IN THE CIRCUIT COURT OF THE STATE OF OREGON FOR LANE COUNTY

Olivia Chernaik, a minor and resident of Lane County, Oregon; **Lisa Chernaik,** guardian of Olivia Chernaik; **Kelsey Cascadia Rose Juliana,** a minor and resident of Lane county, Oregon and **Catia Juliana,** guardian of Kelsey Juliana,

Plaintiffs,

v.

JOHN KITZHABER, in his official capacity as Governor of the State of Oregon; and the **State of Oregon,**
Defendants.

Case No. 16-11-09273

DECLARATION Of ERNEST G. NIEMI

In Support of Plaintiffs' Motion for Summary Judgment

I, Ernest G. Niemi, declare as follows:

The facts set forth in this declaration are based upon my personal knowledge. If called as a witness, I could and would testify to these facts. As to those matters that reflect an opinion, they reflect my personal expert opinion on the matter.

I. Introduction and Summary

1. I am an economist and principal of a consulting firm, Natural Resource Economics Inc., based in Eugene, Oregon, that provides analysis in economics, finance, planning, and policy evaluation for businesses and governments. I received a Master of City and Regional Planning from Harvard University. My professional experience includes analyzing the economic consequences of resource management decisions throughout the Pacific Northwest since 1978, and teaching courses on economic development and benefit-cost analysis at the University of Oregon. I have attached

hereto, as Exhibit A, a copy of my vita.

2. I am familiar with the regional and subregional economies of the Pacific Northwest states, the structure of those economies, the forces affecting them, and the changes occurring in them. For more than two decades I have devoted considerable time and attention to reviewing and understanding the economic effects of various proposals and options for managing the region's forests and other natural resources.

3. I prepared this declaration in response to a request from Plaintiffs, who asked me to evaluate the potential consequences to Oregon's economy resulting from the effects of climate change based on a 2009 report prepared for the University of Oregon entitled "An Overview of Potential Economic Costs to Oregon of a Business-As-Usual Approach to Climate Change" (Overview Report). I have attached a true and accurate copy of this report as Exhibit B to this Declaration. I was the lead author for this report, in collaboration with more than 20 economists. Below, I summarize findings derived from the Overview Report, which I believe remains the most up-to-date synopsis of the potential effects of climate change on Oregon's economy. Throughout this declaration, I use "we" and "us" to refer to my collaborators and me.

4. Extensive research cited in the Overview Report shows that Oregon and other western states already have experienced noticeable changes in climate and predicts that more change will occur in the future. Much of this change is having and will continue to have negative economic consequences on the state economy. Some negative effects are readily recognized: warmer stream temperatures during summer stressing salmon and trout populations, prolonged drought destroying farmers' crops, curtailment of shellfish production, and rapidly growing insect populations attacking commercial orchards and forests. A few studies have attempted to describe the net costs of taking this or that action to limit the impacts of climate change, but undermined their efforts by focusing

mostly on describing the action and not providing a full, easily understandable description of the consequences of not taking it.

5. The first step toward filling the information gap was taken a few years ago by the Climate Leadership Initiative at the University of Oregon, which produced the first climate economic report for Oregon and used information available at that time.

The Overview Report builds on that assessment and additional available data. It illustrates some of the potential costs Oregon's families, businesses, and communities might incur over the next several decades if Oregon, other states, the U.S., and other countries were to extend a business-as-usual approach to climate change. Under this approach, we assumed behaviors do not change and the emissions of carbon dioxide and other greenhouse gases would continue to grow at rates similar to those seen during recent years, leading to increases in global temperature such as those depicted in the high-emission scenarios described by the U.S. Climate Science Program, the Intergovernmental Panel on Climate Change (IPCC), and others.

6. This analysis does not capture all likely costs of climate change for Oregon.

Insufficient data are available to provide estimates for the totality of potential effects scientists have identified, not to mention other effects not yet identified. In addition, Oregonians likely will experience costs that materialize beyond the state's border: as climate change leads to damage from heat waves, droughts, and storms elsewhere in the country and the world, for example, tax dollars and voluntary contributions will flow out of the state to provide assistance. Today's Oregonians also will incur some costs from manifestations of climate change that would occur beyond this century. For these reasons, I am confident that the actual potential costs of climate change in Oregon are larger than the amounts calculated herein as taken from the Overview Report.

7. The following paragraphs provide a summary of the potential costs, and the

change(s) in climate, ecosystems, or social systems that likely will generate that cost, broken down into six categories:

- Public Health
- Energy
- Fish and Wildlife
- Flood and Storm Damage
- Forest and Range Production
- Recreation

8. **Public Health:** Increased temperatures favor the production of low-altitude ozone, which negatively impacts the health of humans that live in urban areas and creates costs associated with increased rates of morbidity, premature mortality, and lost worker productivity. The calculation of increased morbidity costs does not account for costs that would occur outside a hospital (in-patient or emergency room) or for the effects of higher ozone concentrations on all sensitive groups, like children and elderly. EPA's value of statistical life represents the value that people, on average, are willing to pay to avoid premature mortality from exposure to harm, be it pollution, accidents, etc. Researchers have argued that a more appropriate measure to value a life is the willingness to accept fatal consequences of exposure to harm. This value is usually higher than the willingness to pay. This means that the total value of increased mortality from high ozone concentrations likely understate the actual value society places on deaths from climate change. The potential health-related costs from increased low-altitude ozone is summarized as follows for each of the following benchmark years:

2020 2040 2080

a. Value of Premature Deaths

$253 million, $542 million, $1.4 billion

b. Value of Increased Morbidity

$38 million, $49 million, $72 million

c. Value of Lost Productivity

$397 million, $507 million, $745 million

TOTAL

$688 million, $1.1 billion, $2.2 billion

Additional heat waves (days with temperatures consistently above a threshold specific to different geographic areas) are also expected to increase mortality rates and medical costs of those already suffering from cardiovascular, cerebrovascular, and respiratory diseases. They also will reduce work productivity, household productivity, and the value of leisure time. We estimated the value of the additional premature deaths using EPA's current estimate of the value of a statistical life. To calculate medical and other costs, we multiplied Oregon's expected future populations times the per capita daily costs for hospitalization, emergency-room visits, and follow-up medical costs during the 2006 heat wave in California. We estimated the additional, climate-related costs by applying the results of a study that projected Oregon would experience an additional 14 heat-wave days by 2030 and making adjustments to estimate the number of potential additional deaths in 2020, 2040, and 2080. Heat-wave statistics show they cause more deaths than all other natural disasters in the US. Death certificates systematically fail to represent high temperatures as the death cause during heat waves, however, and a full accounting would increase the mortality numbers, perhaps by more than 50 percent. The potential value of health-related and other costs of heat waves are summarized as follows for each of the following benchmark years:

2020 **2040** **2080**

a. Value of Premature Deaths $66 million $153 million $359 million

b. Value of Increased-Medical Care Costs

$9 million, $18 million, $51 million

c. Value of Other Costs

$1 million, $2 million, $5 million

TOTAL

$76 million, $173 million, $415 million

9. **Energy:** The primary energy costs and financial losses derive from reduced hydropower generation. Climate models indicate that changes in the Pacific Northwest's climate likely will cause runoff to increase in winter and decrease in summer, reducing value of hydropower produced by the region's hydroelectric facilities. This reduction in value would ensue due to a mismatch between energy demand, which will increase in summer, and hydropower supplies, which would be lower at the same time. We estimated Oregon's share of the potential reduction in productive capacity for the Northwest to be 175 MW by 2020, 550 MW by 2040, and 1,300 MW by 2080, assuming that its current share of production will persist. We estimated the consequential value of reduction in hydropower generation to be $74 million in 2020, $233 million in 2040, and $552 million in 2080.

Higher temperatures during summer months will also likely induce residential consumers to spend more money on air conditioning. We estimated the potential value of increased energy costs for air conditioning of $16 million in 2020, $37 million in 2040, and $92 million in 2080.

In addition, higher temperatures during climate-related heat waves will increase the amount of energy lost during electricity-transmission lines. During heat waves, the resistance of overloaded transmission lines increases, causing the grid to convert more electricity into heat, which wastes energy. We applied a middle-of-the-road estimate of the potential growth in heat-wave days from 1990 to 2030; linearly interpolate and extrapolate to estimate the number of additional days in 2020, 2040, and 2080; and adjust the numbers to estimate what the impact would be under a business-as-usual approach to climate change. If the additional transmission-line losses during a heat-wave day equal one-third of the electricity being transmitted, the annual losses from energy lost in transmission during heat waves and the consequential value of reduction in hydropower generation would be $29 million in 2020, $58 million in 2040, and $171 million in 2080.

10. **Fish and Wildlife:** Warmer stream temperatures resulting from increased global temperatures reduce the amount of habitat that can viably support salmon, reducing salmon populations. An assessment of stream temperatures indicates increased warming may reduce salmon habitat in Oregon by 13, 23, and 44 percent by 2030, 2060, and 2090, respectively. Adjusting these numbers to be consistent with the 2020, 2040, and 2080 benchmark years, the potential value of reduced salmon populations in 2020, 2040, and 2080 is $632 million, $1.04 billion, $1.87 billion, respectively.

Increased temperatures and changes in precipitation are likely to impact many species other than salmon in Oregon. Scientists have found evidence that climate change can result in changes in species' range, abundance, phenology (timing of an event, such as migration), morphology and physiology, and community composition, biotic interactions and behavior. Data were not available, however, to allow us to estimate the costs associated with these and other potential fish and wildlife-related impacts.

11. **Flood and Storm Damage:** Rising global temperature leads to increased sea levels, which will inundate value property and structures. No direct estimates of the value of coastal property damage due to sea-level rise exist for Oregon, so we applied estimates for California after adjusting for differences in general coastline length, median home value, and coastal population density. Based on this analysis, potential value of

property damage from sea level rise in 2020, 2040, and 2080 is $16 million, $33 million, and $73 million, respectively.

Climate change is also expected to increase storm severity and the frequency of extreme storm events, including high winds, flooding, lightning and fire. Storm events will have direct property-damage effects, as well as increased storm related injuries and fatalities. Potential value of property and crop damage from extreme weather events in 2020, 2040, and 2080 is $48 million, $99 million, and $236 million, respectively.

12. **Forest and Range Production:** Wildland fires become more frequent and severe as climate change increases temperatures and aridity, and accelerates tree mortality from insects and disease. When forests burn, they lose their ability to produce many goods and services, but data are available only to estimate the loss assuming the forest would be managed to produce timber. Projections for climate-related changes in temperature and precipitation suggest that, relative to the 20th century, wildfires in Oregon will burn 50 percent more acreage per year by 2020 and double the acreage by 2040. On average, 137,000 acres of state and federal land burned annually from 1988 to 1999. We assumed that, if private lands burned at the same rate, the average would have been 217,000 acres. State and federal land make up 63 percent of all forestland in Oregon. A 50 percent increase in acreage burned by 2020 would be an increase of 109,000 acres, and a 100 percent increase by 2040 would be an increase of 217,000 acres. We assumed the annual value of lost goods and services when a forest burns is at least $1,000 per acre, a general estimate for the value of lost timber. Based on these assumptions, the potential value of lost forest assets from increased forest fires in 2020, 2040, and 2080 is $109 million, $223 million, and $497 million, respectively.

Furthermore, Oregonians will incur additional fire-control costs as wildfires become more frequent and severe as climate change increases temperatures and aridity and accelerates tree mortality from insects and disease. The potential value of increased control expenditures for wildland fires in 2020, 2040, and 2080 is $97 million, $200 million, and $444 million, respectively.

13. **Recreation:** Higher temperatures reduce snowfall and accumulation, shortening the ski season, degrading skiing conditions, and reducing revenues for the ski industry. We assumed that the snow-recreation season will shrink 14 percent by 2020 and 30 percent by 2040, based on a forecast of temperature increases associated with business-as-usual emissions. We assumed the number of user days, expenditures, and consumer surplus shrinks proportionately. We linearly extrapolated to estimate the reductions for 2080. Industry officials suggest that once the snow-recreation season is shortened to the extent indicated for 2080, snow-related recreation businesses, and the downhill skiing businesses in particular, likely would not be viable and would close. Accordingly, the total potential value of reduced snow-related recreation 2020, 2040, and 2080 will be $46.4 million, $124 million, and $338.2 million, respectively.

In addition, higher stream temperatures reduce the amount of habitat that can viably support salmon, reducing the contribution of cold-water angling to the economy. We assumed the value of cold-water angling will decline proportionate to expected losses of aquatic habitat for salmon and trout. Consequently, the potential value of reduced cold-water angling for 2020, 2040, and 2080 is $121 million, $266 million, and $732 million, respectively.

More numerous and larger wildland fires will also likely reduce recreation opportunities during summer months. Forest closures during wildland fire events and exceptionally dry, high-risk fire seasons limit access to the area, and thus opportunities, available for activities, such as hiking, mountain biking, wildlife watching, and scenic driving. Post-fire landscapes may provide more limited or lower-quality recreation experiences. Low-water levels in streams, especially in late summer, may also reduce some water-related recreation opportunities, such as river rafting and kayaking. Though insufficient data are available to quantify these impacts, research elsewhere suggests that they have the potential to reduce the value (expenditures and consumer surplus) of forest-based and water-related recreation in Oregon.

14. As set forth in the Overview Report, the total potential economic costs to Oregon resulting from climate change in 2020 will be approximately $3.3 billion, or $1,930 per household. In 2040, it will increase to $3.6 billion, or $1,930 per household. In 2080 in will rise to $9.8 billion, or $3,500 per household. Far greater costs might materialize elsewhere or in future centuries, the result of a business-as-usual approach to climate change over the next few decades. If temperatures rise to the maximum levels predicted under the business-as-usual scenario, billions of people in less-developed countries likely would endure increased thirst and starvation, thousands of species would face extinction, sea levels would rise several meters and vast areas of the oceans could become barren. To the extent that these distant effects matter to today's Oregonians, the potential costs would be far greater than indicated herein.

Pursuant to ORCP 1E, I hereby declare that the above statement is true to the best of my knowledge and belief, and that I understand it is made for use as evidence in court and is subject to penalty for perjury.

DATED January 6, 2015

Ernest G. Niemi

Natural Resource Economics

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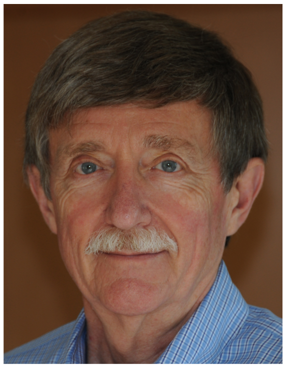
ERNIE NIEMI



Ernie specializes in applying the principles of cost-benefit analysis, economic valuation, and economic-impact analysis to describe the economic importance of natural resources. He formed Natural Resource Economics, Inc. in 2012. From 1978 to 2012, he managed economic and policy analysis for the consulting firm, ECONorthwest, where he was a co-owner, vice president, and senior economist. He has taught cost-benefit analysis and economic development for the University of Oregon's Department of Planning, Public Policy, and Management.

- He has described the economic importance of market and non-market goods and services derived from diverse ecosystems: dryland, montane, riparian, lake, river, forest, grassland, urban, savannah, estuarine, marine, island, and coastal plain.
- His analyses have addressed resource-management programs for water quantity, quality, and reliability; economic security for low-income communities; conservation of at-risk fish, wildlife, and plant species; management of natural-resource risks; adaptation of households, businesses, and communities to expected changes in climate; management of public lands and waters; diversion of surface and ground water for irrigation, livestock, domestic, and municipal-industrial uses; maintenance or enhancement of in-stream flows; water conservation; forest restoration; and floodplain management.
- His descriptions of the economic importance of natural resources have covered both market and non-market values of goods and services derived from ecosystems; impacts of resource-management alternatives on commercial and non-commercial (including subsistence) components of surrounding economies; and the distribution of positive and negative economic outcomes among existing groups and across current and future generations.
- He has presented analytical findings on resource-management issues to congressional, judicial, arbitrative, administrative, multi-national, and scientific/professional bodies.

