Preparing the Pacific Northwest for Climate Change

A Framework for Integrative Preparation Planning for Natural, Human, Built and Economic Systems

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Preface

This framework is the result of our research as well as meetings with and feedback from experts and stakeholders in four defined sectors that are projected to be affected in various ways and degrees by climate change in the Pacific Northwest. The meetings, surveys, and analyses were conducted over the summer and the fall of 2007 by the Climate Leadership Initiative at the University of Oregon as part of its long-term climate preparation program.

The four sectors include: 1) *natural systems*, defined for the purposes of this project as ecosystems and biodiversity; 2) *built systems*, defined as buildings, road, energy and water systems and other critical infrastructure; 3) *human systems*, defined as public health, emergency management, and social service functions; and 4) *economic systems,* defined as forestry, agriculture, high tech and other industries. Preparing each of these sectors for climate change is important for its own sake. Just as important is the integration of each of the preparation efforts because activities in one will affect activities in others.

The development of this framework was co-sponsored by Oregon Governor Kulongoski's Climate Change Integration Group, an advisory committee appointed by the governor charged with making recommendations on climate change impacts, mitigation and preparation strategies. Many of the principle guidelines, strategies, policies and data needs identified herein have been delivered to the Governor and the new State of Oregon Global Warming Commission. However, this framework is intended to assist climate preparation efforts by public agencies, non-profits and private companies throughout the Pacific Northwest. We will also use it to guide our efforts to develop ecoregion specific climate preparation and adaptation strategy and policy recommendations.

Note that the information and findings in this document will be expanded and refined as the project unfolds, with many more people representing different fields, organizations states and geographic areas involved. A series of "Climate Future Forums" are planned in different climate and ecological zones of the Northwest for this purpose. The goal is to test, refine and finalize the framework and develop specific policy and programmatic recommendations for preparing natural, built, human, and economic systems for climate change.

Pacific Northwest Climate Impacts

The following climate-driven impacts will likely occur in the Pacific Northwest (note that this is a preliminary list that is likely to change with further research). Each of the four sectors will be affected in different ways and to different degrees.

- Temperatures increase: 2 degrees F by 2020 and 3 degrees F by 2040. For public health services, there will likely be a higher incidence of heat exhaustion, cramps, heart attacks, stroke, and higher likelihood of food contamination. Photochemical smog and associated respiratory illness, asthma, and cardiovascular disease will increase. Allergens and pathogens increase with higher temperatures and higher CO_2 concentrations. Crop zone changes will increase agricultural losses and may threaten food security.
- Spring and summer will arrive earlier and fall and winter will arrive later.
- Snow pack will decrease (possible 30%-50% loss by mid-century), causing earlier spring runoff. Shifts in snow-transient basins will cause decreasing summer and early fall stream flows and diminished municipal water, irrigation, and hydroelectric power supply in many areas. Heating demands will decrease, but cooling demands for electric power will increase more dramatically.
- Snow dominance will transition to rain dominance in many low elevation basins of the Cascades and eastside regions due to rising temperatures.
- Increased precipitation on average will concentrate primarily in winter months and will not be distributed evenly across state.
- Drier forest and agricultural soil conditions will persist in the summer, especially on east side of the Cascades with increased evaporative demand and reduced precipitation. For forests, mountain pine beetle infestations will increase with warmer temperatures. Ponderosa pine and Douglas-fir compositions will shift as their productivity declines with warmer temperatures, beginning on the east side and then spreading to commercial forests on the west side. For agriculture, weeds will become more competitive and crops will have to adapt to reduced summer precipitation.
- Exposure to ultra-violet radiation and skin cancer will increase with drier climate on east side.
- Fall and winter storm intensity and stream flooding will increase on the west side of the Cascades. For public health services, this will likely cause more water contamination, and higher likelihood of water borne diseases like cholera, cryptosporidiosis, campylobacter, and leptospiriosis. Vector-borne diseases, like malaria and West Nile virus, may increase with higher levels of temperature and precipitation.
- Wildfires will increase, projected to cover 50% more acres by2020’s and 100% by 2040’s (assuming similar patterns hold true as was seen in last part of the past century)
    1. Fire likely to be the “Hurricane Katrina's” of the PNW
    2. Greater CO_2 fertilization leads to increased biomass

3. Decreased soil moisture
4. Increased insect infestation
5. Loss of property and life will increase for people living in forested areas.
6. Illness will increase due to smoke inhalation.

- Sea levels will rise particularly north of Florence, Oregon where coast is subsiding. This is difficult to quantify, as the dynamics of polar ice sheet melting are not well understood. Projections range from a few inches to a foot or more over the next fifty years, depending on mountain glacier and ice sheet melting rates. A significant portion of sea level rise will be due to thermal expansion of oceans, which is inevitable and long lasting over centuries.
- Coastal storm surges will increase, and estuaries will become saltier with rising sea levels and increasing storm activity. Beaches will erode and bluffs will tend to slide. Coastal natural species habitats will become squeezed between rising water levels and upland barriers.
- Some of the natural species most sensitive to these impacts are salmonids, certain endemics in the Klamath/Siskiyou region, and amphibians. Water temperatures greater than 70 degrees F. are harmful to salmon and will increase in the summer, affecting migrating adults and juvenile rearing statewide but particularly in the Columbia and Klamath Basins. Increased fall and winter flooding on the West side will likely reduce egg-to-fry and winter survival rates.
- Mental health impacts such as anxiety, post-traumatic stress, depression, and despair will increase during and after natural disasters.
- Increase in regional, national, and global climate change refugees may trigger economic and social conflict.

Definitions

Biodiversity: The record of successful mechanisms for recovery and renewal of ecosystems including the full range of natural variation of genes, species, ecological communities. Maintaining biodiversity increases the chances that natural systems can successfully adapt. Even though the future course of climate change is unlikely to mirror the past, the current diversity of natural systems is like a library of all the successful adaptations to past climate changes.

Built Environment: The manufactured and constructed buildings, facilities, and sites that function to provide shelter, services, commercial and manufacturing space, transportation, energy and water delivery, food distribution, and communications.

Complementarity: The ability to support practices commonly recommended for maintaining and enhancing natural, human, built or economic while also maintaining, improving and providing co-benefits for one or all of the others.

Ecological Integrity: Natural systems exhibit ecological integrity when they have persistent ecological functions and interactions, self-organized resilience, and representative diversity of genes, species, and ecosystems.

Equity: Maintaining the fullest range of options for present and future generations, both among human communities without regard to economic, political or social status, and among natural, human, built and economic systems.

Human Services: The core services that government and private agencies provide to human populations including public health, emergency and disaster relief, housing, flood and fire protection, and food delivery.

Humility: Recognizing the limits of human ability to successfully control dynamic natural systems and avoid unintended consequences of management.

Mobility/ Connectivity/Porosity: The ability of species to move across the landscape, especially between conservation areas and along north-south gradients and elevation gradients.

Preparation (Adaptation): The capacity of natural, human, built, and economic systems and organisms to withstand and respond to (i.e., to cope with, recover from, or adapt to) external stresses placed on their structures, compositions and functions due to climate-related factors.

Refugia (Conservation Areas): Protected habitats that serve as natural strongholds for the provision of key ecological functions and ecosystem services where natural processes (including autonomous adaptation of natural systems) can operate with minimum human interference. The abundance of habitat in refugia, spacing between refugia, and the quality of intervening habitat are critical considerations.

