FIVE BIG GOALS FOR 2040

Goal 1

[energy]

Rewiring the Northwest's Energy Infrastructure

An Integrated Vision and New Investment Strategy

the evergreen state college

Center for Sustainable Infrastructure

FIVE BIG GOALS FOR 2040

Goal 1

Rewiring the Northwest's Energy Infrastructure

Afforable • Resilient • Sustainable • Integrated

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Introduction and Overview

The Focus

Rewiring the Northwest's Energy Infrastructure paints a picture of an integrated energy system in Oregon and Washington that, by 2040, is among the most sustainable and resilient in the world. At the same time, that 2040 energy system will be beneficial and affordable to the people that will pay for it: rich, middle-class, and lower-income people alike, as well as institutions, communities, and businesses big and small.

The project also explores how our investment strategies for energy infrastructure need to change to achieve performance and cost excellence, and to deliver more long-term community value and benefit for each infrastructure dollar we spend.

The paper is presented in these sections:

- Introduction and Overview
- Key Drivers for Transformative Change
- Window on the Future: A Vision for Our 2040 Energy System
- World Class by 2040: Is It Feasible and Affordable for the Northwest?
- Rethinking Energy Infrastructure Investment
- Two More Audacious Ideas

In rapidly growing swaths of the country, installing rooftop solar power can save customers money. In early 2016, the one-millionth American home installed solar, with another 3 million homes projected for the next five years.

The Five Big Goals for 2040 Program

This project on energy is the first in the "Five Big Goals for 2040" research program of the Center for Sustainable Infrastructure (CSI) at The Evergreen State College, to engage top Northwest thought leaders and innovators in mapping the path to achieve a transformative 2040 infrastructure vision.

CSI champions a new paradigm and discipline for infrastructure investment. During 2014, CSI interviewed 70 of the region's top infrastructure innovators and thought leaders. Our report based on these interviews, *Infrastructure Crisis, Sustainable Solutions: Rethinking Our Infrastructure Investment Strategies*, uncovered both crisis and opportunity. Quality infrastructure is essential to the economic vitality and quality of life of our communities, but billions of dollars will be required to keep the Northwest's aging infrastructure – our energy, water, transportation and waste management systems – in working order. Replicating 'business as usual' infrastructure strategies, however, will lock in unnecessarily wasteful, expensive, polluting, and vulnerable systems for decades to come. The question the inaugural report addresses is: *'How do we get much smarter about how we'll invest that money?'*

Because most infrastructure investment is long-term – facilities are often designed to function and are paid for over 25 years or more – the inaugural report offered "Five Big Goals for 2040" as a conversation starter. The idea was to foster alignment around a vision for how our infrastructure systems will work 25 years from now. This will position us to avoid investments today that are at risk of becoming outdated or obsolete in a decade or two, in favor of investments that move us where we want to go in the longer-term.

The Five Big Goals for 2040 program is diving deep on each goal in turn – starting with energy – to harness the insights of top innovators and thinkers in five special reports, rolled out between 2016 and 2018. These reports will provide both inspiration and guidance to current and future infrastructure decision-makers and professionals.

Approach for This Project

This paper dives into the Energy Goal. The framing question, which CSI posed to some three dozen energy thought leaders and innovators, is: *How can the Northwest build one of the world's most sustainable, resilient, and affordable energy systems by 2040?*

Introduction and Overview

This report distills and synthesizes the insights of these thought leaders, supplemented by targeted research and literature review.

It pays special attention to optimizing the whole energy system across traditional silos. Because we currently manage electricity, transportation, heating, waste, and water infrastructures separately, redirecting investment toward innovative systems that connect these infrastructures to maximize shared benefits will be one of the Northwest's great institutional challenges.

What do we mean by a 'world-class' energy system? *Simply this:* In 2040, Oregon and Washington will be among the best in class, with regions around the world looking to the Pacific Northwest as a center of expertise and groundbreaking examples for super-sustainable, resilient, affordable, and integrated energy infrastructure systems.

