The Economic Impacts of Climate Change in Oregon

A Preliminary Assessment

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EXECUTIVE SUMMARY

Climate scientists are confident that global warming is occurring and that higher temperatures, smaller snowpacks, and rising sea level have resulted in Oregon since the mid-twentieth century. Scientists expect these trends to accelerate during the next several decades. Although much effort has been placed on understanding the climatic changes, little effort to date has been made to assess the economic consequences of those ecological changes. This report describes the results of a first-of-a-kind project organized by Resource Innovations, a research and technical assistance program at the University of Oregon, to engage a team of economists in describing some of the current and likely future economic impacts of climate change in Oregon.

Economists attempting to assess the economic impacts of the ecological changes caused by climate change face a difficult task: climate varies from year to year, even when a long-term trend is well established. Despite these difficulties, the economic team looked at the trends described by scientists and concluded that significant adverse impacts can be anticipated in at least eight key sectors of Oregon's $121 billion economy: municipal water supplies, agriculture, forestry, snow-based recreation, coastal tourism and infrastructure, power generation, salmon recovery, and public health.

Faced with the large but uncertain ecological and economic risks associated with global warming, the economists urge policymakers in the public and private sectors to take steps now to insure society against the impacts. Specifically, the economists urge that prudent steps be taken to reduce greenhouse gas emissions. In addition, the economists urged policymakers to plan now to adapt to ecological and economic changes driven by warming that now seem inevitable. Oregon's leaders can respond, in part, by directing public and private investment toward economic development opportunities that reduce greenhouse gas emissions such as energy efficiency and renewable energy technologies. These investments may also enhance income and job opportunities for Oregonians.

Finally, the economists outline a suite of urgent priorities for future economic research including water management, sector-specific impacts, mitigation of greenhouse gas emissions, risk management, and resource conflict resolution.

Above all, the economists believe that Oregon's leaders and citizens will need exceptional resourcefulness and flexibility to meet the unprecedented economic challenges posed by climate change.

Introduction

On May 3, 2005, a group of economists, scientists, and resource specialists with professional interest in the economy of Oregon and the Pacific Northwest joined stakeholders from Oregon's public and private sectors at Lewis & Clark College in Portland to discuss the likely economic consequences of climate change in Oregon. The Global Warming and Society Program of Resource Innovations, a sustainability research program in the Institute for a Sustainable Environment at the University of Oregon, organized the meeting. Many of the professionals that participated in the May 3 meeting have since signed, along with other colleagues, a public letter to decision makers in Oregon's public and private sectors which, in large part, summarizes the information discussed in this report. The signers to the letter demonstrate the breadth of support received.

The discussion on May 3 took as its point of departure the factual findings of the *Scientific Consensus Statement on the Impacts of Climate Change on the Pacific Northwest* developed at Oregon State University in 2004 (Institute of Natural Resources, 2004). The 50 scientists endorsing that statement agreed that the region's average temperature has already increased and would climb further by approximately 5.4 degrees Fahrenheit by mid-century. Participants in the May 3, 2005 Resource Innovations workshop accepted that estimate as a likely projection, recognizing that the region may warm somewhat less or more.

Participants agreed that the anticipated impacts of this warming on Oregon's environment and resources have no precedent in the state's history. They identified significant new risks to Oregon's economy, and concluded that policy-makers in both the public and private sectors should begin now to understand and manage those risks.

This report is based on analysis and information presented by the scientists, resource specialists, and economists that participated at the May 3, 2005, workshop as well as research from the peer-reviewed literature. It was drafted by a subcommittee of participants and circulated to other participants for review and sign-on. It was then circulated to other noted economists for their review and sign-on.

What Climate Science Tells Us

Higher temperatures, smaller snowpack, and rising sea levels are likely in Oregon

The scientific consensus on climate change is robust. At the global level, the Third Assessment Report of Working Group I of the Intergovernmental Panel on Climate Change (IPCC), provides the most authoritative summary of that consensus (IPCC, 2001). The IPCC Working Group found that during the twentieth century, earth's average surface temperature increased about 1 degree F, and sea levels rose between 4 and 8 inches.

Using state-of-the-art climate models and assumptions about future emissions of greenhouse gases, the IPCC scientists project an additional global average temperature increase during the twenty-first century between 2.5 and 10.4 degrees F, and anticipate an additional rise in sea levels between 4 and 35 inches. (To put temperature increase of this magnitude into perspective, during the last Ice Age, the earth's average temperature was only 9 degrees F cooler than it is today). The IPCC report and more recent findings strengthen a broad international scientific consensus that "most of the warming observed over the last 50 years is attributable to human activities."

The human activities responsible for global warming include emissions of carbon dioxide, methane, and other so-called "greenhouse gases" from the combustion of gasoline, fuel oil, natural gas, and coal for energy production, industry, and transportation. These greenhouse gases increase the capacity of the atmosphere to trap solar heat that would otherwise radiate into space. Since 1850, the carbon dioxide concentration of the earth's atmosphere has increased by 36 percent. Emissions of this gas due to human activities continue to grow by 1 to 1.5 percent each year, augmenting the earth's capacity to trap and hold heat (Hansen, 2005).

Scientists also agree on observed changes in the Pacific Northwest that can be attributed to the steady rise in average temperatures, and on trends that are expected, with high confidence, to continue. Scientists' current projections of temperature, snowpack, and sea level trends for Oregon and the Pacific Northwest provide a sufficient basis for anticipating certain kinds of economic impacts.

The signal of rising temperatures in the Pacific Northwest is strong. The average surface warming recorded in the Northwest during the twentieth century (1.3 degrees F, with a higher average warming during winter months) exceeds the global trend. Consistent with average warming of this magnitude, the average water content of the Northwest snowpack declined by 30 percent between 1950 and the 1990s. The snowpack at lower elevations changed the most, with measurable impacts on the date of peak spring runoff (earlier) and summer water availability (lower). Biological signals, including blooming dates for common plants such as the lilac and honeysuckle, confirm that spring arrives earlier.