Education

- Master of City and Regional Planning, Harvard University, 1978
- Bachelor of Science, Chemistry, University of Oregon, 1970

Advisory Positions

- Commission on Ecosystem Management of the International Union for Conservation of Nature (IUCN)
- Technical Advisory Committee on Land Use and Economic Development for the Oregon Department of Land Conservation and Development

- Citizen's Task Force for Developing a Strategic Plan for the Oregon Department of Fish and Wildlife
- Water Marketing Task Force for the Oregon Water Resources Department
- Technical Team for the Northern Spotted Owl Implementation Team for the Washington Board of Forestry
- Social, Cultural, and Economic Technical Team, Missouri River Ecosystem Restoration Plan, U.S. Army Corps of Engineers
- Climate Leadership Initiative of the University of Oregon
- U.S. Secretary of Agriculture's Large-Cost Fire Independent Review Panel

Representative Projects

Climate Change and Sustainability

- **Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED). Farm Africa (with Mercy Corps and Lion's Head Global Partners). 2014.** Evaluated market-based options for increasing the climate-related resilience of Ethiopia's pastoralist communities and dryland ecosystems.
- **Potential State-Level Economic Costs of a Business-As-Usual Approach to Climate Change. Climate Leadership Initiative, University of Oregon. 2008-09.** Calculation of some of the potential costs that families, businesses, and communities in New Mexico, Oregon, and Washington might expect in the next several decades if the states, the U.S., and countries around the world were to continue their activities in a business-as-usual manner, i.e. without effective steps to rein-in greenhouse gas emissions (GHGs) or to prepare for and adapt to changes in climate that past and future emissions of GHG will bring about.
- **Sonoma County Sustainability Plan. Sonoma County Water Agency. 2007-2009.** Evaluation of the economic issues associated with proposals to reduce Sonoma County's emissions of greenhouse gases and strengthen its ability to anticipate changes in climate.
- **Climate Change, Mountain Pine Beetles, and Forest Management. Confidential Client. 2008-2012.** Evaluation of management options for forests experiencing climate-related increases in mountain pine beetle infestations.
- **Jobs vs. Jobs. The Resource Innovation Group. 2013.** The effects on jobs, the economy, and the climate of the failure to rapidly cut greenhouse gas emissions.

Disadvantaged Communities and Communities at Risk

- **Potential External Costs of a Proposed Commercial Port at Lamu, Kenya. Natural Justice. 2014.** Analysis and workshops to help affected communities, the national government, and investors understand the potential effects of the port and related development on human, natural, social, cultural, and built capital.
- **Valuation of Natural Resources: Environmental Law Alliance Worldwide (ELAW) 2014.** Briefing and workshops for public interest environmental lawyers in East Africa.
- **Impact of and Response to the Affordable Care Act. Planned Parenthood of Southwestern Oregon. 2012-2013.** Construct and apply an economics-based framework for understanding the effects of the Affordable Care Act on PPSO and its clients, defining alternative responses to challenges stemming from the act, and evaluating the alternatives.

- **Potential Tribal Acquisition of Federal Forest Lands. Confidential Client. 2007.** Evaluation for a tribal government of the economic feasibility of a proposal to acquire forest land currently managed by the federal government, managing the land consistent with its goals for providing a natural environment in which its members can live sustainably, and generating revenue through the production of forest-related products.
- **Assessment of Economic Injury and Damages from an Oil Spill. Davis Wright Tremaine LLP. 2003-04.** Determination of the extent to which citizens of Yap, Federated States of Micronesia, had been economically injured by oil spilled by M/V Kyowa Violet and calculation of the economic damages required to compensate them for the injury.
- **Disadvantaged Communities and Integrated Regional Water Resource Management Planning. Cosumnes, American, Bear, and Yuba River Basins (CABY) IWRMP Group. 2009.** Development of guidelines to help disadvantaged communities compete effectively with larger, richer communities for funding to support integrated regional water resource management planning in California.
- **Multimodal Port at Punta Colonet, Mexico. 2009.** Description of the potential economic effects on the local community of the proposed port and its impacts on the physical, economic, and cultural landscape.

Forest and Wildlife Resources

- **Federal Forest Carbon Coalition. The Resource Innovation Group. 2013-2014.** Serve as lead economist and co-chair of a coalition that encourages the federal agencies to account fully for the carbon value of federal forests in management decisions.
- **Economic Importance of Alaska's Wildlife. Alaska Department of Fish and Game. 2012-2014.** Project Manager for assessment of the effects of wildlife on Alaskans' quality of life and their decision to live in Alaska; the impacts of wildlife-related spending on jobs, incomes, and governmental revenues; and the net economic benefit Alaskans and visitors derive from hunting and wildlife-viewing activities.
- **Economic Value of Goods and Services Produced by the O&C Lands. Pacific Rivers Council. 2013.** Comparison of the per-acre value of timber, water, habitat, and carbon.
- **Forest Management and Municipal Water Supplies. University of Oregon, Institute for Sustainable Environment. 2001.** Assessment of the economic consequences of forest-management actions affecting the ability of its watershed to deliver high-quality water to the City of Salem.
- **Economic Benefits of Old-Growth Forests in the Pacific Northwest. Earthjustice. 2006.** Overview of the findings of research regarding several categories of services provided by old-growth forests on federal lands under the Northwest Forest Plan.
- **The Sky Did NOT Fall: The Pacific Northwest's Response to Logging Reductions. Earthlife Canada Foundation and Sierra Club of British Columbia. 1999.** Analysis of the overall economic effects of reductions in logging on federal lands.
- **Salmon, Timber, and the Economy. Pacific Rivers Council, Oregon Trout, Audubon Society, Institute for Fisheries Resources. 1999.** Assessment of the positive, as well as the negative economic effects of restrictions on logging practices aimed at conserving salmon populations.
- **Seeing Forests for Their Green. Sierra Club. 2000.** Economic benefits of forest protection, recreation, and restoration.

- **Potential Economic Consequences of Post-Fire Logging on Federal Lands. Sierra Club. 2006.** Explanation of common errors in economic assumptions and analysis that overstate the economic benefits and understate important economic costs of post-fire logging on U.S. federal lands.

Economic Development

- **Economists' Letter on the Economic Importance of the West's Natural Environment. Center for Watershed and Community Health, University of Oregon. 2003.** Management of the drafting of a letter, to President Bush and the governors of eleven western states, signed by more than 100 leading economists regarding the importance of the contributions the West's natural environment make to the economic development of western communities.
- **The Ecosystem-Economy Relationship: Insights from Six Forested LTER Sites. National Science Foundation. 1996-1997.** Evaluation of the relationships between America's forested ecosystems and regional economies at long-term ecosystem research sites in Alaska, New Hampshire, New Mexico, Oregon, Wisconsin, and South Carolina.
- **Natural-Resource Amenities and Nebraska's Economy. The Nebraska Game and Parks Commission. 2006.** Examination of the current status of, and potential for natural-resource-related, amenity-driven economic growth in Nebraska through quality-of-life enhancements, stronger feedback to the farm sector, expanded recreation, and protection of environmental values.

Ecosystem Restoration

- **Action Agenda. Puget Sound Partnership. 2008.** Analysis of the costs, benefits, cost-effectiveness, and alternative funding mechanisms of options for restoring the ecosystem of the Puget Sound Basin, Washington.
- **Economic Evaluation of River and Wetland Restoration Projects: A Conceptual Manual. US Environmental Protection Agency. 1998.** Co-authored the conceptual manual with Tom Power, University of Montana.
- **Pacific Northwest Ecosystem Research Consortium. US Environmental Protection Agency. 1994-2000.** Economic analysis of competing demands for water and related resources as part of a multi-disciplinary effort to evaluate the potential ecological and economic consequences and feasibility of proposals to manage and restore watersheds and riparian areas in the Willamette River Basin, Oregon.
- **Watershed Restoration in the Sierra Nevada: Ecological and Economic Principles. Pacific Rivers Council. 2002.** Definition of a framework for determining the economic consequences of watershed restoration, and provided baseline information for designing and evaluating proposals to restore watershed in the Sierra Nevada.

Wetlands and Watersheds

- **Socio-Economic Effects of the Lower Snake River Programmatic Sediment Management Plan (PSMP). American Rivers and Others. 2014.** Reviewed and offered recommendations for improving the socio-economic elements of the PSMP prepared by the U.S. Army Corps of Engineers.
- **Integrated Water Resource Management Plan for the Yakima River Basin, Washington. US Bureau of Reclamation and Washington Department of Ecology. 2009-On-Going.** Description of the value of higher salmon populations, increased ability of irrigated agriculture to withstand severe drought, and improvements in

municipal-industrial water supplies, as well as the impacts on jobs and incomes that would result from implementation of an integrated plan for managing water and related resources in the Yakima River Basin.

- **Implementation Funding for the Integrated Regional Water Resource Management Plan of the North Coast, California. West Coast Watershed. 2007 and 2008.** Description of the potential economic benefits and costs of proposed actions for implementing programs of the Integrated Regional Water Resource Management Plan for the North Coast Region that will improve the reliability and quality of water available for out-of stream uses, in-stream flows, and coastal and estuarine areas.
- **Financial Feasibility of a Regional Wetland Mitigation Bank. (Portland Area) Metro Regional Parks and Greenspaces. 2004.** Discussion of how mitigation banks are typically financed, establish mitigation-credit prices, and manage risk.
- **Levee Set-Back Evaluation. King County, Washington, River and Floodplain Management Section. 2010-2011**. Characterization of the market and non-market economic benefits, costs and risks—and their distribution among different income **and** ethnic groups—of alternatives for managing flooding in the Green River Basin.
- **Capitol Lake Adaptive Management Plan, Deschutes Estuary Feasibility Study. Washington Department of Fish and Wildlife. 2007.** Description of the net social and economic benefits of alternatives for managing the Capitol Lake Basin of the Deschutes River in Olympia, Washington.

Water Resources

- **Reclaimed Water Comprehensive Plan. King County, Washington, Wastewater Treatment Division, 2009-2011.** Description of the economic benefits and costs associated with producing and using reclaimed water and incorporated this information into a benefit-cost analysis of potential reclaimed-water projects.
- **Market-Based Tools for Accomplishing Water Quality Objectives. Confidential Client. 2005-2006.** Estimation of the financial savings and broader social economic benefits a public wastewater utility could generate by planting and protecting riparian forests rather than expanding its wastewater-treatment plant to meet water-quality objectives.
- **Financial Capability for Implementing a Long-Term CSO Plan. King County, Washington, Wastewater Treatment Division. 2011.** Assessment of King County's capability to bear the expected financial costs of implementing its Combined Sewer Overflow (CSO) Control Plan.
- **Market-Based Reallocation of Water Resources. Washington Department of Ecology. 2009.** Description of recommended steps for increasing market-based reallocation of water in the Yakima River Basin in a manner that will improve streamflows for anadromous fish, improve water supply for irrigated agriculture, meet future municipal water needs, increase the overall value of goods and services derived from the basin's water resources, and ensure that the interests of third parties receive adequate consideration.

Agriculture and Irrigation

- **Economic Analysis of Irrigation in Montana. Montana Department of Natural Resources and Conservation. 2008.** Description of the relationship between irrigated agriculture and Montana's economy, and examination of how this relationship might be affected by state investments in existing and new irrigation projects.

- **Economic Indicators of Agriculture's Future. Skagit County, Washington. 2010.** Description of the strengths, weaknesses, and long-run viability of agricultural activities in the county.
- **Economic Consequences of the Proposed Columbia River Water Exchange on Irrigated Agriculture in the Walla Walla River Basin. Confederated Tribes of the Umatilla Indian Reservation. 2010.** Description of the expected economic consequences of a proposal to use water from the Columbia River to increase instream flows in the Walla Walla River to support increased salmon populations.

Energy

- **Environmental Externalities and Electric Utility Regulation. National Association of Regulatory Utility Commissioners (NARUC). 1993.** Discussion of the theoretical and practical issues state commissions face when they consider environmental externalities, and the options for resolving them.
- **Electricity-Generating Alternatives in Arkansas. Sierra Club. 2007.** Comparison of the costs, risks, and impacts on jobs of a proposed coal-fire generator relative to those of a more diversified set of clean-energy actions involving investments in energy efficiency and new generators powered by wind, biomass, and other renewable sources of energy.
- **Nevada's Electricity-Generating Alternatives. Nevada Clean Energy Campaign. 2007.** Comparison of the costs to ratepayers and economic risks of a proposal to build coal-fire generators relative to those of an alternative that entails investing in energy efficiency, so that energy savings could be used to meet new demands, and in new generators powered by wind, geothermal heat, and other renewable resources.
- **Alternative Programs for Managing Waste Coal in Central Appalachia. Sierra Club. 2009.** Analysis of the potential economic consequences of alternative approaches for managing waste-coal piles in central Appalachia.
- **I-5 Corridor Transmission Reinforcement EIS. Bonneville Power Administration. 2009-2012.** Description of the potential socio-economic consequences of a proposed 500-kV transmission line and substations in southwest Washington and northwest Oregon.
- **Land/Water External Costs and Electricity Planning. The NGO Caucus for the Eastern Interconnection Planning Collaborative (EIPC). 2010-11.** Description of costs that arise when new generation and transmission facilities reduce the value of goods and services derived from affected land and water resources.

Risk Management

- **Earthquake Risk Assessment. Seattle Public Utilities. 2004.** Description of alternative approaches for valuing the benefits of earthquake protection for municipal services, with a focus on Seattle's water service.
- **FY 2008 Large-Cost Fire Independent Review. US Secretary of Agriculture. 2008-09.** Member of the Secretary's Large-Cost Fire Independent Review Panel that reviewed 22 wildfires in FY 2008 with suppression costs exceeding $10 million and found a need to strengthen the Forest Service's safety culture, improve risk-informed management, develop a better understanding of major cost components including the use of the stratified cost index, develop and employ better strategic thinking, improve the effectiveness of review/oversight processes, and provide a coordinated system of effective incentives.

An Overview of Potential Economic Costs to Oregon of a Business-As-Usual Approach to Climate Change

A Report from
The Program on Climate Economics,
Climate Leadership Initiative,
Institute for a Sustainable Environment,
University of Oregon

Prepared by Ernie Niemi (CLI Fellow and
Member of Economic Steering Committee)
and Staff from ECONorthwest

With Assistance from
Members of the Program on
Economics' Steering Committee

February 17, 2009

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ECONOMICS • FINANCE • PLANNING

AUTHORSHIP AND CONTACT INFORMATION

The Program on Climate Economics of the Climate Leadership Initiative (CLI), Institute for a Sustainable Environment, at the University of Oregon, sponsors research on the potential economic consequences and benefits of climate mitigation, preparation and economic development policies. This report is part of that effort. It calculates some of the potential costs that families, businesses, and communities in Oregon might expect in the next several decades if Oregon, the U.S., and countries around the world were to continue their activities in a business-as-usual manner, i.e. without effective steps to reign in greenhouse gas emissions (GHGs) or to prepare for and adapt to changes in climate that past and future emissions of GHG will bring about.

The work of the CLI Program on Climate Economics is supported by a steering committee of academic and private economists from across the West and nation. Steering committee members provide overall guidance for the program, may be contracted to produce or contribute to economic assessments, and, serve as peer reviewers. Current members of the Steering Committee are:

Katie Baird, *U. of Washington, Tacoma*
Randall A. Bluffstone, *Portland State U.*
Trudy Ann Cameron, *U. of Oregon*
Bonnie G. Colby, *U. of Arizona*
Peter Dorman, *Evergreen State College*
Kristine M. Grimsrud, *U. of New Mexico*
Hart Hodges, *Western Washington U.*
Don Negri, *Willamette U.*
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This report was prepared by Ernie Niemi, a CLI Fellow and member of the Program on Climate Economics' Steering Committee, along with Mark Buckley, Cleo Neculae, and Sarah Reich of ECONorthwest. We gratefully acknowledge the assistance of Katie Baird, Randall Bluffstone, Gardner Brown, Bonnie Colby, Bob Doppelt, Peter Dorman, Kristine Grimsrud, Joel Hamilton, Hart Hodges, Andrew Plantinga, and Michael Scott, for their comments on an earlier version of our manuscript. The assistance from others notwithstanding, ECONorthwest is solely responsible for this report and its content.

We are grateful for the financial support of Nike, Portfolio 21 Investments, and the Energy Foundation for the production of this report.

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I. INTRODUCTION AND SUMMARY

Extensive research shows that Oregon and other western states already have experienced noticeable changes in climate and predicts that more change will occur in the future.[1] Much of this change is having and will continue to have negative economic consequences. Some negative effects are readily recognized: warmer stream temperatures during summer stressing salmon and trout populations, prolonged drought destroying farmers' crops, and rapidly growing insect populations attacking trees. In response, families, businesses, and communities are considering actions that would reduce the emissions of carbon dioxide and other greenhouse gases (GHGs) that contribute to climate change. Amid all this activity, many have concluded that such actions should not be undertaken because their costs are too great. They reach this conclusion, however, without first seeing what the costs would be of not taking these actions and allowing climate change to continue unabated.