The thought leaders whom CSI Director Rhys Roth formally interviewed over the summer of 2015 included top Oregon and Washington utility executives, advocates, business innovators, regulators, analysts, and agency leaders. These thought leaders generously shared their insight and perspectives on crucial questions, such as:

- In 2040, how will a world-class sustainable, resilient, and affordable energy system in the Northwest – including electricity, transportation, and heat – differ from today's?
- What are the right system-wide goals, and the most effective and affordable transition strategies to achieve them?
- Where are the best integration opportunities where energy infrastructure investments can leverage and enhance investment by other infrastructure providers for mutual benefit?
- How can we generate the greatest economic, equity, and community-wide benefits from the transition?
- What high-level policy and regulatory changes can be most helpful in setting the region on the right infrastructure trajectory?
- What do we need to do to build a highly-skilled energy workforce and address the coming retirement wave?

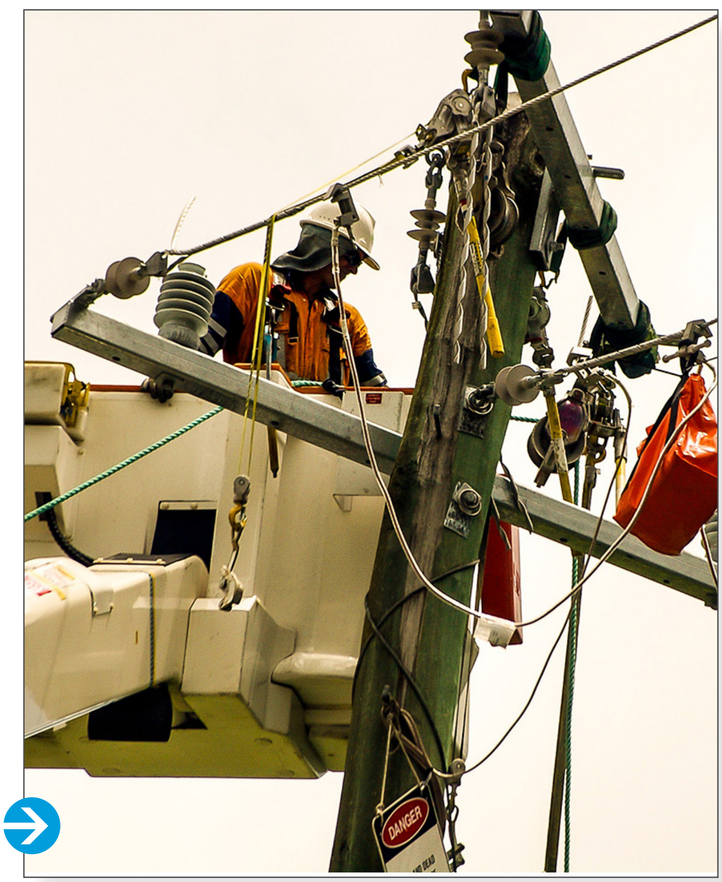
The technology and policy changes transforming the energy marketplace today are astonishing, and the implications for the 25 year time frame of this project are seismic. In many ways, our thinking has yet to catch up. Even the thought leaders interviewed for this project are struggling to understand these implications and to craft effective strategies for adapting to this dynamic playing field.

To test an initial synthesis of the thinking of the thought leaders and other analysts and commentators, an Executive Review Team of 20 leaders provided detailed feedback on a draft of this report in fall of 2015. This review was essential for ground-truthing the report's details and significantly reshaping its conclusions and recommendations toward something closer to a shared perspective. That said, the report's shortcomings, as well as its assertions, remain completely the responsibility of its primary author, CSI Director Rhys Roth.

What You'll Find Here

This paper first overviews some of the most important change drivers transforming the energy marketplace. It then offers a picture of our world class 2040 integrated energy system in the Northwest and highlights the range of technologies converging to transform the energy marketplace and blur the boundaries between electricity, transport, heat, waste and water infrastructures.

