative cover that keeps those soils in place. Windstorms could then carry that radioactive dust to the Wasatch Front, just as prevailing air currents did during the bomb testing of the 1950s.

It is almost certain that dust storms from the Great Basin still carry airborne radioactive isotopes to areas where millions of Utah's residents live. While the risk of radionuclide contamination has not been quantified, we know that the risk that contaminated soil will be resuspended in the atmosphere and exported beyond the original deposition site rises dramatically where the size of the particles of contaminated soil are small, the soil has been mechanically disturbed (by grazing animals' hooves, road cuts, etc.), or the surface has been subjected to fire. (Gilbert, et al., 1988, pp. 869-87). The Department of Energy should conduct a survey of the deposition region that collects data on all of these characteristics to inform future land use plans.

Radiation damage is cumulative and each successive dose builds upon the cellular mutation caused by the last. One mutation, in one gene, in a single cell, if unrepaired, can result in a fatal cancer. Many cancers, especially solid tumors, and other genetic diseases have a latency period of many decades. Utah residents are still contracting new cancers from the original nuclear testing program that was conducted more than 50 years ago.

If a comprehensive study of the potential exposure of Utah residents to dust contaminated with radionuclides were conducted in the future, and it were to conclude that the Nevada Test Site has been thoroughly and effectively decontaminated, the broad fallout path leading to Utah population centers would remain contaminated and susceptible to wind-driven deposition along the Wasatch Front. Even small increases in risk per person become significant public health hazards in the aggregate, when large numbers of people are exposed. In other words, when millions of people are exposed to slightly increased risks, there will be thousands of new victims.

Cancer is not the only health risk from exposure to radiation. Cardiovascular disease causing heart attacks, strokes and diseases consequent to immunosuppression are all correlated with radiation exposure, as are any diseases related to chromosomal dysfunction, such as birth defects. Children are much more susceptible to radiation-caused health effects. Human embryos are perhaps thousands of times more at risk for genetic mutations from radiation exposure than are adults. There are over 2,600 diseases described in the medical literature caused by genetic mutations. Once they occur, mutations are, in a sense, immortal. They are passed down from generation to generation in perpetuity, impacting the health of future generations.

The radioactive contamination from nuclear testing still present in Great Basin soil and dust has medical ramifications that will never cease. It will affect the health and viability of future generations forever; inducing epidemics of cancer, leukemia and genetic disease. There is a critical need for a systematic survey of concentrations of residual radioactive isotopes in the surface soil of the Nevada nuclear test sites and adjacent contaminated areas. This would make it possible to model potential public exposure to radioactive dust from those sites should future climate change and aquifer draining combine to destroy the vegetation that now holds those soils in place.

Mercury exposure

On a per-weight basis, mercury is considered the most toxic substance on earth, after plutonium, and the most toxic natural heavy metal. The exposure of Utah’s residents to mercury can be expected to increase as a result of the effects of climate change in all parts of the globe. Mercury has become a ubiquitous contaminant of the global environment primarily because of industrial emissions from coal power plants and cement production plants. As the Arctic rapidly thaws, mercury from those sources that is now trapped in ice will be released into the global atmosphere.

Forest fires release mercury as well. As the forest fire season becomes longer and more severe, mercury contamination will increase. New studies also suggest that the particulate matter component of forest fire pollution may be as much as ten times more toxic than industrial or vehicle pollution--due, in large part, to its mercury content.

Scientists estimate that fires in the United States release 44 tons of mercury into the atmosphere each year. (National Science Foundation, Scientists Estimate Mercury Emissions from U.S. Forest Fires, October 17, 2007.) In a 2001 study, researchers sampled coniferous and deciduous forest litter and found that it contained from 14 to 71 nanograms of mercury per gram of fuel. When they burned it, they found that from 94 to 99% of it was released into the atmosphere. (Friedli. H., and Radke, L., 2001). A study found that forest fires near Durango, Colorado are likely to have unlocked mercury trapped beneath the soil in the San Juan National Forest and allowed it to wash into the Vallecito Reservoir. Joseph Ryan, CU-Boulder Awarded NSF Grant to Study Effect of Forest Fires on Mercury in Durango, July 15, 2010.

