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University of Washington

Northwest Regional Clean Energy Innovation Partnership Workshop

Seattle, Washington • August 15, 2016

Northwest Regional Clean Energy Innovation Partnership Workshop Report

HOSTED BY THE UNIVERSITY OF WASHINGTON ON AUGUST 15, 2016

Northwest Region Workshop Planning Team:
University of Washington, Pacific Northwest National Laboratory, Idaho National Laboratory, National Energy Technology Laboratory, Washington State University, Oregon State University, University of Oregon

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Executive Summary

The University of Washington hosted the Northwest (NW) Regional Clean Energy Innovation Partnership Workshop on Monday, August 15, 2016, at its campus in Seattle, WA. Coordinated with regional academic and National Laboratory partners in Washington, Idaho, Montana and Oregon, the workshop brought together ~120 participants from NW universities, National Laboratories, industry, state and federal representatives, non-profit organizations and the investment community. The all-day event was focused on the future of clean energy and ways the NW innovation ecosystem can accelerate the development and deployment of clean energy technologies that meet regional, national and international goals for decarbonization while also stimulating regional economic development and advancing U.S. industrial competitiveness globally.

The event featured presentations by U.S. Secretary of Energy Ernest Moniz, U.S. Senator Maria Cantwell, Washington State Governor Jay Inslee and U.S. Representative Derek Kilmer. Five panels were held during the day with representatives from regional universities, National Laboratories, large and small companies, non-profits and investors, to explore different elements of the Northwest Region's clean energy ecosystem.

The workshop promoted a vigorous discussion on the future clean energy system and the technology innovations, partnerships and policy reforms needed to successfully create it. Several themes emerged from the workshop, which were:

- *The NW region is a natural "all-of-the-above" energy testbed for a deeply decarbonized economy.* The NW has a rich and diverse set of natural resources that gives it a uniquely clean energy profile relative to other regions. The NW's long legacy of electricity production from hydropower forms the backbone of its clean electricity system, which is augmented by strong contributions from wind and natural gas. The NW has a growing demand for distributed solar, wave, and geothermal power, which add to the potential mix of energy sources available within the region. Clean fossil energy is being pursued through Carbon Capture Use and Storage (CCUS) research conducted by universities and National Laboratories within the region. There is a significant testbed infrastructure currently residing in the NW that can be networked, which includes the UW-WSU-PNNL transactive campus demonstration, the Pacific Marine Energy Center, and small modular reactors developed at NuScale Power that will be tested at INL. The NW transportation sector's (vehicles, trucks and aviation) primary energy source is petroleum, which is imported from outside the region, but also includes a strong biomass-to-fuels effort that includes regional companies and research institutions focused on the development of drop-in biomass-derived transportation fuels. The NW is showing leadership along the I-5 corridor in advancing electric vehicles (EVs), through National Laboratory and university research on EV batteries and investments in a charging infrastructure.

- *The Northwest is a leader in energy efficiency, making efficiency the second largest resource for the region after hydropower.* Since 1978 the Northwest has saved about 6 GW and met half the load growth in the region through efficiency. Building on this foundation, the Northwest will pursue innovations in energy efficiency and demand response for meeting regional goals related to generation capacity and carbon emissions.

- *The NW region has been a leader in developing and deploying smart grid technologies to increase grid flexibility, reliability, resiliency and cyber security.* The Pacific Northwest Smart Grid Demonstration deployed over 55,000 advanced meters and automated distribution across over 5 states and 11 utilities. With over 6 GW of wind energy, the region is a leader in demonstrating large-scale renewable energy integration along with demand response and energy storage demonstrations and deployments. There is a rich energy ecosystem in the region that includes robust energy R&D, small hardware and software companies, progressive utilities and large multinational energy suppliers.

- *The NW region is integrating core competencies in smart grid and smart building concepts with the internet of things (IoT) to fully realize the benefits of an electricity system that can enable deep decarbonization.* High tech companies like Microsoft and Amazon are investing in cloud computing, Internet of Things (IoT) devices and renewables to build a green economy that is powered by a smart grid which is capable of more autonomous decision making at "the edge" as opposed to at a centralized control room. NW research institutions are partnering with utilities to implement transactive controls[1] between the grid and buildings, along with centralized and distributed renewables integration into the grid.

- *The NW has a robust clean energy innovation ecosystem.* The region's universities are strong in energy R&D. They lead major federal clean energy research centers in areas as diverse as marine renewable energy, biofuels, and catalysis. NW universities host ARPA-E teams, Sunshot Gen3 solar efforts, the Northwest National Marine Renewable Energy Center, and include the 6th largest university recipient of Office of Science funding. The region's three National Laboratories lead nuclear energy, fossil energy, enhanced geothermal energy, and grid modernization R&D efforts, as well as key DOE energy efficiency programs.

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[1] Transactive controls combine financial signals and dynamic control techniques to shift the timing and quantity of energy usage in devices, buildings and campuses.

Northwest research organizations are complemented by an active business community populated by large and small cleantech and high tech companies, an engaged investor community and state and federal representatives who are highly supportive of a shift to a clean energy economy. Post-workshop surveys praised the NW as an ecosystem with a collaborative "ethos" that promotes effective partnering around clean energy challenges.

- *The NW brings a mature and diverse perspective to the conversation about how best to balance trade-offs between clean energy and protecting the environment.* The Energy-Water nexus factors heavily into regional decision-making due to the NW's economic reliance on agriculture, fishing and hydropower. Therefore the environmental focus of the NW has stimulated a healthy debate over the years about the benefits and consequences of clean energy, most notably the impact of hydropower on salmon migration and survival rates. The region is experienced in grappling with complex energy issues and seeks diverse perspectives, such as those from its Indian Tribes, in evaluating potential energy options. With over 22 GW of electricity generated from the Columbia River the renegotiation of the Columbia River Treaty will be critical to the future energy production of the region.

- *The NW region enjoys broad community support for clean energy.* Support for clean energy is wide-spread amongst NW state and federal representatives, who are active champions for legislation and policies that promote clean energy solutions. As examples, the Washington State Clean Energy Fund and Oregon BEST both invest in the marketplace maturation of clean energy technologies.

- *The NW is a clean energy gateway to Asia and to Canada.* The NW has a long history, and partners closely, with Canada on energy issues. An example of the interdependence between the U.S. and Canada is the Columbia River Treaty, which governs the development and operation of dams in the upper Columbia River basin to provide benefits to both countries in the form of added hydropower, irrigation and flood control. The NW is also economically tied to Asia, and those ties are growing tighter. For example, in 2015 Seattle and the State of Washington signed multiple MOUs with Chinese partners in areas such as environmental protection, clean energy and low carbon technologies.

- *The NW region would benefit from the development of a clean energy innovation roadmap.* A recurring observation made throughout the workshop, and in post-workshop surveys, was that the NW innovation ecosystem would benefit greatly from a roadmap that could be used to align and organize the region's efforts and investments in clean energy. This roadmap would define a shared vision and provide a mechanism to continue the conversations initiated at the workshop.

As a result of this workshop, a group of regional research and business stakeholders have committed to collaborate in developing this NW regional roadmap for clean energy innovation focused on pursuing: (1) transformational breakthrough energy innovations aligned with NW strengths and (2) near-term but impactful clean energy innovations across the suite of the NW's energy sectors.

The following report contains a detailed account of the workshop discussions and presentations. Appendices to the report provide the agenda, a roster of workshop participants, and State Energy Profiles for Washington, Oregon, Idaho and Montana.

Workshop Overview

The Northwest (NW) Regional Clean Energy Innovation Partnership (RCEIP) Workshop was held at the University of Washington on Monday, August 15, 2016. Hosted by the University of Washington and coordinated with regional academic and National Laboratory partners in Washington, Idaho, Montana and Oregon, the workshop focused on the future of energy innovation and was an all-day event in The Lyceum of UW's Husky Union Building. The goal of the workshop was to bring together regional stakeholders in academia, industry, National Laboratories, non-profit organizations and state, local and federal agencies to explore ways that they can partner to accelerate the development and deployment of emerging clean energy technologies and stimulate regional economic development.

The workshop agenda (Appendix A) was designed to explore how these stakeholders can join forces across the region to strengthen the NW clean energy ecosystem by:

- Providing a deep and differentiating set of capabilities, resources, markets and opportunities to develop clean energy technologies,
- Leveraging federally funded R&D with state and regional industrial development efforts to create a strong, local clean energy talent and technology base,
- Mobilizing wide community support, including universities, industry, and National Laboratories for regional initiatives,
- Building the NW's clean energy leadership position upon existing knowledge clusters and leveraging the comparative strengths of the NW region,
- Engaging public and private financing entities such as the Washington Clean Energy Fund, Oregon BEST, angel and venture investors, as well as philanthropic organizations to strengthen the local regional clean energy economy, and
- Working together politically to coordinate at local/state/regional/federal levels.

The event featured presentations by national and regional clean energy leaders, including U.S. Secretary of Energy Ernest Moniz, U.S. Senator Maria Cantwell, Washington State Governor Jay Inslee and U.S. Representative Derek Kilmer. Tom Ranken, the President and CEO of the CleanTech Alliance, provided a business organization leader's forward-looking perspective on the NW region's strengths and challenges in clean energy research, policy, and business development.

Five panels were held during the day to explore different elements of the Northwest Region's clean energy ecosystem. The first panel brought together National Laboratory and University leaders to provide a high level analysis of how NW research institutions can strategically partner to build differentiating regional strength in clean energy innovation. The second panel discussed the challenges and opportunities for integration of state and regional actions to help the region address the Nation's clean energy goals.

The third panel highlighted specific multi-institution research collaborations that exist in the NW region today, and the fourth panel assembled industry leaders who have played critical roles taking clean energy products to a global market. The fifth panel included representatives from NW clean energy startup companies and the investment community with experience bridging the "valley of death" between research and a commercialized product.

The knowledge and expertise provided by the ~120 attendees contributed greatly to an informative and constructive dialogue (Appendix B). Contained within this report is a summary of the information that was exchanged during the workshop and key messages that were communicated regarding the future of clean energy innovation, technology development and adoption in the Northwest.

The Northwest as a Clean Energy Leader

The University of Washington's (UW) Provost Gerald Baldasty and Vice Provost for Research Mary Lidstrom provided opening remarks that welcomed workshop participants, recognized distinguished guests, and expressed the imperative for innovation in clean energy. Their remarks acknowledged UW's long-time and enthusiastic support for the region's clean energy innovation ecosystem, the positive impact of DOE and other agency funding on the NW energy research community, and set the stage for the remainder of the workshop.

After the opening remarks, U.S. Congressmen Derek Kilmer shared his perspective on

what makes the NW region special with respect to energy innovation and development. Congressman Kilmer called for concerted regional action on clean energy, citing the need to protect the planet for the next generation. He said that Washington State (WA) recognizes the real threat of global climate change and cited specific examples of the effects of climate change in his district - historic Native American coastal buildings in danger from rising sea levels, ocean acidification effects on the WA fishing industry, and a forest fire burning for months in a rain forest. In the face of this threat, he said that "WA doesn't agonize, we organize". The Nation's response to the existential threat of climate change needs to be similar to the space race with the Soviets. The space race inspired a national effort to address the challenge, and countless innovations resulted.

The U.S. is facing another Sputnik moment and WA is stepping up. Washington produces 30% of the Nation's hydroelectric power, and is ranked in the top 10 state producers of wind power. The Joint Base Lewis-McChord (JBLM) Earthworks program takes 700 tons of waste from JBLM's dining halls and commissaries and converts it to compost. The University of Washington is a leader in solar technologies and energy storage. Puget Sound Energy is making efforts to shift the balance in their energy portfolio.

> *"We will be known forever by the tracks we leave."*
>
> - Native American Proverb, Dakota Sioux

Congressman Kilmer concluded by saying that the region is at the forefront of changing how the Nation produces and uses clean energy. His service on the House Appropriations Committee allows him to advocate for additional funding for clean energy innovation, champion investments in basic research, and invest in basic infrastructure such as the grid. He quoted the Native American proverb "We will be known forever by the tracks we leave" - what we do here matters in protecting the planet for our children.

Dan Schwartz, the Director of the Clean Energy Institute at the University of Washington,

provided a perspective on the history of the NW region in clean energy, and his projections for the future. The region has been in the clean energy innovation business since 1889, when the first AC hydroplant, the Willamette Falls Hydroelectric Plant, was put into operation with the first high voltage transmission (4kV). Hydropower systems are now distributed throughout the NW region and consist of a combination of federal and privately owned systems. The Grand Coulee Dam was the first major element of the current hydropower system. It was a Bureau of Reclamations project with an initial goal to increase water supply, which then grew to be a major power producer for the region.

Shifting from the past, Professor Schwartz then discussed the future of clean energy in the NW. Advances in electricity transmission and distribution will require connecting forecasting science - in hydrology, weather, climate, and energy – to the smart grid, which combines equipment, infrastructure and software. Because of abundant and affordable clean energy, the NW is a leader in the production, modification and manufacture of advanced materials including lightweight metals, alloys, and polymeric composites for the aerospace industry, as well as materials for computing and communications, LEDs, batteries, and photovoltaics. Aviation biofuels research in the NW is driven by our sustained excellence in the aerospace sector. The NW also has regional strength in data management, analysis and cloud computing based on the leadership of Microsoft and Amazon web services.

The NW region’s “green” ethos has driven a conversation about the social, economic, technologic, and environmental impacts of energy. The NW understands the trade-offs associated with clean energy, as exemplified by the benefits of inexpensive energy and irrigated agriculture and the negative consequences on fish populations and the traditions of Columbia River Basin indigenous communities. As a result, the NW has been working on issues such as “food vs. fuel” for a long time, and has deep expertise that can contribute to the Nation and the world in working through these types of trade-offs.

Thomas Ranken, the President and CEO of the CleanTech Alliance then provided a

business leader’s perspective on clean energy in the NW. The CleanTech Alliance represents about 300 member companies and organizations across Washington State. Washington’s cleantech industry encompasses hundreds of companies ranging from the Fortune 50 to emerging players backed by more than $1 billion in venture capital. The sector employs more than 90,000 workers in Washington State, each striving to make a significant contribution to the worldwide demand and deployment of clean technologies. Founded in 2007 by business and cleantech leaders, the Alliance facilitates the generation and growth of cleantech companies and jobs through a variety of educational programs, research, products and services. The CleanTech Alliance has partnered with Oregon BEST (Oregon-Built Environment & Sustainable Technologies Center, Inc.) to form the Cascadia Cleantech Accelerator, which currently has 30+ mentors working with 14 companies.