Until now, attempts to describe the costs of climate change have produced results that are too abstract to matter to most citizens. Some have estimated the global costs, but what does this mean to an average family in Oregon? Others have looked at the costs that will materialize over the next several centuries, but what does that mean to people making decisions today? A few have attempted to describe the net costs of taking this or that action, but undermined their efforts by focusing mostly on describing the action and not providing a full, easily understandable description of the consequences of not taking it.

The first step toward filling the gap was taken a few years ago by the Climate Leadership Initiative at the University of Oregon, which produced the first climate economic report for Oregon and used information available at that time.[2] The current report builds on that assessment and additional data available today. It illustrates some of the potential costs Oregon's families, businesses, and communities might incur over the next several decades if Oregon, other states, the U.S., and other countries were to extend a business-as-usual approach to climate change. Under this approach, we assume behaviors do not change and the emissions of carbon dioxide and other greenhouse gases would continue to grow at rates similar to those seen during recent years, leading to increases in global temperature such as those depicted in the high-emission scenarios

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[1] *See*, for example, the assessments of climate science and other reports prepared by the U.S. Climate Science Program: http://www.climatescience.gov/, and the reports of the Intergovernmental Panel on Climate Change: http://www.ipcc.ch/

[2] Resource Innovations Institute for a Sustainable Environment, University of Oregon. 2005. *The Economic Impacts of Climate Change in Oregon: A Preliminary Assessment*. October. Retrieved December 19, 2008, from http://climlead.uoregon.edu/publicationspress/Consensus_report.pdf. The Institute produced a similar assessment of the impacts of climate change for the State of Washington. *See,* Washington Economic Steering Committee and the Climate Leadership Initiative, Institute for a Sustainable Environment, University of Oregon. 2006. *Impacts of Climate Change on Washington's Economy: A Preliminary Assessment of Risks and Opportunities.* November. Retrieved December 19, 2008, from http://www.ecy.wa.gov/climatechange/economic_impacts.htm

described by the U.S. Climate Science Program, the Intergovernmental Panel on Climate Change (IPCC), and others.

We take this approach with full recognition that it does not address all the potentially important effects of climate change on Oregon's economy. Moderate warming might have some positive economic effects for some Oregonians, by boosting the output of some farmers, for example, or allowing some recreational activities to occur earlier in the spring and later in the autumn. Many of the most serious economic consequences of a business-as-usual approach to climate change will occur elsewhere, or beyond the next several decades, but still are important to today's Oregonians. As Oregonians become more familiar with the prospect of changes in climate they likely will take actions to mitigate the harm. All these concerns must be considered to have a complete picture of how climate change will affect Oregon's economy. This report provides only one piece of the picture: the potential, gross costs that might materialize in this state over the next several decades, if societies here and elsewhere fail to address climate change by proceeding in a business-as-usual manner.

To facilitate better understanding of our findings, we place each potential cost in a setting familiar to today's Oregonians, assuming that families, businesses, and communities will behave in the future essentially the same as they do today and that future prices relative to budgets will be essentially the same as today's. That is, we assume that families, farms, and businesses will continue to go about their activities in a business-as-usual manner. Families will continue with consumption patterns similar to those of today, businesses will continue to produce products similar to their current ones, and communities will follow current behaviors to organize land-use, transportation, and other activities. In short, we provide an estimate of costs that might materialize if climate change is not reined in, not a forecast of how things will actually unfold.

We anticipate that the information in this report will help families, businesses, and communities better understand the nature of the economic threats that climate change poses over the next several decades. We emphasize, however, that the scope of this report is limited. It illustrates only some of the potential costs that might materialize if Oregon, other states, the U.S., and other countries were to fail to address climate change by carrying on in a business-as-usual manner. Insufficient data currently exist, however, for us to account for all the potential costs. Hence, we encourage the reader to bear in mind that Oregonians face substantial, multi-faceted costs in addition to those we describe here, both during the next several decades and beyond.

Our analysis is structured as follows: in Section II, we present a conceptual framework for describing the potential negative economic effects of climate change. In Sections III and IV, we apply the framework and calculate 17 different types of potential costs. We divide these costs into two broad categories: the costs produced by the effects of climate change, and the costs generated by some of the business-as-usual activities that contribute to climate change. In Section V, we discuss the potential implications for Oregon's households.

The 18 costs we describe are already observable. Over time, they will be exacerbated by potential changes in temperature, precipitation and other climate characteristics, or by climate-related changes in the state's ecosystems. The extent of the anticipated climate change is closely related to increases in the atmospheric concentration of carbon dioxide, which was about 260 to 280 parts per million (ppm) before the Industrial Revolution and has risen to about 385 ppm today. Under our business-as-usual assumptions, the concentration would rise to about 400 ppm by 2020, 500 ppm by 2040, and 800 ppm by 2080.[3] At these concentrations, climate modeling indicates that average global surface temperature could rise by more than 5°C (9°F) above pre-industrial levels by the end of this century (during the past century, the temperature rose 0.74°C (1.33°F), mostly in the past three decades).

Economic costs would arise from undesirable changes in climate, ecosystems, or both. Higher temperatures would increase the incidence of heat-related health problems, for example, and ecosystem changes would reduce summertime stream flows. These and similar changes would impose economic costs on Oregon's families, businesses, and communities. In addition, Oregonians would incur costs as they engage in practices that contribute to climate change, such as consuming electricity generated by burning coal and continuing with technologies and practices that waste energy. For each type of cost, we describe the mechanism that produces it, as well as the assumptions, data, and steps we take to calculate it.

Figure 1 summarizes our findings, aggregating the 17 different costs into 9 categories. By 2020, these costs total $3.3 billion per year. The major components of climate-change costs are potential health-related costs of about $770 million per year, potential reductions in salmon populations, with a value of $630 million per year, and recreation costs of about $170 million. In addition, continuing with the activities that contribute to climate change potentially would cost Oregonians almost $1.3 billion per year in missed opportunities to implement energy-efficiency programs and about $33 million per year in health costs from burning coal. The combined total annual costs would increase with time, almost three-fold by 2080.

If spread evenly, Oregon's households, on average, could incur annual costs of $1,930 per year by 2020. Of this amount, $830 relate to expenditures on energy, $460 relate to health-related costs, and $370 to the adverse effects of climate change on salmon populations. These costs are not negligible. The 2020 average of $1,930 represents more than 4 percent of the current median household income in Oregon. Analogously, the potential costs in 2040 represent more than 5

[3] These increases correspond to the A1FI scenario used by the Intergovernmental Panel on Climate Change (IPCC). The IPCC applies the label, business as usual, to another scenario, A2, but, since its development, it has understated the actual, business-as-usual emissions of greenhouse gases. Hence, we use the A1FI scenario, which we believe more closely represents the trajectory of emissions in a business-as-usual world. *See*, IPCC. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/.

Figure 1. Potential Economic Costs in Oregon Under a Business-as-Usual Approach to Climate Change, 2020, 2040, and 2080 (dollars per year)

Potential Cost	2020	2040	2080
Costs of Climate Change			
Increased Energy-Related Costs	$119 million	$328 million	$815 million
Reduced Salmon Populations	$632 million	$1.0 billion	$1.9 billion
Increased Flood and Storm Damage	$64 million	$132 million	$309 million
Reduced Food Production	$13 million	$35 million	$153 million
Increased Wildland Fire Costs	$206 million	$423 million	$941 million
Increased Health-Related Costs	$764 million	$1.3 billion	$2.6 billion
Lost Recreation Opportunities	$167 million	$390 million	$1.1 billion
Subtotal for Costs of Climate Change	*$2.0 billion*	*$3.6 billion*	*$7.8 billion*
Additional Costs from Business-as-Usual (BAU) Activities that Contribute to Climate Change			
Inefficient Consumption of Energy	$1.3 billion	$1.5 billion	$2.0 billion
Increased Health Costs from Coal-Fired Emissions	$33 million	$38 million	$52 million
Subtotal for Costs from BAU Activities	*$1.3 billion*	*$1.5 billion*	*$2.0 billion*
TOTAL	**$3.3 billion**	**$5.1 billion**	**$9.8 billion**
Average Cost per Household per Year	$1,930	$2,400	$3,500

Source: ECONorthwest.

Notes: These numbers illustrate different types of annual costs Oregonians potentially would incur if society were to continue with a business-as-usual approach to climate change. There may be overlap between the values for some of the different types of costs. Nonetheless, adding the different types of costs probably seriously understates the total potential cost of climate change because the table excludes many additional types of climate-related costs that Oregonians would incur under a business-as-usual approach. The numbers do not indicate the net effect of climate change, as they do not represent a forecast of how the economy will respond to the different effects of climate change, or account for potential economic benefits that might materialize from moderate warming and other changes in climate.

percent of median household income and those in 2080 more than 7 percent of the income that half of the households in Oregon earn in a year.

We recognize that families, businesses, and communities in Oregon may be able to offset or mitigate some of the potential costs in the near term by taking advantage of the potential economic benefits of climate change, such as increased production of some crops or reduced expenditures on heating, that might accompany moderate climate warming. Our aim, however, is not to describe this potential adjustment but to describe the potential consequences if such adjustments are not realized. Further investigation is required to determine the extent of these opportunities, but current evidence suggests they will not fully offset the costs likely to materialize with large increases in atmospheric concentrations of GHGs.

Similarly, we recognize that there may be some overlap among our cost estimates and, hence, double counting when they are summed. We're confident,

Figure 2. Some Potential Economic Costs in Oregon Not Incorporated in this Report

Potential Unquantified Cost
Reduced productivity of nearshore marine environments
Increased cooling costs for commercial and industrial businesses
Increased costs for air conditioning and refrigeration in transportation
Increased costs to cope with greater variability in weather conditions
Increased pumping costs to replace surface water with groundwater for irrigation
Increased regulatory costs for protecting additional threatened and endangered species
Increased management costs for controlling invasive species
Increased costs associated with flood and wind damage from more frequent and intense storms
Reduced value of certain crops, such as tree fruits and nursery stock
Increased costs associated with agricultural pests and diseases related to climate change
Increased costs associated with fish and wildlife diseases related to climate change
Reduced value of certain crops due to water stress
Increased costs for families and businesses that move in response to climate change
Reduced productivity of rangelands
Increased health care costs related to expanded range of tropical and sub-tropical diseases
Increased health care costs related to increased incidence of water- and food-borne diseases
Reduced recreation opportunities due to increased wildland fires
Reduced boating and other recreation opportunities due to decreased streamflows
Increased costs to bring warmer streams into compliance with water-quality standards
Increased insurance costs for storms, fires, sea-level rise and other effects of climate change

Source: ECONorthwest.

however, that the potential costs that are not included in the calculations more than offset the double-counts, if any, and that the total potential costs of a business-as-usual approach to climate change are larger—perhaps far larger—than the amounts shown in Figure 1.

Some of these additional costs likely would materialize inside Oregon over the next several decades. Figure 2 summarizes some of these additional costs, for which we were unable to find adequate documentation to quantify in this report.

Far greater costs might materialize elsewhere or in future centuries, the result of a business-as-usual approach to climate change over the next few decades. If temperatures rise to the maximum levels predicted under the business-as-usual scenario, billions of people in less-developed countries likely would endure increased thirst and starvation, thousands of species would face extinction, sea levels would rise several meters. and vast areas of the oceans could become essentially barren. To the extent that these distant effects matter to today's Oregonians, the potential costs would be far greater than we indicate.

II. CONCEPTUAL FRAMEWORK

This analysis is concerned with the climate-related economic costs families, businesses, and communities in Oregon might incur over the next several decades under a business-as-usual approach to climate change. This approach has two major assumptions. One is that Oregon, other states, the U.S., and other countries will not take effective actions to rein in emissions of greenhouse gases (GHGs)and continue to engage in activities that drive climate change. We use the A1FI scenario described by the Intergovernmental Panel on Climate Change (IPCC) to represent the future evolution of emissions and atmospheric concentrations for GHGs, as it seems to trace most closely the recent trends in emissions.[4]

The other major assumption we make in this analysis is that Oregon's households, businesses, and communities will continue to engage in behaviors and adopt technologies similar to those of today. This assumption has several strengths. It reflects the social and economic inertia that arises, for example, insofar as there exists a large amount of residential, commercial-industrial, and public capital built with little or no regard for climate change, and modifying or replacing it likely will take considerable time. It also facilitates both the analysis and the communication of our findings. Limited by time and money, we lacked the ability to construct a scenario of how Oregonians will behave over the next 10, 30, and 70 years that is both more suitable and understandable than the scenario we used: that, absent major effort to rein in climate change, most families, businesses, and communities will try to continue doing tomorrow what they are doing today.

These assumptions yield illustrations of costs that might materialize if business-as-usual activities continue, but fall far short of a worst-case depiction of what the costs of climate change might be. Numerous recent reports of scientific studies, not represented in the most recent assessment of climate prospects by the IPCC from 2007, signal a growing probability that emissions of GHGs and average surface temperatures might rise faster than previously anticipated. Other studies signal a growing probability that, whatever the increase in emissions and temperatures, the effects of climate change will be more severe. Forests will die more rapidly, oceans will become less productive, ice sheets will melt more rapidly, epidemics of disease and pests will spread more quickly, and more. At the same time, meaningful progress on efforts to rein in the global emissions of GHGs has been slow, and many in the state continue to oppose proposals to

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[4] A recent analysis by the MIT Joint Program on the Science and Policy of Global Change confirms our choice of using IPCC's A1FI scenario to represent business-as-usual conditions. Its analysis of uncertainties in emissions, the climate-system's sensitivity to emissions, and the economy predicts a high probability of warming at levels that correspond to the likely range of the A1FI scenario. *See* Sokolov, A.P., P.H. Stone, C.E. Forest, R. Prinn, et al. 2009. *Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters.* Report No. 169. January.

reduce GHG emissions here or to prepare for climate changes that cannot be avoided.

In the following paragraphs we first provide an overview of climate-related risks, and then describe ways in which climate change might impose economic harm on Oregon. We then outline the specific steps we have taken to produce the illustrations of specific types of potential economic harm that we present in Sections III and IV.

A. Overview of Climate-Related Risks

Rapidly accelerating emissions of carbon dioxide, methane, and other GHGs since the beginning of the 20th century have increased the average global temperature by about 0.74°C (1.33°F), and altered precipitation patterns.[5] These changes in climate have had and will continue to have negative effects on the well being of current and future generations of humans.[6] These effects are expected to worsen at an increasing rate as atmospheric concentrations of GHGs increase and global temperatures rise even further.[7] Figure 3 illustrates, briefly and incompletely, the potential impacts of each incremental increase in average global temperature.

Based on this evidence, many have concluded that society should aim to rein in emissions of GHGs so the rise in temperature does not exceed 2°C (3.6°F). There is considerable uncertainty underlying such conclusions, however. As we understand the scientific reports, this uncertainty suggests that the economic risks associated with the smaller increases in temperature (and, hence, with the lower levels of emissions of GHGs) are higher than they first appear, insofar as:

- ***Once set in motion, the processes of climate change cannot easily be reversed, if at all.*** Temperatures will continue to rise in response to GHGs

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[5] Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/

[6] *See*, for example, Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/. Some believe climate change is important not only for what it does for humans, but for its effects on the environment, apart from people. They suggest economics should consider those values, and there are good arguments for doing so. There similarly are good reasons for considering spiritual and other measures of the value of climate change that lie outside the direct purview of economics. Here, however, we focus on the economic connections between climate change and people. We do so not just to keep our task from becoming intractable but also because this relationship underlies many, if not most, of the motivation for human actions to restrict emissions of greenhouse gases and to prepare for unavoidable changes in climate. We take a broad view, though, of the ways in which climate change might affect the economic dimensions of human standards of living and quality of life.

[7] Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/; Lynas, M. 2008. *Six Degrees: Our Future on a Hotter Planet.* New York: National Geographic Society; Stern, N. 2006. *The Economics of Climate Change: The Stern Review*. Cambridge, United Kingdom: Cambridge University Press. Retrieved October 30, 2006, from http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

Figure 3. Potential Impacts of Incremental Increases in Average Global Temperature

1°C (1.8°F)	Increased potential for prolonged drought, converting some parts of the American West to sandy deserts, on a scale much larger than the 1930s Dustbowl.
2°C (3.6°F)	Small mountain glaciers will disappear and mountain snowpack diminish, as will stream flows dependent on snow melt. Large areas of the oceans will become too acidic for organisms with calcium carbonate shells, and for many species of plankton, the basis of the marine food chain. Onset of irreversible melting of the Greenland ice sheet would raise sea levels by about seven meters. Heat waves similar to the most extreme in recent history likely would occur every year in many places. About one-third of all species around the globe may be driven to extinction. Increased risk of hunger for many communities, especially in Africa and Asia.
3°C (5.4°F)	An increase of this magnitude could be a tipping point that causes climate change to become uncontrollable. The middle areas of North America likely would become deserts. Extreme weather, such as hurricanes, may become more intense, doubling damage costs in the U.S. Millions, perhaps billions may face famine from extreme drought, flooding, and insect infestations. Perhaps 50 percent of species face extinction.
4°C (7.2°F)	The West Antarctic ice sheet may collapse and raise sea levels another five meters. Crop yields likely would continue to fall in many regions. Significant shortages of water may affect more than a billion people, as some areas may see runoff increase by one-third. Perhaps 50 percent of species face extinction. Conditions typical of the Sahara Desert probably will materialize across southern Europe.
5°C (9.0°F)	Entire regions of the Earth might see major declines in crop production and ecosystems unable to maintain their current form. Forest fires, droughts, flooding, and heat waves will increase in intensity. Increasing probability of abrupt, large-scale shifts in the climate system, e.g., tropical conditions, may materialize in Arctic regions. Rising sea level threatens major coastal cities.
6°C (10.8°F)	The Earth would experience climate conditions associated with a period, about 250 million years ago, that saw perhaps 95 percent of all species go extinct.