Scientists at the University of Washington's Climate Impacts Group and at other institutions project continued warming during the twenty-first century. Snowpack, the timing and volume of streamflows, and sea levels are expected to continue to change. Current regional models project an additional warming of 2.7 degrees F above current averages by the decade of the 2020s, and approximately 5.4 degrees F by the decade of the 2050s, or a warming of approximately 1 degree F per decade (Institute of Natural Resources, 2004).

Warming of this magnitude is expected to accelerate the reduction of the Cascades snowpack – one projection indicates a reduction of more than half by 2040. One consequence will be very large reductions in summer stream flows – and intensification of summer drought – especially on the east side of the Cascades. Snowpack is Oregon's largest freshwater reservoir, dwarfing the water storage capacity of all of Oregon's dams and impoundments. There are no obvious or affordable substitutes for the services the snowpack provides to Oregon's farms, forests, businesses, and households.

Sea levels will continue to rise during this century, with estimates ranging from a straight-line projection of the current trend (4 to 8 inches per century) to as much as 35 inches for the time period 1990-2100. In Oregon, the effects of rising sea levels will be greatest on the coast north of Florence and somewhat less to the south, where the coast itself is steadily rising due to tectonic forces. Effects associated with this rise, such as accelerated beach erosion, will vary by location, depending on beach slope, landforms, the vulnerability of coastal infrastructures, and other factors.

(For more information on the scientific data described above, please see the "Scientific Consensus Statement on the Impacts of Climate Change on the Pacific Northwest," by Oregon State University, and other studies listed at the end of this document.)

Uncertainty and Economic Analysis

Uncertainties in climate variability make economic analysis difficult

Three uncertainties in the climate models for the Pacific Northwest hold special significance for economic analysis of possible impacts. First, the models contain uncertainty about the long-term trend in regional precipitation. Scientists cannot now say whether the warming trend will bring a somewhat wetter, or somewhat drier, climate regime to our region, although most of the climate models assessed by the Climate Impacts Groups at the University of Washington project wetter winters (Amy Snover, University of Washington, personal communication). While changes in total precipitation are not expected to affect the overall trend towards declining snowpack and shrinking summer water supplies (determined by the temperature trend), changes in seasonal precipitation patterns and water availability do impact economic activities.

Second, the Pacific Northwest is subject to sea surface temperature phenomena that contribute substantially to climate variability, including the El Nino-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The effects of such ocean temperature phenomena can be strong enough to temporarily mask or reinforce underlying long-term climate trends. Climate scientists are working hard to better understand the region's "true" climatic variability, but the complex interactions of regional and global factors suggest that policy makers should not expect global warming to unfold in a consistent or entirely predictable pattern in the Pacific Northwest. This makes the job of anticipating economic impacts more difficult.

Third, climate scientists now acknowledge that abrupt changes to the global climate system are possible and, under the higher-end warming scenarios, may be increasingly probable. Abrupt climate change scenarios include the catastrophic collapse of the West Antarctic Ice Sheet and/or the Greenland Ice Sheet, the acidification of the oceans by carbon dioxide absorption, and the shutdown of the North Atlantic segment of a temperature-distributing current called the thermohaline circulation (the great ocean conveyor). Such low probability events, once begun, may be essentially irreversible and could be extremely costly to Oregon: the collapse of the West Antarctic Ice Sheet, for example, could raise sea levels by 26 feet over time (Williams and Hall, 1993). A change of this magnitude would re-draw the Oregon coastline. Responsible economic analysis attempts to take such low-probability, high-risk outcomes into account.

In summary, the reality and direction of global warming are no longer in question. The pace of climate change remains less certain. Shifts in future precipitation trends are unknown, but will occur. Complex interactions between global climate change and the regional ENSO and PDO cycles may lead to erratic changes in regional climate. Scientists have raised real concerns about abrupt climate change that could impose very high costs on the Oregon economy. Each of these uncertainties reinforces a case for taking prudent steps to estimate and insure against the risks associated with the warming trend.

Mitigation, Adaptation, and Risk

Faced with large but uncertain risks, economists urge buying insurance – in this case by reducing greenhouse gas emissions and preparing now to adapt to change

Planning for climate change represents a fundamentally new challenge. Average temperatures are higher today than at any time in at least the past 1,000 years, and possibly the past 5,000 years (Kerr, 2005). Despite the fact that weather patterns historically did change in the past, farmers, city planners, and water managers often accounted for climate risk by reference to the historical record: they believed weather over the next five or ten years was likely to look, more or less, like the weather over the last fifty. Now, however, the recent past no longer offers a reliable guide to the future.

Oregonians can cope with climate variability. But the “toolbox” of policies for managing resources from forests to reservoirs contains approaches formulated and adopted under climate conditions that no longer prevail. Farmers, industrial water users, timberland owners, and others may be managing and making decisions today based on assumptions that are increasingly at odds with emerging climate conditions.

When potential impacts are large but uncertain, economists recommend that public authorities insure against foreseeable risks on behalf of society, just as families insure against the remote but catastrophic loss imposed by a house fire or an automobile accident. This principle of prudence can strengthen the case for accelerating efforts to reduce global greenhouse gas emissions including those within the state of Oregon, and developing strategies to help Oregon’s citizens, businesses, and communities adapt to the regional warming that is already locked in.

Mitigation denotes efforts to reduce emissions of carbon dioxide, methane, and chlorofluorocarbons, and strategies to “offset” emissions of these greenhouse gases by capturing or absorbing carbon dioxide from the atmosphere. The *Oregon Strategy to Reduce Greenhouse Gas Emissions* (a set of policy recommendations developed by an advisory group to Governor Ted Kulongoski and presented to the governor in early 2005) embodies a mitigation approach (Governor’s Advisory Group on Global Warming, 2004). Adaptation denotes efforts to adjust to altered circumstances. Adaptation without mitigation is insufficient. Both are necessary.