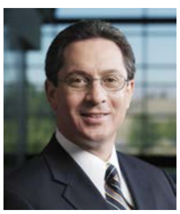
The NW has one of the fastest growing and most vibrant cleantech economies in the world. Washington State is the leading renewable energy producer, with Oregon third, and Idaho seventh. Renewable energy produced in the NW powers 14 states. Hydroelectricity is the backbone of the NW energy system; the energy profile in NW will stay clean. The “secret sauce” of the clean energy ecosystem in the NW is the combination of its universities, National Laboratories, industry and its commitment to conserving the environment. The NW is the home of some of the largest clean energy companies in the world, and nonprofit organizations such as the Gates Foundation and the Breakthrough Energy Coalition that are dedicated to improving the quality of life for all of mankind. The NW is considered to be a leader in the internet, coffee, cleantech, biotech and aviation. Cooperation is part of the NW culture – people in the region work to “bake bigger pies not to take bigger pieces of a fixed pie”. As a result, business people in the community dedicate time and energy to help other clean tech entrepreneurs be successful.

The grid is one area in clean energy where the NW clearly leads. The Washington Clean Energy Fund provided $14M in grid modernization funding to deploy four batteries at three utilities, providing nearly 15 MWh of utility-grade storage. The Pacific Northwest National Laboratory (PNNL), the University of Washington (UW) and Washington State University (WSU) have partnered on a tri-campus transactive energy demonstration. The Pacific NW smart grid demonstration project is the largest of 16 projects funded by DOE.

Panel 1: Emerging Opportunities to Accelerate Clean Energy

The goal of Panel 1 was to bring together National Laboratory and University leaders to provide a high level analysis in answer to the question: Where can we build on multiplicative research strengths across the NW region? Each panelist was asked to spend 5-7 minutes introducing their institution at a high level, describe its differentiating strengths in clean energy, and discuss their vision for the future of clean energy in the NW. The panelists were encouraged to provide examples of how their institution's energy strategy is aligned – or could align - with others in the region to achieve their vision for the future.

The panelists consisted of five high-level leaders from the NW region's research institutions. They represented perspectives from 3 states in the region: Washington, Oregon, and Idaho. The panel was moderated by Thomas Ranken (President and CEO, CleanTech Alliance) and the panelists were:



Steve Ashby

Lab Director

Pacific Northwest National Laboratory

Cynthia Sagers

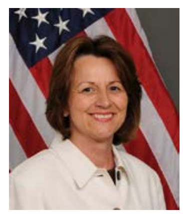
Vice President for Research

Oregon State University

Chuck Staben

President

University of Idaho



Grace Bochenek

Lab Director

National Energy Technology Laboratory

Kelly Beierschmitt

Chief Research Officer

Idaho National Laboratory

OPENING STATEMENTS

Each panelist provided a brief overview of their respective institutions. PNNL is one of 10 National Laboratories stewarded by the DOE Office of Science which employs 4400 and $1B in research funding per year. PNNL is a multi-program laboratory, with missions in earth science, environmental management, energy and national security. In energy, PNNL is focused on the deep decarbonization of our energy system, and has differentiating strengths in the future power grid, energy storage, and energy efficiency. The Lab is a national leader in transactive energy management, the optimization of electricity supply and demand, developing new battery chemistries and enhancing efficiency in lighting, appliances and buildings.

Oregon State University (OSU) is committed to its land grant mission of solving problems to benefit the people. The US is positioned to take a leadership role in addressing climate change and Oregon is shifting to phase out its reliance on coal and move to clean energy sources by 2040. The advancement of this clean energy future is part of OSU's multidisciplinary effort in energy storage, devices, biomass, energy efficiency, solar, nuclear, and wave energy. OSU's wave energy research is led by NNMERC, one of 3 research centers recognized by DOE for wave, tidal and current power.

The University of Idaho is a land grant university which aspires to generate and disseminate knowledge, ensure U.S. global economic competitiveness, act as a trusted public communicator and pass knowledge to the future generation. Energy is a huge challenge, particularly in production and reliability. The University of Idaho has strengths in grid technology, safety and security and power engineering. To have the greatest impact it is important to change partnering practices to move technologies out the door, particularly in executing CRADAs better, supporting internships, and breaking down research silos.

The National Energy Technology Laboratory's (NETL's) research site center in Albany, Oregon works on computational science, materials engineering, geological and environmental systems, energy conversion and systems engineering. Fossil energy must be considered as part of the clean energy calculation because of its large footprint on our current energy system. Clean fossil energy means carbon capture and utilization of carbon, and carbon sequestration in geological formations. NETL is unique in the DOE Lab system in that it is a federal lab, so it partners uniquely with industry and academia with the goal of increasing innovation and the commercialization of clean technologies, including long-term geologic storage of CO_2.

The Idaho National Laboratory (INL) is a multi-program research, development, demonstration and deployment National Lab spanning 890 square miles, with ~4,000 staff focusing on grand challenges to meet energy, climate, and national security goals. It is the Nation's premier nuclear science and technology laboratory, and hosts world-class and unique RD&D facilities in nuclear energy, security, and clean energy deployment. INL addresses physical and cyber-based protection of critical energy infrastructure and integrated energy systems – securing and modernizing critical infrastructure, and conducts clean energy engineering, performance validation, and at-scale systems integration and demonstration. INL plays a significant role in regional energy grand challenges and transitions, and works with academia and industry with an eye to also enhance U.S. industrial competitiveness globally. INL, with regional university partners, created the Center for Advanced Energy Studies to promote regional partnerships in pursuit of energy solutions. Also, Oregon State University is part of INL's National University Consortium, which focuses on selected nuclear energy research topics. Nuclear power is, and will continue to be, a key component to establishing a deeply decarbonized, resilient and secure energy system that is affordable.

DISCUSSION

Following the opening statements was an open discussion, seeded by questions posed by Thomas Ranken. Questions to the panelists were:

How can we (the NW region) play together more nicely?

The NW region is distinguished by having a collaborative ethos. We need to define a clear and shared outcome that the region can agree upon and work together to achieve. Possible rallying points are centered on the region's strengths in renewable energy generation and grid energy management. To achieve our collective goals in clean energy, it is important to engage industry in the right way and bring federal and private funds together at a pace that meets investor's needs. We need to achieve a common understanding of how to manage IP and protect the investment of federal dollars while still making it easy to move technologies to the market. A mechanism is required to align and synchronize clean energy R&D to promote innovation. Once we have established a common vision, the NW needs to pull together – across state, local government, academia, and industry – to be ruthless as a region in achieving our goals.

What distinguishes the NW from other regions in clean energy?

The NW is very diverse – it touches everything in the energy space. It has the right industry partners, three National Laboratories, and is positioned to support the Nation's agenda in clean energy. There is an energy in the NW that is derived from a set of tremendous partnerships that have developed between industry, academia and the Labs. The NW is not bound by the past, which enables us to plan our future without historical constraints. We have the physical resources to explore the potential and limitations of renewable energy – ranging from hydropower to solar, wind, wave, and geothermal. There is a spirit of open-mindedness in the NW which drives this exploration. We have the opportunity now to convert our "potential energy" into "kinetic energy" with the announcement of Mission Innovation. One of the challenges we face is how this conversation continues after this workshop is over.

What is the weakness of the region?

Politically the NW region is diverse with 2 blue states (WA, OR) and 2 red states (ID, MT). This political diversity can be an opportunity or a barrier. WA and OR are larger research ecosystems than ID and MT, and that can be an uncomfortable aspect of partnering within the region. The distance of the NW region from Washington D.C. limits its ability to have influence on energy policy. It is therefore critical to develop a bold, unifying vision and use it to drive action within the region. We also need to think internationally. China is facing the same struggles as the U.S. - they have a dirty economy with an agrarian culture that values the earth. We will see a transition to clean energy by the US and China and we, as a region, have the opportunity to support that transition.

Panel 2: Policies and Activities to Accelerate Regional Leadership

Panel 2 discussed the challenges and opportunities for the integration of state and regional actions to help the NW region address the Nation's clean energy goals. The panelists were asked to spend 5-7 minutes introducing their organization or state, presenting a summary of their current policies or actions that promote the NW region's leadership position in clean energy, and discussing areas in which their organization/state partners effectively with others in the region.

The panel included 5 energy-related policy makers, stakeholders and representatives from non-profit organizations. The moderator was David Kenney who is the Director of Oregon BEST, a state-funded non-profit that "nurtures clean technology innovation by transforming new ideas, research, and products into green collar jobs, greater sustainability, and economic prosperity for Oregon". The panelists were:

Brian Bonlender

Director

WA Department of Commerce

Elliot Mainzer

Administrator

Bonneville Power Administration

Fawn Sharp

President

Quinault Indian Nation

Michael Hagood

Program Development Director

Center for Advanced Energy Studies, INL

Christopher C. Deschene

Director

DOE Office of Indian Energy Policy and Programs

OPENING STATEMENTS

The mission of the Washington Department of Commerce is to build the economy. It houses the state energy office, which is the agency responsible for carrying out Washington State initiatives on energy. The NW is characterized by people who think big and think ahead, and by a community that generally supports investments in cleantech. We lack the same strong market pull that other regions have, and the result is that we develop partnerships quickly in executing some of the challenges we face and we are smart and precise about the policies we pursue. We are very thoughtful about how to use state funds so we invest in areas where we have expertise and history. Washington State has made a $76M investment - mostly in a smart grid demonstration program – through its Clean Energy Fund (CEF). Grid scale storage received an investment because having the ability to store electricity at a utility-scale will reduce the wear on grid hardware. The State of Washington also funded JCDREAM, the Joint Center for Deployment and

Research in Earth-Abundant Materials, to ensure our clean energy future is not too reliant on rare earth products.

The Bonneville Power Administration (BPA) is the part of the DOE that markets the output of hydropower in the NW. Its dams are operated by the Army Corps of Engineers, and serve as the backbone of the NW region's high voltage grid to provide reliable, affordable power. The NW region is a leader in energy efficiency. The first wind boom was due to the renewable portfolio standard (RPS). The addition of 5000 MW of wind power on the grid challenged the grid infrastructure, but led to a greater understanding of the capacity and integration of renewables on the grid. BPA also learned a great deal from the smart grid demonstration project, particularly that transactive energy is the key to understanding energy distribution and how to manage the bulk grid interface. BPA has made $70M of investments over 10 years in technology innovations such as the synchrophaser, state awareness software, and processes for managing dynamic loads that have paid off in a $280M value to consumers. An additional $750M/year investment in infrastructure is needed to keep it in good shape. BPA's focus is on avoiding building unnecessary infrastructure by developing non-wired solutions to manage grid congestion and stretch existing infrastructure as much as possible. Other challenges BPA faces are in salmon restoration and a grid workforce demographic shift that may result in the loss of institutional knowledge when the current workforce retires.

The Quinault Indian Nation, and Indian country in general, is rich in clean energy resources – wind, solar and biomass. The Tribes know that climate change is a huge global crisis, which prompted them to participate in COP14 and other discussions about climate change. Specific climate impacts to the Quinault Indian Nation include salmon stock reduction due to glacier erosion and ocean encroachment and acidification. The Tribes can act as sovereign trade partners which can link domestic industry to international markets in unique ways. An example given was green certified wood, which has an international market that domestic companies cannot access due to the U.S. being a non-signatory of the Kyoto Protocol. Another way that the Tribes can facilitate international partnerships is through the Forum on Indigenous Peoples. The Tribes bring a different perspective on how to balance our energy needs with protecting the environment. If we draw on all forms of knowledge in NW, the region can lead in the clean energy space.

Montana is rich in wind energy and hydropower. It holds the largest U.S. recoverable reserves of coal, and hosts significant crude oil reserves within the western portion of the Bakken oil field. It maintains four oil refineries and provides electricity to several Northwest utilities, including from the Colstrip coal-fired generating plant. Idaho in-state electricity generation is ~85% derived from renewable energy sources (primarily hydropower and wind), but imports ~35% of its consumable electricity mainly from coal-fired power plants located outside the state. Idaho is also intending to host the first-ever

U.S. deployment of a small modular reactor. For both Montana and Idaho, attention will increasingly be paid to energy-water (and food) dynamics and on growing energy interdependencies with bordering Canadian provinces. Borrowing from Montana Governor's energy futures blueprint, the energy landscape in Idaho and Montana "will dramatically change, as old paradigms are challenged by new technologies, the cost burdens of maintaining aging infrastructure, regional market forces driven by shifting customer demand, changing and complex regulatory regimes as well as the consolidation and reorganization of markets".

Both states are positioned well with clean energy RD&D capabilities to assist in addressing this anticipated shift, as well as support overall Northwest energy transitions (participating in Northwest clean energy innovation networks). For example, Montana State University hosts one of U.S. DOE's Energy Frontiers in Research Centers as well as maintains the Energy Research Institute. Idaho, in turn, has located within its boundaries the Idaho National "energy" Laboratory (INL) and supports the Center of Advanced Energy Studies, a consortium comprising three Idaho universities, the University of Wyoming and INL.

The Office of Indian Energy (OIE) was formed by the 2005 Energy Policy Act for the purpose of developing energy policy for the benefit of Indian nations. The OIE works on behalf of 567 recognized tribes and implements initiatives to address tribal issues such as poverty, unemployment, and unelectrified homes. The OIE strategic roadmap for 2025 is focused on 3 main areas: deployment, investments, and policy for tribal-public/private partnerships. It has established MOUs with federal agencies, and states to begin implementing its strategy. Work the OIE has done with the National Laboratories shows that with just 2% of the land base, Indian tribes can account for 5% of the Nation's energy.

DISCUSSION

Questions asked of the panel were:

Are there policy levers that can be pulled that can have regional impact?

When it comes to cleantech there are 2 policy objectives: the reduction of carbon emissions and transferring technologies to the market. It would make sense to have multiple states agree on RPS policies for the west coast. The NW has the ability to capture renewables across the region in a way that could compensate for their intermittent nature. A revenue-based market for reducing carbon emissions could shift the responsibility for managing carbon to individuals. Voluntary systems would give individuals a chance to step up and assist in reducing climate impacts. Europe has adopted this approach and has achieved a 23% reduction of carbon emissions, with a goal of reaching 25% by 2020.

Research and development work best when they support a solid business model. The RPSs in several states do not qualify hydroelectricity for renewable portfolio investments.

However, there is a place to monetize surplus hydroelectricity. If that excess energy could be sold at a cost that incentivizes greater efficiency, it would drive the market.

Indian tribes need to collaboratively develop policy agendas to present to the Secretary of Energy. Tribal-public-private partnerships and loan guarantee programs could be used to fund Indian energy projects which would open up a new dimension of development for the Tribes.

Broader sustainability and systems thinking is part of the NW region's ethos. When we think of a regional collaboration, it is worth considering who else should be part of a regional initiative. Champions for education should be involved. It is important that we have an educational system that can train the next generation to implement the strategic plans that we develop today. We should give "power to the people" by inviting more individuals and communities to be engaged in how they can be generators and participate in a transactive world. It is also imperative to engage industry in this dialogue to get their perspective on what we need to succeed and have global reach.