A California study measured oxidative stress at the cellular level from the mix of toxic chemicals in wildfire smoke. It found that after exposure to wildfire smoke, cells exhibited five times more oxidative stress as reflected in dithiothreitil (DDT) activity than before exposure. Environmental Health Perspectives: Oxidative Punch of Wildfires, 117:A58, February, 2009. Another California study examined the effect of wildfire particulates on the lungs of mice. It observed that, they “showed significant damage, as measured by histologic evaluation of inflammatory cell influx or by relative europhile or total protein count of lung lavage fluid” and that “toxicity was manifested as increased europhiles and protein in lung lavage and by histologic indicators of increased cell influx and edema in the lung.” The study concluded that wildfire particulates are toxic to the lungs, even causing cell death. (Environmental Health Perspectives, 2009).

Because of the damage done by the mix of mercury and other toxins in wildfire smoke, it has been estimated that an increase in wildfire particulates of 10 micrograms per cubic meter of particles sustained over two years, increased the risk of dying by 32% for people with diabetes, increases the risk of dying by by 28% for people with COPD, asthma and pneumonia, increases the risk of dying by 27% for people with congestive heart failure, and increases the risk of dying by 22% for people with inflammatory diseases. Am. J. Respir. Crit. Care Med. March 15, 2006, Vol. 173 (6): Reduction in Fine Particulate Air Pollution and Mortality, Extended Follow-Up of the Harvard Six Cities Study; Lepeule, J., et al., 2012.

A potential source of additional exposure to mercury is windblown dust from the surface soils of central Nevada which have been contaminated by mercury released during the smelting phase of the numerous gold mine operations in the region.

Mercury is a potent neurotoxin. One out of six U.S. women of child bearing age already has high enough concentrations of mercury in her blood that any child she conceives is at risk for some loss of intellectual function. Mercury contamination of fish is already ubiquitous throughout the US. A recent US Geological Survey demonstrated mercury contamination of every fish that was sampled from over 300 streams and rivers in the country. Utah already has a serious problem with environmental mercury contamination. The fish in most of its lakes and streams have so much mercury that they are unsafe for human consumption.

The Great Salt Lake has the highest level of mercury of any inland body of water measured in the United States. Because of toxic mercury levels found in ducks along the Great Salt Lake ecosystem, Utah has the nation's only advisories against eating waterfowl. http://articles.latimes.com/2008/aug/10/news/adme-saltlake10. As Utah's climate becomes hotter and dryer, the level of the lake will inevitably drop, exposing more of the contaminated lake bed to windstorms, increasing the amount of mercury to which the people living along the Wasatch Front are exposed. As noted in more detail below, the Great Salt Lake Minerals Corporation plans to triple the size of its evaporating ponds. If that plan is implemented, it will lower the level of the lake still further, exposing more contaminated lake bed, further increasing the public's exposure to windblown heavy metals, including mercury and selenium.

Particulate exposure

In the Rocky Mountains, and the higher elevations of the Colorado Plateau and the Great Basin, forests have been unable to adapt to the heat and drought of a rapidly warming climate. As a result they are succumbing to fire and pests. Wildfires emit between 1.5 and 2.5 million tons of particulate matter each year—more than fuel combustion, industrial processes, or transportation. Center for Disease Control: A Review of Factors Affecting the Human Health Impacts of Air Pollutants From Forest Fires. Division of Environmental Hazards and Health Effects National Center for Environmental Health. www.forestencyclopedia.net/p/p819. As noted earlier, the annual mean burned area in the forests of the Rocky Mountains is expected to increase by 175% by the year 2050. Increased burned area is expected to cause a near doubling of the region's inhabitants' exposure to wildfire smoke by mid-century. (Spraklen et al., DOI:10.1029.)

Approximately 80 to 90 percent of wood smoke particles are PM2.5 or smaller. These are dagger-shaped particles, so tiny that they penetrate deep into the lungs and even pass into the blood. They damage the lungs, the heart, and human genes. The young, the old, and the sick are most heavily impacted. Center for Disease Control: Forest Fire Impacts) www.forestencyclopedia.net/p/p819.

