Economic Impacts of Climate Change on Nevada

July 2008

**A Review and Assessment Conducted by
The Center for Integrative Environmental Research
University of Maryland**

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INTRODUCTION

Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impact a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Nevada and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues.

A Primer on Climate Change

Earth's climate is regulated, in part, by the presence of gases and particles in the atmosphere which are penetrated by short-wave radiation from the sun and which trap the longer wave radiation that is reflecting back from Earth. Collectively, those gases are referred to as greenhouse gases (GHGs) because they can trap radiation on Earth in a manner analogous to that of the glass of a greenhouse and have a warming effect on the globe. Among the other most notable GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Their sources include fossil fuel combustion, agriculture, and industrial processes.

Each GHG has a different atmospheric concentration, mean residence time in the atmosphere, and different chemical and physical properties. As a consequence, each GHG has a different ability to upset the balance between incoming solar radiation and outgoing long-wave radiation. This ability to influence Earth's radiative budget is known as climate forcing. Climate forcing varies across chemical species in the atmosphere. Spatial patterns of radiative forcing are relatively uniform for CO_2, CH_4, N_2O and CFCs because these gases are relatively long-lived and as a consequence become more evenly distributed in the atmosphere.

Steep increases in atmospheric GHG concentrations have occurred since the industrial revolution (Figure 1). Those increases are unprecedented in Earth's history. As a result of higher GHG concentrations, global average surface temperature has risen by about 0.6°C over the twentieth century, with 10 of the last 12 years likely the warmest in the instrumental record since 1861 (IPCC 2007).

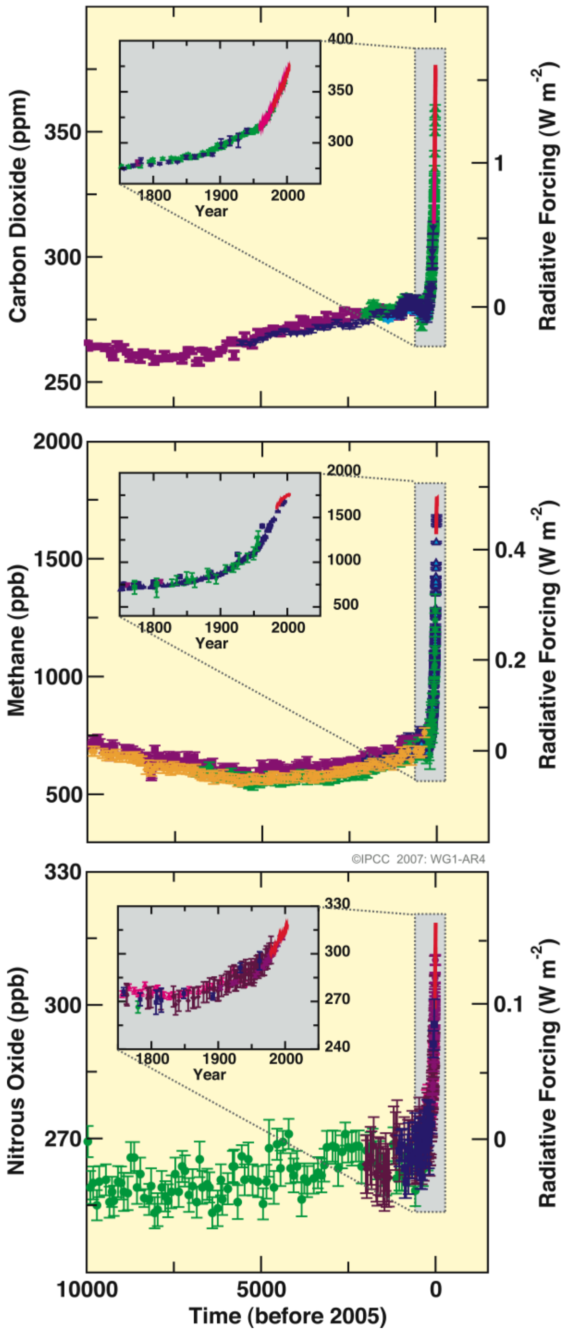

Figure 1: Atmospheric Concentrations of Carbon Dioxide, Methane and Nitrous Oxide (Source: IPCC 2007)

A change in average temperatures may serve as a useful indicator of changes in climate (Figure 2), but it is only one of many ramifications of higher GHG concentrations. Since disruption of Earth's energy balance is neither seasonally nor geographically uniform, effects of climate disruption vary across space as well as time. For example, there has been a widespread retreat of mountain glaciers during the twentieth century. Scientific evidence also suggests that there has been a 40 percent decrease in Arctic sea ice thickness during late summer to early autumn in recent decades and considerably slower decline in winter sea ice thickness. The extent of Northern Hemisphere spring and summer ice sheets has decreased by about 10 to 15 percent since the 1950s (IPCC 2007).