The paper looks at whether a system blending these new technologies is technically feasible and affordable for the region, and then explores a core question: How do our energy infrastructure policies and strategies – which will



A utility worker repairs a power line. Our utilities face some big challenges in the years ahead: upgrading aged infrastructure, adapting to disruptive technologies, and managing a workforce retirement wave.

Introduction and Overview

effect billions of dollars in investment – need to change to get us to this future? To do that, the paper presents a set of system-wide goals for a world-class 2040 energy system, and discusses strategies and reforms to enable better investment outcomes and reward the contributions of key energy transformation participants, from utilities to families, companies, institutions, and communities.

Finally, because this inquiry seeks transformative change to bring home the full benefits of advancements in energy technology, the paper offers 'Two More Audacious Ideas' as broad brush examples of the kind of bold initiatives that can signal and support the Northwest's intent to develop a world-class energy system.

To reveal a critical plot twist right up front: Our energy institutions are too electricity-centric to steer smart system-wide investment, when some two-thirds of our energy use is for transportation and heat. At the same time, electricity will play a much bigger role in our world-class integrated energy system in 2040, with at least 90% of it carbon-free, capturing new market share especially at the expense of fossil fuels now used for transportation.

A lot is being said and written about dim prospects for electric utilities as previously passive customers gain new tools to produce and manage power on-site that save money and reduce the bills they pay utilities. But this paper presents an optimistic story for electric utilities which will have a different but essential role to coordinate and manage the electricity 'backbone' that underlies much of the infrastructure investment that the Northwest needs for our energy system of 2040 to achieve world-class status. Natural gas utilities, which sell a fossil fuel product, on the other hand, are not obvious winners in a 2040 sustainable energy future. But to survive and thrive, these utilities can diversify to provide heating and cooling services powered by renewable energy, waste heat, and organic waste recycling.

The challenges to utilities are real, but utilities need not wither. It will, however, be a time of profound change for the utility business environment. For one, new energy tools will be entering customers' hands en masse, as 'end users' become active participants and value generators in the energy system. Utilities, increasingly, will find they no longer have sole control of the energy infrastructure, especially at the electricity grid's edges where customers, and new and varied generation and storage devices, connect.

A second profound change for utilities is the accelerating retirement wave – the professionals that make up our utilities will hand the reins to a nearly entirely new workforce over the next 25 years. To be successful, we'll need the people in this new workforce to strategically deploy billions of dollars in necessary energy infrastructure investment in new ways, with new partners, under new regulations, policies, and business models, using new technology, and new decision-making and management processes.

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Key Drivers for Transformative Change

Disruptive Technologies

The energy sector, and especially the electricity system, is poised for fundamental changes as new 'disruptive' technologies enjoy explosive growth and declining costs – from solar photovoltaics to new battery and heat pump technologies, electric cars, and smart home energy apps. Smart technologies are enabling a sort of energy internet that networks millions of points of production, use, and storage with instant communication, monitoring and response capability. In the process, customers are gaining tools to become value producers in the energy marketplace.

Silicon Valley entrepreneurs and investors are now aggressively pursuing business models they hope can carve out lucrative customer-facing footholds in the energy system, and tech giants like Apple and Google are probing for rich opportunity as well.

Nest thermostats are widely viewed as today's state-of-the-art. They can be remotely controlled by phone or tablet, can smart-adapt as your needs and the seasons change, and emphasize easy, intuitive use and beautiful design. (Posted to Flickr by Scott Cawley. Cropped. Creative Commons 2.0 Generic License (CC BY 2.0) https://creativecommons.org/licenses/by/2.0/legalcode.)

Together, these new technological capabilities are transformative. Today's energy system, at a basic level, remains little changed from the technology framework established over a century ago. The electric grid still moves power from large, centralized generating stations out to millions of points of consumption, with power flowing in one direction – from central plant to passive consumer. Transportation vehicles still run on internal combustion engines powered by liquid fossil fuel, and most of our heating and cooling systems are inefficient and wasteful. Now, radical changes in energy technology are in motion, following in the footsteps of the astonishing technological transformations we have witnessed in so many sectors of our economy and way of life.