Oregon has already made significant investments in climate change mitigation. Oregon was the first state to adopt a law to regulate carbon dioxide emissions from new power plants. In addition, Oregonians invested nearly $200 million in efficiency and renewable energy in 2004 alone (Oregon Department of Energy, personal communication). Those investments lower the state's greenhouse gas emissions. Per capita carbon dioxide emissions from the City of Portland and metropolitan Multnomah County have declined below 1990 levels without economic penalty, due to investments in public transport, renewable energy, and energy efficiency (Kristof, 2005). Throughout the region, the $2.4 billion that Northwest utilities invested in energy efficiency from 1990 through 2002 is recovered in energy savings every eighteen months. Accelerating mitigation efforts would achieve a tangible and important goal (net reduction in the state's greenhouse gas emissions) while creating expertise, products, and services that Oregon can apply at home and export to the many other states – and, indeed, other parts of the world – already working to reduce greenhouse gas emissions. Meeting this challenge can become a competitive business advantage for Oregon.

Adaptation is more difficult to evaluate. No one has tallied current expenditures incurred by Oregon businesses or agencies to adjust to today's higher temperatures, reduced snowpack, or rising sea levels. Many mitigation expenditures (e.g., investments in green building that reduce electricity use) can also be considered adaptive, since they increase the resilience of private and public infrastructure to many types of risks (fuel price volatility, employee health claims, etc.) in addition to climate risks. But such examples only begin to suggest the scope of adaptation expenditures.

Climate scientists believe that current greenhouse gas concentrations in the atmosphere guarantee centuries of rising temperatures and rising sea levels even if global emissions from human activities are capped now or in the near future. How quickly temperatures and sea levels rise, however, may be subject to human control. Adaptation costs are likely to become increasingly significant to Oregon's future. The following section provides a qualitative look at adaptation costs in several sectors of the state's economy. This analysis should be considered a first step toward the more comprehensive analysis needed to guide public policies and investments in a highly uncertain future.

Economic Impacts in Eight Key Sectors of Oregon's Economy

Significant adverse impacts can be anticipated in key sectors of Oregon's economy

This section presents a preliminary survey of eight sectors of Oregon's economy that appear vulnerable to climate change: drinking water; agriculture; forestry; snow sports and winter recreation; coastal tourism, recreation, and infrastructure; power generation; salmon recovery; and public health. These case studies and analyses are not all-inclusive. The economic impacts of climate change in Oregon are likely to be experienced by many other sectors across the state. The information provided here simply illustrates the magnitude and direction of economic impacts that appear plausible in light of the consensus climate change scenarios.

Climate change impacts resist rigid sectoral classifications. Changes in the timing and volume of streamflows, for example, have implications for power generation, fish survival, river commerce, and agriculture, with numerous second-order connections between these sectors. Snowpack changes influence winter recreation such as skiing, summer recreation activities including boating and fishing, and the tourism each attracts. At the same time, reduced snowpack diminishes summer irrigation flows, and may lead to increased use of energy to pump groundwater while exacerbating the risks of forest fires. Some sectoral effects may reinforce one another. Others tend to offset each other, in particular regions of the state.

Three observations cut across these sector-level examples:

1. Significant economic impacts can be anticipated even at the lower end of the range of temperature increases expected over the next several decades, and regardless of whether Oregon becomes somewhat wetter or somewhat drier;
2. Some of the most significant and most certain impacts relate to the availability and use of fresh water;
3. With few exceptions, long-term resource planning in Oregon does not yet take rising temperatures and sea levels and reduced snowpack into account.

Drinking Water

Public water supplies for municipal and industrial uses will be most severely affected in regions dependent on snowpack. By mid-century, projected reductions in snowpack could well reduce summer stream flows by commensurate amounts (up to 50 percent on the east side of the Cascades, and somewhat less on the wetter west side). Reductions in flow of this magnitude not only reduce available summer water, but may also lead to substantial reductions in water quality—as the reduced volume of water must accommodate the same inputs of pollutants such as sewage and pesticides.

A sophisticated analysis of the impacts of climate change on municipal water supply in Oregon has been performed for the City of Portland (Palmer and Hahn, 2002). With its public water supply from the Bull Run watershed on Mount Hood, Portland is comparatively protected from climate change impacts. A low-elevation watershed, Bull Run receives about 13 percent of its annual water supply from snowmelt. Water is impounded in two storage reservoirs in the basin.

In their analysis of the effects of climate change on both water supply and demand performed for the Portland Water Bureau, Palmer and Hahn estimate that during typical dry years, a warmer climate will reduce water availability by 1.5 billion gallons and increase demand by 2.8 billion gallons, leading to a total dry-year shortfall of 4.3 billion gallons. Taking population growth projections for the metropolitan area served by Bull Run into account, planners anticipate a need for 9.6 billion gallons of additional water storage. Global warming could increase this need by nearly half. The forecasts for years with average precipitation are lower—a decrease in supply of 1.5 billion gallons coupled with an increase in demand of 1.5 billion gallons, producing a total shortfall of three billion gallons. However, planners will need to develop water resources to meet demand in dry year; thus, dry-year shortfalls provide an appropriate measure for evaluating costs.

Palmer and Hahn analyze two adaptation scenarios. One scenario relies on expansion of the 100 million-gallon-per-day groundwater pumping system built on the Columbia River floodplain in 1980. The second scenario assumes construction of a third dam in the Bull Run Watershed. Either scenario can meet the anticipated demand, but each poses different risks and costs that merit thorough evaluation.

So far, the Bull Run system has proved resilient to changes in supply and demand.