As described above, climate change is highly likely to cause further desertification of the Great Basin, threatening to turn its valleys to dust. This is especially true of central Nevada, which lies upwind of the Wasatch Front, and faces the prospect of disastrous drying out and ground cover die off due to Las Vegas's plans to drain those aquifers. Coupling global warming with the planned dewatering of much of the Great Basin that lies upwind from the Wasatch Front has the potential to repeat the ecological and public heath tragedies of the Dust Bowl of the Great Plains in the 1930s, the dust bowl that is now the Owens Valley, and the dust bowl that surrounds the Aral Sea.

The Southern Nevada Water Authority (SNWA) is aggressively pursuing a plan to build a network of pipelines to drain the aquifers of central Nevada and western Utah and transfer the water to Las Vegas. Although the plans are not in final form, what is being discussed in a network would cost more than $15 billion. It would run from Las Vegas 285 miles to the northeast to Spring Valley with three primary laterals connecting Spring, Snake, and Cave Valleys to the pipeline. It would pump up to 180,000 acre feet from valley wells. It would be the biggest groundwater pumping project ever built in the United States, and would have devastating ecological impacts across much of central Nevada and western Utah.

The basic premise of this vast project is to mine water from valleys that receive 6 inches of rain a year, to supply a region that gets 4 inches of rain a year. Clearly, there is no surplus water in these valleys. This is evident from the effect that pumping much smaller amounts to water livestock and crops currently has. This amount of pumping is trivial compared to what SNWA proposes, and it already has caused springs and marshes to dry up. The Snake Valley is known for its fierce winds that can blow as much as 70 miles an hour for anywhere from several hours to several days. According to Snake Valley rancher Dean Baker:

> Virtually any level of pump irrigation here leaves nearby springs dry, and the vegetation dies. And once the vegetation goes, the dust will really start blowing around. If the pipeline dries this county up, and I'm certain the water just isn't there, then what happens?"

(PLAN Report, 2006, at 40). These valleys already live on the margin of viability. Every acre-foot of water taken can be expected to cause plants or animals currently living in these ecosystems to die.

Groundwater is the source of seeps and springs. It can be a major source of marshes, streams, and lakes, as well, which is why these often dry up when groundwater wells are pumped. The aquifers under these valleys are a connected system, so that draining the groundwater under one valley can dry up another. Seventy percent of the 100-mile-long Snake Valley lies in Utah, so this project would dewater a substantial portion of Utah as well. The balance of aquifer systems is delicate, and the balance of desert aquifers is often extremely delicate. It doesn't take much disruption to wreak havoc, as the history of similar dewatering projects in the United States and elsewhere shows.

If $15 billion is sunk into SNWA's project, as a political matter, it will become a beast that must be fed. Rather than be allowed to sit empty, it will be put to work mining water, regardless of the ecological damage that such mining will do. This will accelerate the decline of central Nevada's sagebrush-bunchgrass ecosystems that is already well underway due to climate change, and is almost certain to convert a large portion of central Nevada and western Utah into a dust bowl.

A similar risk of dust pollution from a drying ecosystem is presented by the plans of the Great Salt Lake Minerals Corporation to greatly increase the amount of Great Salt Lake water they are allowed to divert to settling ponds for mineral extraction. If the Army Corp of Engineers approves the plan, the water level will drop further and thousands of acres of dry beach will be exposed. This will create yet another source of new dust pollution contaminating the air shed of the Wasatch Front whenever a storm front moves through.

To evaluate the likely effects of the combination of climate warming and aquifer drainage on the health of the people of Utah, reviewing how the Dust Bowl formed in the Great Plains in the 1930s is instructive. It is also instructive to consider the effects that projects of the kind proposed by SNWA have already had on the Owens Valley and on the Aral Sea.

In his book, "The Worst Hard Time", Pulitzer Prize winner Timothy Egan chronicles the nightmare of the 1930s Dust Bowl, arguably the world's worst environmental disaster. For nine years, tsunamis of dust pounded the Great Plains. Sometimes they lasted for weeks at a time, reached 10,000 feet high and blew as far east as the middle of the Atlantic Ocean. Dirt coated every indoor surface. House cleaning began with a shovel. People and animals trapped outside in the storms risked blindness or suffocation.

Woody Guthrie wrote a song about the chronic "dust pneumonia", a lung disease that sickened or killed thousands of Midwesterners, especially children. In some counties one third of all deaths were due to "dust pneumonia." Heat waves led to plagues of insects. For mile after mile not a single green leaf survived as waves of grasshoppers devoured any plants that survived the weather.