Cars are quickly becoming computers-on-wheels, with electric cars threatening to go mainstream in the decade ahead, with big implications for our future infrastructure. (Photo by Avda (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons.)

"If you think about computer technology, the innovators of 25 years ago couldn't have imagined the iPad and smart phone," says Ron Pernick of Clean Edge.

Meanwhile, energy efficiency technologies and programs are saving Americans billions of dollars, and the U.S. Department of Energy recently published a blueprint to increase the efficiency and productivity of energy use economy-wide by another 50% in just fifteen years, meaning we'll use half the energy to produce each dollar of economic value in 2030.[1]

"There are so many exciting things going on," says Dave Danner, Chair of the Washington Utilities and Transportation Commission. "The public will embrace some of them, some will lose out in the market. In the end, to succeed technology will have to be cleaner and cheaper."

1 U.S. Department of Energy. (2015). Accelerate Energy Productivity 2030: A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness. Prepared by Keyser, D.; Mayernik, J., M.; McMillan, C. of National Renewable Energy Laboratory; Agan, J.; Kempkey, N.; Zweig, J. of U.S. Department of Energy.

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Disrupted Utilities

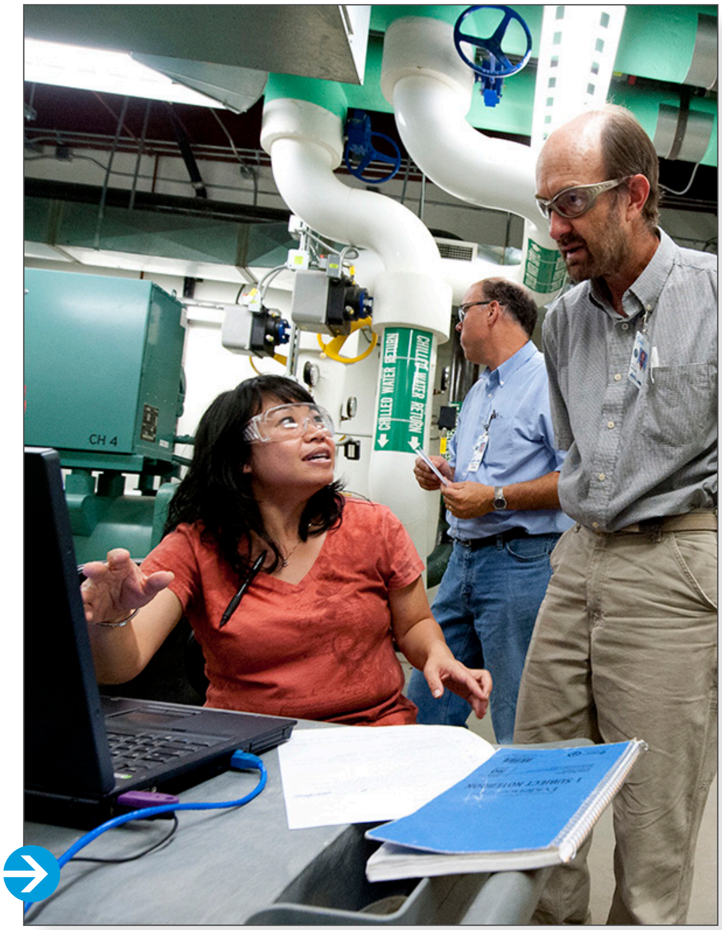
The 100-year history of the electricity industry witnessed the increasing dominance of large centralized power plants – coal, natural gas, hydropower, nuclear – leveraging economies of scale to produce reliable and low-cost power. An extensive, landscape-crossing infrastructure of transmission lines carries high-voltage power vast distances, to substations that ramp down the power voltage for the local distribution wires that deliver the power to millions of consumers. Regulated and public monopoly utilities evolved to cost-effectively own and manage this infrastructure and share the benefits widely, equitably, and affordably with businesses and residences, rural and urban, and low-income, middle-class and wealthy alike.