Resilience: The capacity of natural, human, built, or economic systems to return to a state of high function and integrity after disturbance.

Resistance: The ability of natural, human, built, and economic systems to withstand change. For instance, some ecosystems such as well-established forests have "ecological inertia" which provides conditions favorable to persistence. Some human populations have the economic and infrastructure capacity to withstand moderate degrees of climate change.

Scenario: A coherent, internally consistent and plausible description of a possible future state of the world (Intergovernmental Panel on Climate Change). Scenarios are not predictions or forecasts but are alternative images of how the future might unfold.

Self-organization: The ability of natural systems to be self-maintaining so that ongoing interventions are minimized.

Uncertainty: The inability to accurately predict climate change or its consequences at many scales that are relevant to natural, human, built and economic systems.

Preparation Planning Interactions and Integration Among Four Sectors

One of the chief goals of climate preparation and adaptation must be integration. This means taking explicit steps to ensure that preparation in one sector does not adversely affect preparation in another. In the chart below we identified a myriad of possible interactions among preparation planning for natural, human, built and economic systems. Some of these relationships are clearly cautionary and reflect potential conflicts or competition for scarce water or land resources, such as reservoir storage for irrigation and hydroelectricity production on the one hand, and cold and ample stream flows for fish habitat on the other. Natural shoreline buffering for storm protection will help protect estuarine ecosystems and associated wetlands, but may undermine efforts to armor coastal infrastructure against storm surges and sea level rise.

Although adverse impacts are possible, if done effectively preparation in one area can provide co-benefits for others. Indeed, the largest number of interactions we identified here reflects positive synergies and complementary relationships. Installing adequate culverts to respond to more extreme rain events, for example, can enhance wildlife protection, drinking water quality, public safety and commerce. Adopting measures to provide climate change resilience for endangered ecosystems also enhances the growing tourism and outdoor recreation economy. Distributed renewable energy systems designed to improve reliability during extreme weather or forest fires also stimulates a growing clean energy economic sector in the Pacific Northwest.

The following table describes a number of these conflicts and synergies:

Table 1

Note: A plus (+) sign after a listed interaction indicates a positive or complementary impact and a minus (-) sign indicates a negative or competing impact.

Strategy/Policy	**Natural Systems (NS)**	**Human Systems (HS)**	**Built Systems (BS)**	**Economic Systems (ES)**
NS 1 Avoid even-age tree plantations	//////////////////		Potential increase in building costs (-)	Short-run reduction in timber harvests (-)
NS 2 Retirement of grazing permits	//////////////////			Increases costs of livestock production (-)
NS 3 Restore native grasslands	//////////////////			Limits development and grazing (-)

NS 4 Maintain upstream water for fish	//////////////////	Competes with municipal water storage (-)		Competes with water for irrigated agriculture and hydroelectric power (-) Enhances recreation and tourism (+)
NS 5 Controlled burning and flooding	//////////////////	Potential health hazard (-)		Limits development in forests and flood plains (-)
NS 6 Prevent ecosystem fragmentation	//////////////////			Limits development in forests and flood plains (-)
NS 7 Restore riparian flood plains	/////////////////			Limits riparian and flood plain development (-)
NS 8 Reduce nutrient runoff into estuaries	/////////////////			Limits agriculture and aquaculture (-)
NS 9 Natural coastal armoring vs. sea level rise and storm surges	/////////////////	Enhances public safety (+)		Limits coastal development (-)
HS 1 Local self-sufficiency in food, energy, and health services		////////////////////		Enhances local work force and local economy (-)
HS 2 Preparedness reduces future costs		////////////////////		Good for future economy (+)
HS 3 Public health surveillance system		////////////////////		Enhances viability and resilience of work force and economy (+)
HS 4 State rainy day fund		////////////////////		Good for future economy (+)
BS 1 Improve building durability to withstand extreme weather		Enhances public health and safety (+)	///////////////////	Reduces insurance costs (+)

BS 2 Stop building in hazard areas		Enhances public safety (+)	////////////////////	Reduces insurance costs (+)
BS 3 Expand road culverts, reduce forest roads, and enhance storm run-off protection	Protects rivers from sedimentation and forests from mudslides (+)	Protects municipal water quality (+)	////////////////////	Reduces insurance costs (+)
BS 4 Reduce site disturbance for new construction	Protects ecosystems and species (+)		////////////////////	
BS 5 Energy and water efficiency	Reduces green house gas impacts (+)	Improves air quality (+)	////////////////////	Reduces business costs and reduces wealth export (+)
BS 6 Renewable distributed energy systems	Reduces large generation impacts on ecosystems (+)	Reliability enhances public safety (+) Improves air quality (+)	///////////////////	Reduces business costs from outages (+)
ES 1 Environmental and social externality pricing	Reduces environmental impacts of fossil fuel burning (+)	Improves air quality (+)	Reduces acid deposition on buildings (+)	/////////////////////
ES 2 Innovation	Leads to lighter environmental foot print (+)	Provides local employment (+)	Improves building materials and design (+)	/////////////////////
ES 3 Environmental justice		Prioritizes most vulnerable populations in emergencies (+)		/////////////////////
ES 4 Intergenerational equity	Protects ecosystems for enjoyment of future generations (+)	Enhances well-being of future generations (+)	Improves durability and efficiency of new buildings (+)	/////////////////////

Chapter 1

Framework for Preparing Natural Systems for Climate Change

1.1 Goal

The goal of climate change preparation and adaptation for natural systems is to provide a consistent framework for preparing ecosystems and biodiversity to withstand and adapt to climate change impacts. Natural systems should be prepared for the critical ecological functions they provide for other organisms, for humans, and for their own intrinsic values. In preparing for climate change the primary objective should be to maintain and improve ecological integrity, key ecological functions and structure that support self-maintaining and adaptive natural systems as well as sustainable human systems. The challenge is to maintain desired properties while they are under added stress due to climate change. Existing decision-making bodies such as federal and state land management agencies, cities, counties, and non-profits should be capable of integrating this framework into their programs. New entities, like the State of Oregon Climate Change Commission, should be able to use it to guide their efforts.

1.2 Need

Global warming is likely to produce significant changes in Pacific Northwest ecological systems and biodiversity. The most readily understood effects of climate change include temperature increases and greater fluctuations in moisture availability, which have important influences on the distribution, growth and reproduction of plants and animals and their habitats. Many native species are already showing discernible changes consistent with temperature increase (Root et al. 2003, in Burkett et. al.2005). For example, "many North American trees are coming into leaf earlier, grasses and forbs are flowering earlier, and abundance of many insects is peaking earlier, and some birds and butterflies are migrating earlier." (Burkett et al. 2005)

These observations indicate that changes in temperature and moisture availability are linked with intrinsic mechanisms that govern metabolic and reproductive processes. However, non-linear phenological responses to climate change may also occur. Such responses may trigger changes in morphology and behavior of organisms, such as a "decoupling of organisms from their food sources, a disruption of symbiotic or facilitative relationships among species, and a change in competition among species." (Burkett et al. 2005). Non-linear responses may "more often be the rule rather than the exception in biological systems." (Hilbert, 2002 in Burkett et al. 2005). Despite the general veracity of these observations, projections specific to the Pacific Northwest are still to some degree uncertain and will require more data and analysis.