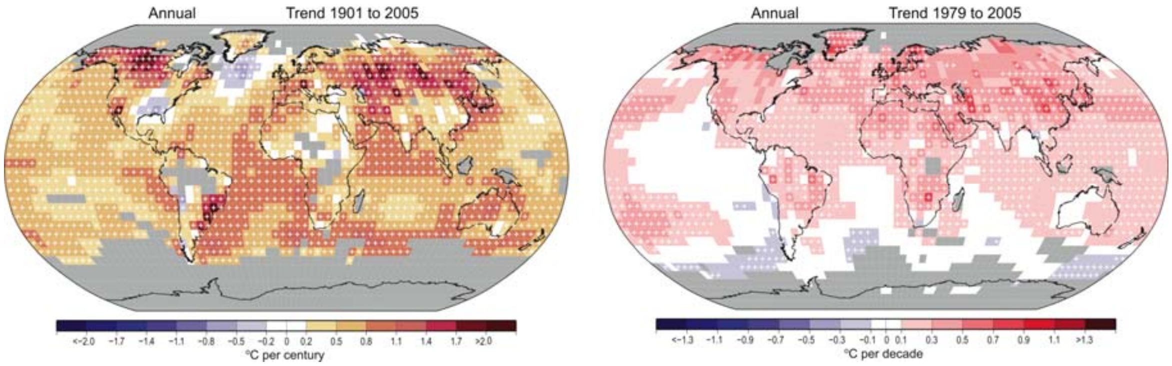

Figure 2: Annual Temperature Trends (Source: IPCC 2007)

The net loss of snow and ice cover, combined with an increase in ocean temperatures and thermal expansion of the water mass in oceans, has resulted in a rise of global average sea level between 0.1 and 0.2 meters during the twentieth century, which is considerably higher than the average rate during the last several millennia (Barnett 1984; Douglas 2001; IPCC 2001).

Changes in heat fluxes through the atmosphere and oceans, combined with changes in reflectivity of the earth's surface and an altered composition of may result in altered frequency and severity of climate extremes around the globe (Easterling, et al. 2000; Mehl, et al. 2000). For example, it is likely that there has been a 2 to 4 percent increase in the frequency of heavy precipitation events in the mid and high latitudes of the Northern Hemisphere over the latter half of the twentieth century, while in some regions, such as Asia and Africa, the frequency and intensity of droughts have increased in recent decades (IPCC 2001). Furthermore, the timing and magnitude of snowfall and snowmelt may be significantly affected (Frederick and Gleick 1999), influencing among other things, erosion, water quality and agricultural productivity. And since evaporation increases exponentially with water temperature, global climate change-induced sea surface temperature increases are likely to result in increased frequency and intensity of hurricanes and increased size of the regions affected.

Impacts of Climate Change throughout the US

This study on the economic impacts of climate change in the State of Nevada is part of a series of state-focused studies to help inform the challenging decisions policymakers now face. It builds on a prior assessment by the Center for Integrative Environmental Research, US Economic Impacts of Climate Change and the Costs of Inaction, which concluded that throughout the United States, individuals and communities depend on sectors and systems that are expected to be greatly affected by the impacts of continued climate change.

- The **construction and development sector** could see economic obstacles to further growth as a result of less drinking, irrigation, and recreational water as a result of increased drought and a general unavailability of water in Nevada.

- The **agricultural sector** is likely to experience uneven impacts throughout the country. Initial economic gains from altered growing conditions will likely be lost as temperatures continue to rise. Regional droughts, water shortages, as well as excess precipitation, and spread of pest and diseases will negatively impact agriculture in most regions.