In many respects, utilities have been remarkably and consistently successful in fulfilling this mission. They have invested in power generation, transmission, and distribution facilities to meet projected demand, recovering their costs by billing customers at reasonable rates for the power they consume. "We've got a pretty good electrical system in this country – it's probably the most amazing machine in the world," says John Savage, Commissioner at the Oregon Public Utilities Commission. "All the generators in the West are synchronized and 60 hertz are coming out of all the outlets."

Today's power industry is facing transformative change as disruptive technologies reconfigure the energy marketplace and open up astonishing new opportunities for customer participation and choice. "Who would have known that the computer company of 10 years ago would now be a phone company, a music company," says Tugrul Daim, Professor of Engineering and Technology Management at Portland State University. "The old phone companies have shrunk, the music stores are gone. Technology companies will figure out how to market innovative energy services – Google, Apple, Tesla are really good at this. The utilities are not really good at customer service in a competitive environment – they need a whole new set of skills."

In the past century's power grid, customers were passive recipients of energy on demand. Today, new technologies are enabling customers at the edges of the grid to produce power, slash demand through more efficient equipment and buildings, and to help grid operators manage peaks and troughs in supply and demand through smart technologies embedded in power-consuming devices. These changes are unlocking the potential for a radically cleaner, more sustainable, more resilient, and more complex energy system – but one that could upend the past century's monopoly utility system.

"The regulatory structure is being challenged," says Jack Speer, a senior executive and engineer with 45 years experience in the energy and aluminum industries. "Historically, we've had this regulatory compact that basically says that utilities are different than private markets – we're not going to let you make a big profit, but we also won't let you go broke. Utilities have put a lot of infrastructure on the ground under this framework," he says. "Now we're entering a time of uncertainty, which raises the question of who should take the risk if the infrastructure investments we make now turn out to be the wrong bets? Risk-reward and winners-losers are really uncertain now."



With energy customers gaining new tools to produce, reduce, and manage their energy, utility professionals are rethinking their long-stable business model. Photo by Dennis Schroeder, NREL 21735.

A major risk for utilities in the new customer-centric energy marketplace is that they may be forced to charge higher rates to cover their fixed costs. Traditionally, utilities charge customers based on the amount of energy they consume, at a per-unit rate set to recover the costs to generate and deliver power through transmission and distribution infrastructure. The utility's costs, however, aren't entirely tied to how much power they deliver – in fact, roughly half their power system costs are typically fixed. Customer-owned

Key Drivers for Transformative Change

power generation and efficiency reduce the amount of energy that customers buy, reducing utility revenue immediately. But fixed costs don't immediately go down in response to declining demand – only the utility's revenues do.

As a result, to bring in the revenue to pay for fixed costs, utilities may have to charge a bit more for each unit of energy they do sell. But charging a higher rate makes it more economically attractive for more customers to conserve and produce their own energy, further reducing power sales for the utility – a potentially vicious cycle. Analysts have warned ominously of a utility 'death spiral' of shrinking customer demand triggering higher rates, encouraging customers to shrink their demand still further.

Utility 'death' may not be inevitable or in the public's interest for a number of reasons, but loss of customer demand is a significant threat to the traditional utility business model that the industry is now taking seriously. According to a survey by UtilityDive.com, a majority of respondents from traditional utilities do not expect their current business model to still be in effect in 20 years.[2]

But a strong majority of the thought leaders interviewed for this project believe utilities will have a very important role in the Northwest energy system of 2040, though it may look different than today. "We can't dismiss or minimize the role of a centralized utility into the future," says Megan Owen, Director of Strategic Market Development at McKinstry, a top energy management and facilities firm based in Seattle. "The poles and wires that allow electrons to move freely, reliably, and productively—the backbone of our electrical grid—are essential to any new utility model that incorporates clean and efficient energy sources at scale."