1.3 Time Frames

Longer time frames (50 to 100 years) will be needed for addressing climate change than most existing planning efforts take into account, but decadal time steps will also remain helpful to capture standard population counting and other processes. Even annual and seasonal time steps may be important; however, over time scales of less than a decade, normal variability in climate is likely to be as great as directional climate change. Some scientists argue that the "sweet spot" for prediction may be the decadal scale, which minimizes the near-term uncertainty related to natural variability of climate, and the long-term uncertainty related to not knowing what the emissions will actually be. (Cox et al, Science, July13, 2007, "A changing climate for prediction "Science 317: 207-208). Policy and decision makers have more interest in the shorter term (1-4 years). Temporal specificity will be especially important in order to link natural systems preparation planning to similar efforts in human, built, and economic systems.

1.4 General Principles

Three over-arching principles apply in preparing both terrestrial and aquatic systems for climate change:

1. Adopt a whole systems approach, paying attention to how multiple natural systems (atmospheric, biological, geological, and hydrological) interact.
2. Understand the limits and potential unintended consequences of human intervention.
3. Adopt an adaptive management strategy to allow for experimentation in the face of future uncertainty.

A flexible and responsive adaptive management approach should be coupled with increased monitoring and, in some cases, active intervention. Examples of active intervention may include assisted migration of stressed species, reintroduction of species, controlling invasive species, non-chemical control of pests and plant diseases, controlled burning, and taking species out of environments where extinction is inevitable.

1.5 Terrestrial Ecosystem Management Principles, Strategies, Policies and Data Gaps

Unique challenges confront land managers due to the rapid environmental changes taking place across the landscape. One challenge is to determine the relevancy of existing reserves that had been determined based on conditions that may no longer persist as habitat becomes modified by rising temperatures, reduced precipitation, and other changes. Another challenge is determining how to ensure species migration to more suitable habitat without compromising the food chains, territorial occupation, and other complex relationships among species and populations.

1.5.1 ***Principle Number One:*** *Maintain* ***diversity*** *of native species, genes, and ecosystem composition and structure given the uncertainties created by rapid and dynamic climate fluctuations.*

1.5.1.1 *Strategies:* Consider the choices between maintaining existing ecosystems and native species and introducing new ones that are now suitable to the new climate. Scientists caution that new species should only be introduced if located in neighboring

ecosystems with an historic connection to existing ones. As this strategy has potential for unintended consequences, well-defined criteria will need to be established prior to implementation. It should not be attempted on a large scale for many species.
Private landowners and the public will need to be educated about the need for diversity in the face of increasing climate change. East of the Cascades and elsewhere (e.g. SW Oregon), there may be a need for a management strategy to control plant density to levels within water and fire tolerance due to climate change induced drought and wild fire.

1.5.1.2 *Policies:* Land management policies (e.g. Forest Plans, Watershed Plans) should be linked to climate change. Land-use plans may need to be amended to ensure that biodiversity is maintained.

1.5.1.3 Information *Needs:* What are the fundamental relationships between species, functional groups, and ecosystem functions? What are the most vulnerable populations, native species, and ecosystems? What areas need protection to ensure diversity? What are the risks and benefits of the various preparation strategies? How will responses to climate change vary by species and by populations within species? Monitoring and surveillance will be needed to determine how systems are changing with the changing climate.

1.5.2 *Principle Number Two:* *Maintain self-organized ecosystem* ***resilience and resistance****.*

1.5.2.1 *Strategies:* For forest lands a strategy to implement self-organizing resilience is to maintain genomes as functional groups, and maintain forests which have "ecological inertia" favorable to persistence. More restoration should be implemented to buy time in the face of climate change. Modeling using a matrix of emission scenarios and stressors is also advised. Mature forests are better able to withstand large climate-induced disturbances such as heavy rainfall or wildfire. Conversion to even-age plantations should be avoided, and low-intensity forestry should be practiced to minimize soil disturbance and introduction of exotic species. For grasslands and prairies, strategies include landscape-level land use planning, slowing or preventing invasive species proliferation, reducing road impacts, implementing science-based adaptive livestock management, and restoring historical grasslands.

1.5.2.2 *Policies:* Agency policies to maintain resilience include determining the size and location of existing conservation areas or refugia, along with migration corridors and buffer zones, and planning for new reserves suitable for new conditions. It may be necessary to locate refugia in areas that experience less change than others, or that maintain assemblages of past climate regimes such as the Klamath/Siskyou in southern Oregon and northern California. One possibility, as an incentive in forest management, is to link carbon credit programs with strategic placement of reserves. Another possible policy is for development mitigation to be made more consistent with ecosystem protection. For grasslands, grazing subsidies should be reexamined and the public informed about them, and voluntary retirement of public land grazing permits should be encouraged. Non-climate stresses such as upland extraction of water for agricultural and municipal water use, livestock grazing on grassland habitat, and logging fragmentation of forests should be reduced or eliminated if unsustainable based on climate projections.

1.5.2.3 *Information Needs:* Research questions include how to define *resilience*, how to map it, and how to determine the management tools required to enhance resilience.

1.5.3 ***Principle Number Three:*** *Maintain* ***natural disturbance regimes*** *such as recurrent wild fire and flood plain inundation.* A strategy consistent with this principle is to incorporate both small- and large-scale disturbances (fire, flood, wind, and even disease) into routine land management decisions. In order to implement this strategy, agency managers will need to define the balance between human protection and land management. This will require resolving conflicts between residences in forests and flood plains and controlled burning and flooding, for example.

1.5.4 ***Principle Number Four:*** *Maintain* ***connectivity*** *for wildlife interaction with food supply and migration to more suitable habitat under new climate conditions.* Consistent with this principle, connections should be planned and managed at large scales (watersheds for example). These would provide movement northward and/or to higher elevations for species seeking cooler temperatures. Land-management agencies will need to adopt policies that ensure permeable landscapes between reserves.

1.5.5 ***Principle Number Five***: *Linking forest management with sustainable* ***carbon-neutral energy planning***. It has been determined that Pacific Northwest forests are the best carbon sink in the world per acre (Turner et.al. 2007). They also provide an opportunity for carbon-neutral power generation in the form of burning forest-thinning residues as a boiler fuel. The small trees or woody debris used for fuel have sequestered carbon over their life time; therefore burning them as boiler fuel is a carbon-neutral method of energy production over the time span of the trees and wood. Grasslands and prairies are also an excellent carbon-sink. They store more carbon than croplands, and may be preferable to forests in drought prone areas.

1.5.5.1 *Strategies:* Quantitative forest management tools should include modeling climate change as a direct input and carbon as an output. Scenario analysis, a range of emissions based on the Intergovernmental Panel for Climate Change (IPCC), linked to a range of temperatures, will produce projections of alternative future ecosystems and native species responses.

1.5.5.2 *Policies:* New policies can provide sequestration incentives, and land-use amendments and better enforcement may expand forested lands and sequestration. Marginal agricultural lands may become forest lands. One caveat is the need for a better understanding of the tradeoffs involved in managing for carbon sequestration. Dense stands of trees, particularly east of the Cascades, cause more transpiration, depleting already stressed water tables, and more trees may lead to higher intensity fires.