Of importance to the NW energy dynamic and associated policy making are the geopolitical relationships between the less populated NW interior and the growing metropolitan centers of the Emerald Corridor; between hydropower rich vs fossil energy rich regions. In addition, it is important to recognize and address policy relationships between the Northwest and adjoining Canadian provinces, given the increasing bi-national regional energy (and water) flows. The NW clean energy vision also necessarily must leverage cross-border energy resources and infrastructure, i.e., electrical transmission, pipeline, waterways, rail.

What other activities can have regional impact?

There are a number of paths that can be pursued that are aligned with cleaner energy futures, including more intense pursuit of deep decarbonization pathways and lessening impacts on our water resources.   Key to facilitating cleaner energy transitions and enhancing industrial competitiveness is creating partnerships, leveraging NW capabilities/investments and directing them towards concrete actions and measurable impact. A roadmap for focused innovation, with associated metrics is needed, that may be constructed working with the appropriate NW stakeholder group. In addition, we need to view the development and use of these resources as part of a greater, more sophisticated, integrated and resilient Northwest system that captures the many and increasing interdependencies.

Critical to the maintenance of the Pacific Northwest energy-water-food lifeblood is the Columbia River drainage system. The Columbia-Snake River drainage system underlies the bulk of the Northwest's electrical power production and agricultural sectors. Potential climate change impacts, energy policy and resource demands may contribute to longer-term negative impacts on the region's hydropower capacity and agricultural economy. Given the fundamental importance of this resource to the Northwest there is a need to focus on addressing greater stewardship of this resource through advances in energy-water innovations.

Panel 3: Energy Innovation at Northwest Research Institutions

Panel 3 discussed specific multi-institution research collaborations that exist in the NW region today. The panelists each gave 5-7 minutes of remarks that provided a high level overview of the clean energy research that is performed at their institutions, including examples of how their institution has teamed with others in the NW region to perform clean energy R&D, develop solutions, or transition technologies to the marketplace. The examples they shared included a variety of collaboration approaches spanning fundamental research, joint institutes and faculty programs, coordinated infrastructure, and testbed demonstrations.

The panelists are representatives from NW academic institutions or National Laboratories with direct experience managing clean energy research programs. The moderator was Malin Young, the Deputy Director for Science and Technology at Pacific Northwest National Laboratory. The four panelists were:

Dan Schwartz

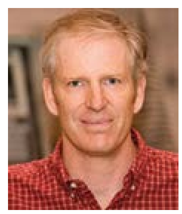
Director

Clean Energy Institute, University of Washington

Jud Virden

Associate Lab Director

Energy and Environment Directorate, Pacific NW National Laboratory



Michael Wolcott

Regents Professor, Louisiana-Pacific Distinguished Professor, and Director

Institute for Sustainable Design, Washington State University

Cynthia Powell

Chief Research Officer

National Energy Technology Laboratory

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There is a line of sight connection between the availability of low-cost energy and the prevalence of advanced alloys and composites, which have been critical to our aerospace and transportation industries. For every 10% reduction in the weight of a vehicle, you gain 6-8% in efficiency improvements. The NW region has a fundamental strength in functional materials which give us the opportunity to make breakthroughs in batteries, solar devices, and others. Fundamental science forms the basis for new technologies, such as lighting. LEDs for lighting applications cost 10% what they did just a few years ago because of the materials and manufacturing processes that underpin them have advanced rapidly. Other examples of technologies with a basis in advanced functional materials are catalysis, next-generation communications, batteries and solar cells. Our region has real strength in materials. DOE has funded 2 DOE energy frontier research centers in catalytic materials (one at Montana State and one at PNNL). New catalytic materials under development will eventually replace rare and expensive platinum group metals from their prominent role in catalysis stream. New 2-dimensional conductive materials with transformational properties for generating and harvesting light and are going to lead to breakthroughs akin to what we have seen with LED lighting. A key manufacturing advance is solutions-processed solar materials, which let devices like batteries and solar cells be manufactured in volume, cheaply. Federal funding remains the foundation for fundamental research, and those funds are augmented and enhanced by states making contributions that bridge between research and industry.

The NW region is really clean – we produce gigawatts of hydro and wind power and we have one of the smartest grids in the country. The NW combines information and energy technologies, drawing on the expertise of companies such Microsoft and Amazon. The NW has the potential to become the scalable clean energy example for the world. For example, Pullman is the smartest smart-grid city in the world, we have tools that enable us to see the grid in real time like never before, and we have smart infrastructure throughout the region to link things on the edge of our energy system. Operating at the edge requires new solutions for energy storage and for enhancing grid-to-building integration. The interface between buildings and the grid is one of our key challenges, which has motivated the campus transactive project to demonstrate what new technologies can be incorporated into buildings. It has been said that Microsoft has this interface figured out, but we need to develop small, inexpensive technologies that independent operators can use, supported by cloud services provided by companies such as Microsoft and Amazon. The next 10 years will all be about data.

Another area to focus on is transportation. With greater electrification of the light duty fleet, more generation requirements will be placed upon our grid. However, regional heavy truck manufacturers such as PACCAR and Freightliner probably won't be on the grid anytime soon and will require a different approach if deep decarbonization of our economy is to occur. To address these challenges, we need to create a regional ecosystem that allows universities to perform as world class research institutions, National Laboratories to deliver impact, while also promoting economic competitiveness.

Washington State University (WSU) has launched a new initiative to connect the Energy Systems Innovation Center and the Institute for Sustainable Design with industrial partners, Avista and Itron, to enable Smart City efforts around the Spokane University District in Spokane. Avista and Itron have 100+ new data nodes deployed around the district that includes the WSU Spokane campus, Gonzaga University, Eastern Washington University, Whitworth College and adjacent residential and commercial sectors to determine how to better control the usage of natural resources (energy, water, etc.) with data analytics and improved controls. The connection between energy consumption and water is an important component, especially with the NW region's focus on agriculture.

Forest and agricultural residues and other bioenergy crops can be used for producing biofuels and bioproducts, which are critical clean technologies because they're vital to meet our liquid fuel needs. Liquid fuel production from renewable sources is strategic for decarbonizing commercial aviation, an area of historic strength in the NW region. The strong regional focus in aviation biofuels has led to several partnerships - one between WSU and MIT to lead a new FAA Center of Excellence called ASCENT (alternative jet fuels in the environment), and the other between PNNL and WSU to found a joint laboratory located at the WSU Tri-Cities campus called BSEL - the Bioproducts, Sciences, and Engineering Laboratory.

The National Energy Technology Laboratory's (NETL's) research programs are focused on developing and deploying innovative technologies through collaboration and increasing industrial engagement to reach the marketplace. An example is the National Risk Assessment Partnership (NRAP) which includes contributions from PNNL and OSU. NRAP was developed to deploy user-friendly tools to quantify uncertainties and risks associated with the long-term geological storage of CO_2. These tools can help assess geological sites for long-term storage and evaluate that CO_2 is contained with minimal environmental impact. Over its 75-year history, NETL's Albany, Oregon, Laboratory has developed production processes for specialty metals such as titanium and zirconium as well as melt process technologies such as VSR and ESR that have enabled the specialty metals industry in the NW. In collaboration with Oregon State, NETL is seeking to advance the production of metal parts through advanced manufacturing methodologies including 3D printing, to produce complex shapes with the necessary chemistry and microstructures.

DISCUSSION

Questions asked of the panel were:

What is the NW region's "secret sauce" in clean energy?

The innovation ecosystem in the NW is fairly new. We are connected internationally; working together we have the opportunity to have impact through global markets and partnerships. The energy ecosystem in the NW is a very collaborative group. We have a critical mass of all the pieces you need in a region to do something special. NW universities are both locally and internationally known, the 3 National Laboratories in the NW are incentivized to be outwardly focused, and we have a policy and a culture that truly wants to develop technologies that create a clean energy future. That future will be about the digitization of energy and the NW has the capabilities to create and scale it for the rest of world.

The NW has tremendous and diverse natural resources. The NW region therefore has the potential to be an ideal laboratory for how a diversity of energy systems can be integrated. The NW has the perspective to use natural resources in an efficient and wise manner. We are unique in that we value our natural resources and have respect for the environment while also promoting a culture of innovative thinking.

How can we enhance collaborations among the NW region's research institutions?

The NW states have built bridges between pillars of technical excellence and federal funding. Federal funding for clean energy must be sustained but we need more bridge funding from the states. Our region has already started and should continue thinking about how to create stronger investments. There is a direct economic benefit of these state-level investments – at UW, 70% of our graduates stay in the state of Washington. Part of it is due to the NW quality of life. The students we grow here want to stay and contribute to the future of the region.

We need a research roadmap to unify us around a compelling problem set. What is important now is defining what is needed to realize the dream of a clean NW energy ecosystem. Coordination of that effort from early stage research through development and ultimately through commercialization to the marketplace is critically important. The roadmap needs buy-in from industry and policymakers. All researchers are good at optimizing themselves for the worlds they usually live in – the special sauce is when industry says "We need researchers to crack the nut on S&T challenges X, Y and Z". The Smart Grid Demonstration Project is an excellent example. The utilities were clear on what they needed to learn and the research community was able to respond. Federal investment is often what brings researchers and industry together to tackle the tough challenges. Providing an incentive to work together combines the strengths of both communities and allows for success.

What barriers currently exist to collaboration? What suggestions can you provide to break down these barriers?

This NW region could focus on incentivizing collaborations through state-based incentives. It would be helpful to combine this focus with an eye toward the next step of commercialization. A sense of common purpose would help us line up and work together. The region should make investments in its technical infrastructure. Clean energy is an expensive field to move forward and we need specialized facilities to be successful. We need to step up the level of coordination around developing our technical infrastructure. We are facing a systems engineering problem to optimize and leverage capabilities that exist across the region in academia, National Laboratories, and industry. To do this optimization requires leadership.

Panel 4: Industry for Regional-to-Global Impact

Panel 4 were large regional industry leaders who have played critical roles turning research ideas into clean energy products. The panelists provided a high level 5-7 minute overview of their company's role in the NW region's clean energy ecosystem, and their perspective on opportunities the region can capitalize on to accelerate the innovation pipeline. They provided examples of how they have interacted with other companies, universities and National Laboratories in the region to develop products or solutions.

The 4 panelists represented large NW companies with global reach into clean energy sectors ranging from the electric grid, utilities, renewable energy, the internet of things, and smart buildings. The moderator was Jud Virden, the Associate Lab Director for Energy and Environment at the Pacific Northwest National Laboratory. The panelists were:

Curt Kirkeby

Fellow-Technology Strategy

Avista Utilities

Michael Atkinson

North American Region General Manager

GE Grid Solutions

Bert Van Hoof

Group Program Manager

Microsoft Corporation

Dave Cuthbert,

Senior Solutions Architect

Amazon Web Services

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The NW is very innovative in energy with a focus on the grid and renewable energy sources, as shown by the region having the largest capacity flow battery in North America, solar farms, and hydroelectric dams. Avista Utilities always thinks about the future grid so it was well prepared to integrate automation as part of the NW Smart Grid Demo, which resulted in 2.5 million customer outage minutes avoided while simultaneously increasing distribution efficiency. A public-private partnership (PPP) was formed with collaborators at WSU, PNNL, Itron and others which created a large set of partners that are experts in the grid. Avista launched a series of grid improvements on a highly accelerated path due to the PNW Smart Grid Demo. This accelerated advanced meter and automated distribution deployment. This was made possible by a network of collaborations in the NW and with the support of public funding.

GE Grid Solutions is focused on energy innovation, but as a private company it approaches innovation differently. A focused R&D effort is underway at GE to develop smart grid real-time control systems, which is a global endeavor with a center of expertise and effort in

Washington State.   The R&D environment is challenging because the low cost of electricity makes it difficult to find solutions that provide a compelling return on investment. An additional layer of complexity is introduced because grid operations and infrastructure are managed differently depending on the region. GE seeks to spur innovation based on customer input and through partnerships with academia and the National Labs. Trust, transparency, tenacity and time are required to make partnerships work.

Microsoft is investing in Internet-of-Things (IoT) technologies for smart buildings and smart cities. In 2011, it begin a smart building initiative that created a testbed of 145 buildings at its Redmond campus. The initiative integrated 7 building management systems and resulted in an energy cost savings of 5-10% in those buildings. Before the initiative, Microsoft was consuming 55 MW per hour so these cost savings were significant. Microsoft has now started deploying this approach in Singapore, and looks to smart buildings technologies to improve energy efficiency at its 34 global data centers. Its Azure IT suite is growing rapidly and is leading to new analytics tools that push what we can do with data in the future.

Amazon Web Services made a commitment in 2014 to run all of its data centers off of renewable energy. As a result, it located data centers in the Columbia River region in order to run them off of hydropower. Today's world is highly distributed, so a company can't just have one central datacenter. This required Amazon to make another commitment to become a renewable energy producer for its data centers. It now has 4 large scale renewable projects – the Fowler Ridge wind farm which produces ~500 MWh per year, a solar farm, and two more wind farms. Amazon's renewable energy projects are now producing enough power to power a city a little larger than Cleveland. Despite Amazon's commitment to renewable energy production, it recognizes that it does not have all of the expertise needed to be successful, so it works with partners to bring their capabilities to bear. It is seeking to partner with other big technology companies like Microsoft, Apple, and Google to bring down data center power footprints.

DISCUSSION

Questions asked of the panel were:

We are seeing a merger of two worlds – power engineering and data analytics. What will things look like 10 years from now? What would you like it to look like? What do we need to do in the region to make that future a reality?

The energy infrastructure of the future will be bidirectional. The transition to a decentralized infrastructure will bring significant challenges as it will break down services that utilities have traditionally provided based on a centralized model. When consumers become independent producers, how do they cover the services that a utility has traditionally provided? Will it be possible for consumers to have affordable energy storage systems in the home so that they can store and use energy when they want, like a propane tank? We will need an energy infrastructure and service models that will help the utilities manage this transition in the future.

It is important to determine what services mean more to consumers. A perfect power system would consist of microgrids that distribute assets within the grid and allow for bidirectional energy flow. The preferred model would be to deliver KVAs (kilo volt amps) not kWh (kilo Watt hours) equitably in a distributed system. With distributed energy resources, the key will be to develop new economic methodologies that capture locational resources, or the "uberization" of energy.

In the future, the core operational infrastructure for buildings will link to smart agents in the building. The smart building, or more generally, smart energy components will be considered as integrated components in the future energy system. Such devices will bring physical sensors into data models that will provide new abilities to adapt energy usage to building occupants. Efforts are underway across the energy sector to develop solutions in storage, microgrids, and renewables integration. To help people manage their energy consumption, IoT devices will be used to measure more accurately where power is used/lost, incorporate machine learning to respond intelligently to inputs and provide alerts to consumers about their energy habits. The field of IoT is at an early stage –people are not yet sure of its potential. The concept of ambient intelligence has great upside potential but the community is cautious about not having IoT become the "security hassle of all things".