Climate change may strain that resilience. The City of Portland is examining ways to increase the system's storage capacity, and evaluating management practices such as injecting Bull Run water into the Columbia River aquifers during high-flow winter months, so that it can be pumped back out in the summer. It may be appropriate to consider the costs of adjustments, such as integrating the current groundwater system (originally built as an emergency back-up water supply) into the base-level water supply system, as costs of climate change. The cumulative impacts of snowpack declines, changes in the timing and quantity of surface flows, and potential for diminished aquifer recharge attributable to reduced snowpack all suggest that the ability of the Bull Run water system to deliver its expected level of service to the Portland metropolitan region can no longer be taken for granted.

As a rain-fed system, Bull Run appears more resilient to the expected impacts of climate change than municipal water systems in many parts of the state. Adaptation may prove more costly for communities that depend more heavily on mountain snowpack and have less recourse to supplemental groundwater sources.

Agriculture

Growing seasons, temperature ranges, and water availability shape Oregon's highly diverse agricultural sector. That diversity, ranging from grass seed and nursery crops to field crops, grains, and winegrapes, is an economic strength. Diversity, however, masks an underlying unity in the sector's sensitivity to climate-linked parameters.

Depending on the crop and its current climatic equilibrium, rising temperatures can either reduce or increase crop yields and/or quality, while rising carbon dioxide concentrations and longer growing seasons can under some circumstances increase yields. Farmers are likely to be able to maintain production and quality levels in the face of modest warming, particularly if water availability is not an issue. But crops have temperature thresholds at which yields and quality begin to decline, and little is known about the yield response of many crops currently grown in Oregon under the warming trend projected by current climate models.

All Oregon farmers deal with drought, sometimes of unusual severity, and they are accustomed to a certain pattern of drought recurrence. However, if the frequency of drought increases, farmers could be faced with a situation in which water supply constraints they formerly associated with infrequent drought years have become the norm. Forward-looking policy could help prepare producers for such a change. If instead farmers are forced to react to such a shift, many farms could fail.

Public and private irrigation systems in many Eastside and Southern Oregon watersheds have until recently given many farmers and state policymakers a sense of security about water availability. However, the assumptions underlying these systems deserve reappraisal given global warming scenarios and relatively recent requirements to ensure in-stream flows to protect fish habitat. Systems like the irrigation canals serving the Klamath Basin, for example, are already highly "efficient" in terms of "irrigation efficiency" (the proportion of diverted water actually consumed by the crop). Higher irrigation efficiency does not necessarily mean more water in-stream, since the return flows of unconsumed water will decline as irrigation efficiency increases. For this reason, under circumstances of diminished summer water supply, increased irrigation efficiency is unlikely to be a major solution for farmers seeking to maintain legally mandated in-stream flows. New investments in storage capacity may not be an option, or may not be cost-effective. Investments in storage to increase or assure water supplies through the growing season can be very costly, and very difficult to justify financially. Recent studies of increased storage options in the Klamath and Yakima basins suggest that the cost of providing additional summer water will be many times greater than the economic benefit of that water to the farmers who would use it.

In an example from Washington state's Yakima Basin, the U.S. Bureau of Reclamation projected the capital cost of one major project designed to more than double the 1.1 million acre-foot capacity of the five existing storage reservoirs at $3.5 to $4 billion. Public investment on this scale might be financially justified if the investment costs significantly less than the crop losses (due to heat-related yield declines) associated with higher average temperatures, or if there are other sufficient project benefits. In the Yakima case, one analysis showed that warming would have to exceed 4 degrees F before the value of averted crop losses began to justify the investment. This analysis suggests that expensive supplements to water supplies may not automatically be justifiable even under scenarios of fairly frequent and costly crop losses likely to occur in the elevated temperature range anticipated during the next 30-40 years. Policymakers may turn to smaller, lower-cost projects that can pass the cost-benefit test (Michael Scott, Pacific Northwest Laboratories, in press).

No Oregon crop better illustrates the sensitivity to and risk of climate change than the state's high-value, and high-value-added, winegrape harvest. Growers take special care to match grapevines and varieties to the temperature ranges and soil types that will reliably produce optimum quality – and thus the greatest financial return. The state is a clear beneficiary of this care, with a harvest valued at $33 million and a related industry whose total economic contribution is $275 million to $300 million per year (Gregory V. Jones, Southern Oregon University, personal communication).

Some scientists believe the general trend of rising temperatures over the past 50 years has improved the quality of Oregon wines and contributed to the emergence of an industry with a global reputation (Gregory V. Jones, personal communication). However, the continued and accelerated warming expected during the early decades of this century may be less benign. While it is difficult to generalize across such a diversified industry, changes in average temperatures coupled with changes in the length of growing seasons, frost dates, and the distribution and availability of water can be expected to displace some grape varieties from regions where they are now grown. Producers will be forced to adjust vineyard care and management practices in an effort to keep other varieties producing near their optimum.

To cite one example, the 2.7 degree F average warming now forecast for the 2020s could potentially displace Pinot Noir grapes from their optimum range in the Willamette Valley (Gregory V. Jones, personal communication). Within as few as twenty years, "Brand Oregon" may no longer feature this signature grape variety, which today represents nearly 50 percent of the state's production and acreage.

A strong market for wine gives the industry great adaptability. Oregon's wine growers can substitute varieties and adjust management practices to maintain and develop the vitality of their industry. But distinct regional wine styles shape the brand identity of production regions and the commercial culture of producers. In farm regions everywhere, such factors can be slow to change.

Orchard-based crops provide another example of the potential economic impacts of climate change associated with rising temperatures. Orchard fruits mature more quickly at higher temperatures. Earlier maturity raises issues of crop quality and marketability. Oregon apples, for example, are sold into a global market in which crop quality and availability confer unique comparative advantages. Future harvests could be several weeks earlier than at present, shifting contracts and the competitive setting in which Oregon producers must sell their crop. Changes to either fruit quality or the timing of availability to buyers, attributable to climate change, could carry important economic repercussions. Since the effects of climate change would presumably also be felt in competing supply regions, the net impact on Oregon is unpredictable but potentially large.