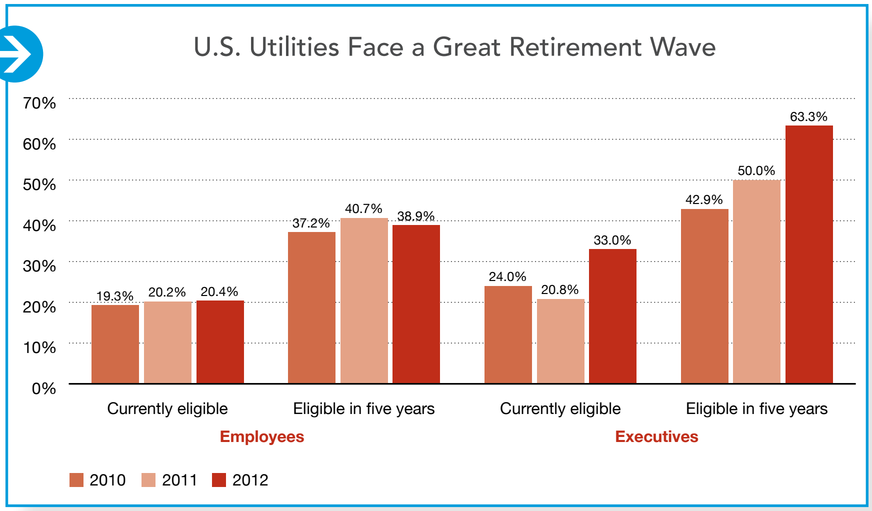
Rob Harmon, Principal at Robert K. Harmon and Company, makes perhaps the most passionate case for why we need utilities and should care about their financial viability: "The grid is an astonishingly valuable public asset, and distributed resources can't exist without it. The notion that we should solve our energy problems by having every person setting up their own energy island," argues Harmon, "is the equivalent of everyone having their own server farm in their basement to store all the information they might want from the Internet, rather than just using the Internet. It's much more efficient for communities to share resources than for every person to attempt to provide all their own resources every minute of every day. Sharing is a good thing, not a bad thing."

2 Gavin Bade, "The Top 10 Trends Transforming the Electric Power Sector," Utility Dive, September 17, 2015, http://www.utilitydive.com/news/the-top-10-trends-transforming-the-electric-power-sector/405798/.

Aging Infrastructure, Aging Workforce

Energy utilities as an industry also face an increasingly urgent need to invest in their own renewal – both in the physical infrastructure of the grid and the people to rebuild, manage, and operate it.

The United States power grid is an engineering marvel, but it was primarily built out 50 years and more in the past. Today, the U.S. "endures more blackouts than any other developed nation as the number of U.S. power outages lasting more than an hour have increased steadily for the past decade."[3]



Utilities are losing lots of experienced employees and executives to retirement. A key challenge: retain core know-how through personnel transitions and transmit knowledge to a new generation. © PricewaterhouseCoopers LLP ("PwC"). Not for further use or distribution without the permission of PwC.

The necessity to renew the grid infrastructure is clear to utility executives. UtilityDive.com asked 433 U.S. electricity executives to identify their three most pressing concerns – at the top of list was aging infrastructure, cited by nearly half of respondents.[4] Rachel Shimshak, Executive Director of Renewable Northwest, points out that to keep rates low, public utilities until now have put off maintenance of the region's system of major hydropower dams, "the crown jewel of the Northwest electricity system." In 2015, however, Northwest utilities marshalled $700 million for vital repairs to the hydropower system, much of which was built out some eight decades ago.

The second most important challenge, cited by 40% of utility executives, in the UtilityDive.com survey is the industry's aging workforce. Across the entire range of infrastructure

3 Meagan Clark, "Aging US Power Grid Blacks Out More Than Any Other Developed Nation," International Business Times, July 17, 2014, http://www.ibtimes.com/aging-us-power-grid-blacks-out-more-any-other-developed-nation-1631086.