- Current **energy** supply and demand equilibria will be disrupted as electricity consumption climbs when demand grows in peak summer months. At the same time, delivering adequate supply of electricity may become more expensive because of extreme weather events.

- Increased incidence of asthma, heat-related diseases, and other respiratory ailments may result from climate change, affecting **human health** and well-being.

- More frequent and severe **forest fires** are expected, putting ecosystems and human settlements at peril.

- The reliability of **water supply networks** may be compromised, influencing agricultural production, as well as availability of water for household and industrial uses.

As science continues to bring clarity to present and future global climate change, policymakers are beginning to respond and propose policies that aim to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions.

While climate impacts will vary on a regional scale, it is at the state and local levels where critical policy and investment decisions are made for the very systems most likely to be affected by climate change – water, energy, transportation and public health systems, as well as important economic sectors such as agriculture, fisheries, forestry, manufacturing, and tourism. Yet, much of the focus, to date, has been on the perceived high cost of reducing greenhouse gas emissions. The costs of inaction are frequently neglected and typically not calculated. These costs include such expenses as rebuilding or preparing infrastructure to meet new realities and the ripple economic impacts on the state's households, the agricultural, manufacturing, commercial and public service sectors.

The conclusions from our nation-wide study highlight the need for increased understanding of the economic impacts of climate change at the state, local and sector level:

- Economic impacts of climate change will occur throughout the country.
- Economic impacts will be unevenly distributed across regions and within the economy and society.

- Negative climate impacts will outweigh benefits for most sectors that provide essential goods and services to society.
- Climate change impacts will place immense strains on public sector budgets.
- Secondary effects of climate impacts can include higher prices, reduced income and job losses.

Methodology

This report identifies key economic sectors in Nevada, which are likely affected by climate change, and the main impacts to be expected for these sectors. The report provides examples of the direct economic impacts that could be experienced in the state and presents calculations of indirect effects that are triggered as impacts on individual sectors in the economy ripple through to affect others.

The study reviews and analyzes existing studies such as the 2000 Global Change Research Program National Assessment of the Potential Consequences of Climate Variability and Change which identifies potential regional impacts. Additional regional, state and local studies are used to expand on this work, as well as new calculations derived from federal, state and industry data sources. The economic data is then related to predicted impacts of climate change provided from climate models. To standardize the results, all of the figures used in this report have been converted to 2007 dollars (BLS 2008).

Since the early 1990s, and especially during the 21st century, significant progress has been made in understanding the impacts of climate change at national, regional, and local scales. The Canadian and Hadley climate change models are cited most frequently and we look first to these, yet there are many other valuable models used by some of the specialized studies we cite in this report.

In addition to using data that illustrates the direct economic impacts of climate change, the report also provides examples of the often overlooked ripple economic effects on other sectors and the state economy. To calculate these, we employed a modified IMPLAN™ model from the Regional Economic Studies Institute (RESI) of Towson University. This is a standard input/output model and the primary tool used by economists to measure the total economic impact by calculating spin-off impacts (indirect and induced impacts) based upon the direct impacts which are inputted into the model. Direct impacts are those impacts (jobs and output) generated directly by the project. Indirect economic impacts occur as the project (or business owners) purchase local goods and services. Both direct and indirect job creation increases area household income and results in increased local spending on the part of area households. The jobs, wages, output and tax revenues created by increased household spending are referred to as induced economic impacts.

After reviewing climate and economic information that is currently available, the study identifies specific data gaps and research needs for further understanding of the significant economic impacts. There is no definitive total cost of inaction. Given the diversity in approaches among existing economic studies and the complexity of climate-induced challenges faced by society, there is a real need for a consistent methodology that enables more complete estimates of impacts and adaptation costs. The report closes with basic recommendations and concluding lessons learned from this series of state-level studies.

Not all environmentally induced impacts on infrastructures, economy, society and ecosystems reported here can be directly or unequivocally related to climate change. However, historical as well as modeled future environmental conditions are consistent with a world experiencing changing climate. Models illustrate what may happen if we do not act now to effectively address climate change and if adaptation efforts are inadequate. Estimates of the costs of adapting environmental and infrastructure goods and services to climate change can provide insight into the very real costs of inaction, or conversely, the benefits of maintaining and protecting societal goods and services through effective policies that avoid the most severe climate impacts. Since it is typically at the sectoral and local levels where those costs are borne and benefits are received, cost estimates can provide powerful means for galvanizing the discussion about climate change policy and investment decision-making.