We are now in a world where every light bulb can be an IP point, or have an integrated gunshot detector and alarm. Companies have evolved from selling light bulbs to marketing lighting solutions. The energy system needs to grow to accommodate the connected devices that are being added to the grid, which is now up to 75 billion connected devices. Utilities have embraced "big data" and have avoided outages due to new grid analytics control tools, but the decentralization of the future energy system will require them to move decision making out to the edge of their energy system. Connected devices are doing analytics now to create "on premise" solutions. The challenge termed "big data" should be called "ambiguous data" because it's nebulous for R&D and its end use is unclear. It is not productive to move massive amounts of low utility data into the cloud. Ultimately, targeted data will need to be collected to provide customer solutions.

How do we deal with "the edge" and with the data requirements needed for effective electricity distribution?

The future energy system will require utilities and potentially customers to install diagnostics into the grid in order to feed information to decision points situated in places that make sense for the distribution system – perhaps at local centralized stations. The approach needed will vary depending on the structure and operation of the overall system. In the design of a distributed system, it is necessary to be careful because a local optimum does not often equal a global optimum.

The next generation of IT carries with it the danger of "splicing of personhood" for commercial gain. Could you discuss privacy and security of data, particularly in energy usage?

Utilities have never sold any customer data. The data they collect is only for the purpose of improving operations. Utilities have provided usage data to their customers but it proved to be of insufficient granularity to be useful in driving consumer decisions. It is possible to protect data if you collect and serve it to customers at the edge in such a way that the utility never sees the data. On the data platform side of the equation, there are many approaches to secure data in the cloud and limit a customer's access to their data only.

Panel 5: The Innovation Ecosystem - From Research to Startup

Panel 5 included representatives from NW clean energy startup companies and the patient capital community who specialize in longer-term investments and have experience with bridging the "valley of death" between research and a commercialized product. This panel addressed the needs and opportunities to strengthen the NW region's energy innovation ecosystem at the earliest stages of product development. Each panelist provided a high level overview of his organization, and his perspective on what works well, and what doesn't, in transitioning technologies out of research institutions. Specific experiences were shared regarding partnerships with other institutions in spinning out clean energy technologies, or investing in startups that originated in academia or the Labs.

The 4 panelists represented a range of perspectives from the patient capital community, National Laboratory spin-outs, and companies with ties to universities. They work in sectors that span nuclear power, energy storage, and the grid. Brian Young, the Cleantech Sector Lead for the State of Washington, was the moderator. The panelists were:

Scott Forbes

Director, Computer Science & Engineering

FedIMPACT

Rick Luebbe

Chief Executive Officer

EnerG2

Gary Yang

Chief Executive Officer

UniEnergy Technologies

John Hopkins

Chairman & Chief Executive Officer

NuScale Power

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FedIMPACT is a patient capital company which invests in the NW region. FedIMPACT works with the National Laboratories to commercialize technologies, for instance FedIMPACT has $4M invested in PNNL technologies. The energy sector is not conducive to venture capital due to the high failure rates of startups and the long lead time to products due to regulatory constraints. FedIMPACT is a division of larger parent, IPGroup, which is a UK-based company that is partnering with academic institutions, such as the UW. FedIMPACT and IPGroup believe in investing in an innovation ecosystem and building a network of relationships that can be leveraged to commercialize technologies. As we think about the energy system of the future, increasingly the community talks about data connectivity and integrating systems and not as much about traditional challenges such as energy transmission and storage.

Energ2 took a circuitous route to success. It was founded in 2003 with the original intent to produce nanostructured carbon for hydrogen storage. Due to market forces, it pivoted in 2004 to natural gas storage and pivoted again in 2005 to develop carbon materials for ultracapacitors. In 2009, Energ2 received ARRA funding to build a factory for the production of carbon nanostructures. The factory was went into production in 2012, and can now supply large quantities of battery materials to manufacturers. Market forces required another pivot to producing an additive for lead acid batteries that extends their duty cycle for grid applications. Recently, Energy2 was purchased by BASF and is now deploying commercial systems for natural gas storage.

UniEnergy Technologies (UET) is a local cleantech company focused on delivering large-scale energy storage solutions for the grid. There is an increasing demand for the grid to be reliable, resilient, flexible and clean. UET's product is a system based on a vanadium flow battery technology that originated at PNNL. The product is non-flammable and therefore inherently safe; it can cycle forever, making its operational life equal to shelf life, not cycle life. Its energy density is lower than alternatives on the market but it is still viable for grid applications. In launching UET, the team did not realize all of the challenges up front. Time and money are the principal challenges - the time-to-product in the renewable energy market is 5-10 years. The long time scale is less attractive to investors, therefore companies like UET need support from public funds. Such support from DOE OE and the Clean Energy Fund proved to be critical to developing the largest redox flow battery in operation. UET is currently installing systems in California, New York, Italy, Germany, and other locations around the globe.

NuScale Power started in 2000 with DOE funds with the goal to redesign an advanced light water nuclear reactor with safety in mind. In 2011, a board investment hypothesis was presented to Fluor Corporation which resulted in a major investment by Fluor in 2012. The DOE held a small modular reactor (SMR) competition, and NuScale Power won. Cumulatively, NuScale has received $500M in investments to construct a SMR that generates 50MW of electricity and is scaled to be built in a factory. NuScale Power has 23 utility partners, and 5 technical advisors (3 of which are from the NRC). It plans to submit a NRC application this year after completing 8 years of testing.

DISCUSSION

Questions asked of the panel were:

What could regional universities and National Laboratories do to make companies like yours grow and thrive?

The NW region has a huge software development community. The "hackathon", or rapid iteration model, may be a model that would be useful to adopt in specific areas in energy such as transactional controls and IoT. Some startups are working with the National Laboratories to get support; for example, in leveraging their supercomputer capabilities. It would be beneficial to see more integration of public-private partnerships at the idea stage rather than at higher technology maturity levels in order to get aligned priorities at the earliest stages possible. A program could provide funding to a private entity to give to universities or other research organizations, freeing the holder of the funds to direct the research in a way that is most commercially viable. In the U.S., technology commercialization is a weak point. Other countries such as Japan, China and South Korea, make big bets on technologies and move quickly. The Washington State Clean Energy Fund is a good example of a model that works to accelerate technology commercialization because it supports small companies in bridging the "valley of death" from a research prototype to a product. We need to think globally about technology commercialization – we can start in the NW but we have to consider other countries as viable markets because they increase the scale of the market space available for new technologies.

Until there is an alignment between the stakeholders in the energy ecosystem and the regulatory process, startups will continue to innovate without a path to a commercially viable product. What are your thoughts on how to overcome this challenge?

This observation is spot on. A big influence on the success of technology commercialization is the price of natural gas. Companies need to project where gas prices are going to be in 2022-3 and invest their time and money accordingly. Large investments are needed to bridge the "valley of death" and weather the fluctuations in the market.

BASF acquired Energ2 and Duson acquired 1Energy Systems – how important is it for our region to mobilize global companies as strategic partners and investors?

A start up cannot sell battery materials to manufacturers because the supply chain is too vulnerable. BASF was therefore a big factor in Energ2's success. We need to find ways to pull big companies into the National Laboratories and universities, and into the NW region, to accelerate the commercialization of technologies.

There is a gap between the research community and industry. It is very difficult for the U.S. to compete with Japan and South Korea in battery manufacturing. If we want to compete on the world stage, we need to think about a new model.

Leadership Speaker Series – The Future of Clean Energy

The final session featured three talks by state and federal leaders in clean energy – Washington State Governor Jay Inslee, the U.S. Secretary of Energy Dr. Ernest Moniz and U.S. Senator Maria Cantwell.

JAY INSLEE, GOVERNOR (D-WA)

Governor Jay Inslee spoke of the clean energy sector in the state of Washington. His focus is on building businesses in the state. He knows how important clean energy is, but clean energy solutions are opposed by entrenched interests that are interested in maintaining their hold on an energy monopoly. An argument is often made that transitioning to clean energy is too costly, but this is "bunk". The smartest minds know that the pace of technology innovation far exceeds predictions. Another argument is that moving to clean energy will have a negative impact on jobs and the economy. Currently, the clean energy sector employs 90,000 people in Washington State, and the number of jobs will only grow. Clean energy jobs are growing at 9.7% per year in the transit and green energy sectors. The West Coast collaborative is the 8th largest economy in the world and Washington's economy in particular is booming; it is in the top 5 states in job growth. So the bottom line is "embrace clean energy and get a great economy".

The state's cleantech economy has increased 20% since 2010. We know we can build on our historic base in hydropower with intellectual power. Governor Inslee's very first priority as governor was to establish a Clean Energy Fund to invest in technologies that save energy, cut energy costs and create jobs. One hundred million dollars have been secured which have leveraged $200M in private funds to produce clean energy technologies. Two companies funded through the CEF have secured major new investment funding. In the second round of CEF funding, investments made will go beyond batteries to microgrids and the transactive grid. Governor Inslee announced five CEF awards to Washington utilities – Avista, Seattle City Light, Orcas Power and Light, Snohomish County Public Utility District and Energy Northwest.

DR. ERNEST MONIZ, U.S. SECRETARY OF ENERGY

Secretary Ernest Moniz shared his perspective on DOE activities in the NW region which include the National Laboratories NETL, INL and PNNL, Hanford, and Bonneville Power. He thanked Senator Cantwell for her invitation and commended her leadership in advancing regional approaches to innovation and for looking carefully at the QER to advance recommendations into law.

DOE is participating in Mission Innovation – which is a commitment made by 20 countries and the E.U. to double funding for clean energy R&D over the next 5 years. It is important to connect to investable opportunities to accelerate the clean energy transformations needed to meet our climate goals. A path to do so is through regional teams; the Presidential budget request included a $110M proposal to fund up to 10 regional innovation partnerships which can take advantage of the specific resources and tools each region has to offer. This workshop is one of a number of forums that have been held across the country to discuss regional approaches and the message that have come out of these meetings is that regions are focused on different things.

Mission Innovation is the culmination of a year of focused effort by the DOE and the Obama Administration to put innovation at the center of the climate challenge. The result was the first Innovation Day, featured at COP21. It is clear that the pace of innovation needs to be picked up and scaled up. In June 2016, at the Clean Energy Ministerial, the E.U. was added to the original Mission Innovation group of 20 countries. These 20 countries and the E.U. will start with $15B of energy R&D funding with the plan to double that to $30B in 5 years. It would be ironic if the rest of the group move forward and U.S. does not. The DOE and Administration are working with Congress to achieve this 5 year goal. The President requested a 20% increase, despite the flat budget. Although the Mission Innovation allocation wasn't made, it received strong bipartisan support for the innovation agenda. Senator Cantwell introduced language to authorize the clean energy innovation partnerships, and it passed in this year's budget process.

When a substantial increase in the budget is requested, the question often is asked if there is the capacity to absorb the additional resource allocation. In this case the answer is "yes". An example of a similar initiative is ARPA-E, which was established in 2009. ARPA-E has funded 200 projects as of the end of last year, which have produced 36 companies and 10 commercial products on the market. Intermediate metrics show it to be very successful, despite the fact that it was funded at 25% of the target funding recommended by a National Academy of Science study. The demand for ARPA-E funding is high - just over 2% of proposals were funded so it is very likely we're leaving a lot of innovation on the table.

In parallel with the announcement of Mission Innovation, Bill Gates announced the formation of the Breakthrough Energy Coalition. He pulled together a group of 28 investors from 10 countries to support innovation in the Mission Innovation countries. The BEC is planning to begin making investments late in calendar year 2016.

It is the role of governments to open up the innovation pipeline by buying down the R&D risks. To move forward on the Paris agreement this year, we will need 55 countries that emit 55% of GHG emissions to sign up. Innovation is central to our agenda. We need policy innovation as well - it needs to go hand in hand with technology in order to achieve our clean energy goals. A credible scenario for reaching deep decarbonization needs 2 common elements – success on the demand side (e.g. energy efficiency) and a decarbonized electricity sector. We need an economy-wide decarbonization of our energy system, including buildings, transportation and industry. Electricity will not be the only answer, we need innovations in low carbon fuels as well, particularly aviation. We need to think about the whole energy portfolio in achieving our climate goals and look at really tough problems such as negative carbon technologies. It's time to open our intellectual aperture and drive toward a really aggressive portfolio with a timescale of 30-40 years. As the NW is an innovation center in the energy space, Secretary Moniz is looking for this region to be a big player.

Questions asked during the question and answer period were:

The NW is a special region – there are remarkable philanthropic efforts ongoing in the NW – what is the potential to attract philanthrophic efforts to the energy sector?

After the Paris Agreement, philanthropists are making approaches to engage but those engagements are currently at very early stages. The Bullitt Center resulted from the Living Building Challenge and represents an example of how philanthropy can get involved in energy initiatives. Prizes such as the XPRIZE are another way. The key is leverage as philanthropic dollars can be used to leverage other investments.

Increased speed and scale are needed to win the battle against climate change. If you were able to take what we're doing and scale it to what's needed, what would be your blue sky approach to make this change happen at the speed and scale needed?

If you take the Paris goals as an intermediate step, it is a big first step. In terms of the technology space, we have the tools at hand to meet the 2025 goals. However a 25% reduction in carbon emissions is very different than an 80% reduction. Our success will have to come from a synergy between the innovation agenda and policy. On policy, we will need an economy wide approach, such as carbon pricing. We also need tools to help us accelerate innovation – some options are through the tax code or the DOE loan program. The loan program has played a major role in kickstarting utility scale photovoltaics. Five companies were started initially, and now 30 more are coming on line without federal support. We also need to invest in rebuilding our energy infrastructure. A little money has to be spent upfront to make money and clean up the environment.

MARIA CANTWELL, U.S. SENATOR (D-WA)

Senator Maria Cantwell discussed innovation priorities for the NW region. She began by discussing the energy bill - the first in 8 years - that is currently in conference. It includes a $1B increase in DOE science funding over the next five years, motivated in part by the challenges posed by decarbonization of the economy and cybersecurity. As we continue to diversify and electrify our economy we need to invest in cybersecurity.

Energy innovation is much about software as it is about the physical infrastructure. Mission Innovation should accept this challenge and create programs in smart buildings and carbon fiber recycling. Boeing is bringing back airplane parts manufacturing to

Washington and it wants to work with recycled carbon fiber to drive down its manufacturing costs. Port Angeles has been given the responsibility to figure out how to do this nationwide. Smart buildings can potentially save 40% of the energy we spend on buildings; it is possible to achieve greater energy savings from smart building technologies supported by the current energy bill than from the CAFE standards established by the last energy bill. Senator Cantwell called on the workshop attendees to act as an ecosystem to support the bill and its efforts to support energy research.