4 Utility Dive, "State of the Electric Utility," 2015.

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sectors, not just energy, there is a looming wave of workforce retirement, from engineers to planners, managers, operators, field staff, and leadership. As a result, many of our utilities and infrastructure agencies are grappling with a serious loss of talent and institutional knowledge. "During the next five to ten years, many utilities will lose 50% of their current workforce to retirement, and no job classification is immune," warn Brad Kitterman and Jack Dugan of LogicaCMG.[5]

Roger Gray, General Manager of the Eugene Water and Electric Board (EWEB), says, "We are looking at one-third of our workforce retiring within 5 years. The baby boomers will be virtually gone from the workforce." In Gray's view, "This has significant training and cultural challenges, but also opportunity as people who grew up in the digital age take over."

Clean Air and Climate Change Policy

The energy we use to power our homes, our machines, our vehicles, and our facilities relies heavily on the burning of fossil fuels. But burning oil, coal, and methane (natural gas) releases a variety of harmful contaminants into the air. Coal-fired power plants are especially harmful: according to the American Lung Association, coal plants release more toxic pollutants to the air than any other industrial source, including 84 separate hazardous substances.[6] Cars and trucks are also major polluters, pouring carbon monoxide, hydrocarbons, nitrogen oxides, and particulates into the air.[7]

As public health and environmental science has advanced, demonstrating harm to people and public resources caused by air contamination, regulations to reduce the damage have evolved. In the resulting clean energy marketplace, coal-fired power plants – especially those that have aged past their design life – are poorly-equipped to compete. As a result, the U.S. coal fleet is producing less energy now than any time since the early 1980s, with another 90,000 megawatts of coal plant retirements – over 25% of the coal fleet – projected by the Energy Information Administration for 2030.[8]

Fossil fuels are also the primary source of human-caused additions of carbon dioxide – the leading greenhouse gas implicated in climate change – to the atmosphere[9]. Climate change is emerging as a powerful driver for rethinking infrastructure – both our reliance on carbon-based fuels and the vulnerabilities of our critical infrastructure to extreme weather.

The U.S. Environmental Protection Agency recently adopted a Clean Power Plan to establish an enforceable timeline for reducing carbon dioxide pollution. While these federal rules still face legal challenges, California and a coalition of Northeast and Mid-Atlantic states have already implemented systems to control CO2. To date, the Northeast system has reinvested $1 billion in 'carbon revenues' into clean energy

Advancing public health and environmental science has sharpened our understanding of the harm caused by fossil fuel pollution, driving stronger regulations. (Posted to Flickr by michael davis-burchat. Cropped. Creative Commons Attribution-NoDerivs 2.0 Generic (CC BY-ND 2.0) https://creativecommons.org/licenses/by-nd/2.0/legalcode.)

5 J. Dugan & B. Kitterman, "The Disappearing Utility Workforce," Electric Energy Online, accessed December 16, 2015, http://www.electricenergyonline.com/show_article.php?mag=&article=261.

6 American Lung Association, "Toxic Air: The Case for Cleaning Up Coal-Fired Power Plants," March 2011.

7 Linda C. Brinson, "How Much Air Pollution Comes from Cars?," HowStuffWorks, accessed December 21, 2015, http://auto.howstuffworks.com/air-pollution-from-cars.htm.

8 Gavin Bade, "The Top 10 Trends Transforming the Electric Power Sector," Utility Dive, September 17, 2015, http://www.utilitydive.com/news/the-top-10-trends-transforming-the-electric-power-sector/405798/.

9 Lauren Shoemaker, "The Basics: Isotopic Fingerprints," U.S. Dept. of Commerce: NOAA August 2010, http://www.esrl.noaa.gov/gmd/outreach/isotopes/.