These cost estimates may understate impacts on the economy and society to the extent that they simply cover what can be readily captured in monetary terms, and to the extent that they are calculated for the more likely future climate conditions rather than less likely but potentially very severe and abrupt changes. The broader impacts on the social fabric, long-term economic competitiveness of the state nationally and internationally, changes in environmental quality and quality of life largely are outside the purview of the analysis, yet likely not trivial at all. Together, the monetary and non-monetary, direct, indirect and induced costs on society and the economy provide a strong basis on which to justify actions to mitigate and adapt to climate change.

CLIMATE CHANGE IN NEVADA

In the last century Nevada has experienced a slight increase in temperature, increased precipitation, a shortening of the snow season, and increased storms in general (USGCRP 2000). A .5° F increase over the last 100 years has resulted in more heat waves and more aridity (EPA 1998). As shown in Figure 3, precipitation has increased throughout Nevada with some locations receiving 20 percent more annual precipitation compared to 1900 levels.

Precipitation patterns along Nevada's Sierra Mountains are strongly influenced by El Niño events, a phenomenon in the equatorial Pacific Ocean characterized by sea surface temperatures that are warmer than normal[1] (NOAA 2005). The 1998 El Niño event created extreme weather conditions and severe flooding as winter storms climbed the Sierra mountain range and produced up to three times the average amount of seasonal precipitation (USGCRP 2000). Furthermore, El Niño is predicted to increase in frequency

[1] El Niño is defined as an increase over the base period of 1971-2000 greater than or equal to 0.5 degrees C (0.9 degrees Fahrenheit) averaged over three consecutive months (NOAA 2005).

and duration as a result of global climate change (Trenberth and Hoar 1997). However, warmer and more arid conditions, coupled with a 16-day shorter snow season relative to 1950, has actually led to limited water supplies and severe drought in parts of the state, particularly over the last seven years (USGCRP 2000; USGCRP 2007).

By 2100, the average temperatures for Nevada are expected to increase by 3-4° F in the spring and fall and by 5-6° F in the summer and winter (EPA report 1998). El Niño also is predicted to increase in frequency and duration as a result of global climate change (Trenberth and Hoar 1997). Increasing temperatures will affect the rate of water evaporation and precipitation in the state. Precipitation will become increasingly erratic in the coming century with decreases expected in the summer months of about 10 percent and potential increases of 15-40 percent in the fall, spring, and winter months (EPA Nevada Report, 1998). In general, Nevada is expected to have wetter winters and more arid summers as the subtropical dry zones for the whole planet are projected to increase (USGCRP 2000; Fang Ting, Science). Higher temperatures and increased winter rainfall will be accompanied by a reduction in snow pack, earlier snowmelts, and increased runoff. (IPP Regional projections report 2008).

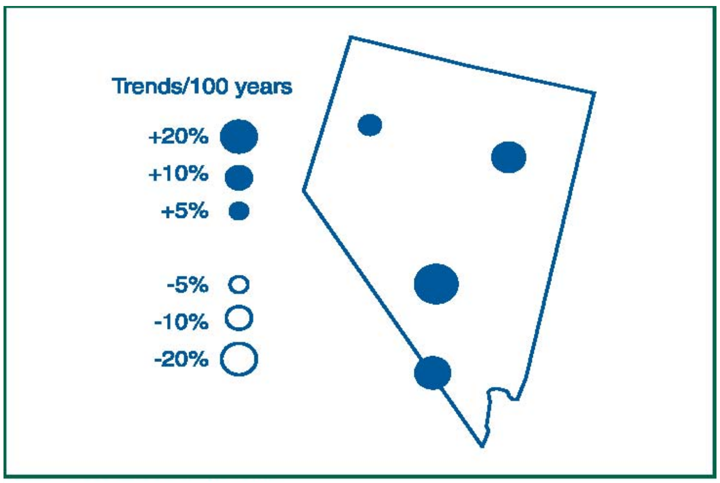

Figure 3. Precipitation Increases in Nevada Since 1900 (Source: EPA 1998)