Source: ECONorthwest, adapted from Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report.* Retrieved January 22, 2009, from http://www.ipcc.ch/; Lynas, M. 2008. *Six Degrees: Our Future on a Hotter Planet.* New York: National Geographic Society; and Stern, N. 2006. *The Economics of Climate Change: The Stern Review.* Cambridge, United Kingdom: Cambridge University Press. Retrieved October 30, 2006, from http://www.hm-treasury.gov.uk/independent_reviews/ stern_review_economics_ climate_change/stern_review_report.cfm; and

already in the atmosphere, and additional GHG emissions will only reinforce the momentum. There may be no corrective actions available to arrest or reverse some of the processes, and their ecological and economic consequences, once they have been triggered.

- ***Some major impacts of climate change are occurring faster than anticipated.*** Sea ice in the Arctic Ocean is melting at rates unforeseen by the IPCC in its 2007 integrated assessment of climate-related research through the early part of 2007.[8] The melting of the sea ice means that solar energy that the ice would reflect now will be absorbed by open water,

[8] Stroeve, J., M. Holland, W. Meir, T. et al. 2007. "Arctic Sea Ice Decline: Faster than Forecast." *Geophysical Research Letters* 34: L09501, doi:10.1029/2007GL029703.

further accelerating increases in temperature. Some ice structures in the Antarctic Peninsula also are melting faster than expected.[9] The global sea level has been rising faster than expected, and recent analyses conclude during this century it will rise twice as much as IPCC predicted in 2007.[10] The processes that enable the oceans and other elements of the global ecosystem to remove GHGs from the atmosphere are slowing down faster than anticipated.[11] Trees in the U.S. and Canada are dying at unforeseen rates, so that some forests, rather than increasing their removal of carbon dioxide from the atmosphere, are contributing the greenhouse gas to the atmosphere.[12]

- ***Recent research suggests that, for a given concentration of GHGs in the atmosphere, the temperature will rise higher than previously anticipated.*** The 2007 report of the IPCC, for example, reported that, if carbon dioxide concentrations were to stabilize in the range of 350 to 400 ppm, warming likely would stabilize within the range of 2°C to 2.4°C (3.6°F to 4.3°F), but it warned that larger temperature increases might occur.[13] Research not represented in the IPCC report looks more directly at the possibility that temperatures will increase faster than expected. The authors of one recent paper find that, if carbon dioxide concentrations stabilize at 450 ppm (or higher) there is a substantial probability that the increase in temperature will rise to 6°C (10.8°F).[14]
- ***The atmospheric concentration of GHGs has been rising faster than expected.***[15] The acceleration stems from faster than expected burning of

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[9] Pritchard, H.D. and D.G. Vaughan. 2007. "Widespread Acceleration of Tidewater Glaciers on the Antarctic Peninsula." *Journal of Geophysical Research* 112: F03S29.

[10] Rahmstorf, S., et al. 2007. "Recent Climate Observations Compared to Projections." *Science* 316(5825): 709; and Rohling, E.J., et al. 2008. "High Rates of Sea-Level Rise During the Last Interglacial Period." *Nature Geoscience* 1: 38-42.

[11] Le Quéré, C., et al. 2007. "Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change." *Science* 316(5832): 1735-1738.

[12] Van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, et al. 2009. "Widespread Increase of Tree Mortality Rates in the Western United States." *Science*. 323:521-524. January 23; and Kurz, W.A., C.C. Dymond, G. Stinson, G.J. Rampley, et al. 2009. "Mountain Pine Beetle and Forest Carbon Feedback to Climate Change." *Nature*. 452:987-990. April 24.

[13] Solomon, S., D. Qin, M. Manning, M. Marquis, et al. (eds.). 2007. *Climate Change 2007: The Physical Science Basis.* Intergovernmental Panel on Climate Change Working Group I. New York: Cambridge University Press. An average global temperature increase of 2°C to 2.4°C (3.6°F to 4.3°F) would mean higher temperature increases over land and in some regions. Scientists anticipate that the increase in temperatures over land will be larger than the global average increase, perhaps as great as two times larger, because land absorbs more heat than the oceans.

[14] Hansen, J., et al. 2008. "Target Atmospheric CO_2: Where Should Humanity Aim?" Retrieved January 14, 2009, from http://www.columbia.edu/~jeh1/2008/TargetCO2_ 20080407.pdf

[15] Raupach, M.R., et al. 2007. "Global and Regional Drivers of Accelerating CO_2 Emissions." *Proceedings of the National Academy of Sciences* 104(24): 10288-10293.

fossil fuels for electricity, transportation and other purposes, but also from other contributing factors, such as a slowing in oceanic absorption of carbon dioxide and unexpected releases of methane, a potent GHG, trapped in soils.[16] Several authorities have warned of the potential consequences. The authors of one study of past changes in climate concluded, for example, that warmer temperatures likely would accelerate the emission of GHGs into the atmosphere, and "promote warming by an extra 15 to 78 percent on a century scale" relative to the projections presented by the IPCC.[17]

- ***Leading researchers are urgently calling for faster and steeper curtailment of GHG emissions to prevent catastrophic damage from climate change.*** The International Energy Agency has observed that, given the recent, rapid increases in the burning of fossil fuels, the average global temperature will rise 6°C (10.8°F) unless there is a quick and rigorous change in policy.[18] The head of Britain's Met Office recently warned that, if emissions keep rising, the average temperature could increase by more than 5°C (9°F) by the end of the century.[19] Some scientists conclude that, to sustain climatic and ecological conditions similar to those that have existed during the development of human civilization, society must do more than just arrest growth in the atmospheric concentration of GHGs, it will have to be reduce them below the current level, with the concentration of carbon dioxide falling to no more than 350 ppm within the next several decades.[20]

Not all of these (and many related) impacts would occur immediately. There is considerable uncertainty about how long it would take for some of the impacts to

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[16] Park, G.-H., K. Lee, and P. Tishchenko. 2008. "Sudden, Considerable Reduction in Recent Uptake of Anthropogenic CO2 by the East/Japan Sea." *Geophysical Research Letters* 35: L23611, DOI:10.1029/200GL036118.; Le Quéré, C., M. Raupach, P. Ciais, T. Conway, et al. 2008. "Carbon Budget 2007." Global Carbon Project. Retrieved January 6, 2009, from http://www.globalcarbonproject.org/carbontrends/index.htm; and Canadell, J.G., C. Le Quéré, M.R. Raupach, C. B. Field, et al. 2007. "Contributions to Accelerating Atmospheric CO2 Growth from Economic Activity, Carbon Intensity, and Efficiency of Natural Sinks." *Proceedings of the National Academy of Science* 104 (47): 18899-18870. DOI: 10.1073/pnas.0702737104. For additional references, see http://www.globalcarbonproject.org/carbontrends/index.htm#References.

[17] Scheffer, M., V. Brovkin, and P.M. Cox. 2006. "Positive Feedback between Global Warming and Atmospheric CO_2 Concentration Inferred from Past Climate Change." *Geophysical Research Letters* 33, L10702, DOI: 10.1029/2005GL025044.

[18] International Energy Agency. 2008. *Energy Technology Perspectives: Scenarios and Strategies to 2050, Executive Summary*. Retrieved January 15, 2009, from http://www.iea.org/Textbase/npsum/ETP2008SUM.pdf

[19] Pope, V. 2008. "Met Office Warn of 'Catastrophic Rise' in Temperature." *(London) Times Online.* December 19. Retrieved January 14, 2009, from http://www.timesonline.co.uk/tol/news/environment/article5371682.ece

[20] Hansen, J., et al. 2008. "Target Atmospheric CO_2: Where Should Humanity Aim?" Retrieved January 14, 2009, from http://www.columbia.edu/~jeh1/2008/TargetCO2_ 20080407.pdf

materialize, but some of the most extreme impacts likely would not materialize for decades or centuries. This delay does not, however, mean that the far-distant impacts have no economic relevance today. Decisions now that affect the atmospheric concentration of GHGs may set in motion climate-relate processes that lead to irreversible consequences. Moreover, current Oregon residents may have strong feelings, and thus realize a marked reduction in their economic well-being, knowing that today's decisions might have catastrophic consequences for future generations.

Having recognized the importance of these more distant and extreme effects, we now set them aside, and focus on the task at hand: describing the business-as-usual potential harm of climate change for families, businesses, and communities in Oregon over the next several decades. In the next section we describe the general mechanisms through which such harm can materialize in this context.

B. Climate Change and the Economy

Figure 4 illustrates some of the potential changes in climate expected over the next two decades. The top two maps depict the average annual temperature (left) and heat waves (right), and the bottom two maps depict the annual average precipitation (left) and extreme precipitation (right) expected by about 2030, relative to conditions in about 1990, under a middle-of-the-road scenario regarding future emissions of GHGs and their impacts. These anticipated changes point toward some of the ways that climate change can impose harm on the western states. The lower left map, for example, shows that the southwestern region can expect reductions—marked reductions in some areas—in precipitation, while some of the northern parts of the region likely will see precipitation increase. Individually and together, these maps indicate the potential for some or all in the region to realize economic harm through any number of mechanisms: increased droughts and floods, higher air-conditioning costs to cope with higher temperatures, higher incidence of morbidity and mortality for those without access to air conditioning, more frequent wildfires, loss of habitat for important species—the list is perhaps without end.[21] Moreover, under a business-as-usual scenario, the physical changes depicted in Figure 4, and thus the resulting economic impacts, would likely be magnified.

To provide some structure for thinking about the different ways in which climate changes can produce economic harm, Figure 5 identifies different types of change that can generate harm and the different ways in which harm might materialize. In some cases, the harm can originate directly from a change in the climate itself, through changes in temperature, precipitations, or storms and other extreme events. An increase in heat waves, for example, might increase the

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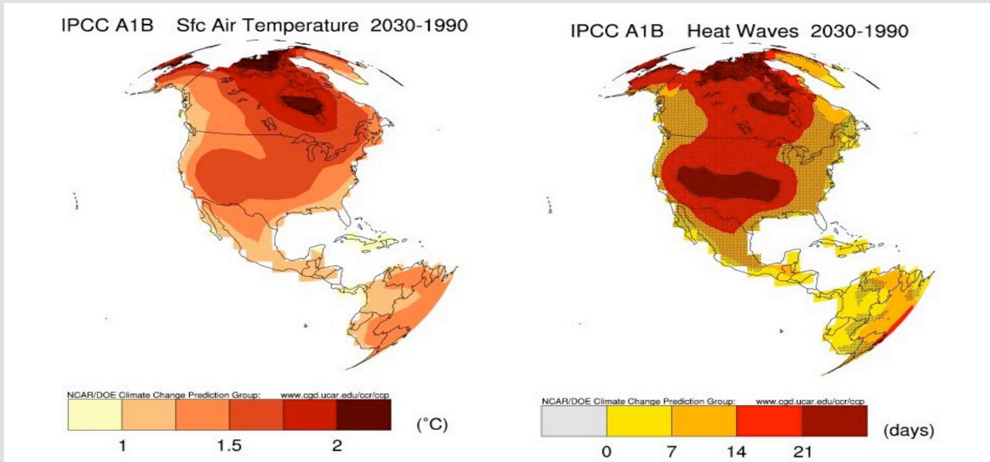
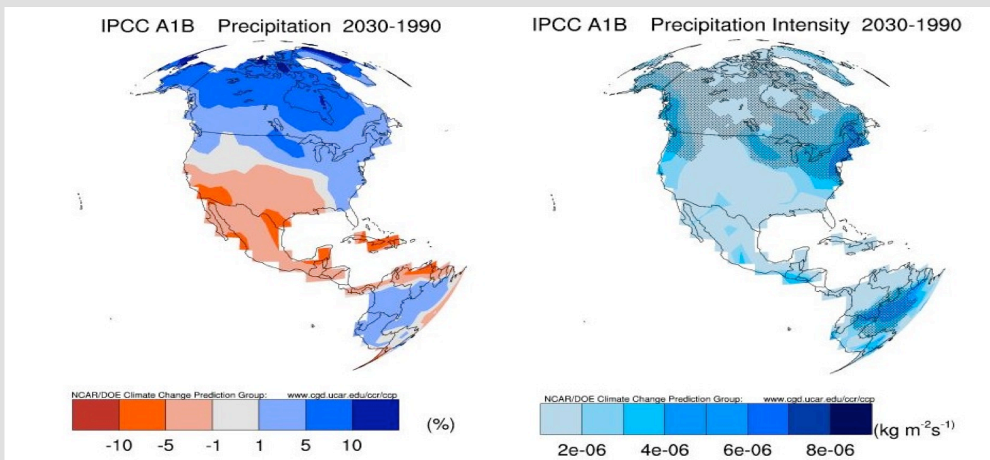
[21] We understand that the results from the temperature models generally are more robust than the results from the precipitation models. Nonetheless, most models generally support the expectations indicated by the lower left map in Figure 4.

Figure 4. Expected Changes in Annual Temperature, Heat Waves …



… Annual Precipitation and Extreme Precipitation, 2030 Relative to 1990



Source: Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl. 2006. "Going to the Extremes; An Intercomparison of Model-Simulated Historical and Future Changes in Extreme Events." *Climatic Change* 79(3-4): 185-211. Adapted by Lawrence Buja and Julie Arblaster. Retrieved January 21, 2009, from http://www.cgd.ucar.edu/ccr/climate_change_gallery_test/

Note: Please refer to the original source for definitions and descriptions of units displayed in each figure.

incidence of heat-related human illness and death,[22] high temperatures plus reduced precipitation might reduce the productivity of crops that wither under

[22] *See*, for example, Kalkstein, L.S. and J.S. Greene. 2007. *An Analysis of Potential Heat-Related Mortality Increases in U.S. Cities under a Business-as-Usual Climate Change Scenario.* Environment America. September 6. Retrieved January 13, 2008, from http://www.environmentamerica.org/uploads/Js/tF/JstFE5oHrsQJi5ifIA931Q/Heat-Mortality_Report_.pdf

drought conditions,[23] and higher flooding from more severe storms might damage property, disrupt commerce, and take lives.[24]

In other cases, climate change indirectly diminishes well-being by inducing changes in ecosystems or social systems. Warmer temperatures have been associated, for example, with ecosystem changes, such as epidemic outbreaks of insects that kill pine trees and reduce the productivity of the timber industry,[25] rises in sea level that erode ocean-front property and increase the cost of maintaining coastal homes and highways,[26] and contractions of fish habitat that diminish salmon populations and eliminate opportunities for recreational fishing.[27] Climate-related changes in social systems that can diminish economic well-being might arise if families and businesses conclude they must move to avoid the effects of climate change, or if the costs of climate change fall disproportionately on poor families and communities, diminishing their prospects for climbing out of poverty.

The bottom of Figure 5 illustrates that climate-related economic harm can occur in several ways. This summary illustrates each mechanism in greater detail:

- ***Reduction in human health and other constituents of quality of life.***

  Hotter temperatures can increase human mortality; reductions in stream flows can reduce boating, fishing, and other recreational opportunities.

- ***Reduction in the value of assets or in the level of income.***

  Increased flooding from climate-related storms can reduce the value of exposed properties and disrupt employment for workers at commercial and industrial enterprises in low-lying areas.

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[23] *See*, for example, Hatfield, J., et al. 2008. "Agriculture." *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States.* U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington D.C., USA.