1.5.5.3 *Information Needs:* Biomass energy production, as an alternative to fossil fuel electric power generation, is a promising strategy for reducing carbon emissions. More research is advised on the impacts of small-scale biomass energy production on forest ecosystems. Some fear that the practice might produce an unsustainable and ecologically harmful demand for material in a specific locality.

1.5.6 ***Principle Number Six: Complementarity*** *captures the co-benefits that climate change preparation strategies will create by improving wildlife habitat, water quality, carbon storage, and other ecosystem "services."* Creating these co-benefits also reduces the costs of restoration, and acting in the short run avoids more expensive and more challenging efforts to restore deteriorating landscapes and habitats in the more distant future.

1.5.7 ***Principle Number Seven: Equity*** *should be adhered to across generations, among human communities and between human and natural systems.* . Intergenerational equity acknowledges that past and present generations bear the responsibility for climate change impacts on natural systems occurring today due to the emissions they produced but future generations will be bear most of the burdened with coping with the impacts of these emissions. The current generation therefore has the responsibility of reducing its greenhouse gas emissions to stabilize the climate while also preparing natural systems to withstand and adapt to climate change. Environmental justice requires recognizing that low income persons, and persons with other limitations, are certain to disproportionately experience the effects of environmental degradation through outcomes such as poor drinking water, landslides, and increased disease. Equity among human and natural systems recognizes that it is human action that is the primary cause of climate change, not the activities of other species that do not control their own destiny and have limited capacity to adapt.

1.5.8 ***Principle Number Eight: Uncertainty*** *requires recognition that it is best to act on less than complete knowledge, which is the case in making climate projections.* The costs, benefits, and risks of certain actions or inactions within a range of climate scenarios can be reasonably calculated. One significant uncertainty is the political and regulatory commitment to reduce green house gasses to avoid extreme climate impacts.

1.5.9 ***Principle Number Nine: Humility*** *requires recognizing that interventions to prepare ecosystems for climate change should be informed, limited, and strategic.* Managers should understand that natural systems have some innate capacity to adapt. As a matter of policy, interventions that cause more problems than they solve should be avoided.

1.5.10 ***Principle Number Ten: Abundance and redundancy*** *will spread the risks of habitat loss due to climate change spatially across landscapes*. Allowing populations to decline and ecosystems to become fragmented will put natural systems under greater risk, given climate and other stressors such as land development, roads, and invasive species.

1.6 Aquatic and Marine Ecosystem Principles, Strategies, Polices, and Data Gaps

Four principles stand out for preparing aquatic and marine ecosystems for climate change. Although these principles share common elements with those identified by terrestrial scientists, they differ in methods and strategies for implementation.

1.6.1 ***Principle Number One:*** *As with terrestrial systems, the over-arching principle is maintaining **ecosystem function, composition, and structure**,* Adhering to this principle maintains the species diversity and integrity necessary for aquatic and marine ecosystems to withstand climate change impacts such as more intense storm events, higher water temperatures, and sea level rise and higher salt concentrations for marine systems and estuaries.

1.6.1.1 *Strategies.* Strategies consistent with ecosystem function and composition include maintaining refugia and protected areas, avoiding stream channelizing and fixing past mistakes, and linking rivers and flood plain restoration to bordering wetlands. These actions will also provide increased water storage during anticipated periods of drought. Marine reserves should be designed to provide cold spots, maximize topographical relief, and provide for pole ward movement with migration corridors between reserves. Marine reserves should be managed adaptively to account for uncertainty around climate impacts on the marine environment. By maintaining breeding stocks, marine reserves also contribute to food security.

1.6.1.2 *Policies.* Policies consistent with the ecosystem structure and function principle include reducing or eliminating invasive species expected to flourish with higher CO2 concentrations. Transportation development mitigation policies should provide for better replacement of disturbed function with a similar function; wetlands that provide habitat for the particular species affected by the road development as an example. Policies should make explicit the need to consider carbon storage in preparation measures, such as those that retain vegetative cover.

1.6.1.3 *Information Needs:* How can wetlands and floodplains serve ecosystem needs and accommodate human development at the same time? How do elevated CO2 concentrations affect water use efficiency of different species? How does climate change induced wild fire impact ecosystem structure and function?

1.6.2 ***Principle Number Two:*** *Maintaining **natural flow regimes** to provide sufficient water quantity, water quality and cooler temperatures for aquatic species.* This principle is increasingly important given the higher temperatures and periods lower summer flows and drought projected for the future. A strategy consistent with this principle is to use the natural floodplain for water storage, and retain upland wetlands for the same purpose. There is a need for better enforcement of existing wetlands law, and accounting for both surface and groundwater in water permitting. Vegetation and hydrological modeling will be needed to predict changes in terrestrial vegetation and river discharge.

1.6.3 ***Principle Number Three: Connectivity between refugia****, and between refuges and habitat.* This may require policies that amend land-use codes and require further limitations on development. More research may be needed on the consequences of all land-use policies and decisions in the context of climate change.

1.6.4 ***Principle Number Four:*** *Maintaining* ***disturbance regimes*** *such as frequent flood plain inundation.* This will ensure the dynamic river and streamside interaction necessary for nutrient and sediment interception. It will also contribute to the maintenance of a diverse and vital riparian area.

1.6.5 ***Principle Number Five: Chemical health and integrity*** *of freshwater, marine and estuarine regimes.* This is needed to eliminate endocrine disrupters that are damaging to both vertebrates, shellfish, and crustaceans. Marine coastal ecosystems are already subject to stresses from non-climate impacts from commercial fisheries, aquaculture, development, tourism, noise and light pollution, oil spills, industrial and shipping dumping, pesticides, and fertilizers. One strategy is to reduce nutrient laden runoff into estuaries (for example, limiting dairy farm runoff into Tillamook Bay). Agency policies that maximize use of natural coastal geomorphology rather than artificially constructed jetties should be adopted to better protect shorelines against sea level rise and storm surges. Research will be needed on viable approaches to coastal armoring.

1.6.6 ***Principle Number Six:*** *The principle of* ***complementarity*** *should be followed to ensure that efforts to prepare aquatic and marine systems for climate change do not undermine or have unintended consequences for other aspects of natural systems as well as built, human and economic systems.*

1.7 Issues to Be Resolved

Certain issues, some specific to the Pacific Northwest and others dealing with climate change preparation in general, require thoughtful analysis and more research,

1.7.1 Increasing connectivity among ecosystems is typically viewed favorably in conservation biology, but may at the same time increase the spread of pathogens and wildfire given the added stress of climate change. Climate change effects in other areas may increase pests and pathogens in the Pacific Northwest through wind or commercial transport. The tradeoffs between maintaining connectivity and protecting native species from invasive species will require further research and resolution.

1.7.2 Fires are a natural part of many Pacific Northwest ecosystems, but they transport carbon from the land (storage) to the atmosphere (dynamic). They also provide the disturbance necessary for vegetation to track or respond to changing climate through succession. The tradeoffs between natural fire and carbon emissions will need further research.

1.7.3 Decadal projections are the norm in climate modeling and the best game in town, but their reliability, while favored by some, is disputed by others.

1.7.4 Some regional impacts, such as precipitation changes and sea level rise, are currently not well understood and therefore difficult to predict; therefore, management practices should be robust to a range of possible scenarios.