She then spoke about Bill Gates and the Breakthrough Energy Coalition's intent to invest in early stage clean energy innovations. A barrier faced by the BEC is that they want to see that the U.S. Congress is committed to funding the level of innovation called for by Mission Innovation. The BEC's view is that other countries will not invest if the U.S. does not lead. Members of Congress must be convinced that regional innovation can make a difference in our economy. Washington State is committed to Mission Innovation – it is time for the rest of the country to wake up and realize the advantages of a clean economy.

Workshop Summary

The Northwest (NW) Regional Clean Energy Innovation Partnership Workshop was hosted by the University of Washington on Monday, August 15, 2016. The workshop brought together ~120 participants from regional universities, National Laboratories, industry, state and federal stakeholders, non-profit organizations and the investment community to focus on the future of clean energy in the NW. The workshop was designed to explore how the regional innovation ecosystem can accelerate the development of emerging clean energy technologies and stimulate economic development.

The event featured presentations by U.S. Secretary of Energy Ernest Moniz, U.S. Senator Maria Cantwell, Washington State Governor Jay Inslee and U.S. Representative Derek Kilmer. Five panels were held during the day with representatives from different elements of the NW clean energy ecosystem, including universities, National Laboratories, large and small companies, non-profits and patient capital investors.

Several themes emerged from the discussions and presentations that took place during the workshop. The NW region:

- Is a natural "all-of-the-above" energy testbed for a deeply decarbonized economy.
- Is a leader in energy efficiency, making efficiency the second largest resource for the region after hydropower.
- Has been a leader in developing and deploying smart grid technologies to increase grid flexibility, reliability, resiliency and cyber security.
- Is integrating core competencies in smart grid and smart building concepts with the internet of things (IoT) to fully realize the benefits of an electricity system that can enable deep decarbonization.
- Has a robust clean energy innovation ecosystem.
- Brings a mature and diverse perspective to the conversation about how best to balance trade-offs between clean energy and protecting the environment.
- Enjoys broad community support for clean energy.
- Is a clean energy gateway to Asia and to/from Canada.
- Would benefit from the development of a clean energy innovation roadmap.

A group of regional research and business stakeholders who participated in the workshop have committed to collaborate in developing this NW regional roadmap for clean energy innovation.

Appendix A – Workshop Agenda

Mission: Innovation

Northwest Regional Clean Energy Innovation Partnership Workshop

The Lyceum, Husky Union Building
University of Washington, Seattle
August 15, 2016

Agenda

7:30 - 8:00 a.m. Registration

8:00 - 8:05 a.m. Welcome

Gerald Baldasty
Provost, University of Washington

8:05 - 8:15 a.m. Mission: Innovation

Mary Lidstrom --*Introduction by Jerry Baldasty*
Vice Provost for Research, University of Washington

8:15 - 8:35 a.m. The Northwest as a Clean Energy Leader

Derek Kilmer --*Introduction by Mary Lidstrom*
U.S. Representative, State of Washington

Daniel T. Schwartz – *introduction by Mary Lidstrom*
Director, Clean Energy Institute

8:35 - 8:45 a.m. Emerging Opportunities & Challenges for Clean Energy

Thomas J. Ranken -- *introduction by Dan Schwartz*
President and Chief Executive Officer, CleanTech Alliance

8:45 - 9:45 a.m. **Panel 1: Emerging Opportunities to Accelerate Clean Energy**

Moderator: Thomas J. Ranken
President and Chief Executive Officer, CleanTech Alliance

Panelists: Steve Ashby
Director, Pacific Northwest National Laboratory

Kelly Beierschmitt
Chief Research Officer, Idaho National Laboratory

Grace Bochenek
Director, National Energy Technology Laboratory

Cynthia Sagers
Vice President for Research, Oregon State University

Chuck Staben
President, University of Idaho

9:45 - 10:00 a.m. **Break**

10:00 - 11:00 a.m. **Panel 2: Policies and Activities to Accelerate Regional Leadership**

Moderator: David Kenney -- *introduction by Dan Schwartz*
Director, Oregon BEST

Panelists: Brian Bonlender
Director, Washington State Department of Commerce

Christopher C. Deschene
Director, U.S. Department of Energy Office of Indian Energy Policy and Programs

Michael Hagood
Program Development Director, Center for Advanced Energy Studies and Idaho National Laboratory

Fawn Sharp
President, Quinault Indian Nation

Elliot Mainzer
Administrator, Bonneville Power Administration

11:00 a.m.- 12:00 p.m. **Panel 3: Energy Innovation at Northwest Research Institutions**

Moderator: Malin Young -- *introduction by Dan Schwartz*
Chief Research Officer, Pacific Northwest National Laboratory

Panelists: Cynthia Powell
Chief Research Officer, National Energy Technology Laboratory

Daniel Schwartz
Director, Clean Energy Institute, University of Washington

Jud Virden
Associate Laboratory Director — Energy & Environment,
Pacific Northwest National Laboratory

Michael Wolcott
Regents Professor, Louisiana-Pacific Distinguished Professor, and Director, Institute for Sustainable Design, Washington State University

12:00 - 1:00 p.m. **Lunch**

1:00 - 2:00 p.m. **Panel 4: Industry for Regional-to-Global Impact**

Moderator: Jud Virden-- *introduction by Dan Schwartz*
Associate Laboratory Director — Energy & Environment,
Pacific Northwest National Laboratory

Panelists: Michael Atkinson
North American Region General Manager, GE Grid Solutions

Curt Kirkeby
Fellow Technology Strategy, Avista Utilities

Bert Van Hoof
Group Program Manager, Microsoft Corporation
Dave Cuthbert

Senior Solutions Architect, Amazon Web Services

2:00 - 2:15 p.m.	Break	
2:15 - 3:15 p.m.	**Panel 5: The Innovation Ecosystem - From Research to Startup**	
	Moderator:	Brian Young-- *introduction by Dan Schwartz* Director, Economic Development for the Clean Technology Sector, State of Washington
	Panelists:	Scott Forbes Director, Computer Science & Engineering, FedImpact
		John Hopkins Chairman and Chief Executive Officer, NuScale Power
		Eric "Rick" Luebbe Chief Executive Officer, EnerG2
		Gary Yang Chief Executive Officer, UniEnergy Technologies
3:15 - 5:00 p.m.	**Leadership Speaker Series – The Future of Clean Energy**	
	Jay Inslee –*Introduction by Steve Ashby* Governor, State of Washington	
	Ernest J. Moniz—*Introduction by Grace Bochenek* U.S. Energy Secretary *Q&A moderated by Jaime Shimek*	
	Maria Cantwell--*Introduction by Dan Schwartz* U.S. Senator, State of Washington	
5:00 - 7:00 p.m.	**Reception**	
	University of Washington Club, Yukon Pacific Room	

Appendix B: Workshop Participants

Name	Title	Organization
Aaron Feaver	CTO	EnerG2
Alvin Kwiram	Vice Provost Emeritus	University of Washington
Amy Lientz	Director, Partnerships, Engagement, Tech. Transfer	Idaho National Laboratory
Ann Goos	Strategic Communications Specialist, Government Relations & External Affairs and University Communications	Washington State University
Austin Wright-Pettibone	Regent	University of Washington
Benjamin Rushwald	Director of Technology Innovation	
Bert Van Hoof		Microsoft
Bob Kirchmeier		
Brad Cebulko	Energy Policy Advisor	Washington Utilities and Transportation Commission
Brenda White	Government Relations	Snohomish PUD
Brian Bonlender	Director	WA Department of Commerce
Brian Polagye	Director of UW Node	NW National Marine Renewable Energy Research Center
Brian Young	Governor's Clean Tech Sector Lead	Washington
Bryce Yonker	Executive Director	Smart Grid Northwest
Cameron Fisher	Principal - Aquatic Sciences	48 North Solutions, Inc.
Chris Ajemian	Principal	Chris Ajemian Consulting
Chris Davis	Gov. Inslee's office	State of Washington
Chris Mulick	Director of State Relations	Washington State University
Christopher C. Deschene	Director	DOE Office of Indian Energy Policy and Programs
Chuck Hersey	Forest Health Planner	WA DNR
Chuck Staben	President	University of Idaho
Curt Kirkeby	Fellow-Technology Strategy	Avista Utilities
Cynthia Powell	Deputy Director for Science & Technology	National Energy Technology Laboratory
Cynthia Sagers	VP of Research	Oregon State University
Dan Schwartz	Director, CEI	UW
Daniel Malarkey	Vice President, Business Development and Public Policy	1EnergySystems
Dave Curry	Board Chairman	Demand Energy
Dave Cuthbert		Amazon
David Ginger	Kwiram Professor of Chemistry and Associate Director	Clean Energy Institute
David Kenney	CEO	Oregon BEST
David McCaughey		ESCO Industry
Derek Kilmer	Representative	US House of Representatives
Devin MacKenzie	WRF Professor	University of Washington
Elliot Mainzer	Administrator	Bonneville Power Administration
Emily Abdon	Video Producer	UniEnergy Technologies
Eric "Rick" Luebbe	CEO	EnerG2

Erick Flieger	EED Manager	Pacific Northwest Site Office
Erin Bennett	Video Producer	UniEnergy Technologies
Fawn Sharp	President	Quinault Indian Nation
Gary Yang	CEO	UET
Gerald Baldasty	Provost	University of Washington
Glynda Becker	Director of Federal Relations	Washington State University
Grace Bochenek	Director	National Environmental Technology Laboratory
Holly Bentz	Engineering Staff Officer	
Hugh Hillhouse	Rehnberg Professor of Chemical	University of Washington
Jack Faris	Council Chairman	Clean Energy Institute
Jaime Shimek	Director, Federal Affairs	Pacific Northwest National Laboratory
Janet Nelson	VP for Research and Economic Development	University of Idaho
Jay Inslee	Governor	Washington
Jay Kimball	Managing Director	Orcas Power & Light
Jeff Canin	Fund Manager	Element 8
Jerry Seidler	Professor	University of Washington
Jessica Matlock	Director, Government Relations	Snohomish County PUD
Jill Aronson Pfaendtner	Assistant Director	Clean Energy Institute
Jill Brandenberg	Manager	PNNL
John Gibson	Manager Distribution System Operations	Avista
John Hopkins	CEO	NuScale Power
John Plaza	CEO	Kopius Energy Solutions
John Reagh	Managing Director	Washington Research Foundation
Jud Virden	ALD, Energy and Environment	PNNL
Jun Liu	Program Director and Laboratory Fellow	PNNL
Karen Blasdel	Manager, Community Affairs	Pacific Northwest National Laboratory
Keith Phillips	Gov. Inslee's office	State of Washington
Kelly Beierschmitt	CRO	INL
Kimberly Rasar		DOE
Lars Johansson	Manager	Element 8
Lilo D. Pozzo	Associate Professor	University of Washington
Lisa Graumlich	Dean & Professor	UW College of the Environment
Malin Young	CRO	PNNL
Marcia Burkey	SVP	TerraPower
Marcia Garrett	Director of Regional Relations	Washington State University
Marco Lowe	Vice President	Enwave Seattle
Maren Disney	Communications Specialist	Pacific Northwest National Laboratory
Maria Cantwell	US Senator	Washington
Maro Imirzian	Partner	Pathbridge Associates
Mary Lidstrom	VP for Research	University of Washington
Michael Bragg	Dean of Engineering	University of Washington
Michael Lakeman	Associate Technical Fellow and Biofuel Regional Director	Boeing
Michael Marchand		

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Michele Miranda	Federal Government Affairs Manager	Portland General Electric
Mike Atkinson	Grid Solutions	General Electric
Mike Hagood	Director, Program Development	INL and Center for Advanced Energy Studies
Mike Wolcott	Regents Professor Louisiana-Pacific Distinguished Professor and Director, Institute for Sustainable Design	Washington State University
Norma Smith	Representative	WA House of Representatives
Paula Linnen	Director, External Relations	Pacific Northwest National Laboratory
Peter Moulton	Alt Fuels & Vehicles/Bioenergy Coordinator	Washington State Dept of Commerce
Peter Vierthaler	Manager	Northwest Partners
Philip Jones	Commissioner	WUTC
Phillip Stevenson	General Manager	PACCAR
Renee Gastineau	Business Development Analyst	UniEnergy Technologies
Rick Gustafson	Professor	University of Washington
Robin Rego	Manager, Generation Project Development	Energy NW
Roger Snyder	Site Office Manager	Pacific Northwest Site Office
Ron Stimmel	Sr. Manager	Amazon Global Renewable Energy Strategy
Ross Macfarlane	Former Senior Advisor	Climate Solutions
Russ Weed	VP Business Development	UniEnergy Technologies
Sam Ricketts	Director, Washington Office	State of Washington
Sanjay Kumar	Tech Entrepreneur and Investor	
Sarah Castro		University of Washington
Scott Forbes	Director, Computer Science & Engineering	FedIMPACT
Scott Gibson	Principal Engineer	Snohomish PUD
Scott Harden	Principal, Industrial IoT	OSI Consulting
Sean James	Tech Research Program Manager	Microsoft
Shaun Taylor	Education Director	Clean Energy Institute
Steve Ashby	Lab Director	PNNL
Steve Hoberecht		Montana State University
Steven Gottlieb		
Suresh Baskaran	Chief Science and Technology Officer, Energy and Environment Directorate	Pacific Northwest National Laboratory
Tammie Borders	Business Development	INL and the Center for Advanced Energy Studies
Tara Lee	Gov. Inslee's office	State of Washington
Terry Oliver	Chief Officer of Tech Innovation	Bonneville Power Administration
Thomas Ranken	Executive Director	CleanTech Alliance
Todd Currier	Assistant Director	Washington State University Energy Program
Tony Usibelli	Spec. Asst. for Energy and Climate	WA State Dept. of Commerce
Toya Beiswenger	Scientist	PNNL
Uzma Siddiqi	Principal Engineer, Innovation	Seattle City Light

Wei Hibeln	Consultant	Demand Energy
Yi Liu	Deputy Director	Energy Internet Research Institute, Tsinghua University

Appendix C: Washington State Energy Profile

Source: U.S. Energy Information Administration

WASHINGTON QUICK FACTS

- Washington leads the nation in electricity generation from renewable resources. The state generates more than three-fourths of its electricity from renewable resources, predominantly hydroelectric power, and it produces about one-sixth of the electricity generated nationwide from these resources.
- Net electricity generation exceeds retail electricity sales in Washington. The state is an exporter of electricity to the Canadian power grid and supplies U.S. markets as far away as California and the Southwest.
- The Grand Coulee Dam on Washington's Columbia River is the largest hydroelectric power producer in the United States, with a net summer generating capacity of 7,079 megawatts.
- In 2014, Washington was the leading producer of electricity from hydroelectric sources and produced 30% of the nation's net hydroelectricity generation.
- Although not a crude oil-producing state, Washington ranked fifth in the nation in crude oil-refining capacity as of January 2015.
- Washington ranked 10th in the nation in net generation of electricity from wind energy in 2014.
- In 2014, Washington had the lowest average residential retail electricity prices in the nation and the lowest average combined retail electricity price across all sectors.