Forestry

With respect to Oregon's public and private forests, the increasing risk of large-scale fires and insect infestation attributable to decades of fire suppression has received wide attention. In contrast, the degree to which regional climate variability has heightened these risks has not been widely noted.

In general, the forests of the Pacific Northwest have "greened up" in the last half-century. The effect is what one would expect as temperatures warm, growing seasons lengthen, and carbon dioxide levels rise. Fire suppression efforts have reinforced the trend on millions of acres. Some forest scientists now believe that Eastside forests are approaching, and in some cases may have already exceeded, physiological limits beyond which insect outbreaks and fires become more probable. Such a stage can involve forest die-back on a very large scale ("brown down").

On average, warming increases the risk of wildfire, especially on the east side of the Cascades. Even if the temperature increase is accompanied by more rainfall, as some climate scenarios project, additional tree growth can increase, rather than reduce, the risk of widespread "brown down." Higher average temperatures increase evapo-transpiration and respiration by trees. Eventually, the energy consumed by plant metabolism and enhanced transpiration outstrips the energy fixed by new growth. Risks of fire and insect epidemics both increase in forests under such physiological stress. Signs of damage from bark beetle infestations, which may resemble other forms of physiological stress, are easily visible in many public and private forestlands on the Eastside.

Under most climate scenarios, wildfire response and management, dependent on public institutions and coordinated action with private landowners, could become far more costly. The costs of the fire management infrastructure (labor, equipment, and logistical capacity) now borne across Oregon's communities already constitute a significant charge against the gross value of the state's timber and non-timber products and services. That charge is likely to grow larger.

The risks to life and property in Oregon's rapidly expanding wildland-urban interface increase the potential costs and exacerbate the challenges posed by changes in forest condition linked to rising temperatures. Additional public investment in fire management capacity, though difficult to advocate under the state's fiscal constraints, could well prove prudent for decades to come. Forested landscapes change over decades, and the state's capacity to manage them must change as well.

Snow-based Recreation

Oregon's snow sport destinations (Mount Hood, Mt. Bachelor, Willamette and Santiam Passes, and others) have been a bright spot in the state's economy during the recent recession, attracting tourists from within the state and around the country. The state's snow sports industry counts more than ten thousand full- and part-time employees. The total payroll for these workers was $13.5 million in 2000. Total revenues for snow-related tourism probably exceed $200 million in a normal year; the last time total revenues for skiing and snowboarding were tallied (in 1990-91) they were estimated between $109 and $183 million (Tauer, 2001). Investments in facilities and skiable terrain have increased since then.

The winter of 2005 was a disaster for much of Oregon's snow sports industry. Key mountain resorts were forced to shut for weeks during their peak winter season because of a lack of snow, with economic effects that rippled through thousands of households. The anomalous winter of 2005 (due to an unusual split in the jet stream that normally directs winter storms into Oregon) cannot be attributed with certainty to climate change. Nonetheless, it brings into focus questions about the industry's ability to adapt to future conditions of diminished or absent snowcover. Under some climate scenarios, Oregon's high-elevation ski areas could be essentially snowless by the end of the twenty-first century (Mote et al., 1999). At a minimum, ski area operators with access to water supplies will face increased trade-offs between new investment in artificial snowmaking and investments in other, more conventional efforts to increase revenues by expanding terrain or adding lifts.

Coastal Tourism, Recreation, and Infrastructure

Oregon's beaches offer significant economic and intangible benefits to residents of the state. Scientists are confident that sea levels will continue to rise along the Oregon Coast north of Florence during the twenty-first century, and global projections indicate a rise of about one-half inch to as much as three and a half inches every decade. This continuous rise in sea levels will quicken as time goes on and will accelerate beach erosion. Increased erosion will affect the very existence of some beach areas, diminish the attractiveness of other sections of the coast to visitors, and diminish (or eliminate) the value of some coastal properties. In addition, increased wave heights and storm hazards related to rising sea levels can be expected to affect bridges, tide gates, port facilities, and other public infrastructure.

The economic literature on beach erosion and the costs of efforts to control or reverse it is limited. Most studies to date have addressed the question on the Outer Banks and barrier islands of the Carolinas and in parts of Florida, areas more populous and highly developed than most of the Oregon Coast. Nonetheless, such studies suggest ways to incorporate recreational benefits and property values into economic assessments of shoreline management alternatives. New research underway in California, including the Southern California Beach Valuation Study and a collaborative effort to study the impacts of sea level rise on coastal California, are likely to prove more applicable to Oregon conditions (Michael Hanneman, University of California, Berkeley, personal communication). In California, visits to beaches generated revenues exceeding $60 billion in 2002 (California Department of Boating and Waterways and State Coastal Conservancy, 2002); in Oregon, with a state economy less than one-tenth the size of

California's, the annual value of all beach-oriented economic activity may exceed $5 billion (Oregon estimate by resource innovations based on data in California Resources Agency, 2005). The potential impacts of sea level rise on this sector have substantial economic implications for the state.

Power Generation

Climate change has two likely impacts on the Columbia River hydrosystem: on the services it supplies (power, navigability, fish survival) and on the demand for those services. According to the Northwest Power and Conservation Council (NWPCC), a trend toward higher winter streamflows and lower summer flows portends a decline in potential power generation and an associated economic loss to the region of some $230 million by 2020. If total precipitation also declines, as some climate scenarios suggest, losses would become larger.

The shift in streamflow seasonality would increase power generation during winter months, when regional demand for heating is high, but reduce power generation during the summer months, when total demand for power is lower. In the summer, surplus power is typically now sold out-of-state. Summer demand for electricity within Oregon could increase, as demand for air conditioning and irrigation pumping rise with warmer temperatures. Any shift in reservoir operations these trends may prompt could be constrained by the need to maintain mandated in-stream flows for anadromous fish such as salmon.