1.7.5 Some scientists believe that climate models won't work well when setting priorities for specific organisms; others contend that conceptual models are essential when dealing with projected responses to novel environmental situations. More research is needed to identify the best method of projecting species-specific impacts.

1.7.6 Some current communities, alpine communities for example, are likely to disappear. Are we trying to manage for a different future? If so, do we know enough to design for that future, or do we just manage for resiliency? Does classic conservation biology work in the climate change context?

1.7.7 Mature forest trees, especially Douglas fir, are fairly adaptable to climate variations. However, longer, drier summers will increase vulnerability to fire, and it may be more difficult to regenerate forests under future climate scenarios because seedlings are more vulnerable to stress than are mature trees. Should Douglas fir and other commercial timber cultivation in certain more marginal and stressed locations be maintained under a new climate regime?

1.7.8 Climate change will exacerbate non-climate stressors like non-sustainable timber harvest, road construction, and over-grazing. To what extent should these activities be further reduced under various climate change scenarios?

1.8 Contributors and Interested Parties

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Chapter 2

Framework for Preparing Human Systems for Climate Change

2.1 Goal

The goal of climate change preparation for human systems is to provide a consistent framework for preparing public health, social service and emergency management and safety managers to respond effectively to a changing climate. It is also important to understand how activities aimed at preparing human systems for climate change may affect similar efforts for natural, built, and economic systems. Fire fighting or forest thinning to reduce the risk of fire, for example, may have significant implications for preparation planning within natural systems. Similarly, construction of water storage facilities to cope with diminishing municipal water supplies in drought prone areas will exacerbate competition with water for farm irrigation or stream flows for threatened fish species.

2.2. Need

Human beings are highly adaptable and able to survive extreme heat, cold, storms, and seasonal variations in weather. But the climate of the past will not be the climate of the future. Those poor, disadvantaged and elderly are most vulnerable to heat–related stress, disease, impacts of forest and grassland fires and other climate change related stresses. Climate change will therefore present serious challenges for the public health, emergency response, housing, and food delivery systems. There will need to be a concerted effort to improve awareness and education for health professionals, and to expand health services to the public to prevent and treat new climate related illness.

Climatic conditions have wide–ranging impacts on human health, including heat stroke (a particular risk for the elderly), diseases and allergies. Enhanced public health measures will be needed to reduce or prevent completely heat related illness and death, including information for older persons on coping with heat and assistance to low-income persons living in poorly ventilated housing. Redesign of buildings may be needed to reduce heat absorption and retention. The urban heat island effect can be reduced with more parks, ponds, open spaces, and roof gardens. Building design and land-use planning is also important to reduce the impact of injury and death from heat waves and intense storms.

2.3 Most Vulnerable Populations

The most vulnerable populations are as always the poor, elderly, infants and children, and persons residing in hospitals and state and local institutions. Other persons that may be more difficult to serve during climate-related emergencies such as fires, floods or storm surges are populations in areas distant from food supply, persons disconnected from state systems, persons without English language skills (for example, climate refugees), persons in areas prone to power outages, persons dependent on prescription drugs and other pharmaceutical needs, persons with drug and alcohol problems, and persons prone to mental illness.

Low-income persons are affected disproportionately by climate change impacts. They tend to live in the more affordable properties of a given community that already experience poor air quality and are prone to flooding and fires. As temperatures increase, air quality degrades and heat-related illnesses, including those borne by increasing pests and vectors, also become more frequent. The poor often have difficulty getting access to medical services due to affordability and/or lack of private vehicles. They tend to lack adequate public health and safety information, such as should be provided by a public health surveillance system that tracks climate-related disease and other health impacts and communicates the information to all segments of the population. They also often lack health care, homeowner, decent auto insurance and other safety nets which makes it much more difficult to recover after a crisis.

2.4 Principles, Strategies, Policies, Data Gaps and Monitoring

A number of climate change preparation principles have been identified to guide development of methods and strategies, policy actions, and to fill data gaps associated with implementing a climate change preparation plan.

2.4.1 ***Principle Number One:*** *An overarching principle is the reduction of risk to human populations through* ***prevention and preparedness****.* Because climate change poses serious threats to the state's human service systems, and because it is not possible to know in advance when significant impacts will occur, preparation planning should begin as quickly as possible. Impacts can be prevented or mitigated by assessing potential vulnerabilities, and developing plans to increase resiliency by enhancing capacity, flexibility, and response before major impacts occur. Prevention will be much less costly than repairing damage to systems and structures after impacts occur.

2.4.1.1 *Strategies:* Methods to implement prevention should include a public health surveillance system, educating the public health workforce in response strategies, and developing climate change plans at all levels including the local level.

2.4.1.2 *Policies:* State policies to support prevention planning should include funding for scenario planning and preparedness that identifies a range of potential impacts and associated preparation strategies. A state rainy day fund should be established by the legislature. State land-use goals (coast and energy, for example) should be amended to better address climate change impacts such as expansion of flood plains, hazard areas, and carbon sequestration in forests, and model climate change plans should be developed for use by local governments. Finally, climate change should be placed on Oregon's priority funding list.

2.4.1.3 *Information Needs:* Robust preparation planning will require more study of the links between climate change and health, a tracking system for climate-related diseases including infectious water-, food-, and vector-borne disease outbreaks, and better data on climate-related pathogens and allergens. There will be a need for environmental refugee data and trends.

2.4.2 ***Principle Number Two:*** *The principle of* ***environmental justice calls for*** *governments and social service agencies to assess the needs of those with a low capacity to cope with the impacts of climate change because they are already under stress or are disadvantaged.* This applies particularly to the poor and low-income families, elderly, infant and juvenile populations, as well as those who are residents of state or county institutions. Hurricane Katrina and other catastrophic weather events, have demonstrated that the poor, the elderly, and the hospitalized are particularly vulnerable to climate impacts. These persons tend to live in the more affordable areas of a given city or rural jurisdiction that are more prone to flooding and poor air quality, both exacerbated by climate impacts. The poor also tend to lack affordable access to medical services and private transportation in the event of emergencies. They tend to be more susceptible to vector and pest borne diseases, all more frequent with increasing temperatures and flooding events.

2.4.2.1 *Strategies:* Implementing environmental justice will require fairness in the allocation of resources when responding to climate change, such as an equitable allocation of funds for mapping and creating defensible spaces from fires and coastal storm surges. A priority system may be needed based on credible assessments to identify the most vulnerable persons in different situations or climate impact events, removing language and other cultural barriers, and coordinating with tribal entities.

2**.4.3** ***Principle Number Three:*** *Due to the long-term trends of climate change, coursing over decades and even centuries, climate change strategies and policies must consider the principle of* ***intergenerational equity****.* Since the causes of climate change are rooted in large part in the activities of past and present generations, and due to the enormous inertia in atmospheric and ocean systems, the impacts of climate change will affect future generations more than those who have caused the problem due to action or inaction in the past.

2.4.3.1 *Policies:* A policy to implement intergenerational equity should be for governments at all levels to fund and implement climate action planning as soon as possible.

2.4.4 ***Principle Number Four:*** *Creating* **resiliency** *should be the overriding goal of climate preparation planning* . Resiliency is the capacity for individuals and communities to withstand and fully recover from the numerous, sometimes cumulative, impacts of climate change such as extreme weather events, fires, infectious disease outbreaks, or forced migration due to sea level rise.