MAJOR ECONOMIC IMPACTS

In the future, Nevada's economy will be most affected by the availability of water resources. Adequate water resources are relied upon to provide drinking water, recreation and hydroelectric power to the State's growing population. Some two million people in Las Vegas alone depend on Lake Mead for daily water needs and the Hoover Dam provides energy to roughly 1.3 million people in Nevada, Arizona, and California (US Bureau of Reclamation 2006). As a result of climate change, Lake Mead has been dropping in elevation considerably over the last twenty years and is facing challenges in satisfying a rising demand for water from Greater Las Vegas (Figure 4). As of October 2007, both Lake Mead and Lake Powell, another major provider of Nevada water, stood at only 49 percent capacity (FDCH Congressional Testimony 110/11/2007).

One study suggests that unless water consumption is drastically reduced, Lake Mead will dry up by 2021 leaving between 12-36 million people without a secure water supply (Scripps News 2008). Additionally, an end to hydroelectric power generation from dams such as the Hoover Dam, which supplies 4 percent of Nevada's energy, would likely be reflected in the market by higher energy bills. (Review Journal 2004).

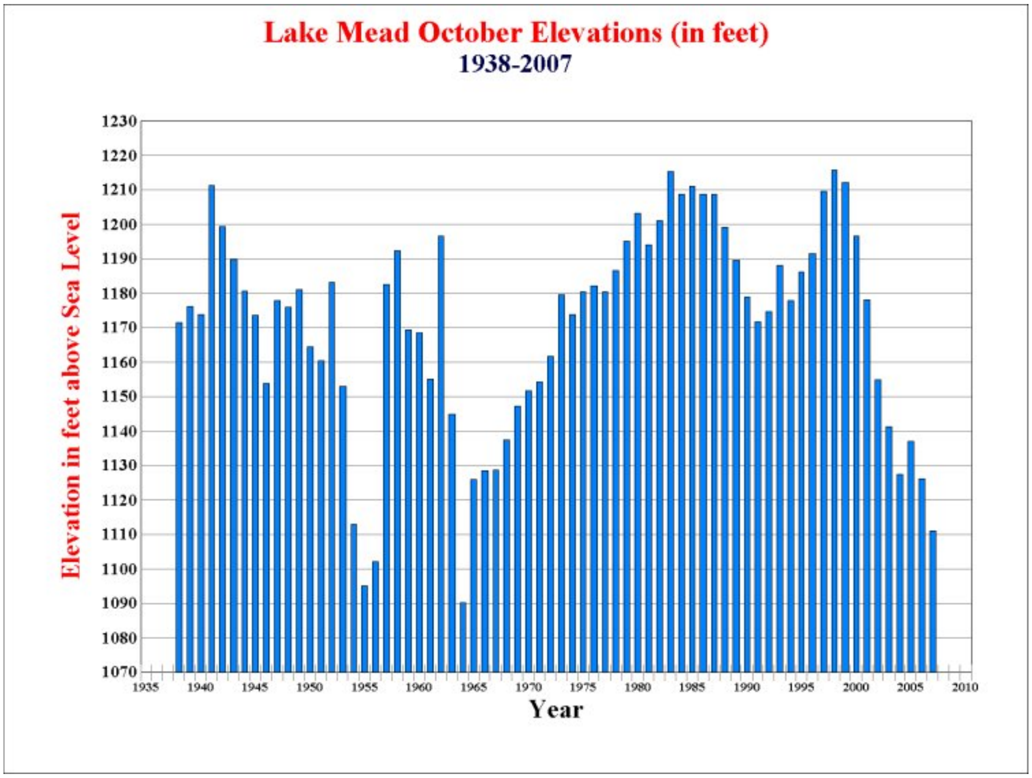

Figure 4: Annual Lake Mead Elevations (Source: www.hprcc.unl.edu/nebraska/Lake-Mead-2007.html)

Tourism

Leisure and hospitality is the largest economic sector in Nevada, accounting for 27 percent of the state's workforce (Nevada Office of Employment, 2008). In 2006 metropolitan Las Vegas had close to 39.5 million tourists who spent almost $41.62 billion (2007 $) (Center for Business and Economic Research, 2007). How water shortages and increased temperatures will affect this sector is relatively unknown, as it is dependent on how much increased water costs are put off on the consumer. However, it is likely that outdoor recreational activities will be hit the hardest by the effects of climate change.