[24] *See,* for example, Munich Re Group. 2008. *Catastrophe Figures for 2008 Confirm that Climate Agreement is Urgently Needed.* December 29. Retrieved January 16, 2009, from http://www.munichre.com/ en/press/press_releases/2008/2008_12_29_press_release.aspx

[25] *See*, for example, Carroll, A., S. Taylor, J. Regniere, and L. Safranyik. 2004. "Effects of Climate Change on Range Expansion by the Mountain Pine Beetle in British Columbia." In T.L. Shore, J.E. Brooks, and J.E. Stone, (eds.) *Mountain Pine Beetle Symposium: Challenges and Solutions.* October 30-31, 2003, Kelowna, British Columbia, Canada. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, Information Report BC-X-399. Pp. 223-232.

[26] *See*, for example, Mote, P., A. Petersen, S. Reeder, et al. 2008. *Sea Level Rise in the Coastal Waters of Washington State.* University of Washington Climate Impacts Group and the Washington Department of Ecology. January.

[27] *See*, for example, United States Environmental Protection Agency. 1995. *Ecological Impacts from Climate Change: An Economic Analysis of Freshwater Recreational Fishing.* EPA Report No. 220-R-95-004. April.

Figure 5. Changes in Climate Can Have Negative Effects on the Economy Over the Next Several Decades

Changes in Climate…

Higher Temperatures
Increases in short- and long-run temperatures.

Changes in Precipitation
Decreases or increases in snow or rain, and shifts in seasonal precipitation patterns.

Increases in Extreme Events
More frequent or more severe storms, droughts, heat waves.

Climate-Related Changes in Ecosystems
Losses of habitat for species of concern, increases in undesired species (diseases and pests), reductions in ecosystems' ability to produce desired goods and services.

Climate-Related Changes in Social Systems
Increases in climate-related expenditures, behaviors, and institutions, including migrations of population and economic activity away from areas facing high climate-related risks.

…can lead to… **Economic Harm**

Economic Costs
Reductions in the value of goods and services available to society.

Negative Economic Impacts
Reductions in jobs, income, and related variables.

Increases in Risk and Uncertainty
Risk: Higher probability that harmful events will materialize in the future, or that harmful events will become more severe, or both.

Uncertainty: Diminished ability to anticipate the future.

Increases in Unprecedented Economic Conditions
Information costs, adaptation costs, and increased economic impacts.

Increases in Undesirable Distribution of Economic Well-Being
The effects of climate change accrue in a manner people consider to be unfair and inappropriate.

- ***Increase in climate-related expenditures and, hence, decrease in income available for other purposes.***

  Households, businesses, and government are likely to increase spending on health-related issues in response to higher temperatures, leaving less money for discretionary household spending, business investment and profits, and government services.

- ***Reduction in the value of goods and services derived from the ecosystem.***

  Changes in climate can diminish an ecosystem's ability to provide valuable goods and services, such as those illustrated in Figure 5. The reduced supply of ecosystem goods and services can reduce the quality of life in a community and increase costs for families, businesses, and governments.

- ***Loss of employment or reduction in employment opportunities.***

  Workers may be harmed when climate-related events, such as floods or wildland fires, cause them to lose their jobs and incomes. The indirect effects of climate change also may lead to similar outcomes, as businesses move away from areas affected by drought to areas with greater availability of water.

- ***Increase in risk or uncertainty about future economic conditions.***

  All else equal, the economic well-being of most families, businesses, and communities is diminished when they experience higher risk, i.e., a higher probability of having bad things happen to them, and greater uncertainty about the probability that such events will occur. The prospect of climate change increases both.

- ***Increase in unprecedented economic conditions.***

  Preparation for and adaptation to new conditions will generate new costs that were not necessary to address similar concerns in the past. Climatic, environmental, and economic variations in the past provide reference for families, businesses and communities to anticipate impacts and adapt their activities. Insofar as climate change generates conditions not experienced in the past, preparation and adaptation will be more costly in terms of requiring new information, institutions, infrastructure, and behaviors.

- ***Undesirable shift in the distribution of wealth, income, and other indicators of economic well-being.***

  Many Americans may experience harm when climate change, or changes in ecosystems and social systems that stem from it, generate economic benefits for one group while imposing costs on another, especially if the latter is poor or otherwise disadvantaged. Similar harm may occur if changes in climate cause the extinction of species or the loss of notable landscapes and other natural resources so they will not be available to future generations.

Oregonians potentially will incur additional costs not as a result of changes in climate but from activities that contribute to climate change. We examine two of these. One is the cost households and businesses would incur by continuing with technologies and behaviors that inefficiently use energy, even though more-efficient alternatives are available at little or no cost. The other is the health-related cost individuals and families would incur by being exposed to harmful pollutants produced by burning coal to produce electricity.

The analysis we present in Section III focuses on the potential economic costs of changes in climate, ecosystems, and social systems. We adopt this focus fully recognizing the importance of the other types of harm and with the hope that future investigations soon will be undertaken to describe them. In the following section, we describe our analytical approach.

C. Calculating the Business-As-Usual Potential Economic Harm

Our objective is to illustrate the potential economic harm to families, business, and communities in Oregon over the next several decades under conditions likely to materialize if society continues to conduct its affairs without an effective program to rein in GHGs. We call this the business-as-usual potential economic harm.

The reasoning underlying the calculation is straightforward. We begin with a credible, quantitative estimate of a climate-related potential worsening in some factor (public health, agricultural production, energy costs, etc.) that contributes to the economic well being of families, businesses, or communities in Oregon. We then multiply this times a credible estimate of the per-unit value of the factor. The product is an initial estimate of the potential harm per year.

We complete the calculations by adjusting the initial estimate to represent business-as-usual expectations for three target years: 2020, 2040, and 2080. This adjustment may have three steps. First, if the literature provides estimates of the quantitative impact of climate change for years other than a target year (2020, 2040, or 2080), we linearly interpolate to get a value for a target year when it falls between two values available from the literature, or linearly extrapolate when it falls outside them. For example, the maps in Figure 3 show expected changes in climate from 1990 to 2030. If we were to use the underlying data for our calculation, we would interpolate to find the expected change in 2020, and extrapolate to find the expected change in 2040 and 2080. The values would be 70, 125, and 225 percent of the 1990 to 2030 change. We anticipate that linear interpolative and extrapolative adjustments likely understate and overstate the impact in the target year, respectively, as the underlying climate relationships apparently are nonlinear.

Second, we adjust the initial estimate to account for business-as-usual conditions. This adjustment is required because most of the studies that offer a quantitative estimate of the impact of future climate change employ a scenario of emissions, temperature, and climate that assumes business-as-usual behaviors will not continue (i.e., society begins to act to rein in emissions). Other studies employ middle-of-the-road assumptions about the sensitivity of temperature and climate to GHG emissions, and thus potentially underestimate the possible effects of climate change. Accordingly, we adjust our initial estimate of the potential harm to reflect more closely what it would be under a business-as-usual scenario, based on differences among scenario assumptions of CO_2 concentrations in a

Figure 6. Adjustment Factors for Estimating the Business-As-Usual Impacts of Climate Change from Initial Estimates Based on Other Scenarios

Adjustment to A1FI from…	2020	2040	2080
A1B	0.9929	1.0265	1.2311
A2	1.0000	1.0286	1.1447
B1	1.0121	1.0886	1.4879
B2	1.0221	1.1126	1.4293
IS92a	1.0048	1.0611	1.2825

Source: ECONorthwest, with data from IPCC. 2008. *Carbon Dioxide: Projected Emissions and Concentrations.* Retrieved on January 16, 2009, from http://www.ipcc-data.org/ddc_co2.html

given time period. For this exercise, we employ Scenario A1FI, as represented by the IPCC.[28] We anticipate that using this scenario may still understate the potential harm under business-as-usual conditions, as actual emissions in recent years have exceeded the level embedded in the scenario, and recent research suggests the climate and ecosystem may be more sensitive than previously anticipated to increases in greenhouse gases. Figure 6 lists the adjustment factors applicable to the calculations we present in Section III. As Figure 6 shows, the differences between A1FI and the other emission scenarios are fairly small for 2020 and 2040 but they increase substantially by 2080.

Third, we adjust for anticipated changes in population. This adjustment is appropriate, for example, when a study estimates the future impact of higher temperatures on human morbidity, expressed as a change in the death rate per hundred-thousand population. We adjust the population of Oregon, assuming it will experience population growth at the rates estimated by the state through 2040, and for the nation as a whole by the Bureau of Census after 2040.[29]

The product of these steps is a representation of the potential future cost in this state over the next several decades if the global society should extend a business-as-usual approach to addressing issues associated with climate change. We anticipate that our results will provide a useful introduction to the potential economic consequences of climate change, at a spatial and temporal scale that is useful for many Oregonians. We also anticipate that our results will provide a

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[28] IPCC, Data Distribution Centre. 2008. "Carbon Dioxide: Projected Emissions and Concentrations." December 5. Retrieved January 22, 2009, from http://www.ipcc-data.org/ddc_co2.html

[29] U.S. Department of Commerce, Census Bureau, Population Division. 2000. *Annual Projections of the Total Resident Population as of July 1: Middle, Lowest, Highest, and Zero International Migration Series, 1999 to 2100.* February 14. Retrieved January 16, 2009, from http://www.census.gov/population/projections/nation/summary/np-t1.txt

useful basis for future investigations to describe these other facets of the economic consequences of climate change:

- A full assessment of all the potential near-term costs in this region, encompassing the many costs that are too poorly understood to describe today.
- An assessment of the potential costs that might materialize outside this region and beyond the next several decades.
- An estimate of the present expected value of the overall potential cost of climate change, reflecting the many alternative ways in which climate change might play out and the probability that each will occur.
- A comparison of the potential costs and benefits associated with different levels of GHG emissions, actions to rein in emissions, or actions to prepare for and adjust to changes in climate that cannot be avoided.
- An estimate of the costs associated with continued dependence on foreign oil, including payments to foreign countries.
- A forecast of what the economy will look like in the future. Such a product would require information about all the potential costs and benefits of climate change, the climate-related actions society might take, and the probabilities associated with different potential outcomes.

Some of the potential costs, called market costs, would materialize as reductions in cash: lower disposable incomes for households, net revenues for businesses, and financial resources for communities. Increased expenditures to cope with climate-related illness, for example, would lower household incomes, while reductions in workers' productivity could also reduce business earnings and public tax revenues. Other potential costs, called non-market costs, would not have an immediate cash effect on incomes, earnings, and public finance. Much of the cost associated with potential reductions in salmon populations, for example, reflects the public's desire to ensure that salmon will be available for future generations to enjoy. Both market and non-market costs are important.

This analysis does not capture all likely costs of climate change for Oregon. Insufficient data are available to provide estimates for all of the potential effects scientists have identified, not to mention other effects not yet identified. In addition, Oregonians likely will experience costs that materialize beyond the state's border: as climate change leads to damage from heat waves, droughts, and storms elsewhere in the country and the world, for example, tax dollars and voluntary contributions will flow out of the state to provide assistance. Today's Oregonians also will incur some costs from manifestations of climate change that would occur beyond this century. Many Oregonians strongly want to pass to future generations the beaches, salmon populations, and skiing opportunities that exist today, for example, and will experience in economic well-being to see that climate change will make this unlikely, if not impossible. For all these reasons, we are confident that the actual potential costs of climate change in Oregon are larger than the amounts we have calculated.

III. The Potential Economic Costs Associated with the Effects of Climate Change

In this section we present our illustrative calculations of the business-as-usual, potential economic costs to families, businesses, and families in Oregon of climate change over the next several decades. In Section IV, we present another set of costs resulting from activities associated with the business-as-usual pathway that contribute to climate change. For each type of cost in this section and in Section IV, we present this information:

Description: We provide a short description of the potential cost, and the change(s) in climate, ecosystems, or social systems that likely will generate it. To facilitate the presentation, we organize the potential costs into these categories:

A. Energy
B. Fish and Wildlife
C. Flood and Storm Damage
D. Food Production
E. Forest and Range Production
F. Recreation
G. Public Health

Assumptions, Data, and Calculation: We describe our assumptions, identify the information we use to quantify the business-as-usual potential cost and estimate its economic value, and demonstrate how we make the calculation.

Results: We report each business-as-usual, potential annual cost in 2020, 2040, and 2080. Our findings represent the costs, expressed in today's dollars, that Oregonians potentially would bear if Oregonians, in concert with others around the world do not take meaningful action and climate change occurs as represented by the A1FI scenario from the IPCC.

We anticipate that our results generally understate the potential economic costs climate change would impose on Oregonians if they and the residents of other states and nations continue in a business-as-usual manner. The degree of understatement increases the further one looks into the future. As atmospheric concentrations of GHGs increase, it becomes increasingly likely that higher temperatures will trigger processes that bring about even faster change in climate and initiate irreversible changes in ecosystems and social systems.

We recognize that families, businesses, and communities in Oregon may be able to offset or mitigate some of the potential costs in the near term by taking advantage of the potential economic benefits of climate change, such as increased production of some crops or reduced expenditures on heating, that might accompany moderate climate warming. Our aim, however, is not to describe this potential adjustment but to describe the potential consequences if such adjustments are not realized. Further investigation is required to determine the extent of these opportunities, but current evidence suggests they will not fully offset the costs likely to materialize with large increases in atmospheric concentrations of GHGs. Similarly, adaptation opportunities may not offset the costs of small increases, or even the costs of increases that already have occurred. In sum, our results do not represent a forecast of what will happen, but a description of what might happen. We do not present a forecast because doing so would inject into the calculations many variables about which little is known, at odds with our objective to provide results that are defensible, comprehensible, and useful.

A. Energy

1. Reduced Hydropower Generation

Description

Climate models indicate that changes in the Pacific Northwest's climate likely will cause runoff to increase in winter and decrease in summer, reducing value of hydropower produced by the region's hydroelectric facilities. This reduction in value would ensue due to a mismatch between energy demand, which will increase in summer, and hydropower supplies, which would be lower at the same time.

Assumptions, Data, and Calculation

We apply the findings of a recent regional assessment, which concludes that climate-related changes in streamflow could reduce the annual average production of the hydropower system in the Pacific Northwest by 664 megawatts (MW) in 2020, and 2,033 MW in 2040. We assume the trend will continue and extrapolate to estimate the potential effect in 2080. We estimate Oregon's share of the potential reduction in productive capacity to be 175 MW by 2020, 550 MW by 2040, and 1,300 MW by 2080, assuming that its current share of production will persist. We estimate the value of the reduction in the production of energy assuming the forgone generation otherwise would have produced electrical energy year-round and applying $48.25 per MW-hour as the estimated bulk electricity price.[a]

Results

Potential Value of Reduction in Hydropower Generation

2020	2040	2080
$74 million	$233 million	$552 million

Source: ECONorthwest

References and Notes

[a] Northwest Power and Conservation Council. 2005. *The Fifth Northwest Electric Power and Conservation Plan; Appendix N.* Retrieved on December 12, 2008, from http://www.nwcouncil.org/energy/powerplan/5/Default.htm

2. Increased Energy Consumption for Residential Indoor Air Cooling

Description

Higher temperatures during summer months will induce residential consumers to spend more money on air conditioning, decreasing the amount they can spend on other things.

Assumptions, Data, and Calculation

A regional assessment concludes that average July-August temperatures will increase 2.9°C (5.2°F) by 2040, and the associated increases in air conditioning will increase average regional residential demand for energy from the power system by about 200 megawatts (MW).[a] We linearly interpolate to estimate the increase in 2020 and extrapolate to estimate the increase in 2080. Assuming that Oregon's 2000 share of regional consumption in 2000 will extend into the future, the additional average demand will be about 23 MW by 2020, 54 MW by 2040, and 140 MW by 2080. We use the average monthly residential prices in Oregon between 1990 and 2008 for July and August to estimate consumers' additional cooling costs.[b]

Results

Potential Value of Increased Energy Costs for Air Conditioning

2020	2040	2080
$16 million	$37 million	$92 million

Source: ECONorthwest

This calculation does not include additional expenditures for commercial or industrial consumers, which we expect to be small relative to the potential increase in Oregonians' home electricity bills.

References and Notes

[a] Northwest Power and Conservation Council. 2005. *The Fifth Northwest Electric Power and Conservation Plan; Appendix N.* Retrieved on December 12, 2008, from http://www.nwcouncil.org/energy/powerplan/5/Default.htm

[b] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector* (Form EIA-826). Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_ revenue.xls.