2.4.4.1 *Strategies:* Resiliency can be enhanced by means of long-term recovery and post-disaster work-force assessments, and by incorporating redundancy and diversity into climate action plans. An example of diversity and redundancy is providing on-site distributed power generation in rural communities and on-site at health facilities in the event of power outages during storm events. Resiliency will require the capacity of local communities to be self-sufficient for food, shelter, and clothing in extreme weather events.

2.4.4.2 *Policies:* The value of climate change action planning can be enhanced by incorporating climate action into existing strategies and programs. Climate change preparation and mitigation through reduction of greenhouse gasses both contribute to existing sustainability initiatives. Existing Rural Development Initiatives can incorporate climate-related economic measures such as new and more suitable crop selection.

2.4.4.3 *Information Needs:* Data related to the drought and temperature tolerances of specific farm and forest crops will be needed. Self-sufficiency assessments should be part of local climate plans including acquiring data on stores of water, food, crops, and energy resources.

2.4.5 *Principle Number Five:* *The **public's need for reliable information** about climate change impacts, vulnerabilities, and coping strategies is paramount.*

2.4.5.1 *Strategies:* One strategy for public information and communication will be to hold climate change scenario workshops tailored for local climate regions. These would include providing projections on the potential costs of specific impacts and preparedness measures.

2.4.5.2 *Policies:* An ongoing and comprehensive climate education program should be implemented, and a politically neutral message tailored for different audiences should be designed. Economic impacts should be identified and highly impacted businesses and trade sectors should be targeted. A climate teacher-training curriculum should be implemented in all school districts, local messengers should be empowered, and OSU extension service should engage forest and farm communities. The Local Government Advisory Council, League of Oregon Cities, Association of Oregon Counties, Oregon Business Council, and the Oregon Volunteer Organizations Active in Disasters should engage in this educational effort.

2.4.6 *Principle Number Six:* *The principle of **complementarity** should be followed to ensure that efforts to prepare human systems and services for climate change do not undermine or have unintended consequences for natural, built and economic systems.*

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Chapter 3

Framework for Preparing Built Systems for Climate Change

3.1 Goal

The goal of climate change preparation planning for built systems is to provide a consistent framework for designing and siting buildings and public infrastructure to withstand and adapt to climate change.

3.2. Need

All buildings, and all transportation, energy, water and communication infrastructure are directly vulnerable to climate change. Projections of increased storm activity mean that the impact could be severe, particularly if intense weather events occur where buildings and infrastructure are not designed for them. Structural fatigue and greater demands on construction durability, storm drainage and other factors may result from longer periods of heat, wind, and rainfall.

3.2.1 Coastal regions are especially at risk, with higher sea-levels and more frequent and more extreme storms likely to impacting bridges, roads, culverts, ports, industrial infrastructure and residential and commercial housing. Coastal land-use planning and management will need to address revisions in development zoning. The risk of structural damage will need to be reflected in rate calculations by the insurance industry. Design standards that are usually based on historical climate records may need to be revised. Building codes based on 1 in 100 year storm events may need amending given the likelihood of more frequent and severe storm activity. Pressure to abandon Oregon's moratorium on the construction of sea walls and rock buffers may result as coastal residents and businesses seek more protection from storm erosion and sea level rise.

3.2.2 East of the Cascades higher temperatures and reduced snow pack will likely reduce water storage for irrigated agriculture, fish, and summer hydroelectric power. West of the Cascades, reduced snow pack and earlier run off may reduce water storage for urban areas in populated areas such as the Willamette Valley.

3.3 Time Frames

A 50-year time frame is appropriate since buildings and public infrastructure are usually designed to last at least 50 years. Hydroelectric dams are relicensed at intervals of 50 years for the same reason.

3.4 Vulnerabilities

After identifying the most vulnerable components and aspects of the built environment, building experts consulted for this document recommend a triage approach to preparation planning in order to set priorities assuming limited preparation investment funding. They identify three categories of building vulnerability: 1) catastrophic failure due to extreme storm (wind, flood, soil erosion) or fire events; 2) long-term failure such as thermal stress, moisture and insect damage; and 3) economic failure due to unmanageable increases in energy, water, or insurance costs.

3.4.1 According to experts in building design and construction, particularly vulnerable are buildings with extensive east-west glass given higher summertime temperatures, and commercial buildings with high internal gain due to heating, high occupancy, and extensive lighting. Also vulnerable are buildings located in drought prone areas, particularly east of the Cascades, which would be competing for scarce water, aquifer recharge, and requirements for fire suppression water storage. Buildings in urban areas will be under increasing stress from the urban heat island effect. Multi-family apartment buildings, ironically sometimes constructed to accommodate climate refugees, will be particularly susceptible to heat impacts. These same buildings also tend to be occupied by the poor and the disadvantaged. Endangered species act requirements, elevated due to projected species extinction threats due to climate change, and other steps to prepare natural systems for climate change, would further restrict building development, particularly in rural areas.

3.4.2 Public infrastructure experts identify vulnerabilities in three categories: energy, water and sanitation, and communication and transportation. Public infrastructure includes gas and electric power, water and communication utilities, roads and railroads, port facilities, wireless towers, and dams and reservoirs for flood control, municipal and irrigation water storage.

3.4.2.1 Energy facilities are especially vulnerable to heat and drought. Oregon's only coal fired power plant, located east of the Cascades, is less efficient at higher temperatures, as are Oregon's numerous natural gas fired power plants and even photovoltaic solar systems. Power lines experience higher losses at higher temperatures and will expand and sag into foliage causing grid outages (as occurred in 1996 in northwest Oregon). Heat stress will cause increasing depreciation of power generation facilities. Drought and reduced snow pack will diminish hydroelectric power reservoir storage, putting additional stress on the power system with increasing summer air conditioning demands and irrigation pumping demands. Wind energy systems may be adversely affected by rising temperatures that shift wind patterns, or they may benefit. Finally, there will be a higher risk to energy infrastructure, power and telephone lines and rural substations due to increasing wildfires.

3.4.2.2 Municipal water storage and waste water treatment facilities will be under increasing demands due to drought, higher temperatures and evaporation, and coupled with increasing population pressures. There will also be less pervious surface for groundwater recharge with increasing development, and lower water tables in drought-prone areas. Pumping costs and water rationing and the potential for water pricing will increase the delivery costs of water and water treatment to consumers.

3.4.2.3 Transportation facilities will be impacted by an increasing number of extreme storm events, wildfire, and slow but sure sea level rise. Low stream flows in the summer on the Columbia River will present shipping challenges for the Port of Portland. Winter storm surges will cause shipping challenges at the Columbia bar and for the commercial fishing ports along the coast.

3.5 Principles, Strategies, Policy Actions, and Information Needs for Buildings

A number of principles are identified to guide development of preparation strategies, set local and state government climate policies, and identify research and monitoring needs for the reinforcement, design, construction and siting of buildings.