The Dust Bowl of the 1930s had three ingredients: unusual heat and drought, coupled with land use mismanagement. With roots 18 feet deep, native prairie grasses had kept the soil in place for centuries. But, encouraged by ignorant government agencies and greedy real estate speculators, settlers were duped into plowing under native grasses to plant winter wheat that had no chance to survive extreme conditions.

The same three ingredients that led to the formation of the Dust Bowl are now coming together in the Great Basin. Scientists expect that climate change, if unchecked, will bring heat and drought worse than 1930s. If SNWA's groundwater mining project is implemented, it will supply the third ingredient that led to the Dust Bowl--land-use mismanagement and the loss of native vegetation that for centuries anchored the soil.

In the 1930s the ecological disaster of the Dust Bowl got little attention in Washington, D.C., until the dust started filling the skies and affecting the air quality of the Nation’s capital. But despite reform of Federal land use policies, the Dust Bowl of the 1930s did not end until normal rain patterns finally returned to the Great Plains. Regular, reliable rain has not been available in the Great Basin since the last Ice Age. There is no reason to think that it will be available to reverse the environmental damage that draining its aquifers will cause.

In the 1930s Los Angeles intercepted the streams that fed Owens Lake on the east side of the Sierras, and piped the water to the coast. The dry bed of what was once Owens Lake is now the largest source of particulate air pollution in the United States. The nearest downwind settlement (Keeler, California) now sets records for particulate pollution, which violates the applicable Federal particulate limits about 25 days per year.

Dr. Bruce Parker, one of the emergency room physicians at Ridgrecrest Community Hospital made this statement:

> When we see the white cloud headed down through the pass, the ER and doctors' offices fill up with people who suddenly got worse. It's pretty straightforward cause and effect. http://geochange.er.usgs.gov/sw/impacts/geology/owens/.

An additional health hazard presented by the particulate pollution generated in the Owens Valley is arsenic and other trace metals carried by the dust. These appear in concentrations as high as 400 ng/m3. http://geochange.er.usgs.gov/sw/impacts/geology/owens/.

To predict what will happen if climate warming is coupled with the planned draining of central Nevada's aquifers, Kazakhstan's diversion of the inlet waters to the Aral Sea provides a valuable precedent. In the 1960s, the Soviet Union decided to divert the rivers that fed the Aral Sea to a massive cotton irrigation project. Once one of the four largest lakes in the world, it is now 10% of its original size. The result has been called one of the world's worst environmental disasters by the UN's Secretary General Ban Ki-Moon. Increased dust storms generated in the now-dry lake bed now cause respiratory illnesses, including drug resistant tuberculosis, brucellosis, cancer, digestive disorders, anemia, and infectious diseases are now common ailments in the region. Liver, kidney and eye problems can also be attributed to the toxic dust storms. There is an unusually high fatality rate amongst vulnerable parts of the population. The child mortality rate is 75 in every 1,000 newborns, and the maternity death rate is 12 in every 1,000 women.

In 2002 the UN estimated that winds carried an average of 200,000 tons of salt and toxic dust every day throughout the Aral Sea region and thousands of miles beyond, as far as Russia's arctic north. The dust is heavily polluted with herbicides, heavy metals, and salt. http://www.columbia.edu/~tmt2120/impacts%20to%20life%20in%20the%20region.htm; http://www.reuters.com/article/2008/06/24/idUSL23248577.

Average life expectancy in the Aral Sea region has declined from 64 to 51 years. Reproductive pathologies and adverse pregnancy outcomes are much higher than the rest of the former USSR and present-day Russia. Eighty-seven percent of newborn babies are anemic and 5% have birth defects. Ataniyazova, O., 2003). Health authorities in the area are largely in agreement that the newly formed dust bowl and the toxic chemicals contained in the dust is the primary cause of these disturbing public health trends. It is likely that a similar fate awaits those downwind of the soon-to-be dewatered valleys of central Nevada.