3. Increased Energy Loss During Transmission

Description

Higher temperatures during climate-related heat waves will increase the amount of energy lost during electricity-transmission lines. During heat waves, the resistance of overloaded transmission lines increases, causing the grid to convert more electricity into heat, which wastes energy.[a]

Assumptions, Data, and Calculation

We assume summertime consumption of electricity in 2008 will increase in accord with the rate projected by the Energy Information Administration for Oregon.[b] We apply a middle-of-the-road estimate of the potential growth in heat-wave days from 1990 to 2030;[c] linearly interpolate and extrapolate to estimate the number of additional days in 2020, 2040, and 2080; and adjust the numbers to estimate what the impact would be under a business-as-usual approach to climate change. If the additional transmission-line losses during a heat-wave day equal one-third of the electricity being transmitted,[a] the annual losses would total 410,000 MW-hours by 2020, 820,000 MW-hours by 2040, and 2.4 million MW-hours by 2080. We assume the average summertime wholesale price of electricity, $71 per MW-hour in 2008 dollars, will apply in the future.[d]

Results

Potential Value of Energy Lost in Transmission During Heat Waves

2020	2040	2080
$29 million	$58 million	$171 million

Source: ECONorthwest

References and Notes

[a] Ackerman, F. and E.A. Stanton. 2008. *The Cost of Climate Change: What We'll Pay If Global Warming Continues Unchecked.* Natural Resources Defense Council. May. Retrieved January 20, 2009, from http://www.nrdc.org/globalwarming/cost/cost.pdf

[b] Energy Information Administration. 2008. *EERE State Activities and Partnerships: Electric Power and Renewable Energy in Oregon.* Retrieved January 23, 2009, from http://apps1.eere.energy.gov/states/electricity.cfm/state=OR

[c] Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl. 2006. "Going to the Extremes; An Intercomparison of Model-Simulated Historical and Future Changes in Extreme Events." *Climatic Change* 79(3-4): 185-211. Adapted by Lawrence Buja and Julie Arblaster. Retrieved January 21, 2009, from http://www.cgd.ucar.edu/ccr/climate_change_ gallery_test/

[d] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector* (Form EIA-826). Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_ revenue.xls

4. Other Potential Costs of Climate Change Related to Energy

Description

Climate change undoubtedly will affect other parts of Oregon's energy system but there is little research to substantiate the magnitude of these impacts. For instance, a recent report showed that industry may increase its energy consumption on days with high temperatures, people may consume higher amounts of gasoline due to increased use of air conditioning in their cars, and trucks that transport perishables may increase their fuel use to refrigerate their cargoes. Equally uncertain is how much farmers' energy demand will increase on hot days when they ramp up irrigation to maintain soil moisture.[a] Other potential costs include damages to electricity-transmission equipment during floods and storms, which are expected to become more frequent and intense because of climate change[b] and costs associated with an increased probability of blackouts. A study by researchers at Los Alamos National Laboratory found that an increase in air temperature of 1.5°C (2.7°F) would increase the probability of a blackout occurring from 1 time per year to 8-10 times per year. The researchers estimated economic loss associated with this increased probability at 1 percent of gross state product.[c]

References and Notes

[a] Scott, M.J. and Y.J. Huang. 2007. "Effects of Climate Change in Energy Use in the United States." In Wilbanks, T.J., V. Bhatt, D.E. Bilello (eds.). *Effects of Climate Change on Energy Production and Use in the United States*. A Report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research.

[b] Bull, S.R., D.E. Bilello, J. Eckmann, et al. 2007. "Effects of Climate Change on Energy Production and Distribution in the United States." In Wilbanks, T.J., V. Bhatt, D.E. Bilello (eds.). *Effects of Climate Change on Energy Production and Use in the United States*. A Report by the U.S. Climate Change Science Program and the subcommittee on Global Change Research.

[c] Personal communication with Gary Geernaert, Director, Institute of Geophysics and Planetary Physics, Los Alamos National Laboratory. February 6, 2009.

B. Fish and Wildlife

1. Reduced Salmon Habitat and Populations

Description

Warmer stream temperatures resulting from increased global temperatures reduce the amount of habitat that can viably support salmon, reducing salmon populations.

Assumptions, Data, and Calculation

We assume salmon populations will decline proportionate to expected losses of aquatic habitat. An assessment of stream temperatures under an A2 emissions scenario indicates increased warming might reduce salmon habitat in Oregon by 13, 23, and 44 percent by 2030, 2060, and 2090, respectively.[a] We interpolate and adjust the percentages to reflect the potential changes in 2020, 2040, and 2080, as well as the A1FI scenario. To determine the value of the loss of salmon, we rely on a study of Washingtonian's willingness to pay for changes in the size of anadromous fish runs.[b] The methodology in this study was vetted and adopted by a panel of economists for Washington State's Columbia River Initiative, who recommended that "any reliable estimates of impacts on salmon and steelhead should be assigned values based upon the methodology."[c] We assume that the value Washingtonians are willing to pay to protect salmon in Washington provides a reasonable indication of the value Oregonians are willing to pay to protect salmon in Oregon. Using results from Layton et al., we derive the value Oregonian's place on the potential loss of salmon populations in Oregon in 2020, 2040, and 2080, adjusting for growth in households over time.

Results

Potential Value of Reduced Salmon Populations

2020	2040	2080
$632 million	$1.04 billion	$1.87 billion

Source: ECONorthwest

These results are based on an analysis of the value of increasing salmon stocks, which diminishes as fish populations become more robust. Climate change impacts reduce stocks, which should lead to an increasing, rather than decreasing value as salmon become more rare. Consequently, these estimates likely understate the value of salmon losses. The results also probably understate the total impact of climate change on salmon populations, because they overlook stresses from potential changes in ocean conditions, climate-related increases in disease, and reduced effectiveness of habitat restoration efforts, among other effects.[d] They also may not fully account for ecosystem goods and services other than salmon that would be lost as changes in climate affect salmon habitat.

References and Notes

[a] O'Neal, K. 2002. *Effects of Global Warming on Trout and Salmon in U.S. Streams.* Defenders of Wildlife and Natural Resources Defense Council. May.

[b] Layton, D.F., G.M. Brown, and M.L. Plummer. 1999. *Valuing Multiple Programs to Improve Fish Popu*lations. April. Retrieved January 24, 2009, from http://www.econ.washington.edu/user/gbrown/valmultiprog.pdf

[c] Huppert, D., G. Green, W. Beyers et al. 2004. *Economics of Columbia River Initiative*. Washington Department of Ecology and CRI Economics Advisory Committee. January 12.

[d] *See*, for example, Battin, J., M.W. Wiley, M.H. Ruckelshaus et al. 2007. "Projected Impacts of Climate Change on Salmon Habitat Restoration." *Proceedings of the National Academy of Sciences* 104 (16): 6720-6725. Retrieved January 23, 2009, from http://www.pnas.org/content/104/16/6720.full.pdf+html; Independent Scientific Advisory Board. 2007. *Climate Change Impacts on Columbia River Basin Fish and Wildlife*. ISAB Climate Change Report ISAB 2007-2. Northwest Power and Conservation Council. May 11; and Richter, A. and S.A. Kolmes. 2005. "Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest." *Reviews in Fisheries Science* 13: 23-49.

2. Other Potential Costs Related to Impacts of Climate Change on Fish and Wildlife

Description

Increased temperatures and changes in precipitation are likely to impact many species, other than salmon in Oregon. Scientists have found evidence that climate change can result in changes in species' range, abundance, phenology (timing of an event, such as migration), morphology and physiology, and community composition, biotic interactions and behavior.[a] Many of these impacts on populations and ecosystems would potentially result in economic harm. For example, sea level rise, changes in ocean currents, and increases in ocean acidity are likely to impact the species and ecological communities in Oregon's coastal and near-shore environments, including coastal wetlands and rocky intertidal areas. Disruptions in these ecosystems could adversely affect Oregon's commercial and recreation fishing industries.[b] Temperature increases also are likely to disrupt montane ecosystems, particularly those associated with glaciers and snowpack. Some invasive species and pests, which have historically been limited by temperature or moisture, may be able to expand their range and pose new threats to native populations of fish and wildlife.[c] Data are not available, however, to allow us to estimate the costs associated with these and other potential fish and wildlife-related impacts.

References and Notes

[a] Root, T.L. and S.H. Schneider. 2002. "Climate Change: Overview and Implications for Wildlife." In S.H. Schneider and T.L. Root (eds.). *Wildlife Responses to Climate Change: North American Case Studies.* Island Press: Washington D.C.

[b] Stanford, E. 2002. "Community Responses to Climate Change: Links Between Temperature and Keystone Predation in a Rocky Intertidal System." In S.H. Schneider and T.L. Root (eds.). *Wildlife Responses to Climate Change: North American Case Studies.* Island Press: Washington D.C.

[c] Janetos, A.C. 2008. "Chapter 5: Biodiversity." In Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

C. Flood and Storm Damage

1. Costs Related to Sea-Level Rise

Description

Rising global temperature leads to increased sea levels, which will inundate value property and structures.

Assumptions, Data, and Calculation

No direct estimates of the value of coastal property damage due to sea-level rise exist for Oregon, so we apply estimates for California.[a,b] After adjusting for differences in general coastline length, median home value, and coastal population density, the potential damage for Oregon in 2070 would be $56 million per year, under the A2 scenario for future emissions and climate change.[c] Hence, we linearly interpolate and extrapolate to obtain estimates for 2020, 2040, and 2080, and adjust to represent the A1FI scenario.

Results

Potential Value of Property Damage from Sea Level Rise

2020	2040	2080
$16 million	$33 million	$73 million

Source: ECONorthwest

These results embody considerable uncertainty, as there exists no direct measurement of the potential damage from climate-related increases in sea level and storm surges. The estimate does not account for the interactive effects of higher sea levels and increased storm surges that would further increase damages. Sea-level rise and increased storm surges would generate increased risk of flood and storm damage for inland areas reached by the tides such as downtown Portland and other urban areas.

References and Notes

[a] Neumann, J., D. Hudgens, J. Herr, and J. Kassakian. 2003. "Market Impacts of Sea Level Rise on California Coasts." 2003. Appendix XIII in Wilson, T. L. Williams, J. Smith, and R. Mendelsohn, *Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy*. Consultant report 500-03-058CF to the Public Interest Energy Research Program, California Energy Commission.

[b] Kahrl, R. and D. Roland-Holst. 2008. *California Climate Risk and Response.* Research Paper No. 08102801. University of California. November. Retrieved January 23, 2009, from http://are.berkeley.edu/~dwrh/CERES_Web/Docs/California%20Climate%20Risk%20and%20Response.pdf.

[c] Oregon's general coastline is 35 percent as long as California's, its 2000 median home value was 72 percent, and its 2008 coastal population density is 22 percent National Oceanic and Atmospheric Administration. 2004. *Population Trends Along the Coastal United States: 1980-2008.* http://oceanservice.noaa.gov/programs/mb/supp_cstl_population.html.

2. Costs Related to Extreme Weather Events

Description

Climate change is expected to increase storm severity and the frequency of extreme storm events, including high winds, flooding, lightning and fire. Storm events will have direct property-damage effects, as well as increased storm-related injuries and fatalities.[a]

Assumptions, Data, and Calculation

The National Oceanic and Atmospheric Administration's National Weather Service and National Climatic Data Center collect information on fatalities, injuries, property damage, and crop damage resulting from extreme weather events, including weather-influenced wildfires.[b] The U.S. Climate Change Science Program provides rough estimates for increases in extreme weather events, including an increase in frequency of extreme precipitation events by 2.5 times under A1B by 2100. Wildfire forecasts for the west follow similar increases rates with two to five times the acreage burnt at the end of the 20th century by late in the 21st century.[c] Using the average total property and crop damage estimates from 1996 to 2007, we linearly interpolate an increase in these impacts 2.5 times by 2100 for 2020, 2040 and 2080, and adjust for the A1FI scenario. We do not monetize fatalities and injuries, but the increase by 2080 would be 12 fatalities and 38 injuries due to extreme weather events. These include heat-related effects that are further described and valued in the *Public Health* section below.

Results

Potential Value of Property and Crop Damage from Extreme Weather Events

2020	2040	2080
$48 million	$99 million	$236 million

Source: ECONorthwest

References and Notes

[a] U.S. Climate Change Science Program. 2008. Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. In Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple and W.L. Murray (eds.). *Weather and Climate Extremes in a Changing Climate.* Synthesis and Assessment Product 3.3. Washington, DC.

[b] Consistent damage cost estimates are available from 1996-2007. National Weather Service and National Climatic Data Center. 1996-2008. "Summary of Hazardous Weather Fatalities, Injuries and Damage Costs by State." *Natural Hazard Statistics.* Accessed February 3, 2009 from http://www.weather.gov/os/hazstats.shtml#. Adjusted to 2008 dollars.

[c] Mckenzie, D., Z. Gedalof, D. Peterson, and P. Mote. 2004. "Climatic Change, Wildfire, and Conservation." *Conservation Biology* 18: 890-902.

3. Other Potential Costs from Climate-Related Sea-Level Rise and Extreme Weather

Description

The combined impact of multiple storm and ocean effects from climate change is likely to be greater than the sum of the individual impacts, as interactions increase severity. Similarly, damages from storm events tend to increase relative to storm severity more than linearly.[a] Thresholds exist in current infrastructure designed to protect property and people from storm impacts.

Sea-level rise and extreme weather events will impact natural structures and functions and the resulting ecosystem services communities rely upon. Storm events increase erosion, create landslides, damage forests and habitat, and injure wildlife.

References and Notes

[a] U.S. Climate Change Science Program. 2008. Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. In Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple and W.L. Murray (eds.). *Weather and Climate Extremes in a Changing Climate*. Synthesis and Assessment Product 3.3. Washington, DC.

D. Food Production

1. Reduced Beef Production

Description

Higher temperatures slow the rate of growth for beef cattle and reduce the production and sales of ranches and feedlots.

Assumptions, Data, and Calculation

We assume ranchers and feedlot operators will continue the practices of 2007 and that prices will remain at 2007 levels, which produced sales of $444 million.[a] We also assume that the temperature increases accompanying a doubling of carbon dioxide emissions would increase the time required for a cow to reach finished weight in a feedlot in the western United States by 2.5 percent; a tripling might increase the time by 15 percent.[b] The potential harm equals the value of annual beef production times the percentage loss of production from climate change, adjusted to reflect potential doubling of carbon dioxide emissions by 2040 and tripling by 2080, under scenario A1FI.

Results

Potential Value of Reduced Beef Production

2020	2040	2080
$7 million	$11 million	$67 million

Source: ECONorthwest

Potential losses would be greater if ranchers tried to expand their production, so that higher temperatures would affect the maturation of a larger number of animals. Also, additional beef production losses, especially for range-fed cattle, may occur as range productivity declines with increasing temperatures and reduced water availability during summer months.[c]

References and Notes

[a] United States Department of Agriculture, National Agricultural Statistics Service. 2008. *Meat Animals Production, Disposition, and Income: 2007 Summary*. April.

[b] Frank, K.L. 2001. *Potential Effects of Climate Change on Warm Season Voluntary Feed Intake and Associated Production of Confined Livestock in the United States*. Masters of Science Thesis. Kansas State University, Manhattan. As cited in Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

[c] Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

2. Reduced Wheat Production

Description

Temperatures above 5°C (9°F) reduce the yields of winter wheat production.

Assumptions, Data, and Calculation

We assume farmers will continue with the practices that produced the 2007 crop and that prices will remain at 2007 levels, which produced a crop worth about $311 million.[a] We apply the results of a study that indicates wheat production in eastern Oregon will decline by approximately 20 percent with a 5°C (9°F) increase in global mean temperature, and an atmospheric carbon-dioxide concentration of 365 ppm.[b] We extrapolate and adjust this finding to estimate the potential reduction in production under the A1FI scenario in 2080, the only one of our target years that would experience a temperature increase of at least 5°C (9°F). The potential harm equals the value of the potential reduction in wheat production.

Results

Potential Value of Reduced Wheat Production

2020	2040	2080
--	--	$62 million

Source: ECONorthwest

We do not include costs for 2020 and 2040, because reduced wheat production does not occur until temperatures reach approximately 5°C (9°F). This magnitude of temperature increase is not expected to occur in the A1FI scenario until the later part of the 21st century.

References and Notes

[a] U.S. Department of Agriculture, National Agricultural Statistics Service. 2008. *U.S. & All States Data – Winter Wheat* [2007, Value of Production, All Winter Wheat, Oregon].

[b] Brown, R.A. and N.J. Rosenberg. 1999. "Climate Change Impacts on the Potential Productivity of Corn and Winter Wheat in their Primary United States Growing Regions." *Climatic Change* 41: 73-107. Although the authors hold carbon dioxide concentrations constant to control for any so-called fertilization effect, in which higher concentrations of CO_2 accelerate plant growth, they conclude that even at concentrations of carbon dioxide at 750 ppm, a 5°C (9°F) increase in temperature causes wheat yields to decline.

3. Reduced Production of Certain Wine Grapes

Description

Temperature increases are expected to reduce the production of certain high-value wine grape varietals.