3.5.1 ***Principle Number One:*** *The first over arching principle is* ***human safety****.*

3.5.1.1 *Strategies:* New buildings will need to be designed with features to provide greater structural integrity to cope with new climate factors such as heat stress, increased cooling demands, intense wind and rain, and storm water management. There will be a need to use materials designed for greater durability. There will be a greater demand for external fire protection, both in materials and using vegetation management. Multi-family and commercial high-rise buildings will need to be designed to mitigate the stairwell chimney effect which funnels heat to upper floors. Low-income, elderly, and infants are particularly vulnerable during heat storms and concurrent power outages. The World Bank has estimated that in hurricane prone areas building losses can be reduced by one-third with an investment of just 1% of the structure's value (USAID, "Adapting to Climate Variability and Change," 2007).

3.5.1.2 *Policies:* The best and most efficient approach is to avoid hazardous areas in the first place through effective land-use regulation, expanded flood plain designations to account for sea level rise and increased flood events, wild fire, and drought. Existing buildings, many grandfathered under revised building codes, may need upgrading to new performance standards for hazards in flood plains, steep slopes, windy and fire-prone areas.

3.5.1.3 *Information Needs:* There will be a need for better information on the condition of existing buildings and their capacity to withstand climate-related impacts. There is a need for better local information on projected day and night time temperatures.

3.5.2 ***Principle Number Two:*** A second principle experts label ***"building ethics"*** and it encompasses both intergenerational equity and "information transparency."

3.5.2.1 *Strategies:* A building constructed to last fifty years and more will be passed on to future generations and climate change impacts are long-term, over decades and even centuries. Past and present generations bear a large measure of responsibility for causing climate change, but future generations will experience the greatest impacts. Buildings should be built to not only endure projected impacts but also, since future upgrades or replacements will likely by more costly, the costs of construction to endure climate impacts should not be borne solely by future generations.

3.5.2.2 *Policies:* State and local building codes should require opening a building's "black box" to provide full disclosure of building performance and structural parameters, and a transfer of property should be accompanied by a disclosure of performance standards between contractor and client or buyer and seller.

3.5.2.3 *Information Needs and Monitoring:* A climate change research agenda should include better building monitoring and performance data, and research on how to teach owners to make better use of the building in real time. At a minimum, building operations should be archived, construction documents should be disclosed, and a maintenance manual made available to owners. This should apply to all residential, commercial, and industrial buildings.

3.5.3 ***Principle Number Three:*** *A third principle is* ***flexibility and adaptability****, important given expected climatic changes over the life of the building.* This principle invokes a need for designing for multiple uses, loose fit, disassembly, and recyclability both to adapt to rapid changes and conserve scarce material and energy resources. Design parameters should be widened to account for greater extremes of both temperature and precipitation.

3.5.4 ***Principle Number Four:*** *A fourth principle is achieving an integration* ***of technical considerations on the one hand and social and aesthetic considerations on the other****.* This applies to both the building itself and the building site.

3.5.4.1 *Strategies:* Green building and sustainability principles should be incorporated in materials and operation. Buildings should be sited close to services and work to reduce transportation impacts. Site disturbance should be mitigated to protect natural systems and provide natural buffering against temperature and precipitation extremes.

3.5.4.2 *Policies:* Local communities should be engaged directly or by polling to determine aesthetic preferences, and to communicate why climate related adaptations may trump traditional aesthetic considerations. Land-use code changes will be required to capture transportation efficiencies and environmental protection in siting.

3.5.5 ***Principle Number Five:*** *A fifth principle is that of* ***water and energy efficiency and redundancy*** *for both green house gas reduction purposes and reliability during extreme storm events and heat waves.*

3.5.5.1 *Strategies:* A number of water and energy efficiency strategies are available including providing more natural ventilation, green roofs to combat the urban heat-island effect, night time ventilation of mass, impounding building runoff with cisterns and bioswales, more outdoor living spaces such as patios, decks, and terraces, and photochromic surfaces which reflect sunlight with warm temperatures and absorb heat with cold temperatures.

3.5.5.2 *Policies:* Local and state policy formulations include requiring better consumer and builder information, carbon reduction feebates for contractors and/or building owners, a recommissioning process for existing buildings, building code upgrades, and more monitoring and research on the carbon footprint of buildings. To achieve both greenhouse gas reduction and a higher degree of reliability state tax and utility incentives should be implemented or maintained for the deployment of distributed renewable energy systems such as wind, solar, and geothermal. These will reduce a building's carbon footprint and provide power in the event of outages during heat waves or storm events.

3.6 Principles, Strategies, Policies and Data Gaps for Public Infrastructure

Experts express some concern about the difficulty of projecting site-specific climate impacts, and recommend adopting the scenario planning process used by the Intergovernmental Panel for Climate Change (IPCC) and scaling impacts down to the regional, state, and local levels based on a range of temperature increases. The new Climate Change Research Institute may need to research and provide more data on locational-specific impacts.

3.6.1 ***Principle Number One. Public safety*** *is paramount.*

3.6.1.1 *Strategies:* Strategies should include limiting infrastructure in high risk areas subject to storm damage, sea level rise, or wild fire through land-use code changes. Existing activities, roads or railroads for example, may have to be moved from high risk areas, or discontinued altogether once impacts occur.

3.6.1.2 *Policies:* The existing Oregon state Big Look Task Force should examine current state land planning goals to determine how climate change might be incorporated into state and local land-use planning. More financial incentives and flood and fire insurance adjustments should be implemented to encourage safe siting. Existing planning for a 100-year flood event may no longer be relevant.

3.6.1.3 *Information Needs:* Research and informational needs include updating flood plain maps, determining rain/snow transition zones, data on changes in river hydrology and frequency and intensity of storms, impacts of sea level rise on coastal infrastructure, and the impact of wild fires on rail systems, power lines, and roads.

3.6.2 ***Principle Number Two:*** *A second principle is* ***integrating natural systems*** *with infrastructure and site planning.* A particular need on the coast is to identify how sand supply is affected by climate change impacts such as sea level rise and storm surges on the one hand and public infrastructure including harbor protection such as jetties on the other.

3.6.3 ***Principle Number Three: Energy efficiency*** *should be deployed throughout all public infrastructure.* The national mayors' agreement on energy efficiency in public buildings should be adopted.

3.6.4 ***Principle Number Four:*** *The principle of* ***complementarity*** *should be followed to ensure that efforts to prepare built systems for climate change do not undermine or have unintended consequences for natural, human and economic systems.*

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Chapter 4

Framework for Preparing Economic Systems for Climate Change

4.1 Goal

Climate change preparation for economic systems is the development, funding, and implementation of governmental, community, and private business sector plans for the purpose of ensuring continued economic prosperity and security in the face of changing climate conditions. It is important to make a distinction between preparation and adaptation on the one hand, and mitigation, the reduction of green house gasses, on the other. While successful personal, business, and governmental greenhouse gas reduction strategies will reduce the severity of the impacts and the degree to which preparation is required in the long term, mitigation policies will primarily affect the climate in 30 to50 years. Preparation will be needed until the climate is stabilized, which will take centuries and even longer due to the inertia from ocean warming and lingering concentrations of green house gasses in the atmosphere.

4.2 Need

The projected direct and indirect impacts and consequences of climate change in the Pacific Northwest threaten the viability of our economic system as a whole and certain sectors and regions in specific. Higher temperatures, sea level rise, increased winter storm activity, reduced snowpack, summer drought significant change in our economic systems over the next fifty years and beyond. Observed impacts such as drought and increased storm surges over the past fifty years are already causing damage to forests and coastal infrastructure, and these impacts will almost certainly grow in the future. Economic impacts occurring elsewhere in the West, such as stresses to the power grid due to storm events and heat waves, are likely to impact the Northwest even when the region itself does not experience those same events.