Some skepticism may be natural that dust originating in central Nevada could travel 200 miles downwind to be deposited on the Wasatch Front. Large particulates (PM10), however, can be transported more than 1,000 km even in light storms. (Tsoar and Pye, 1987, p. 139-153.) Researchers from the University of Washington found that dust from the Gobi and Taklimakan deserts in China is routinely detected in the air over the Western United States. http://www.sciencedaily.com/releases 2007/12/071213000427.htm. The National Weather Service has stated that dust generated in the Gobi Desert affects the air quality and sunsets visible in Utah. http://www.usatoday.com/weather/news/2001/2001-04-18-asiandust.htm. Researchers from the University of California at Davis, using a monitoring station at the top of Donner Summit, concluded that most of the particulate pollution measurable over Lake Tahoe originates in China and that one third of it is dust from drought and deforestation occurring there. http://www.sierrasun.com/article/20060731/NEWS/60731006. NASA has documented that forest fires in Russia and Canada have created a poisonous ring of particulate pollution that circles the planet. http://www.thehindu.com/news/internationalarticle566562.ece.

As noted above, dust from the Southwest has already been shown to hasten the melting of snow in the Rocky Mountains, reducing the amount of runoff into the upper Colorado River by 6%, ultimately causing a loss of 250 billion gallons of water a year. http://latimesblogs.latimes.com/greenspace/2010/09/colorado-river-water-california-dust-grazing.html; (Painter T, et al., 2010, pp. 17125-17130). It is a major reason that Lake Mead and Lake Powell have dwindled to half capacity. Climate models predict a decline in Colorado River runoff of from 10% to 45% by 2050. (Vano, J., et al., 2014). These projected declines, amplified by the increased dust induced by global warming, will prevent the fulfilling of current water allocations, and require rationing of what remains.

Dust blown from the Sahara Desert regularly settles over Europe. In fact, a recent study demonstrated that Sahara Desert dust is frequently responsible for violating the European Union's standard for PM10. Furthermore, a study of over 80,000 residents in Rome, Italy, found increased death rates from cardiac, respiratory, cerebrovascular, and natural causes related to increases in PM10 from Saharan dust outbreaks. The relationship held even at levels that would have satisfied the EPA's PM10 standards in the United States. http://www.thehindu.com/news/internationalarticle566562.ece.

The World Health Organization published a hundred-page study titled, “The Health Risks of Particulate Matter from Long-Range Transboundary Air Pollution.” It observes that PM in the size between 0.1 μm and 1 μm can stay in the atmosphere for days or weeks and thus can be transported over long distances in the atmosphere (up to thousands of kilometers). The coarse particles are more easily deposited and typically travel less than 10 km from their place of generation. However, dust storms may transport coarse mineral dust for over 1000 km.

By 2006, medical research had identified ultrafine particle pollution as the most dangerous because it travels deeper into body membranes when inhaled, can invade virtually any cell in the body, penetrate cell membranes, and create a chemical toxicity within organelles and the nucleus of the cell. (Geiser, et al., 2005, pp.:1555-1560). The WHO report goes on to state,

> Health effects are observed at all levels of exposure, indicating that within any large population there is a wide range of susceptibility and that some people are at risk even at the lowest end of the observed concentration range.

Medical research has since strengthened that contention significantly. In the United States, the current annual standard of allowable fine particulate pollution is 35 micrograms per square meter (35 µm²).[20] The corresponding European standard is a more stringent 25 µm². A large European study of the health effects of fine particulate pollution (PM 2.5) was published in the December 9, 2013, issue of *the Lancet*. That study concludes that both of the U.S. and the European standard for fine particulate are too lax to adequately protect public health.[21]

The study found that there is no safe level of fine particulate pollution. It estimates that the risk of death goes up by 7% with each 5 µm² increase in concentrations of PM2.5. (Beelon, R., et al., 2013). This study brings new urgency to lower the study for fine particle pollution to the standard of 10 µm² that the World Health Organization recommends. Currently, the air along the Wasatch Front greatly exceeds this standard, and unchecked global warming will

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[20] The concentration is defined as the 98th percentile concentration averaged over 3 years.

[21] The study analyzed 22 European cohort studies conducted in 13 countries to investigate the link between natural-cause mortality and long-term exposure to fine particulate pollution. Approximately 370,000 participants were monitored for an average of 14 years. The study controlled for all other major factors known to influence mortality.

cause the air to exceed this standard still further through the mechanisms of increased heat, drought, dust, and fire, as described above.