Outdoor activities in Nevada include fishing, bird hunting, wild life watching, hiking, water activities and golfing. Warmer temperatures and drought will negatively affect most of these activities. Las Vegas' local golf courses, which are used by 3 out of every 10 tourists, are major consumers of water and will likely, be economically unviable due to water shortages and aridity (Zimmer 2004). Tourists and related parties spend an estimated $1.1 billion annually on golf (Zimmer 2004). In 2004 the golf industry contributed over $300 million in local wages, salaries and operational expenses. It also sustained 4,481 jobs, which represent a figure of $114.6 million in personal income. In 2002, the economic output of the Southern Nevada golf industry stood at $776,472,276. If the Nevada golf industry were to experience a 50 percent decrease in their clientele, the economic losses would be upward of $445 million (Table 1) (Zimmer 2004).

Table 1: Impact to Southern Nevada Economy as a Result of Golf Course "Browning" (Source: Zimmer, 2004).Note: Totals may not sum due to rounding.

	Economic Output ($MN)	# Jobs	Personal Income ($MN)	Total Economic Impact ($MN)
Southern Nevada Golf Industry	$776,472,276	4,481	$114,594,797	$891,067,073
Scenario: 25% of golfers do not play	$194,118,069	1,120	$28,648,699	$222,766,768

Drought will also impact biodiversity and nature-related tourism. Nevada State parks receive between 5,000 to 50,000 visitors per year, depending on the park, but the increasing threat of fire, especially during the peak visitor season, will have an impact on the number of tourist visiting the state (NNRSR: State Parks and Wildlife Management 2008).

Water-related activities such as boating, fishing, and water skiing are popular recreational activities on Lake Tahoe, Lake Mead, and Lake Mohave. Lake Mead and Lake Mohave have around 8 million visitors per year and Lake Mead generates $1 billion annually from tourism and recreation (Porter 2004). A drastic drought would diminish the economic revenue from water recreation on these lakes and declining water levels are already having an effect. Facilities around Lake Mead spent nearly $1 million in adjusting to low water levels during 2002 (Hayes et al. 2003). Calville Bay alone is losing $2 million per year on account of the receding lake. Furthermore, the lowing water levels on Lake Mead have forced changes in the recreational services within the park. For example, National Park Service Rangers moved the Las Vegas Bay Marina and Lake Mead Ferry Service to Hemenway Harbor to keep them operational. It is estimated that each twenty feet that the water-level decreases costs the National Park Service around $6 million (Allen 2003).

If climate impacts cause only a 3 percent drop in visitor numbers, it will result in an indirect economic impact of $323 million from lower occupancy rates in the hotel sector and economy-wide losses of $332 million from impacts on eating establishments (RESI 2008). The combined direct and indirect job losses associated with impacts on these two sectors alone may be as large as 21,000 (RESI 2008).

Construction and Development
It is imperative to note that increasing demand for water due to population growth is not the primary cause for diminished water levels in the State of Nevada. Nevada has implemented very successful water conservation strategies that have allowed the state to reduce its water consumption by about 18 billion gallons from 2002 to 2006. This is significant because during this time period the population of southern Nevada grew by 330,000 and the region sustained about 40 million visitors. (FDCH Congressional Testimony 2007). This means that declining water levels at this point in time are due primarily to diminishing levels of water capture and replenishment induced by climate change, and not due primarily to an increase in population. Nevertheless, with population growth and development driving much of the state's economy, financial losses will likely arise from a limited capacity to meet increasing water demands.

Furthermore, A long term, region-wide water shortage would prove devastating for the construction sector, which currently accounts for 11 percent of the state's industrial sector (Figure 5) (Nevada Department of Employment 2008). More significant, however, are the ripple effects relating to a stall in the state's population boom and subsequent losses on the job market and consumer spending.