4.2.1 The Pacific Northwest's agricultural wealth is impressive, yet it is also highly vulnerable to climate impacts. Most valuable Oregon crops, ranking from first to fifth in production nationwide are plums, Christmas trees, cherries, onions, hops, berries, herbs, potatoes, pears, grass seed, crabs, grapes, and hazelnuts. The most sensitive to climate changes are pears, grapes, and hazelnuts. Warmer dormant periods lead to pest and pathogen infestation. The forest trade is also concerned about impacts of disease and pests. Agricultural experts acknowledge that crop studies and water availability have not been integrated into possible climate scenarios.

4.2.2 Experts agree that the Pacific Northwest has the advantage of climate zone diversity, and some conclude that climate impact studies can be downscaled to a relatively fine resolution. One issue is whether or not to adopt a scenario approach based on a range of greenhouse gas emissions and selection of best crops, or rather let farmers experiment because of the uncertainties inherent in predictions based on these scenarios. Another question is whether or not to take advantage of the globalization of agricultural trade, or to opt for a self-sufficiency path, which will reduce transportation-related emissions and other risks. Finally, an unknown impact of climate change is the potential for increased labor force due to climate refugees from highly impacted areas of the world immigrating to the Pacific Northwest.

4.2.3 The U.S. Government Accounting Organization (GAO) recently admonished its principal land management agencies for not incorporating climate change preparation into their strategic plans and management actions, and for focusing on the short-run. Like this report, it based its findings on the views of scientists, economists, and resource managers. Similar conclusions could be drawn for state and local government agencies, as well as the private sector in the Pacific Northwest: few have yet to meaningfully incorporate climate change preparation into their plans and activities.

4.3 Time Frames

A 50 to 75 year frame is appropriate since buildings and public infrastructure are usually designed to last at least 50 years. Hydroelectric dams are relicensed at intervals of 50 years for the same reason.

4.4 Principles, Strategies, Policies, and Data Gaps

The following principles strategies, policies, and data needs will guide preparation planning for businesses in the Pacific Northwest.

4.4.1 ***Principle Number One:*** *The primary over-arching principle is to take a* ***"whole systems" approach*** *to climate change including identifying trade-offs, unintended consequences, and impacts of actions between and among sectors.*

4.4.1.1 *Strategies:* One strategy for implementing a whole systems approach is to let market forces play out by allowing prices to drive changes (water pricing during shortages for example, and higher insurance premiums in flood zones commensurate with risk), as long as environmental and societal externalities are reflected in market prices. Most experts agree this is currently not the case. Models should be developed for identifying externalities for different sectors. Distributed energy systems for power reliability during storm events may also provide economic development opportunities in the new clean energy sector of the economy.

4.4.1.2 *Policies:* Increasing property insurance risk should be incorporated into all business decisions. Governments and regulators should adopt policies and provide tools for quantifying climate change externalities, the costs to society at large caused by the green house gas emissions of a few sectors or specific activities. This can be accomplished by regulators requiring utilities to include a carbon adder in their charges for fossil fueled power generation. Water resource agencies should consider an expanded definition of beneficial use, including climate resilience purposes, and the water allocation process should be streamlined. Forestry and energy agencies should clarify policies that would consider both carbon neutrality and the contribution that forest thinning might make to limit forest fire impacts from climate change. These policies would address credits for sequestration of carbon, length of timber harvest rotations, and harvest transportation emissions. Climate policies should be incorporated into existing state, local, and business sustainability programs, and that these preparation and mitigation policies can be linked since greenhouse gas reduction will potentially reduce the severity of climate impacts.

4.4.2 ***Principle Number Two: Innovation*** *is a necessary catalyst in implementing strategies to cope with climate changes.*

4.4.2.1 *Strategies:* This will require investing in education, communications, and other human capacities necessary for innovation. It will require an adaptive management approach in agriculture and forestry so that farmers and foresters can experiment with new techniques and plant varieties. Knowledge-based adaptation will contribute to greater resilience and resistance to climate change impacts. It may also require flexible contracting, avoiding long-term contracts and practices that commit to a fixed path in a changing environment. It may require multiple-use approaches, modifying a recreational resort focused on winter sports like skiing for example to take advantage of summer recreation opportunities like tennis and boating.

4.4.2.2 *Information Needs:* It will require research and disseminating information on drought and temperature tolerant plant species and animal breeds, genetic tools for adaptation (not applicable to food crops), new crop varieties suitable for new local climate conditions, and research on timescales for effective action. Forestry research needs will include data on genetic changes taking place among tree species, data on carbon emissions from wild fires, and local potential and risks of biomass energy development using forest residues. For both agriculture and forestry more research is needed on the link between higher $CO2$ concentrations and water efficiency. Information on impacts to tourism, commercial and recreational fishing, manufacturing, and transportation sectors will also be needed.

4.4.3 ***Principle Number Three:*** *Principles of* ***environmental justice should be followed*** *to identify and protect the most vulnerable groups (the poor, children, the elderly, those living in high-risk locations) and set priorities during climate related disasters to assist these groups* Businesses may be called upon to assist these groups during storm events or more chronic droughts or heat waves by providing access to emergency supplies and volunteer support.

4.4.4 ***Principle Number Four: Intergenerational equity should be a priority****, ensuring that the tax burden to pay for planning and preparation measures falls on current taxpayers who bear some responsibility for their actions or inactions contributing to the more severe impacts that future generations will experience.*

4.4.4.1 *Strategies:* This will require a cost-benefit analysis for climate preparation. It will require assessing the co-benefits of climate preparation actions like energy and water efficiency and reliable, clean distributed power generation to determine appropriate levels of both public and private investment. It will call for educating the public about the economic benefits of climate change preparation as well as its moral imperative.

4.4.4.2 *Policies:* Intergenerational equity also requires the adoption of commercial and industrial buildings codes that provide more efficiency and reduce a building's carbon foot print and also provide for greater structural integrity in extreme weather events. These buildings may be passed on to future owners and may well face more severe challenges than when originally constructed.

4.4.5 ***Principle Number Five:*** *To address climate impact uncertainty, a* ***scenario approach should be used*** *to identify impacts and vulnerabilities based on a range of temperatures and emission scenarios (the Intergovernmental Panel for Climate Change scenario methodology is an example).* A long-range planning horizon of 50 to 75 years will account for the inexorable, long-term increase in climate change impacts. The most vulnerable economic sectors under a range of temperature thresholds should be identified.

4.4.6 ***Principle Number Six: Cooperation and coordination*** *with other states like California and Washington, as well as federal and international agencies is vital.*

4.4.6.1 *Policies:* States should take advantage of emergency planning and preparation funding through the federal homeland security program. States should participate in robust and dynamic international climate mitigation, preparation, and monitoring efforts. Governments should also conduct an inventory of current research and research plans. States can develop a climate change observation and monitoring system, and coordinate data gathering and research with other states in the region.

4.4.7 ***Principle Number Seven:*** *The principle of* ***complementarity*** *should be followed to ensure that efforts to prepare economic systems for climate change do not undermine or have unintended consequences for natural, human and built systems.*

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