These alarming conclusions were recently reinforced by a pair of studies in the United States. They found that if concentrations of fine particulates are increased by 10 micrograms per cubic meter, and the increase persists for two years, mortality rates go up by 32% for people with diabetes, by 28% for people with COPD, asthma and pneumonia, by 27% for people with congestive heart failure, and by 22% for people with inflammatory diseases. Am. J. Respir. Crit. Care Med. March 15, 2006, Vol. 173 (6): Reduction in Fine Particulate Air Pollution and Mortality, Extended Follow-Up of the Harvard Six Cities Study; Lepeule, J., et al., 2012.

As already noted, exposure to fine particulates in the western United States is expected to double by mid-Century due to increased forest fires alone. The desertification of the Great Basin's valleys will add still more fine particulates to the region's air. There are now one million Utahns who fall into categories that have been identified as especially vulnerable to particulate pollution. This number is projected to double by mid-Century. The climate change studies summarized above indicate that there will be large increases in their exposure to fine particulate pollution by mid-Century. The results of the epidemiological studies summarized above indicate that this increase will severely damage the health of two million Utahns who will be especially vulnerable to its effects.

Pathogen exposure

Soils in the Western United States harbor significant concentrations of microorganisms that cause disease. Of particular concern is *coccidiodomycosis*, the fungal spore that causes Valley Fever. Valley Fever is a disease with flu-like symptoms that is difficult to diagnose, and is sometimes fatal. It is spread by inhaling windblown *coccidiodomycosis* spores, known by the inhabitants of the Southwest as "Death Dust."

Valley Fever has quadrupled in the last ten years in the Southwest. The American Academy of Microbiology estimates that 200,000 people per year contract the disease, which is fatal in about one in 1,000 cases. People who are immunosuppressed, women who are pregnant, and diabetics, are particularly susceptible to serious courses of this disease.

Hotter temperatures associated with global warming will give the cocci a survival advantage over other microorganisms. More frequent and intense dust storms are the perfect delivery system for increasing this infectious disease among residents of the western United States. Dale Griffin, a USGS microbiologist, says that one gram of desert soil can contain as many as one billion of such microorganisms. Fungi can travel long distances because the spore "housing" acts like a cocoon, protecting the fungus from environmental stresses.

More than 140 different pathogens have been identified that "hitchhike" on dust particulates." These include SARS, meningitis, influenza and foot and mouth disease. http://wwwp.dailyclimate.org/tdc-newsroom/valley-fever/Valley-Fever-blowin2019-on-a-hotter-wind. The weather extremes, pollution, habitat fragmentation and destruction, and widespread stressing of species that are associated with climate change are undermining the viability of world's ecosystems. If we continue to follow the "business as usual" approach to dealing with climate change, and these ecosystems continue on their path to collapse, they are likely to be a major contributor to future pandemics of infectious disease.

VI. CONCLUSION

Sustaining life as we have known it in Utah presumes a future climate that is at least as favorable as it has been in the past 160 years. The science is very clear: we are headed into a hotter, drier climate that will threaten our forests, rivers, streams, lakes, pastures, and air quality, and virtually all of the resources we depend on for our quality of life. It will also threaten the continued viability of many of the industries that support our economy. The health of the public depends heavily on what happens to the community's economy and quality of life. Climate change threatens everything that makes this desert we call Utah beautiful, unique, and life sustaining.

We join thousands of other scientists throughout the world who believe that prompt government action and international cooperation are necessary to avoid the multi-dimensional catastrophe that unchecked climate change will bring. No ideological tug-of-war should be allowed to obscure this message: climate change is the greatest public health threat of the 21st century—in Utah, as in the rest of the planet. Falling to respond to this threat is the riskiest course of all, because climate change is a long-term problem that carries with it a huge procrastination penalty.

To impose a surcharge on customers who provide carbon-free power to the grid, as Rocky Mountain Power proposes in this docket, would be to march backward down the hill toward obsolete and unsustainable carbon-based power. This attempt to postpone the inevitable transition to clean and sustainable sources of power, if successful, will undermine the health of Utah's environment and its people.

Sincerely,

Brian Moench, MD

President, Utah Physicians for a Healthy Environment