Such a shift in the power generation profile would be expected to influence the region's future investments in the alternative generating capacity needed to maintain power supplies during periods when the Columbia River reservoirs must be refilled. Investments in renewable power generating capacity, especially wind, may become more important complements to the Columbia River hydrosystem capacity. Some additional reserve capacity is needed in the hydrosystem to offset times when wind power is not productive. However, at this time no one is certain how much reserve capacity is needed. A MW of backup is not needed for every MW of wind. Less reserve capacity is needed the more geographically diverse the wind resource, as wind doesn't blow everywhere at the same time (Michael Scott, Pacific Northwest Laboratories, personal communication).

Salmon Recovery

Both protected wild salmon and hatchery-bred salmon are subject to a range of climatic influences that shape their abundance and distribution. These influences range from streamflows and water temperatures in inland basins to ocean circulation patterns. Warmer temperatures, reduced summer flows, increased risk of winter flooding, and altered timing of run-off are all likely to have negative impacts on salmon survival, and to make the management of salmon recovery much more difficult.

Policy makers concerned with salmon recovery will have to plan for the variability and unknowns posed by climate change while also investing resources wisely. The recovery enterprise is a multi-billion dollar effort involving dozens of agencies and parties, aiming to re-establish healthy river and watershed conditions that were, in the past, associated with salmon abundance. Given emerging climate change scenarios for the Northwest, efforts to restore watershed health will become even more challenging (ISAB, 2005). Efforts to maintain and increase the adaptability of native salmon populations (by conserving the diversity of habitats, stocks, life history strategies, etc.) involve on-the-ground activities that enhance water retention capacities and improve soil health. The economic value of these and other key watershed attributes appears likely to increase as snowpack declines and summer flows diminish.

It will not be easy to evaluate salmon recovery spending priorities under altered climate conditions. However, it would be prudent to factor global warming into such assessments.

Public Health

The direct costs that climate change can impose on human beings are manifest first in the health care and public health sectors. Some costs are likely to be straightforward and well understood. As temperatures rise, certain infectious diseases may become more prevalent. Disease vectors such as mosquitoes, ticks, and rodents are likely to increase with warmer temperatures and more gentle winters. Colder winters tend to keep these vector populations in check while warmer winters allow their populations to flourish. In addition to the recent introduction of West Nile Virus into Oregon, which scientists believe is moving north due to rising temperatures, it is possible that Oregon will also see an increase in Lyme Disease and other infectious diseases transmitted by these vectors. The public health costs associated with monitoring, preventing, and treating infectious diseases will increase as their vectors spread. With first-line responsibilities borne by local health departments, questions of capacity to deal with new threats, rising caseloads, and increasing costs need to be taken seriously (Physicians for Social Responsibility, 2002).

Heat-related illnesses would also be expected to increase with rising temperatures and an increasing incidence of drought. More difficult to evaluate, but no less real, are the health costs associated with increasing psychological stress as people seek to adjust lives and livelihoods to changing circumstances due to global warming. As a psychosocial driver of many medically treatable conditions, elevated stress will increase doctor and clinic visits, consumption of prescribed medications, etc. Farm communities in particular are likely to experience such stress if the frequency and duration of droughts increases.

Economic Development Opportunities

Oregon should not overlook the economic opportunities that climate change creates

Typical of changing times, new technologies, businesses, and jobs are emerging around the world in response to the challenges posed by global warming. Change stimulates new knowledge and can spur creativity as enterprising individuals find ways to meet new needs in innovative ways. Entrepreneurship includes both the willingness of individuals to create new solutions and form new businesses and the desire of existing businesses to pursue new ideas that create profits and jobs. With foresight and sound leadership, Oregon could create competitive advantage by focusing public policy and public and private investments on the technologies and practices needed to meet society's need to reduce greenhouse gases and adjust to global warming.

While it would be irresponsible for policymakers to embrace climate change as a "business opportunity" for Oregon, there is much the state's leaders can do to anticipate and encourage the innovation needed to create new businesses and jobs throughout the state that benefit society as the climate warms (see, for example, Millennium Ecosystem Assessment, 2005).

Economists acknowledge at least two reasons creative mitigation and adaptation strategies may enhance regional economic development. First, investments in renewable energy such as wind, solar, and biofuels, as well as in energy efficiency, can create jobs directly through "import substitution." When energy can be produced cost-effectively using local sources, the dollars that stay within the region employ local workers and support other local businesses. Wind power, for example, is already generating jobs and income in rural Oregon communities.

Second, emerging markets in energy management offer opportunities for companies in Oregon and the Pacific Northwest. The region is well positioned to take a global leadership role in so-called "smart energy" technologies that apply computer capability to manage grid-delivered power. In addition, a concerted effort to lead in the development of technologies and practices in the key sectors of climate change mitigation (e.g., energy management and renewable energy, energy efficiency, green manufacturing, remanufacturing, sustainable supply chain management and reverse logistics etc.) and adaptation (e.g., flexible water markets, sustainable agriculture and forestry) could build on existing businesses and generate many new opportunities for Oregon companies and workers. Making these and related fields a priority for higher education in Oregon could provide new career opportunities for graduates.

The investment required to help grow a "forest of new energy technologies" could be a reasonable component of new economic development strategies. Such private and public investment in the "silicon forest" helped diversify Oregon when its traditional resource industries – forest products, fisheries, etc. – began to struggle. Oregon's success in realizing the new economic opportunities offered by climate change could catalyze business activity and generate new revenue that the state will need to address the many costs of climate change mitigation and adaptation.