OVERVIEW

Washington's economy developed around the fishing and logging industries during the 19th century.[1] The state's industrial base has expanded with increased access to abundant and affordable energy.[2,3] Energy resources in Washington include little in the way of fossil fuels;[4,5] however, the state is the crude oil refining center for the Pacific Northwest.[6] Washington's greatest energy supply comes from its significant renewable energy resources, especially hydroelectric power.[7,8] The state's climate ranges from the rainforest in the extreme western part of Washington, where the heaviest precipitation in the continental United States occurs, to near desert conditions in areas east of the Cascade Range.[9] Washington's western forests provide ample biomass, and many areas of the state are conducive to wind and geothermal power development.[10,11,12]

Washington is a leader in the energy-intensive forest products industry and the transportation equipment manufacturing industry.[13] The industrial sector and the transportation sector each consume almost three-tenths of the total energy used in the state.[14] The residential sector accounts for only about one-fourth of the state's total energy consumption, in part because Washington's more densely populated areas are west of the Cascade Range where the summers are cool and comparatively dry, and the winters are mild.[15,16,17] Overall energy consumption in Washington is well below the national median on a per capita basis, and electric power generation in Washington exceeds the state's needs.[18,19]

PETROLEUM

Early oil exploration activity in Washington was largely unsuccessful. Only small amounts of oil were found, and no oil production has been reported since the early 1960s.[20] Nonetheless, Washington is a principal refining center serving Pacific Northwest markets.[21] The five refineries in Washington receive crude oil supplies primarily from Alaska by tanker.[22,23] However, Alaskan production is declining, and Washington's refineries have become increasingly dependent on crude oil from other sources. In addition to imports from Canada and other countries, all five refineries are now receiving or plan to receive crude oil by railcar from the Bakken shale formation in North Dakota.[24,25,26]

Motor gasoline accounts for nearly half of Washington's consumption of petroleum products.[27] The use of oxygenated motor gasoline is required throughout the state.[28] Motor gasoline is produced at Washington's five oil refineries. The largest oil refinery in the state can process about 225,000 barrels of crude oil per calendar day. The other four refineries each process between about 40,000 and 145,000 barrels of crude oil per day.[29,30,31,32,33] Some refineries produce CARB (California Air Resources Board) motor gasoline, as well as conventional motor gasoline.[34] Most of these refineries also produce jet fuel. Washington is among the top 10 states in the nation in jet fuel consumption.[35,36] Several large U.S. Air Force bases and U.S. Navy installations located in the state contribute to the considerable amount of jet fuel consumed.[37]

NATURAL GAS

A small amount of natural gas was produced in south-central Washington in the mid-20th century, but there has not been any production in the state since then. Exploration wells drilled in the state have resulted in the development of Washington's only natural gas storage field.[38] Because Washington has no natural gas production, the state relies heavily on natural gas produced in Canada that is transported by pipeline to U.S. markets.[39] The Sumas Center, in Canada, near the border between Washington and British Columbia, is the principal natural gas trading and transportation hub for the U.S. Northwest.[40] The Northwest Pipeline system supplies natural gas to markets in western Washington,[41] and the Gas Transmission Northwest Pipeline enters the state from Idaho, bringing Canadian natural gas to the eastern part of Washington.[42,43] More than three-fifths of the natural gas entering Washington flows south to Oregon and beyond.[44]

The residential sector is typically the leading natural gas-consuming sector in Washington, followed closely by the industrial sector. Occasionally the electric power sector consumes the largest share.[45] More than one-third of Washington households use natural gas as their primary energy source for home heating.[46]

COAL

Washington's last remaining coal mine was closed in 2006.[47] The mine had provided most of the coal used at the large coal-fired power plant in Centralia, Washington.[48] Fuel for the Centralia power plant is now delivered by train from the Powder River Basin of Wyoming and Montana.[49] Small amounts of coal are delivered to industrial facilities in the state.[50] Large amounts of western coal are shipped by rail through Washington's Seattle Customs District, the fifth-largest coal export center in the nation and the largest on the West Coast, on the way to Canada for export to Asia.[51] Several proposals for the construction of coal export terminals in Washington have been made, but only two are still under consideration-one in Bellingham, Washington and one in Longview, Washington.[52]

ELECTRICITY

Washington is the leading U.S. producer of hydroelectric power, routinely contributing more than one-fourth of the nation's total net hydroelectric generation.[53] Eight of the state's 10 largest power plants are hydroelectric facilities,[54] and most of them are located on the Columbia River.[55] The largest hydroelectric facilities in Washington are, at more than 60 years of age, among the oldest generating facilities in the nation.[56,57] Federal entities built and continue to own or operate the largest hydroelectric facilities in Washington.[58] The Bonneville Power Administration, one of four federal power marketing administrations,[59] is the marketer of electricity produced at the federal dams in the state.[60] Hydroelectric power accounts for about seven-tenths of Washington's electricity generation and dominates the state's electricity market, providing abundant and relatively inexpensive electricity.[61,62]

Natural gas-fired power plants, the state's one nuclear power plant, wind turbines, a single coal-fired power plant, and, to a lesser extent, biomass, account for almost all of Washington's remaining net electricity generation.[63] The state's two largest nonhydroelectric power plants by capacity are the coal-fired power plant and the nuclear generating station.[64] Washington's one large coal-fired power plant generates enough electricity each year to supply a city about the size of Seattle. The site's two coal-fired units are scheduled to be decommissioned, one in 2020 and the other in 2025, as part of a plan to reduce emissions.[65,66] Conversion of the units to natural gas or construction of a new natural gas-fired power plant at the site is being considered.[67] Nuclear power provides less than one-tenth of Washington's net electricity generation.[68] The state's only nuclear power plant, the Columbia Generating Station, is located near the Columbia River in the south-central part of the state on the U. S. Department of Energy's Hanford site.[69]

Net electricity generation exceeds retail electricity sales in Washington. The state is an exporter of electricity to the Canadian power grid and supplies U.S. markets as far away as California and the Southwest.[70,71] Large amounts of cheaply produced hydroelectric power leave Washington via the Western Interconnection, which runs from British Columbia and Alberta, Canada through Washington and Oregon to southern California and the northern part of Baja California, Mexico. The entire system covers all or parts of 14 states.[72] Because of the relatively low operating costs of hydroelectric power generation, Washington's average retail electricity prices are the lowest in the nation.[73] More than half of all Washington households are heated with electricity.[74]

RENEWABLE ENERGY

Washington leads the nation in electricity generation from renewable resources.[75] The state generates more than three-fourths of its electricity from renewable resources, predominantly hydroelectric power, and it produces about one-sixth of the electricity generated nationwide from these resources.[76] Some renewable resources provide energy in forms other than electricity, such as the wood used in wood stoves.[77] When these other types of energy are included, renewable resources account for more than nine-tenths of Washington's total overall energy production.[78] The Columbia River, second only to the Mississippi River in the volume of its flow, enters Washington near the state's northeastern corner and flows in an arc through the eastern half of the state, before forming much of the boundary between Washington and Oregon. Draining all of eastern Washington and the western slopes of the Cascade Range south of Mt. Rainier, the river provides water for vast hydroelectric projects.[79] The Grand Coulee Dam on Washington's Columbia River is the largest hydropower producer in the United States. The dam's power plant is the nation's largest electricity generating facility of any kind when measured by capacity. [80]

Although nonhydroelectric renewable energy sources provide less than one-tenth of Washington's net electricity generation,[81] the state is among the top 10 in electricity generation from these resources.[82] Washington's more than 3,000 megawatts of installed capacity make wind energy the second-largest contributor to the state's renewable generation after hydropower.[83,84] Washington's first utility-scale wind project came online in 2001, and development of resources along the Columbia Gorge, a high wind resource area, has continued in recent years.[85] Washington is also a substantial producer of energy from wood and wood waste, [86] and the state accounts for almost 3% of the nation's net electricity generation from biomass.[87] Mountainous areas throughout the state and a major portion of the lowlands west of the Cascades are covered by timber.[88] Despite the large biomass resource, Washington generates more than four times as much electricity from wind as from biomass.[89,90]

Washington has both low- and high-temperature geothermal resources, primarily in the Columbia Basin and in the southern Cascade Range.[91,92] Although low-temperature geothermal resources do not have a large impact on the energy economy as a whole, they have direct-use applications, such as heating buildings, greenhouses, and water, and for use in geothermal heat pumps. More than 900 low-temperature geothermal wells have been drilled in the Columbia Basin. Undeveloped high-temperature geothermal areas in Washington's volcanic Cascade Range have an estimated electric potential of up to 300 megawatts. If fully developed, it is estimated that this 300-megawatt potential could produce about 2.5 billion kilowatthours of electricity per year, enough to provide electricity to more than 265,000 average U.S. homes.[93]

Washington has several programs focused on energy independence, energy conservation, and energy efficiency. The state provides incentives for investment in production and distribution facilities for biofuels created from agricultural product wastes from Washington's almost 15 million acres of farmland and for electricity generation from anaerobic digestion.[94,95] Facilities in Washington have the capacity to produce more than 100 million gallons of biodiesel per year.[96] The state's Energy Independence Act, enacted in 2006, seeks energy independence for Washington, and the Pacific Northwest region as a whole, through increased energy conservation and through the use of appropriately sited renewable energy projects.[97] The act requires utilities with at least 25,000 retail customers to obtain 15% of their electricity from qualified new renewable resources by 2020 and to undertake cost-effective energy conservation.[98,99] In 2005, Washington became the first state in the country to adopt high-performance green buildings standards for new state-funded buildings. [100]

ENERGY ON TRIBAL LANDS

Washington is 1 of 14 states with more than 100,000 Native American residents.[101] The 29 federally recognized tribes in the state have more than 2.5 million acres of tribal land.[102,103,104] Like much of Washington, tribal lands in the state have substantial renewable resource potential. Hydropower, biomass, and geothermal energy are abundant. The largest reservation in the state, the Colville Reservation, is working on creating a reservation-wide tribal utility that will use distributed generation and renewable energy projects to support the tribal goals of self-reliance and environmental sustainability.[105] Land that was once part of two Washington reservations, the Confederated Tribes of the Colville Reservation and the Spokane Tribe Indian Reservation along the Columbia River, is now the site of Grand Coulee Dam.[106] Smaller hydroelectric projects on tribal lands in Washington include power generated from water flowing in the Wapato Irrigation Project canals on the Yakama reservation.[107] Hydropower generation potential on the Yakama reservation, the second-largest reservation in the state, is among the highest of any reservation in the nation.[108] The Yakama tribe is also investigating opportunities to use its solar and woody biomass resources.[109,110]

Washington tribal lands also have substantial biomass and geothermal resources. The Yakama and Coeur d'Alene tribal lands of Washington are among the top five reservations in the nation in their potential for electricity generation from solid biomass.[111] The Quinault Indian Nation on Washington's Pacific Coast has abundant woody biomass and is working toward using it for heat and energy through the development of wood pellet manufacturing on the reservation.[112,113] The greatest potential for significant geothermal generation on Washington's tribal lands is in the south-central part of the state, but tribal lands in the northeastern and the northwestern parts of the state also have geothermal electricity generation potential. [114]

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Appendix D: Oregon State Energy Profile

Source: U.S. Energy Information Administration

OREGON QUICK FACTS

- In 2014, 73% of Oregon's net electricity generation came from conventional hydroelectric power plants and other renewable energy resources.
- Major transmission lines connect Oregon's electricity grid to California and Washington, allowing for large interstate electricity transfers.
- The Mist field in northwestern Oregon is the only producing natural gas field in the Pacific Northwest.
- Oregon's geothermal potential is ranked third in the nation after Nevada and California.
- Oregon has teamed with Washington, California, and British Columbia to create the West Coast Green Highway, a collaborative effort to promote sustainable transportation solutions through the use of high-efficiency and cleaner-fuel vehicles.
- There are 404 electric vehicle charging stations in Oregon, with a total of almost 1,000 charging outlets.

OVERVIEW

Oregon's economy is closely tied to its climate. The heavy sustained runoff from the snowpack in high elevations, as well as high annual rainfall, makes it possible to generate substantial amounts of hydroelectric power. Large dams along the Columbia River generate most of the hydroelectric power in the Pacific Northwest. The Columbia River cuts through both the Cascade Range and the Coast Range of Oregon, forming the Columbia Gorge, an area of high wind energy potential.[1,2] The geologically active Basin and Range country in southern and eastern Oregon, as well as the Cascades in western Oregon, are promising sites for geothermal energy development.[3,4] The mild temperatures and abundant rainfall in the western part of the state contribute to rapid tree growth, which, along with agricultural waste-products, provides an ample source of biomass.[5,6]

Manufacturing made up about one-fourth of Oregon's gross state product in 2014, a share that is more than three times the proportional contribution of manufacturing to the nation's economy as a whole.[7] Computers and electronics are the state's most important manufactured products.[8] Although the energy-intensive lumber business, including the manufacture of related forest products, is one of Oregon's principal industries, the state's total energy consumption per capita is moderate.[9,10,11] Most of Oregon's population lives in mild climate zones west of the Cascades, along the Pacific Coast, and in the Willamette Valley. The residential sector uses less energy per capita than it does in most of the states, ranking Oregon 39th in the nation.[12,13,14] Seven-eighths of Oregon households use electricity or natural gas for home heating, and most of the rest heat with wood.[15] Transportation is Oregon's leading energy-consuming sector.[16]

PETROLEUM

Oregon does not produce any crude oil, does not have any crude oil reserves, and has not had an operating oil refinery since 2008.[17,18,19] The Puget Sound refineries in Washington provide more than nine-tenths of the refined petroleum products used in Oregon. Those products arrive in the state by way of the Olympic Pipeline and by barge. Refineries in Salt Lake City, Utah, and British Columbia, Canada, also provide refined petroleum products to Oregon, and small amounts come by tanker from California and the Pacific Rim countries of Indonesia, South Korea, and Japan. [20] The use of oxygenated motor gasoline is required throughout the state.[21]

NATURAL GAS

The Mist field in northwestern Oregon is the only producing natural gas field in the Pacific Northwest.[22] More than 50 reservoirs have been found in the field since its discovery in 1979.[23,24] The Mist field includes underground natural gas storage projects in some of its depleted natural gas reservoirs.[25] Oregon has a total of seven underground natural gas storage fields with a combined capacity of almost 30 billion cubic feet.[26,27] Natural gas in storage reservoirs flows into the pipeline system to meet peak customer demand during colder months and to meet the needs of wind power generators as they respond to rapidly changing wind conditions.[28,29] Exploration wells continue to be drilled in the Mist field; however, production has declined markedly from its high of 4.6 billion cubic feet of natural gas per year in the mid-1980s. Natural gas production from the Mist field is now less than 0.8 billion cubic feet.[30,31]