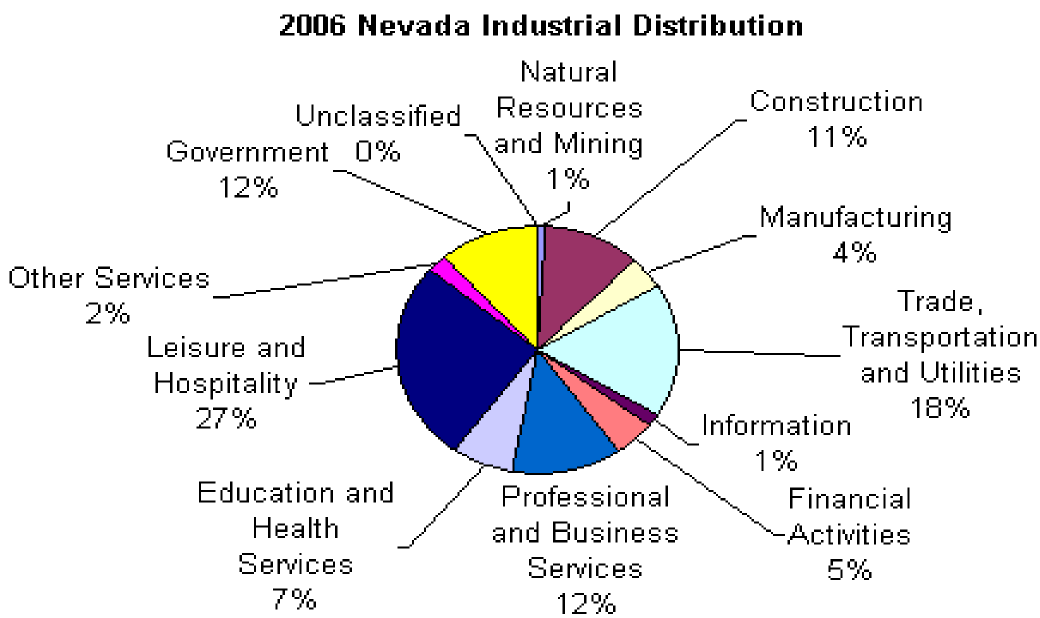

Figure 5: Nevada's Industrial Distribution (Source: Nevada Department of Employment 2008)

Residential development and population growth are major drivers of Nevada's economy, but limited water supplies will make continued population and economic growth challenging. Although the population density in Nevada is relatively low (18 persons per square mile), urban areas such as Las Vegas and Reno represent densely populated, heavily water dependent and water constrained locations (Leahy 2007). Further expansion of these urban areas should prove difficult in light of the stress climate change will place on water supplies.

As water resources such as Lake Mead dwindle and possibly run dry, water resources will need to be directed toward existing commercial and residential sites while further development will need to be halted. The construction, development, and real estate sectors in Nevada would face serious economic setbacks under such circumstances. Construction and related industries currently employ 17 percent of the State's workforce, or about 157,000 people (Hobbs, Ong & Associates Report 2004).

In 2004, the Southern Nevada Water Authority (SNWA) commissioned a study to explore the economic impacts involved with restricting the development industry as well as population growth of the state in order to successfully manage the problem of water loss. According to the study, a proposed reduction in Nevada construction related sectors to about 65 percent of the current level would translate into $16.99 billion (2007 $) in federal, state, and local tax revenue losses. This would translate into $3.26 billion (2007 $) collection losses for state and local governments over 14 years (Hobbs, Ong & Associates 2004). A struggling construction and development sector would have ripple effects in the rest of the state due to decreased consumption and availability of labor. An estimated $4.28 billion (2007 $) per year could be lost in labor income and the value of lost services and goods not produced could total $166.57 billion (2007 $) over 14 years according to the most extreme scenario (Hobbs, Ong & Associates 2004). The study concluded that halting economic development in Nevada was not economically viable. However, four years after the SNWA study was released, drought continues and water shortages, irrespective of successful conservation efforts, continue to pose severe problems for developers attempting to gain water rights for new development. It should be noted that a proposed solution to water shortages involves constructing a set of pipelines from eastern Nevada to Las Vegas. The cost of this proposal has been estimated at $3.5 billion (2007 $). This figure is deemed to be a conservative estimate. (Break, Review Journal).