Assumptions, Data, and Calculation

We assume vintners will continue with production at 2004 levels, and prices will remain at 2004 levels.[a] We apply the results of a study that indicates that if average growing season temperatures increase by 2°C (3.6°F), production of Pinot Noir and Pinot Gris may cease in Oregon as average growing season temperature increases above the optimal for these grapes.[b] This occurs by approximately 2040 under the A1FI scenario, and a 0.5°C (0.9°F) increase is expected by 2020. The potential harm in 2040 equals the total value of the wine grape production in 2004, the last year for which data are available. The potential harm in 2020 is about one-quarter of this amount.

Results

Potential Value of Lost Production of Certain Wine Varietals

2020	2040	2080
$6 million	$24 million	$24 million

Source: ECONorthwest

References and Notes

[a] Full Glass Research. 2006. *The Economic Impact of the Wine and Wine Grape Industries on the Oregon Economy*. January.

[b] Jones, G. 2006. "Climate Change and Wine: Observations, Impacts, and Future Implications." *Wine Industry Journal* 21(4): 21-26.; and Jones, G.V. 2005. "Climate Change in the Western United States Grape Growing Regions." *ISHS Acta Horticulturae 689: VII International Symposium on Grapevine Physiology and Biotechnology*. Retrieved February 2, 2009, from http://www.actahort.org/books/689/689_2.htm

4. Other Potential Costs from the Effects of Climate Change on Food Production

Description

Changes in precipitation and temperature are likely to impact Oregon's agricultural industry in ways other than those reported above. For example, higher temperatures may reduce the yield or cease production altogether in some regions of some additional crops, such as tree fruits and nursery stock. Changes in temperature may also increase the occurrence of pests and plant diseases, requiring famers to expend more resources on pest and disease management.[a] Increased evaptranspiration and reduced availability water supplies may lead to reductions in yield for a variety of crops due to water stress. Insufficient data are available, however, to allow us to estimate the costs associated with these and other potential food-production-related impacts.

References and Notes

[a] Hatfield, J.L. 2008. "Chapter 2: Agriculture." In Backlund, P., A. Janetos, and D. Schimel. 2008. *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*. Synthesis and Assessment Product 4.3. U.S. Climate Change Science Program and the Subcommittee on Global Change Research. May.

E. Forest and Range Production

1. Lost Forest Assets from Wildland Fires

Description

Wildland fires become more frequent and severe as climate change increases temperatures and aridity, and accelerates tree mortality from insects and disease. When forests burn, they lose their ability to produce many goods and services, but data are available only to estimate the loss assuming the forest would be managed to produce timber.

Assumptions, Data, and Calculation

Projections for climate-related changes in temperature and precipitation suggest that, relative to the 20th century, wildfires in Oregon will burn 50 percent more acreage per year by 2020 and double the acreage by 2040.[a] On average, 137,000 acres of state and federal land burned annually from 1988 to 1999.[b] We assume that, if private lands burned at the same rate, the average would have been 217,000 acres. State and federal land make up 63 percent of all forestland in Oregon.[c] A 50 percent increase in acreage burned by 2020 would be a marginal increase of 109,000 acres, and a 100 percent increase by 2040 would be a marginal increase of 217,000 acres. We assume the value of lost goods and services when a forest burns is at least $1,000 per acre, a general estimate for the value of lost timber.[d] We use the projected increase in burn rates for the A2 scenario, which we linearly extrapolate for A1FI and 2080.

Results

Potential Value of Lost Forest Assets from Increased Forest Fires

2020	2040	2080
$109 million	$223 million	$497 million

Source: ECONorthwest

These results do not include the value of ecosystem services distinct from the production of timber that would be lost with increased forest fires. The loss of structures to fire is included under extreme weather events because the data are collected by the National Weather Service and aggregated with other weather-related structural losses.

References and Notes

[a] Mckenzie, D. Z. Gedalof, D. Peterson, and P. Mote. 2004. "Climatic Change, Wildfire, and Conservation." *Conservation Biology* 18: 890-902.

[b] Climate Leadership Initiative. 2007. *Economic Impacts of Climate Change on Forest Resources in Oregon*. University of Oregon. May. This estimate is consistent with estimates by the U.S. Forest Service. See Fried, J. and G. Christensen. 2008. "Fire Incidence." In J. Donnegan, S. Campbell, and D. Azuma (eds.). *Oregon's Forest Resources, 2001-2005. Five-Year Forest Inventory and Analysis Report.* U.S. Department of Agriculture, Forest Service. General Technical Report No. PNW-GTR-765. November. Pp. 76-77.

[c] National Association of State Foresters. *2006 State Forestry Statistics.* http://www.stateforesters.org/files/2006%20State%20Forestry%20Statistics-Web-Final.pdf

[d] Titus, J.G. 1992. "The Costs of Climate Change to the United States." in: Majumdar, S.K., L.S. Kalkstein, B. Yarnal, E.W. Miller, and L.M. Rosenfeld (eds). *Global Climate Change: Implications, Challenges, and Mitigation Measure*s. Pennsylvania Academy of Sciences.

2. Increased Control Expenditures Related to Wildland Fire

Description

Wildfires become more frequent and severe as climate change increases temperatures and aridity, and accelerates tree mortality from insects and disease. As wildland fires become more widespread Oregonians will incur additional fire-control costs.

Assumptions, Data, and Calculation

Projections for forests in Oregon based on temperature and precipitation suggest that wildland fires will impact 50 percent more acreage than during the 20th century by 2020 and a doubling by 2040.[a] We assume suppression costs will increase proportional to acres burned, fire suppression costs will increase as well, or alternatively.[b] We base our calculation on these rates and historical expenditures.[c]

Results

Potential Value of Increased Control Expenditures for Wildland Fires

2020	2040	2080
$97 million	$200 million	$444 million

Source: ECONorthwest

References and Notes

[a] Mckenzie, D. Z. Gedalof, D. Peterson, and P. Mote. 2004. "Climatic Change, Wildfire, and Conservation." *Conservation Biology* 18: 890-902.

[b] National Association of State Foresters. *2006 State Forestry Statistics.* http://www.stateforesters.org/files/2006%20State%20Forestry%20Statistics-Web-Final.pdf

[c] Climate Leadership Initiative. 2007. *Economic Impacts of Climate Change on Forest Resources in Oregon*. University of Oregon. May.

3. Other Potential Costs from the Effects of Climate Change on Forests and Range

Description

Numerous studies based on climate forecasts as well as impacts already occurring indicate that climate change is likely to increase the forest damages resulting from disease and pests such as the mountain pine beetle. Mountain pine beetle populations are historically held in check by cold winters. As the frequency of cold winters decreases, the mountain pine beetle's exponential growth rate goes unfettered and leads to rapid and widespread tree mortality, as seen throughout the western United States and Canada.[a] The mountain pine beetle is now beginning to show a potential to jump to non-pine species after locally exhausting the supply of pines. Mountain pine beetles could conceivably impact the majority of remaining forest in Oregon. Mountain pine beetles can interact with other effects that stress forests in Oregon such as increased temperatures and decreased soil moisture to hasten tree mortality.[b]

Lost forest will lead to lost ecosystem services for Oregonians, such as water filtration, water storage and air filtration. The City of Portland avoids purchasing a $200 million filtration treatment system for its water supply by protecting 102 square miles of its watershed. This equates to an avoided cost benefit of $3,000 per acre for water filtration services.[c] We do not make an estimate of the total value of ecosystem services lost with forest loss because there currently are not equivalent identifications of demand for the state as a whole. While the forest value from Portland is likely high for most forest in Oregon, it is a value for only one ecosystem service, and as the population grows, demand for these services will increase as well.

References and Notes

[a] Carroll, A.L., J. Régnière, J.A. Logan et al. 2006. *Impacts of Climate Change on Range Expansion by the Mountain Pine Beetle*. Working Paper No. 2006-14. Canadian Forest Service, Natural Resources Canada, Pacific Forestry Centre. Retrieved May 18, 2007, from http://mpb.cfs.nrcan.gc.ca/research/projects/1-02_e.html

[b] van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, et al. 2009. "Widespread Increase of Tree Mortality Rates in the Western United States." *Science* 323: 5913.

[c] ECONorthwest, with data from the Portland Water Bureau, http://www.portlandonline.com/water/index.cfm?c=29784; and Krieger, D. 2001. *Economic Value of Forest Ecosystem Services: A Review.* The Wilderness Society.

F. Public Health

1. Increased Low-Altitude Ozone

Description

Increased temperatures favor the production of low-altitude ozone, which negatively impacts the health of humans that live in urban areas and creates costs associated with increased rates of morbidity, premature mortality, and lost worker productivity.[a]

Assumptions, Data, and Calculation of Mortality

We apply findings from an assessment of the A2 scenario, which indicate elevated ozone levels related to climate change could increase nonaccidental mortality by 0.27 percent by 2050.[b] We linearly interpolate and extrapolate to estimate the effect in 2020, 2040, and 2080, then adjust for higher temperatures expected in the A1FI scenario. We assume that, absent climate change, nonaccidental mortality would rise proportional to future increases in the state's metropolitan population and estimate that the higher ozone concentrations would increase annual mortality by 37 in 2020, 77 deaths in 2040, and more than 180 in 2080.[c] We estimate the value of the additional premature deaths using EPA's current estimate of the value of a statistical life.[d]

To calculate the potential costs of increased morbidity we rely on the results of an employee survey, that estimated expenditures associated with conditions, such as allergies, asthma, and other respiratory affections, incurred by employees, including those who do not suffer from the particular condition.[e] Using these results, we first estimate what the costs would be absent climate change by assuming that current costs of hospitalization for conditions related to ozone in metropolitan areas will increase proportionate to expected growth in Oregon's labor force. We then apply the results from a study that concluded current hospitalization costs related to high ozone concentrations in California might triple under the A2 scenario,[f] and make adjustments to reflect the higher temperatures expected under the A1FI scenario. The results represent the potential increases in medical costs for 2020, 2040, and 2080.

To estimate the value of increases in lost productivity as more workers become ill from climate-related increases in ozone concentrations, we rely on the findings of the same employee survey[e] and first assume that, absent climate change, current levels of lost productivity in metropolitan areas would grow proportional to expected growth in Oregon's labor force. We then apply the results of a study that estimated the productivity losses in California related to ozone could increase 62 percent under the A2 scenario,[f] and make adjustments to reflect the higher temperatures expected under the A1FI scenario. The results represent the potential increases in workers' lost productivity for 2020, 2040, and 2080.

Results

Potential Health-Related Costs from Increased Low-Altitude Ozone		
2020	**2040**	**2080**
Value of Premature Deaths		
$253 million	$542 million	$1.4 billion
Value of Increased Morbidity		
$38 million	$49 million	$72 million
Value of Lost Productivity		
$397 million	$507 million	$745 million
TOTAL		
$688 million	$1.1 billion	$2.2 billion

Source: ECONorthwest

The calculation of increased morbidity costs does not account for costs that would occur outside a hospital (in-patient or emergency room) or for the effects of higher ozone concentrations on all sensitive groups, like children and elderly.

EPA's value of statistical life represents the value that people, on average, are willing to pay to avoid premature mortality from exposure to harm, be it pollution, accidents, etc. Researchers have argued that a more appropriate measure to value a life is the willingness to accept fatal consequences of exposure to harm. This value is usually higher than the willingness to pay.[g] This means that the total value of increased mortality from high ozone concentrations, that we estimate above, understate the actual value society places on deaths froom climate change.

References and Notes

[a] Ebi, K.L., J. Balbus, P.L. Kinney et al. 2008. "Effects of Global Change on Human Health." In J.L. Gamble, ed., *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems.* Washington, D.C.: U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Environmental Protection Agency. Retrieved December 23, 2008, from http://www.climatescience.gov/Library/sap/sap4-6/final-report/sap4-6-final-all.pdf.

[b] Bell, M.L., R. Goldberg, C. Hogrefe et al. 2007. "Climate Change, Ambient Ozone, and Health in 50 U.S. Cities." *Climatic Change* 82: 61-76.

[c] Oregon Department of Human Services, Center for Health Statistics. No date. *Age-Adjusted Death Rates for Selected Causes of Death, 2000-2004.* Retrieved on January 6, 2009, from http://www.dhs.state.or.us/dhs/ph/chs/data/death/aadeath/aadeath.shtml; Office of Economic Analysis. 2004. *State and County Population Forecast and Components of Change, 2000 to 2040.* Retrieved on January 6, 2009, from http://www.oea.das.state.or.us/DAS/OEA/docs/demographic/pop_components.xls; and Yohannan, J.J. 2006. *Another Look at Oregon's Urban Versus Rural Trends.* Oregon Employment Department. July 27. Retrieved on January 13, 2009, from http://www.qualityinfo.org/olmisj/ArticleReader?itemid=00005023.

[d] Borenstein, S. 2008. *American Life Worth Less Today.* July 10. Associated Press. Retrieved on December 23, 2008, from http://www.huffingtonpost.com/2008/07/10/american-life-worth-less_n_112030.html

[e] Goetzel, R.Z., S.R. Long, R.J. Ozminkowski et al. 2004. "Health, Absence, Disability, and Presenteeism Cost Estimates of Certain Physical and Mental Health Conditions Affecting U.S. Employers." *Journal of Occupational and Environmental Medicine* 46: 398-412.

[f] Kahrl, F. and D. Roland-Holst. 2008. *California Climate Risk and Response*. Department of Agricultural and Resource Economics, University of California Berkeley. November. Retrieved January 7, 2009, from http://are.berkeley.edu/~dwrh/CERES_Web/Docs/California%20Climate%20Risk%20and%20Response.pdf.

[g] *See*, for example, Guria, J., J. Leung, M. Jones-Lee, and G. Loomes. 2005. "The Willingness to Accept Value of Statistical Life Relative to the Willingness to Pay Value: Evidence and Policy Implications." *Environmental and Resource Economics* 32: 113-127.

2. Increased Heat Waves

Description

Additional heat waves (days with temperatures consistently above a threshold specific to different geographic areas) are expected to increase mortality rates and medical costs of those already suffering from cardiovascular, cerebrovascular, and respiratory diseases.[a] They also will reduce work productivity, household productivity, and the value of leisure time.

Assumptions, Data, and Calculation

We apply to the entire state the results of a recent study, which estimated climate-related heat waves would cause an additional 14 deaths in Portland by 2055 under the A2 scenario,[b] and make adjustments to estimate the number of additional deaths in 2020, 2040, and 2080 under the A1FI scenario. We estimate the value of the additional premature deaths using EPA's current estimate of the value of a statistical life.[c]

To calculate additional medical and other costs, we multiplied Oregon's expected future populations times the per capita daily costs for hospitalization, emergency-room visits, and follow-up medical costs during the 2006 heat wave in California.[d] We estimate the additional, climate-related costs by applying the results of a study that projected Oregon would experience an additional 14 heat-wave days by 2030 under the A1B scenario[e] and making adjustments to estimate the number of additional deaths in 2020, 2040, and 2080 under the A1FI scenario.

Results

Potential Value of Health-Related and Other Costs of Heat Waves

2020	2040	2080
Value of Premature Deaths		
$66 million	$153 million	$359 million
Value of Increased-Medical Care Costs		
$9 million	$18 million	$51 million
Value of Other Costs		
$1 million	$2 million	$5 million
TOTAL		
$76 million	$173 million	$415 million

Source: ECONorthwest

Heat-wave statistics show they cause more deaths than all other natural disasters in the US. Death certificates systematically fail to represent high temperatures as the death cause during heat waves, however, and a full accounting would increase the mortality numbers, perhaps by 54 percent.[f]

EPA's value of statistical life represents the value that people, on average, are willing to pay to avoid premature mortality from exposure to harm, be it pollution, accidents, etc. Researchers have argued that a more appropriate measure to value a life is the willingness to accept fatal consequences of exposure to harm. This value is usually higher than the willingness to pay.[g] This means that the total value of increased mortality from high ozone concentrations, that we estimate above, understate the actual value society places on deaths froom climate change.

References and Notes

[a] Knowlton, K., M. Rotkin-Ellman, G. King et al. 2009. "The 2006 California Heat Waves: Impacts on Hospitalizations and Emergency Department Visits." *Environmental Health Perspectives* 117: 61-67.

[b] Kalkstein, L.S. and J.S. Greene. 2007. *An Analysis of Potential Heat-Related Mortality Increases in U.S. Cities under a Business-as-Usual Climate Change Scenario.* Environment America. September 6. Retrieved January 13, 2008, from http://www.environmentamerica.org/uploads/Js/tF/JstFE5oHrsQJi5ifIA931Q/Heat-Mortality_Report_.pdf.