Oregon receives natural gas by pipeline from British Columbia and Alberta in Canada and from Wyoming, Colorado, and New Mexico.[32] The Northwest Pipeline system supplies the Portland area and western markets, as well as the northeastern corner of the state.[33] The Gas Transmission Northwest system serves the central portion of the state between Stanfield and Malin, Oregon's two natural gas market hubs.[34] The Ruby pipeline, which began operations in the summer of 2011, brings natural gas from the Opal Hub in Wyoming, crossing through Utah and Nevada before terminating at the Malin hub. The Ruby Pipeline's initial design capacity of up to 1.5 billion cubic feet per day increased the regional capacity to move natural gas from the major Rocky Mountain basins to consumers in California, Nevada, and the Pacific Northwest by more than 50%.[35,36]

Several liquefied natural gas (LNG) terminals have been proposed in Oregon, and all were originally planned as import terminals. As a result of changing market conditions, only two proposals remain active. Those two proposed LNG terminals-Jordan Cove at Coos Bay and Oregon LNG at Warrenton-have pursued federal permits to build export facilities.[37]
In Oregon, the electric power sector consumes the largest share of natural gas. The industrial sector is the next largest user followed by the residential sector.[38] Almost two-fifths of Oregon households use natural gas as their primary energy source for home heating.[39]

COAL

Although coal was mined in southwest Oregon in the late 19th century and in the early 20th century, there are no active commercial coal mines operating in Oregon today.[40,41] Instead, limited amounts of coal are shipped by rail from the Powder River Basin in Wyoming to fuel a small percentage of the state's electricity generation. The state's only coal-fired power plant is scheduled to stop burning coal by the end of 2020.[42] Minor amounts of coal are shipped from Utah to industrial plants in the state as well.[43]

ELECTRICITY

Hydroelectric power dominates the electricity market in Oregon, providing more than half of the net electricity generated in the state.[44] In some years that share can approach three-fourths of net generation.[45,46] Oregon's four largest electricity generating facilities-John Day, The Dalles, Bonneville, and McNary-are all hydroelectric plants located on the Columbia River. [47] They account for two-thirds of the net summer capacity from the 10 largest power plants in the state.[48] Smaller hydroelectric plants generate power along several rivers flowing from the Cascade Mountains.[49]

Natural gas-fired power plants supply about one-fifth of the state's net electricity generation.[50] Although as much as one-third of the Oregon's total electricity supply is generated at coal-fired power plants, most of that generation occurs out-of-state.[51,52] Oregon's only coal-fired power plant provides about 5% of Oregon's in-state electricity generation.[53] There are no nuclear power plants in Oregon.[54]

Oregon's net electricity generation is greater than its consumption,[55] and some electricity is delivered to other states by way of the Western Interconnection, which runs south from western Canada to Baja California in Mexico and reaches eastward across the Rocky Mountains to the Great Plains. The Western Interconnection is one of the principal power grids in North America.[56] Major transmission lines of the Western Interconnection, called the Pacific Intertie, connect Oregon's electricity grid to California's grid, allowing for large interstate energy transfers between the Pacific Northwest and the Southwest. There is an alternating current (AC) intertie and a direct current (DC) intertie. The Pacific DC Intertie originates near the Columbia River at the Celilo Converter Station on the Bonneville Power Administration's grid outside The Dalles, Oregon, and is connected exclusively to the Sylmar Converter Station north of Los Angeles, California. The Pacific DC Intertie is capable of transmitting power in either direction, but power flows mostly from north to south.[57] Although it was originally designed to transmit electricity south during California's peak summer demand season, flow is sometimes reversed overnight and during periods of reduced hydroelectric power generation in the Pacific Northwest.[58]

RENEWABLE ENERGY

Renewable resources, including hydroelectric power, contribute almost three-fourths of the net electricity generated in Oregon.[59] In years with increased or prolonged precipitation or snowmelt, renewable resources contribute as much as four-fifths of net electricity generation because of the state's abundant hydroelectric generation capacity.[60,61,62] Oregon is the second-largest producer of hydroelectric power in the nation.[63] Wind energy provides most of the state's net generation from nonhydroelectric renewable resources.[64] With facilities in the Columbia Gorge and eastern Oregon hills, Oregon has more than 3,100 megawatts of operational wind farms; and, in 2014, wind provided one-eighth of Oregon's in-state net electricity generation from all sources.[65,66] Some of Oregon's electricity is generated from biomass, primarily from wood and wood waste but also from landfill gas.[67,68] Smaller amounts of electricity are generated from the state's significant geothermal resources and its more limited solar resources.[69,70,71]
Oregon's geothermal potential is ranked third in the nation, after Nevada and California.[72]

Although Oregon currently has only small amounts of geothermal electricity generation, the state's high-temperature geothermal areas have the potential to generate as much as 2,200 megawatts of electric power.[73,74] A 22-megawatt electricity-generating unit using geothermal energy is now operating in Malheur County.[75] This larger unit follows the installation of a 0.3-megawatt geothermal unit that began producing electricity at the Oregon Institute of Technology's Klamath Falls campus in 2009.[76] A second unit (1.2-megawatts) at the Oregon Institute site began operating in 2014.[77] A 3.1-megawatt unit is currently under construction in Lake County.[78] Oregon's geothermal resources have also long been used in direct heat applications.[79] Almost the entire state east of the Cascade Range has ample low- to mid-temperature geothermal resources.[80,81] Oregon has about 2,200 thermal wells and springs that furnish direct heat to buildings, communities, and other facilities.[82] Oregon residents have been using low-to-moderate temperature geothermal resources for more than a century, but biomass is the most abundant and widely used source of renewable thermal energy in Oregon.[83,84] Forest covers almost half of the state, and many industrial facilities in Oregon use woody biomass to provide heat and generate electricity.[85] Oregon gives tax credits for the production, collection, and transportation of biomass used for energy production.[86]

Oregon has teamed with Washington, California, and British Columbia to create the West Coast Green Highway, a collaborative effort to promote sustainable transportation solutions through the use of high-efficiency and cleaner-fuel vehicles.[87,88] When complete, the Electric Highway, a network of fast-charging stations for electric vehicles along Interstate 5 and Highway 99, will span the 1,300 miles from the Canadian border to the Mexican border with public fast-charging locations every 25 to 50 miles.[89,90] As of August 2015, there were about 400 electric charging stations in service across Oregon, with almost 1,000 charging outlets.[91] In May 2014, Oregon joined with seven other states across the nation to form the collaborative Multi-State ZEV Action Plan. The plan's goal is to get 3.3 million zero-emission vehicles on the nation's highways by 2025.[92]

Oregon's renewable energy portfolio standard requires the state's largest utilities-those with more than 3% of the state's load-to meet 25% of their electricity sales with new renewable energy sources by 2025. Small utilities with 1.5% to 3% of the state's load have a target of 10%, and the smallest utilities have a target of 5%.[93] Overall, Oregon's electricity generation from renewable resources, other than hydroelectric power, has increased dramatically in recent years. From 2007 through the end of 2014, electricity generation from nonhydroelectric renewable resources more than quadrupled. In-state electricity generation from all renewable resources, including hydropower, was two-thirds of the state's total net generation in 2007 and almost three-fourths of total generation in 2014. The change was almost entirely the result of increased generation from renewable resources other than hydropower. [94]

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Appendix E: Idaho State Energy Profile

Source: U.S. Energy Information Administration

IDAHO QUICK FACTS

- Idaho is rich in renewable energy resources; the state's volcanic formations provide substantial geothermal energy potential.
- In 2014, 82% of Idaho's net electricity generation came from renewable energy resources, a larger share than any other state.
- Idaho had the fifth lowest average electricity prices in the United States.
- In 2014, Idaho's in-state net electricity generation equaled 65% of the state's total electric industry retail sales. The remainder came from other states and international imports.
- Hydroelectric power supplied 60% of net electricity generation in Idaho in 2014, the second largest share in the nation, after Washington state.
- Idaho Power's Hells Canyon dam system is the nation's largest privately owned hydroelectric facility.
- Idaho's wind generation increased by 13% in 2014 and provided 18% of net electricity generation.

OVERVIEW.

Idaho's river valleys offered shelter and passage through rugged western mountains to early North American hunters, French trappers, and the Lewis and Clark expedition.[1] The plains flanking the Snake River stretch all the way across southern Idaho, from the Teton Mountains on the Wyoming border to Hells Canyon at the Oregon border. The valleys of the Snake River and its tributaries are home to most of Idaho's population, more than one-third of whom live in the Boise area,[2,3,4] while vast stretches of the state remain wilderness.[5,6] Idaho's altitude varies from mountains more than 12,000 feet high to river valleys just a few hundred feet above sea level.[7] Temperatures across the state range just as widely, from a record high of 118 degrees Fahrenheit to a record low of 60 degrees below zero.[8]

Idaho's panhandle, which borders Canada on the north, is home to ski resorts.[9] Mountains capture moisture-laden clouds coming east from the Pacific in winter. Those clouds typically produce plentiful mountain snowfall for winter sports, for hydroelectric power from fast-running rivers, and for irrigation in the lowlands in spring and summer, when the weather turns hot and dry.[10] Idaho, also known as the Gem State, is rich in minerals like silver and phosphate, but the state has few reserves of fossil fuels.[11] About three-fourths of the energy Idahoans consume comes from out of state.[12,13,14] Idaho's energy potential lies in its substantial geothermal, hydropower, wind, solar, and biomass resources.[15]

Idaho's energy consumption per capita is above the national average,[16] and the state's energy intensity, measured by energy consumption per real dollar of gross domestic product, is well above the national median.[17] The industrial sector leads energy consumption, followed by the transportation sector. [18] Agriculture, forest products, and mining have long been important to Idaho's economy. Science and technology, electronics manufacturing, food processing, and tourism are growing economic sectors.[19,20,21]

PETROLEUM

Idaho does not produce[22] or refine petroleum.[23] Exploration for petroleum began in 1903, but, despite promising geology in the state's southeast and southwest, no commercial reserves have been discovered.[24] Idaho consumers receive petroleum products by two pipelines, one running west along the Snake River Valley from refineries in Utah and another crossing the northern part of the state from refineries in Montana.[25,26,27] Some petroleum products from Puget Sound refineries are also sent by pipeline to Portland, Oregon, and then by barge up the Columbia and Snake Rivers to Lewiston, Idaho.[28]

Petroleum is the leading energy source in Idaho. Consumption per capita is slightly below the national median.[29,30] Nearly four-fifths of petroleum products in Idaho are consumed in the transportation sector, and most of the rest is used in the industrial sector.[31] Idaho is one of the few states that allow use of conventional motor gasoline statewide.[32,33] However, much of the motor fuel sold in the state contains 10% ethanol because more populous states around Idaho do require oxygenated blends.[34] Idaho has one operating ethanol plant. A smaller plant, which used potato waste as a feedstock, has shut down.[35,36] The productive capacity of the operating plant is nearly equal to Idaho's annual consumption of ethanol.[37]

NATURAL GAS

Commercial natural gas production is being developed in southwestern Idaho, but output has been small.[38,39,40,41,42] Idaho consumers receive nearly all their natural gas supply by pipeline from Canada and from other western states.[43,44,45] One pipeline system enters Idaho at its northern border with Canada, crosses the panhandle, and continues to Washington, Oregon, and California.[46] The other system runs from the San Juan Basin in southwestern Colorado across Idaho's Snake River Plain to the Pacific Northwest and Canada. That system is bi-directional, so it can supply natural gas to Idaho either from Canada or from Wyoming and Colorado.[47] About 85% of the natural gas entering Idaho continues on to Washington, Oregon, and Nevada.[48] The residential and industrial sectors are Idaho's largest natural gas-consuming sectors.[49] Slightly more than half of Idaho households use natural gas as their primary energy source for home heating.[50]

COAL

Idaho has no coal mining[51] and few estimated recoverable reserves.[52] There are no electric utility-owned coal-fired generating plants within Idaho.[53] Electricity is generated with coal at only two industrial cogeneration facilities.[54,55,56] Coal is supplied primarily from mines in Wyoming and Utah and shipped to Idaho by rail.[57] However, Idaho gets about two-fifths of the electricity consumed in the state from coal-fired power plants located in other states. Citing uncertainty about future regulatory requirements for coal, the state government has deferred decisions on proposals for new coal-fired generating plants in Idaho.[58]

ELECTRICITY

Hydroelectric power plants dominate Idaho electricity generation, typically supplying between three-fifths and four-fifths of in-state net generation. The balance of Idaho's net electricity generation is supplied by wind, natural gas, biomass, geothermal, and coal generation.[59,60] Idaho has among the lowest average electricity rates in the nation, mainly because of its large proportion of hydroelectric generation.[61,62] About one-third of Idaho households use electricity as their primary energy source for home heating.[63]

Idaho typically consumes twice as much electricity as it generates and depends on power supplied via interstate transmission lines from out-of-state resources owned by Idaho utilities and others.[64,65,66] Those power lines have grown increasingly congested, and projects are under way to expand capacity both to supply Idaho and to transport power from other mountain states to the West Coast markets.[67,68,69,70,71] Most new generating capacity planned in the region is natural gas-fired, but the transmission projects also aim to enable development of the region's renewable resources.[72,73]

The Idaho National Laboratory, a federal nuclear power and energy research center, is the state's second largest employer and the site of the first U.S. nuclear electricity generation in 1951.[74,75,76] The state has no commercial nuclear power plants.[77]

RENEWABLE ENERGY

Idaho typically gets nearly 85% of its net electricity generation from renewable resources, a larger share than any other state.[78,79] Most of the state's renewable power comes from hydroelectric sources,[80] and 4 of Idaho's 10 largest generating facilities run on hydropower.[81] The three dams making up Idaho Power's Hells Canyon complex on the Snake River constitute the nation's largest privately owned hydroelectric facility.[82,83]

Idaho has no renewable portfolio standard (RPS) or other renewable requirements,[84,85] but its three major electric utilities do offer net metering programs that take electricity from small wind, solar, biomass, and other renewable sources. Commercial, residential, and agricultural customers are eligible for net metering.[86,87]

Although a relatively small percentage of the state's land area is available for wind development, Idaho has substantial wind energy potential along the Snake River and on mountain ridges across the state.[88] The first commercial wind energy project began operating in 2006, and, by 2014, wind provided 18% of the state's net electricity generation.[89,90] At the end of 2014, Idaho had 16 wind facilities online with a total capacity of 973 megawatts,[91] all located in the Snake River Valley.[92] A number of other wind projects have been proposed.[93] Wind developers typically sell their electricity to Idaho electricity retailers and sell their renewable energy certificates to electricity providers who are subject to RPS requirements in neighboring states.[94,95,96]

Idaho has no utility-scale solar generation,[97] but solar photovoltaic and solar thermal installations are widely used in the state's rural areas. The state offers low-interest loans[98] and tax deductions for small-scale solar facilities.[99] Idaho's volcanic landscape has a wealth of hot springs and other geothermal resources that have long been used for aquaculture, greenhouses, spas, resorts, and city district heating.[100] The state has among the best geothermal potential in the nation.[101] In 2014, Idaho was 1 of 10 states with operating geothermal power capacity[102] and 1 of 7 with commercial geothermal electricity generation.[103] Idaho's sole geothermal generating plant, a 13-megawatt facility, is built on the site of the federal government's first geothermal experiment, at Raft River in the state's southeast.[104] Geothermal development in Idaho may be limited by availability of groundwater, since utility-scale geothermal technology is water-intensive.[105,106,107] Idaho gets about 4% of its net electricity generation from biomass,[108] primarily waste and cogeneration from the wood products and agricultural industries.[109,110]

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Appendix F: Montana State Energy Profile

Source: U.S. Energy Information Administration

MONTANA QUICK FACTS

- The Williston Basin of Montana and North Dakota holds one of the largest accumulations of crude oil in the United States; its Bakken and Three Forks formations are currently estimated to be capable of producing 7.4 billion barrels of oil.
- As of the end of 2013, Montana held more than one-fourth of the nation's estimated recoverable coal reserves and was the seventh-largest coal-producing state. It produced 4.3% of U.S. coal in 2013 and distributed coal to nine other states.
- Montana's four refineries, with almost 30% of U.S. Petroleum Administration for Defense District 4 (Colorado, Idaho, Montana, Utah, and Wyoming) refining capacity as of January 1, 2015, are able to process heavy Canadian crude oil for regional markets.
- Wind electric power generation in Montana grew by 12% in 2014 and supplied 6.5% of the state's net electricity generation.
- The state is the fifth-largest producer of hydropower in the nation and has 23 hydroelectric dams.
- Montana created a Renewable Energy Resource Standard requiring that public utilities and competitive electricity suppliers obtain 15% of electricity sales from renewable energy resources by 2015. The standard requires electricity suppliers to buy a set amount of power from smaller community-based renewable energy projects.