The Risk of Abrupt Climate Change

Harmful surprises cannot be ruled out – it is prudent to plan for them now

Adaptation to climate change could prove especially costly if global warming triggers an abrupt change in the climate system. Abrupt climate change scenarios are no longer simply the fodder for Hollywood blockbuster movies. Scientists now agree that the geological record yields instances of large-magnitude climate changes that in some cases occurred not on a timescale of thousands of years, but on a scale of decades to centuries. Those concerned with the impacts of climate change on Oregon would be prudent to consider such possibilities.

Some forms of abrupt climate change involve complex changes to ocean chemistry or ocean and atmospheric circulation patterns. Others are as simple to grasp as dropping an ice cube into a soft drink. The melting of polar ice is a special concern, because the displacement of large bodies of ice from Antarctica or Greenland into sea water could raise sea levels worldwide by 15 meters (50 feet). The West Antarctic Ice Sheet, whose volume could raise sea levels by over 8 meters (26 feet), is held in place by two smaller ice shelves considered vulnerable to sea level rise and ocean warming. The 2001 scientific report of the IPCC stated that such collapse was unlikely for centuries. Since them, research on the dynamics of ice movement suggests that such a change could occur in as little as one century (Hansen, 2005).

A several-meter rise in sea levels, even if extended over a period of decades, would cause dramatic, and indeed catastrophic, inundation and displacement of coastal settlements around the world. In Oregon, it would reconfigure the coastline and the estuary reaches of the state's major rivers, including the Columbia River upstream as far as Portland Harbor (See Figure 1). A preliminary geographic information system (GIS) analysis of coastal and riparian areas susceptible to inundation (commissioned by Resource Innovations for this report) suggests that more than 375,000 acres of land in Oregon could be submerged by a complete melting of the Greenland and West Antarctic ice sheets. Inundation would submerge more than 120 miles of Highway 101 and 2,600 miles of other major and minor roads. Existing ports, jetties, harbor facilities, and other infrastructure would be rendered useless, and hundreds of millions of dollars of coastal property value could be lost.

The purpose of illustrating and analyzing such a speculative scenario is to clarify the physical extent of vulnerability to a remote but plausible risk. As such, it is a way to help society begin to evaluate the risk and to determine how much citizens might be willing to pay now to insure against such an eventuality.

The physical impacts of sea level rise of this magnitude are analogous to the impacts of a major tsunami or a Magnitude 9 earthquake, both of which are plausible possibilities in Oregon. Just as communities prepare for these sudden disasters, the state could benefit from greater public awareness of the impacts of large-magnitude sea level rise. It may prove easier to adapt to such seemingly remote changes if preparations are made now. For example, efforts to anticipate and prepare for the slow-motion impacts of rising sea levels may enhance tsunami preparedness in coastal communities.