OTHER IMPACTS OF CLIMATE CHANGE

Health

Health impacts related to warmer temperatures and water quality are likely to develop in Nevada in the coming century. The urban heat island effect – the phenomena that causes cities to be 7^{o} F to 10^{o} F warmer than neighboring areas – will have a detrimental impact on Las Vegas residents and tourists. Additionally, higher temperatures will decrease ozone levels; this will lead to increase chances of developing asthma, reduced lung functioning and other respiratory diseases. Another health risk posed to citizens as a result of decreased water supplies is water pollution, which is more common as low water supplies concentrate pollutants. Percholorates, which cause hyperthyroidism and other negative health effects, are particularly high in Lake Mead and along the Colorado River and they will likely become more prevalent with lowering water levels (US Department of Health and Human Services 2005). Also, if as predicted, Nevada will experience a greater degree of water runoff and flashfloods, the water stagnation that is likely to follow will be conducive to breeding mosquitoes carrying malaria and other water borne diseases such as giardia and cryptosporidium. Such health problems could discourage tourist from choosing Nevada as a destination and impact the economy.

Agriculture

Agriculture represents a small portion of the state's economy, but it is an important source of revenue for rural communities. The main crops include winter and spring wheat, barley, onions, garlic, and potatoes. In 2006, field and miscellaneous crops totaled $231.81 (2007 $) million in economic value while the value of livestock is $2339.40 (2007 $) million annually (USDA-NASS 2006). Dairy operations in Nevada are few, but they accounted for 558 million pounds of milk production in 2006 (USDA-NASS 2006).

Higher temperatures and increased annual precipitation may lead to temporary increases in productivity and yield, particularly for low irrigation crops. However, the increasing unpredictability of the seasons and competition for water resources are likely to make agriculture a risky economic venture in the future. Milk production and livestock development in general will suffer from heat waves and warmer temperatures. Additional economic pressures on the agricultural sector come from the sale of water rights and farming land to accommodate the state's growing population.

MISSING INFORMATION AND DATA GAPS

Due to the topographical complexity within Nevada, general climate predictions relating to the entire state must be made cautiously. Additionally, this study is subject to uncertainties inherent to making predictions about climate change and its possible impacts. There are many possible scenarios likely to result from climate change, so although likely, predicted economic impacts must be viewed as malleable. Additionally, further research is necessary to look at the economic ramifications of Nevada's drought on the rest of the country and the ripple effects of reduced population growth on the state's economy.

CONCLUSIONS

Critical assessments will be needed to determine the amount of population growth Nevada can undergo while realistically sustaining its water resources. Decision-makers may explore short versus long-term economic costs of water management and related policies. Moreover, understanding how climate change affects water availability will be crucial to reconciling development and population growth in urban locations with decreasing water supplies.

Lessons Learned

As we begin to quantify the potential impacts of climate change and the cost of inaction, the following five lessons are learned:

1. There are already considerable costs to society associated with infrastructures, agricultural and silvicultural practices, land use choices, transportation and consumptive behaviors that are not in synch with past and current climatic conditions. These costs are likely to increase as climate change accelerates over the century to come.

2. The effects of climate change should not be considered in isolation. Every state’s economy is linked to the economies of surrounding states as well as to the national and global economy. While the economic costs of climate change are predicted to vary significantly from state to state, the negative impacts that regional, national and global markets may experience are likely to affect all states and many sectors.

3. While some of the benefits from climate change may accrue to individual farms or businesses, the cost of dealing with adverse climate impacts are typically borne by society as a whole. These costs to society will not be uniformly distributed but felt most among small businesses and farms, the elderly and socially marginalized groups.

4. The costs of inaction are persistent and lasting. Benefits from climate change may be brief and fleeting - for example, climate does not stop changing once a farm benefited from temporarily improved growing conditions. In contrast, costs of inaction are likely to stay and to increase.

5. Climate models and impact assessments are becoming increasingly refined, generating information at higher spatial and temporal resolutions than previously possible. Yet, little consistency exists among studies to enable "summing up" impacts and cost figures across sectors and regions to arrive at a comprehensive, state-wide result.

6. To provide not just a comprehensive state-wide assessment of impacts and cost, but to develop optimal portfolios for investment and policy strategies will require support for integrative environmental research that combines cutting-edge engineering solutions with environmental, economic and social analysis. The effort and resources required for an integrative approach likely pales in comparison to the cost of inaction.

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