OVERVIEW

Montana is the fourth largest state in the nation and the third least-densely populated.[1,2] The state is a net supplier of energy to the rest of the country, producing energy from both fossil and renewable resources.[3] About one-fourth of the nation's estimated recoverable coal reserves are in Montana,[4] and the northern and eastern areas of the state also are believed to contain large deposits of crude oil and natural gas.[5,6] The Missouri River, the longest river in the United States and the fourth longest in the world, begins in the Rocky Mountains in western Montana and flows eastward across the state.[7,8] The river basin stretches from Montana to Missouri and has substantial hydroelectric energy resources.[9,10] The state's vast plains, punctuated by mountains and canyons, provide Montana with some of the best wind potential in the nation.[11]

The Continental Divide cuts east and then north through the mountains of western Montana, making Montana the only state in the nation with rivers that drain into the Pacific Ocean, the Gulf of Mexico, and the Hudson Bay.[12] The mountains capture warm, moist air from the Pacific Ocean, creating a more moderate climate in the western third of the state than further east, where the Rocky Mountains give way to dry, wind-swept plains that stretch to the Dakotas. While summer days can exceed 100 degrees Fahrenheit on the plains, winter can bring Arctic blasts. Montana recorded the lowest temperature ever measured in the contiguous 48 states: 70 degrees below zero.[13,14] The state's population is clustered in and around a few towns, mainly in the valleys of the Missouri River and its tributaries.[15] Much of the eastern third of Montana has, on average, less than one resident per square mile.[16]

Montana's early economy was built around ranching, wheat, mining, and timber. After World War II, spurred by such popular destinations as Glacier and Yellowstone National Parks, tourism increased, and, by 1970, it became the second largest industry in the state, after agriculture.[17]

Mining, oil and natural gas production, petroleum refining, agriculture, and the state's vast open spaces and long travel distances make the Montana economy energy-intensive, and per capita energy consumption is among the top one-third of all states.[18,19,20] The transportation and industrial sectors lead state energy consumption. Together they account for about three-fifths of Montana's energy use.[21]

PETROLEUM

Montana produces about 1 in every 100 barrels of U.S. oil.[22] Production is concentrated in the northeastern part of the state near the North Dakota border.[23] Montana's Elm Coulee field was initially the most prolific oil field in the Williston Basin, a geologic basin that spreads from eastern Montana into North Dakota and Canada.[24,25] However, Montana oil production declined substantially from its 2006 peak, as drilling activity moved to North Dakota, where the productive Bakken Shale formation is thicker.[26,27] Recently, production has rebounded as drilling activity has increased in northeastern Montana's portion of the Williston Basin.[28] At the end of 2013, Montana had about 1% of proved U.S. petroleum reserves, but potential recoverable resources in the state are believed to be much greater.[29,30]

Montana has four operating oil refineries, three in the Billings region and one at Great Falls.[31] Those refineries receive crude oil mainly from Canada and Wyoming and produce a full range of refined products, including motor gasoline, diesel fuel, propane, and asphalt.[32,33,34,35] Pipelines and railroads both are used to ship crude oil into and refined products out of the refineries. Several pipelines carry Montana crude oil to refineries in other states as well.[36] New production in the region has been constrained by the lack of pipeline takeaway capacity. A number of new pipeline projects are in development, primarily to transport crude oil to major refining centers in the Midwest, in Oklahoma, and on the Gulf Coast. The transport of crude oil by rail has increased substantially as an alternative to pipeline shipment.[37,38,39]

About two-thirds of Montana's petroleum consumption occurs in the transportation sector, and almost one-fourth is used by the industrial sector.[40] Although Montana's total petroleum consumption is low compared with that of other states, it is among the top 10 states in terms of per capita consumption.[41,42] During the winter months, federal air quality standards require oxygenated motor gasoline use in the Missoula area.[43] The use of conventional motor gasoline is allowed during the winter in the rest of the state.[44,45] Montana has no ethanol refineries,[46] although some have been proposed.[47] Ethanol is brought in from nearby states and blended with conventional motor gasoline at two locations in the state.[48]

NATURAL GAS

Montana produces less than 0.5% of the nation's natural gas.[49] Production from natural gas wells and coalbed methane wells in the state has been trending downward from its peak in 2007 and 2008, as exploration activities have focused more on drilling for oil than natural gas.[50,51,52] More than three-fourths of Montana's natural gas wells are in the northern part of the state, near the Canadian border. Almost all of the remaining production comes from wells in smaller fields in the Williston Basin in northeastern Montana near the North Dakota border and from wells in south-central Montana.[53]

Montana is crossed by natural gas pipelines from Canada and Wyoming, and most of the natural gas entering the state comes from Canada and continues on to North Dakota on its way to Midwestern markets.[54,55,56,57,58] In 2014, three-tenths of net U.S. natural gas imports from Canada entered the country through Montana.[59,60,61] Montana has more underground natural gas storage capacity than any other state in the Rocky Mountain region, and its Baker/Cedar Creek field in the Williston Basin is the nation's largest single underground natural gas storage facility.[62,63]

More than half of Montana households use natural gas as their primary energy source for home heating.[64] Overall consumption is fairly evenly divided among the industrial, residential, and commercial sectors. Despite cold winters that can be especially harsh in eastern Montana, the state's per capita natural gas use is near the national median.[65,66,67] In recent years Montana residents have consumed more natural gas than the state produces, making the state a net importer.[68]

COAL

Montana produces more than 4% of U.S. coal from just half a dozen mines.[69] The majority of Montana's coal production comes from several large surface mines in the Powder River Basin in southeastern Montana.[70,71,72] One of Montana's largest coal mines, the Rosebud surface mine, supplies almost all of its production to the state's largest electricity generating station, the coal-fired power plant at Colstrip, Montana.[73,74,75] Almost all of the coal used in-state fuels electricity generation and is delivered to generating plants by conveyor. In 2013, about one-fifth of the coal mined in Montana was consumed in the state, and all but a small fraction of that coal was used to generate electric power. Almost half of Montana's coal production was sent by rail to other states in 2013. The remaining three-tenths of Montana production was exported to western Canada, where much of it continued on to Asia.[76,77,78,79]

Montana has the nation's largest estimated recoverable coal reserves and holds one-fourth of the nation's demonstrated coal reserve base.[80] U.S. coal demand has been declining because of competition from cheaper natural gas and more stringent environmental regulations.[81,82] U.S. electricity generators are also retrofitting coal-fired generating plants with emission controls that allow use of higher-sulfur coal, thereby reducing demand for low-sulfur Powder River Basin coal.[83] Montana coal mine development projects have been proposed to supply a growing export market, but U.S. exports of coal have also declined in recent years.[84,85,86]

ELECTRICITY

More than half of Montana's net electricity generation comes from coal, but new federal environmental rules are affecting coal-fired generation.[87] One of Montana's older coal-fired power plants is being shut down because of the projected costs of the new pollution controls needed to meet federal restrictions on emissions of mercury and other toxins produced by burning coal.[88] Montana is hosting a test of carbon sequestration in a formation near the Canadian border, which could help coal-fired power plants reduce the impact of carbon emissions.[89,90] Most of the rest of Montana's electricity generation comes from hydroelectric power plants. Wind generation is a small but growing component, and the state has a small amount of natural gas-fired generating capacity.[91,92]

Montanans use about half of the electricity generated in the state. The rest is sent to other western states by high-voltage transmission lines.[93] Generating more electricity for sale in other states is seen as an economic opportunity for Montana, but current transmission lines are congested, and new capacity must be built in order to expand sales. Most of Montana is part of the Western Interconnection grid serving western states and Canadian provinces.[94,95,96] Several transmission projects are being developed to increase capacity to move electricity from both conventional and renewable sources out of Montana to states in the west and southwest and to expand an intertie between the Montana and Alberta, Canada, grids.[97] Part of eastern Montana is connected to the eastern U.S. grid.[98]

Montana deregulated its electricity system starting in 1997, but the state experienced rising retail electricity costs and later re-regulated some aspects.[99,100] However, more than seven-tenths of Montana's net electricity generation still comes from independent power producers.[101] The state's average retail electricity prices are well below the national average and are among the lowest one-fourth of states.[102] The commercial and residential sectors each consume a little more than one-third of the electricity used in Montana, and the industrial sector consumes the balance.[103]

RENEWABLE ENERGY

Montana has substantial renewable energy resources. Its mountainous terrain along the Continental Divide creates fast-running rivers, and the eastern two-thirds of the state is drained by the Missouri River and its tributaries.[104] The state is the fifth-largest producer of hydropower in the nation and has 23 hydroelectric dams.[105,106] Six of Montana's 10 largest power plants by generating capacity are hydroelectric facilities,[107] and hydroelectric generating capacity is being expanded around the state.[108,109,110]

With its wide plains crossed by mountains, buttes, and canyons, Montana also has some of the best utility-scale wind potential in the nation.[111,112] Montana has several electric utility-scale wind farms in the center of the state, and more in various stages of development.[113,114] However, new wind projects depend in part on demand for renewable energy from other states and on available transmission capacity. To provide a stable supply of wind-based power to the grid, a large transmission and closed loop pumped hydro storage project is in development about 100 miles northwest of Billings, Montana.[115,116]

Montana has both geothermal energy resources and biomass energy resources.[117] The state has identified more than 50 geothermal areas and about one-third of them are high-temperature sites. Montana's most significant geothermal resources are in the mountainous southwest, but, so far, they have not been tapped for electricity generation. Low- and moderate-temperature resources are found in nearly all areas of the state.[118] Those geothermal resources can be used for aquaculture, greenhouses, spas, resorts, and space heating. Several hot springs resorts and public bathing facilities in Montana take advantage of that resource and many also use it for space heating.[119] Advanced geothermal technology is being explored as a means to tap into the energy from hot fluids (formation waters) that are produced along with crude oil and natural gas from wells in eastern Montana. The heat from those fluids may be enough to support small geothermal power plants at the sites.[120] The state is also looking at increasing the use of biomass from wood waste, particularly trees culled as part of efforts to fight pine beetle infestations. Most of Montana's biomass comes from and is used at wood-processing facilities. Although Montana had 4 megawatts of installed solar generating capacity by the end of 2014, none of it was at electric utility-scale solar facilities. There are a variety of residential and commercial distributed solar generation installations around the state.[121,122]

Montana's renewable resource standard (RRS) requires retail electricity suppliers to get at least 15% of the electricity they sell in-state from renewable energy sources beginning in 2015. Power must come from renewable facilities that began operation after January 1, 2005. The RRS recognizes renewable energy from wind, solar, geothermal, biomass, small hydroelectric facilities, landfill gas, anaerobic digesters, and fuel cells that use renewable fuels as qualifying renewable resources. The standard requires electricity suppliers to buy a set amount of power from smaller community-based renewable energy projects. [123]

ENERGY ON TRIBAL LANDS

More than 5.5 million acres of Montana, about 6% of the state's land area, is held by Native Americans.[124] Montana's tribal lands sit on top of a wealth of coal, crude oil, and natural gas resources. The largest of the seven federal reservations in the state, the Crow Nation Reservation, with more than 2 million acres in south-central Montana, is underlain by one of the largest coal reserves in the United States.[125,126,127] The North Cheyenne Reservation in southeastern Montana, adjacent to the Crow Nation Reservation, also has a large coal resource.[128] In addition to an estimated 9 billion tons of low-sulfur coal, the Crow Nation Reservation has oil and natural gas resources.[129] The Blackfeet Reservation on the eastern slopes of the Rocky Mountains has, on its more than 1.5 million acres, oil and natural gas resources that are being developed.[130,131] Oil was discovered in the early 1950s on the Fort Peck Reservation, the second-largest reservation in the state.[132] The Fort Peck Reservation is located in northeastern Montana, above the western edge of the Bakken formation. There are several oil and natural gas fields near the reservation's borders, but the tribe has not yet had any successful Bakken wells drilled on its lands.[133]

Much of Montana's tribal land has abundant renewable resource potential, and several tribes are focusing their energy development on those resources. The Salish-Kootenai tribe, on the Flathead reservation in western Montana, became the first tribal hydroelectric owners and operators in the nation when they acquired sole ownership of the Kerr Dam on the boundary of their reservation in September 2015.[134] The Flathead and the North Cheyenne reservations, with their timber resources, have significant biomass potential.[135,136] The best wind potential in Montana is in the eastern three-fourths of the state, particularly in the northern and northeastern regions where the Blackfeet, Rocky Boy, Fort Belknap, and Fort Peck reservations are located.[137,138] The Blackfeet Reservation, the third largest reservation in Montana, has pursued wind energy projects for several years. In 1996, a utility-scale wind project came online at the Blackfeet Community College in Browning, Montana, offsetting the college's electricity costs.[139] In 1999, the four 10-kilowatt wind turbines installed by the tribe at a wastewater treatment plant in Browning began supplying one-fourth of the plant's electricity needs.[140,141]

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