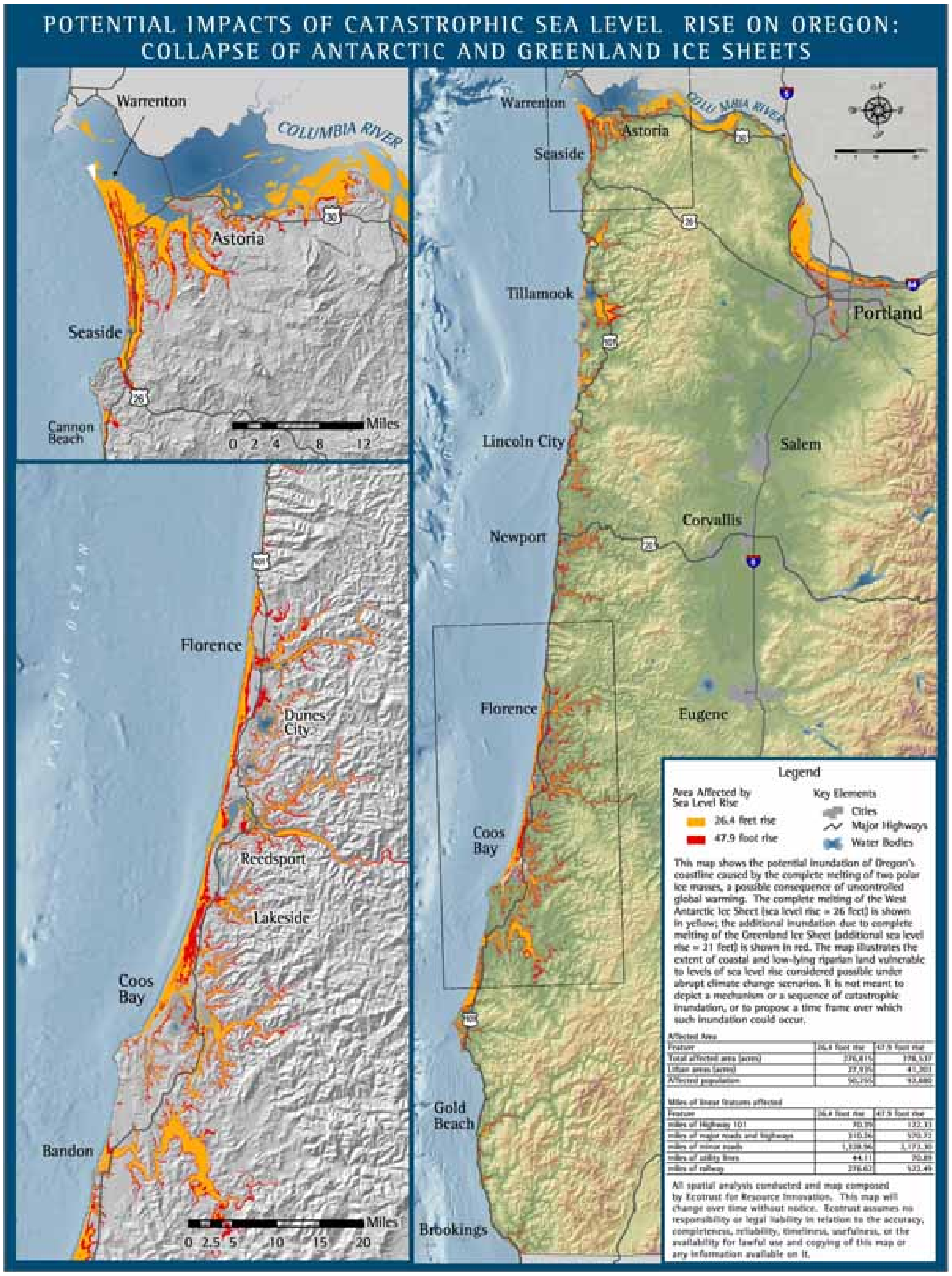

Figure 1. Potential Impacts of Catastrophic Sea Level Rise on Oregon

Urgent Research Priorities

Several areas of economic research are of high importance

New economic research is needed to improve economists' and policymakers' abilities to anticipate and evaluate the costs of climate change. Below we offer five immediate priority areas for economic research. This should be considered a preliminary list. Much more immediate and long-term research is needed to help policymakers at all levels understand and plan for the economic impacts of climate change in Oregon.

1. Water Management

Reduced snowpack and resulting reduced summer flows seem imminent in Oregon. Key research questions that should be assessed include: What adjustments can Oregon make to anticipated reductions in summer/fall water availability? What are the most cost-effective ways to prepare Oregon's residents, industries, and farmers for the likelihood of more frequent and intense drought? What policy and management approaches address ground and surface water management in an integrated manner? Can water markets make water transfers more efficient, reducing transaction costs and increasing public benefits?

2. Sectoral Impact Assessments: Agriculture, Public Health, Recreation and Snow Sports, Coastal Communities and Industries, Salmon Recovery, and Others

Additional research is needed to understand the economic impacts of climate change on key economic sectors. In the agriculture sector, for example, key questions include: What lessons can be learned from crop substitution in other regions of the United States and the world? Can yield responses of Oregon crops under plausible changes in water availability associated with warming scenarios be incorporated into economic models now?

3. Mitigation Spending

Given limited resources, one of the most pressing challenges posed by climate change will be how to set spending priorities. Key research questions include how to determine which mitigation investments and expenditures will also improve the capacity of businesses and communities to adapt to climate change.

4. Risk Management Approaches

Risk management will be an important tool in mitigation and adaptation planning. Key research questions include an effort to rank risk management approaches best suited to the types of risks associated with different global warming impacts.

5. Resource Conflict Resolution Methods

Conflicts over dwindling supplies of water and other resources are certain to increase as warming and sea levels increase and snowpack and summer water supplies decrease. Improved conflict resolution methods will be vital. Key research questions include what pre-crisis planning and crisis management practices may improve the chances of reaching agreement in resource negotiations when climate parameters intensify the conflicts.

Conclusion

Oregon faces a time of decision

With climate change, Oregonians, along with people around the world, confront challenges unlike any in their experience. The more populous and economically dynamic parts of Oregon are vulnerable to warming because of dependence on mountain snowpack for summer water supplies, impacts on the supply and cost of electricity, increased risks to public health, and the vulnerability of coastal communities to rising sea levels. Rural, resource-dependent communities and the local governments that serve them, as well as poor and infirm residents throughout the state, are even more vulnerable. The state's leaders and citizens will need to show exceptional resourcefulness and flexibility to meet these challenges.

This report represents a first attempt to integrate the work of economists, climate scientists, and resource specialists in an effort to clarify the likely economic impacts of climate change in Oregon. The economists and stakeholders who met at Lewis & Clark College on May 3, 2005 shared many perspectives, and one common view: Oregon's future is at stake.

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Appendix 1. Ice Sheet Collapse: Science and Policy
by Eban Goodstein, Ph.D., Professor of Economics, Lewis & Clark College

The map included in this report (Figure 1.) illustrates the impact on Oregon of a complete collapse of the West Antarctic Ice Sheet (in yellow) and the Greenland Ice Sheet (in red). Global warming presents some risk of ice sheet collapse of this magnitude, with clearly catastrophic economic consequences for the state. Although an ice sheet collapse is far from certain, and the consequences would not be felt for some time, the likelihood of their occurrence will be determined by decisions we make today. Taking reasonable measures to reduce the emission of heat trapping gases thus may make economic sense as an insurance policy for Oregon's long-run economic health.

Much of the world's fresh water is locked up in the massive ice sheets on Greenland and Antarctica. Sea level can rise rapidly when the melting of ice sheets is lubricated by meltwater, creating a "collapse". Coming out of the Ice Age 14,000 years ago, sea level rose by about 3 feet every twenty years. And during the peak of the last interglacial warm period, about 100,000 years ago, the planetary temperature was 2 degrees F warmer than today, and sea level was 20 feet higher. However, collapse of the continental ice sheets are by no means certain: warming may lead to increased snowfall which could help offset ice-sheet melting, and hold sea level rise at a minimum.

Sea level rise of this magnitude, if a collapse was initiated, would likely not be completed for several hundred years. However, once a temperature threshold that initiates a collapse was crossed, catastrophic sea level rise would be extremely difficult to prevent. Moreover, on a much shorter timeframe of decades, ice sheet collapse would inundate Oregon's coastal regions, and flood large portions of Bangladesh, the Nile Delta, Florida, and many island nations, leading to the forced migration of hundreds of millions of people.

What we know is that sea levels can rise by more than ten feet a century, and that in a slightly warmer world, sea level has been substantially higher than it is today. The risk of ice sheet collapse is thus very real, though with highly uncertain probability. Although the most extreme consequences would not be felt for over a hundred years, decisions made today regarding the emissions of heat-trapping gases will either increase or decrease the likelihood of a collapse.

Appendix 2. Acknowledgments and List of Participants in the May 3, 2005, UO Resource Innovations Workshop at Lewis & Clark College, Portland, Oregon

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