[c] Borenstein, S. 2008. *American Life Worth Less Today.* July 10. Associated Press. Retrieved on December 23, 3008, from http://www.huffingtonpost.com/2008/07/10/american-life-worth-less_n_112030.html

[d] Srinivasan, T. 2008. *Cost of Excess Hospitalization and Emergency Department Visits for the 2006 California Heat Wave.* Natural Resources Defense Council. August 28. Retrieved January 11, 2009, from http://docs.nrdc.org/health/files/hea_08082601a.pdf.

[e] Tebaldi, C., K. Hayhoe, J.M. Arblaster, and G.A. Meehl. 2006. "Going to the Extremes; An Intercomparison of Model-Simulated Historical and Future Changes in Extreme Events." *Climatic Change* 79(3-4): 185-211. Adapted by Lawrence Buja and Julie Arblaster. Retrieved January 21, 2009, from http://www.cgd.ucar.edu/ccr/climate_change_gallery_test/.

[f] Luber, G.E. and C.A. Sanchez. 2006. "Heat-Related Deaths--United States, 1999-2003." *Morbidity and Mortality Weekly Report* 55 (29): 796-798. Retrieved January 13, 2009, from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5529a2.htm

[g] *See*, for example, Guria, J., J. Leung, M. Jones-Lee, and G. Loomes. 2005. "The Willingness to Accept Value of Statistical Life Relative to the Willingness to Pay Value: Evidence and Policy Implications." *Environmental and Resource Economics* 32: 113-127.

3. Other Potential Costs from the Efffects of Climate Change on Human Health

Description

Impacts of climate change on human health are not restricted to those caused by high levels of ozone or heat. Studies have shown that climate change will make wider areas hospitable to vectors that produce diseases, such as the West Nile virus, encephalitis, and Lyme disease. At the same time, water- and food-borne diseases likely will increase in incidence and cases of *Giardia*, *salmonellosis*, *E. coli* will become more frequent.[a]

We have found no data to quantify these future impacts associated with climate change but the lack of quantifiable information does not mean that the value is zero.

References and Notes

[a] Ebi, K.L., J. Balbus, P.L. Kinney et al. 2008. "Effects of Global Change on Human Health." In J.L. Gamble, ed., *Analyses of the Effects of Global Change on Human Health and Welfare and Human Systems.* Washington, D.C.: U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Environmental Protection Agency. Retrieved December 23, 2008, from http://www.climatescience.gov/Library/sap/sap4-6/final-report/sap4-6-final-all.pdf.

G. Recreation

1. Reduced Opportunities for Snow-Related Recreation

Description

Higher temperatures reduce snowfall and accumulation, shortening the ski season, degrading skiing conditions, and reducing revenues for the ski industry.

Assumptions, Data, and Calculation

We assume that, absent climate change, downhill skiing participation would grow from the 2001-2002 level, 2,279,201 skier-days,[a] based on population growth rates and that the average expenditures and consumer surplus per skier day would remain at $70[b] and $28[c] per day, respectively. For cross-country skiing and snowshoeing, we assume participation would grow from the 2001-2002 level, 553,446 user-days, [a] based on population growth and expenditures and consumer surplus would remain at $17[d] per day and $54[c] per day, respectively. We assume that the snow-recreation season will shrink 14 percent by 2020 and 30 percent by 2040,[e] based on a forecast of temperature increases associated with business-as-usual emissions. We assume the number of user-days, expenditures, and consumer surplus shrinks proportionately. We linearly extrapolate to estimate the reductions for 2080. The potential harm equals the number of user-days times the expenditures and consumer surplus per day times the percentage loss of recreation opportunity from climate change.

Results

Potential Value of Reduced Snow-Related Recreation

2020	2040	2080
Reduced Value for Downhill Skiing		
$39.5 million	$105.5 million	$287.6 million
Reduced Value for Cross-Country Skiing and Snowshoeing		
$6.9 million	$18.5 million	$50.6 million
TOTAL		
$46.4 million	$124 million	$338.2 million

Source: ECONorthwest

Industry officials suggest that once the snow-recreation season is shortened to the extent indicated for 2080, snow-related recreation businesses, and the downhill skiing businesses in particular, likely would not be viable and would close.[f]

References and Notes

[a] Oregon Parks and Recreation Department. 2003. *2003-2007 Oregon Statewide Comprehensive Outdoor Recreation Plan.* January.

[b] Berry, M. 2008. *Overview of the U.S. Ski Industry.* National Ski Areas Association. June 27.

[c] Loomis, J. and J. Crespi. 1999. "Estimated Effects of Climate Change on Selected Outdoor Recreation Activities in the United States." In Mendelsohn, R. and J. Neumann (eds.). *The Impact of Climate Change on the United States Economy.* Cambridge University Press: Cambridge, UK.

[d] Stynes, D.J., and E.M. White. 2006. *Spending Profiles for National Forest Recreation Visitors by Activity*.

[e] Casola, J.H., J.E. Kay, A.K. Snover et al. 2005. *Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture*. Climate Impacts Group, University of Washington, Seattle. and Nolin, A.W. and C. Daly. 2006. "Mapping 'At Risk' Snow in the Pacific Northwest." *Journal of Hydrometeorology* 7: 1164.

[f] Zimmerman, G., C. O'Brady, and B. Hurlbutt. 2006. *Climate Change: Modeling a Warmer Rockies and Assessing the Implications.* The 2006 Colorado College State of the Rockies Report Card.

2. Reduced Opportunities for Cold-Water Angling

Description

Increased stream temperatures reduce the amount of habitat that can viably support salmon, reducing the contribution of cold-water angling to the economy.

Assumptions, Data, and Calculation

We assume the value of cold-water angling will decline proportionate to expected losses of aquatic habitat for salmon and trout. An assessment of the A2 emissions scenario indicates increased warming might reduce salmon habitat in Oregon by 16, 30, and 40 percent by 2030, 2060, and 2090, respectively.[a] We interpolate and adjust the percentages to reflect the A1FI scenario, and apply them to 4,861,000,[b] the number of stream-based angling days in 2006 to estimate the reductions in angling in 2020, 2040, and 2080. We adjust for population growth in 2020, 2040, and 2080, and value the reductions applying the estimated consumer surplus and expenditures per salmon-angler per day: $140[c] and $67,[b] respectively.

Results

Potential Value of Reduced Cold-Water Angling

2020	2040	2080
$121 million	$266 million	$732 million

Source: ECONorthwest

These results may overstate the potential harm by applying values associated with salmon angling to trout angling. They probably underestimate the total harm from climate change, insofar as it also might lead to degraded ocean conditions, increased incidence of disease, and other factors that would affect future salmon and trout populations.[d]

References and Notes

[a] O'Neal, K. 2002. *Effects of Global Warming on Trout and Salmon in U.S. Streams.* Defenders of Wildlife and Natural Resources Defense Council. May.

[b] U.S. Fish and Wildlife Service. 2008. *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: Oregon.* Report No. FHW/06-OR. April.

[c] Ransom, M.M. 2001. *Economic Impacts of Salmon Fishing*. U.S. Department of Agriculture, Natural Resources Conservation Service. February 12.

[d] Battin, J., M.W. Wiley, M.H. Ruckelshaus, et al. 2007. "Projected Impacts of Climate Change on Salmon Habitat Restoration." *Proceedings of the National Academy of Sciences of the United States of America* 104 (16): 6720-6725. from http://www.pnas.org/content/104/16/6720.full.pdf+html; Independent Scientific Advisory Board. 2007. *Climate Change Impacts on Columbia River Basin Fish and Wildlife*. ISAB Climate Change Report ISAB 2007-2. Pacific Northwest Power and Conservation Council. May 11; and Richter, A. and S.A. Kolmes. 2005. "Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest." *Reviews in Fisheries Science* 13: 23-49.

3. Other Potential Costs from the Effects of Climate Change on Recreation

Description

Increased wildland fires will potentially reduce recreation opportunities during summer months. Forest closures during wildland fire events and exceptionally dry, high-risk fire seasons may limit the area, and thus opportunities, available for activities, such as hiking, mountain biking, wildlife watching, and scenic driving. Post-fire landscapes may provide more limited or lower-quality recreation experiences.[a, b]

Low water levels in streams, especially in late summer, may also reduce some water-related recreation opportunities, such as river rafting and kayaking. As peak flows shift earlier in the season due to earlier snowmelt, they may not longer overlap with the summer season in which many people enjoy river recreation. Lower flows during peak summer months may limit boating on certain stretches of river and lower the quality of the recreation experience.[c]

Though insufficient data are available to quantify these impacts, research elsewhere suggests that they have the potential to reduce the value (expenditures and consumer surplus) of forest-based and water-related recreation in Oregon.

References and Notes

[a] Starbuck, C.M., R.P. Berrens, and M. McKee. 2006. "Simulating Changes in Forest Recreation Demand and Associated Economic Impacts Due to Fire and Fuels Management Activities." *Forest Policy and Economics* 8: 52-66.

[b] Scott, D., G. Wall, and G. McBoyle. 2005. "Chapter 7: Climate Change and Tourism and Recreation in North America: Exploring Regional Risks and Opportunities." In C. M. Hall and J. Higham (eds.) *Tourism, Recreation and Climate Change. Aspects of Tourism.* Clevedon: Channel View Publications.

[c] Mickelson, K.E., and A.F. Hamlet. 2008. "Effects of Climate Change on White-Water Recreation on the Salmon River, Idaho." American Geophysical Union, Fall Meeting.

IV. The Potential Economic Costs Associated with Activities that Contribute to Climate Change

In this section, we describe costs that are produced by activities associated with the business-as-usual pathway that contribute to climate change. Although these are not costs resulting directly from the effects of climate change *per se*, they represent important sources of economic harm society incurs by proceeding with business-as-usual activities.

A. Wasteful Use of Energy

Description

Consumers incur costs by using technologies and behaviors that are less efficient than available substitutes in their use of energy.

Assumptions, Data, and Calculation

We assume Oregon's consumption of electricity and natural gas in 2007[a] will increase at rates estimated by the Energy Information Administration[b] for Oregon and use percentages reported by several studies[c] to estimate the amount of energy Oregonians will waste by not implementing cost-effective programs and technologies to increase energy efficiency. We estimate the value of the expenditures on wasted energy using recent average prices.[d]

Results

Potential Value of Wasted Electricity and Natural Gas

2020	2040	2080
$1.27 billion	$1.47 billion	$1.97 billion

Source: ECONorthwest

References and Notes

[a] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector (Form EIA-826)*. Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls; and Energy Information Administration. 2008. *Oregon Natural Gas Consumption by End Use: 2002-2007*. Retrieved January 22, 2009, from http://tonto.eia.doe.gov/dnav/ng/ng_cons_sum_dcu_sor_a. htm.

[b] Energy Information Administration. 2008. *EERE State Activities and Partnerships: Electric Power and Renewable Energy in Oregon*. Retrieved January 23, 2009, from http://apps1.eere.energy.gov/states/electricity.cfm/state=OR

[c] Nadel, S., A. Shipley, R.N. Elliott. 2004. *The Technical, Economic and Achievable Potential for Energy Efficiency in the U.S.-A Meta Analysis of Different Studies*. American Council for an Energy-Efficient Economy.

[d] Energy Information Administration. 2008. *Current and Historical Monthly Retail Sales, Revenue and Average per Kilowatthour by State and by Sector (Form EIA-826)*. Retrieved January 15, 2009, from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls; and Energy Information Administration. 2008. *Oregon Natural Gas Prices: 2002-2007*. Retrieved from http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_SOR_m.htm

B. Emissions from the Generation of Coal-Fired Electricity

Description

Burning coal to generate electricity in Oregon will impose health-related spillover costs on Oregonians, i.e., costs not reflected in the price of the electricity.

Assumptions, Data, and Calculation

The Boardman generating plant, with a generating capacity of 585 megawatts (MW), emitted 7,890 metric tons of sulfur dioxide and 5,367 metric tons of nitrogen oxide in 2006,[a] and 239 metric tons of particulate matter less than 10 microns in diameter in 1999 (the last year for which data are available).[b] The health-related externality costs associated with these pollutants are $2,556 per ton for sulfur dioxide, $1,505 per ton for nitrogen oxides, and $3,976 per ton for particulate matter.[c] We assume that, in a business-as-usual future, emissions would continue at these rates and that coal-fired electricity generation in Oregon would grow at the expected rate for total electricity consumption, 0.8 percent per year.[d] The potential harm is the sum of the cost of the health-related spillover costs for the three pollutants.

Results

Potential Value of Health-Related Spillover Costs of Coal-Fired Electricity

2020	2040	2080
$33 million	$38 million	$52 million

Source: ECONorthwest

These results likely underestimate the total health-related spillover costs associated with coal-fired electricity generation, insofar as they do not include other harmful pollutants, such as mercury, volatile organic compounds, and carbon monoxide.

References and Notes

[a] Energy Information Administration. 2008. *U.S. Electric Power Industry Estimated Emissions (EIA-767 and EIA 906)*. Retrieved January 23, 2009, from http://tonto.eia.doe.gov/state/SEP_MoreEnviron.cfm.

[b] Northwest Environmental Defense Center. 2008. "Breakdown of PGE Boardman Pollution." *PGE Boardman Coal-Fired Power Plant.* Retrieved January 23, 2009, from http://www.lclark.edu/org/nedc/pge.html.

[c] Matthews, H.S. and L.B. Lave. 2000. "Applications of Environmental Valuation for Determining Externality Costs." *Environmental Science and Technology.* 34 (8) 1390-1395. Values converted to equivalent 2008 dollars.

[d] U.S. Department of Energy, Energy Efficiency and Renewable Energy. 2008. *Electricity Power and Renewable Energy in Oregon*. Retrieved January 23, 2009, from http://apps1.eere.energy.gov/states/electricity.cfm/state=OR

V. POTENTIAL ECONOMIC COSTS PER HOUSEHOLD

The preceding sections illustrate some specific types of potential economic costs Oregonians as a whole would face if Oregon, other states, the U.S., and other nations adopt a business-as-usual approach to climate change. Here, we scale down our findings to illustrate the potential costs per household.

In 2005, Oregon had 1.42 million households.[30] We assume this number will grow at the same rates projected for Oregon's population through 2040 and at the rates projected for the U.S. population from 2040 until 2080, reaching 1.71 million in 2020, 2.11 million in 2040, and 2.79 million in 2080. Dividing these numbers into the estimates of statewide potential costs from the preceding section for each of these years yields the per-household costs shown in Figure 7. These costs are not negligible; based on the median income of a household in Oregon in the 2005-2007 period,[31] these costs represent 4 percent of household earnings in 2020, 5 percent in 2040, and 7 percent in 2080.

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[30] U.S. Census Bureau. 2006. "Selected Social Characteristics: Oregon." *2005 American Community Survey*. Retrieved January 25, 2009, from http://www.census.gov/acs/www/Area%20Sheets/Area%20Sheet%20OR.doc.

[31] U.S. Census Bureau. No date. "Oregon-Fact Sheet—American FactFinder." *2005-2007 American Community Survey*. Retrieved January 26, 2009, from http://factfinder.census.gov/

Figure 7. Potential Economic Costs Per Household in Oregon Under a Business-As-Usual Approach to Climate Change, 2020, 2040, and 2080 (Dollars per Year)

Potential Cost	2020	2040	2080
Costs of Climate Change			
Increased Energy-Related Costs	$70	$155	$292
Reduced Salmon Populations	$370	$473	$671
Increased Flood and Storm Damage	$37	$62	$111
Reduced Food Production	$8	$17	$55
Increased Wildland Fire Costs	$121	$200	$337
Increased Health-Related Costs	$447	$615	$932
Lost Recreation Opportunities	$98	$185	$395
Subtotal for Costs of Climate Change	*$1,150*	*$1,707*	*$2,793*
Additional Costs from Business-as-Usual (BAU) Activities that Contribute to Climate Change			
Inefficient Consumption of Energy	$761	$710	$717
Increased Health Costs from Coal-Fired Emissions	$19	$18	$19
Subtotal for Costs from BAU Activities	*$780*	*$728*	*$736*
Average Cost per Household per Year	**$1,930**	**$2,435**	**$3,529**

Source: ECONorthwest.

Notes: These numbers illustrate different types of annual cost Oregonians potentially would incur if society were to continue with a business-as-usual approach to climate change. There may be overlap between the values for some of the different types of cost. Nonetheless, adding the different types of costs probably seriously understates the total potential cost of climate change because the table excludes many additional types of climate-related costs that Oregonians would incur under a business-as-usual approach. The numbers do not indicate the net effect of climate change, as they do not represent a forecast of how the economy will respond to the different effects of climate change, or account for potential economic benefits that might materialize from moderate warming and other changes in climate.