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measures with positive return-on-investment for the region's economy of "more than $2.9 billion in lifetime energy bill savings to more than 3.7 million participating households and 17,800 businesses," according to an April 2015 report.[10]

In December 2015, the Paris climate talks resulted in an unprecedented agreement among over 190 nations to limit climate warming to 2 degrees C, which will require dramatic reduction in the carbon-intensity of the global economy. Successful implementation is not guaranteed at this point, but if put into effect, the new accord will become a huge market driver for clean energy technologies.

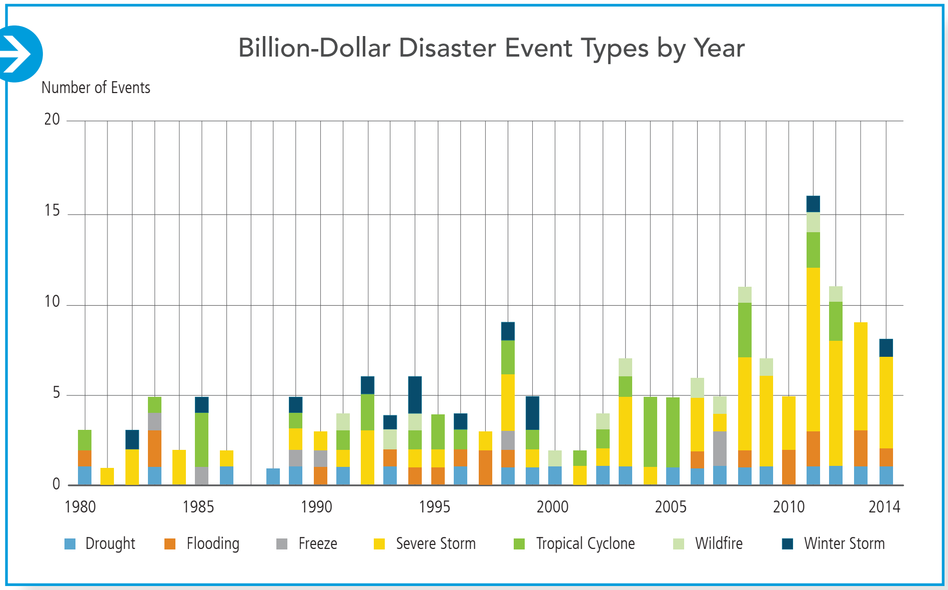
As clean energy costs have dropped dramatically, the strongest argument for opponents of climate policy – that a switch to low-carbon energy will drive radical cost increases – may no longer be credible. Ensuring system reliability at a reasonable cost as high volumes of variable renewable energy sources come online will be a key challenge. But as the cost differential narrows between an energy future little changed from today and one that eliminates most air contaminants and carbon emissions, public support for clean air policies will likely widen.

The Resilience Imperative

Infrastructure systems are vulnerable to a variety of natural and human hazards, from extreme weather events and earthquakes to terrorist attack and large-scale accidents. And when they happen, public attention can focus, powerfully if episodically, on infrastructure vulnerabilities and on the need for more resilient systems. Superstorm Sandy devastated critical infrastructure over large areas, knocking out power to over 8 million people across 17 states, for example. Gas rationing was put in place in New Jersey and New York City for 11 and 15 days, respectively.[11]

Resilient systems are more diversified and less 'brittle' – less vulnerable to catastrophic failure – than standard systems, and recover to restore service more quickly in the event of disruption. The U.S. Department of Homeland Security's National Infrastructure Advisory Council says, "The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event."[12]

In the Northwest, major risks include earthquakes, tsunamis, volcanoes, wildfire, droughts, and floods. According to Diane Broad, Senior Policy Analyst for Oregon's Department of Energy, the state's key at-risk facilities include long transmission lines serving coastal regions, major liquid fuel port terminals and pipelines, natural gas pipelines, liquefied natural gas storage facilities, and electrical substations. The interdependencies among these facilities can be critical – many fuel storage facilities need electricity to pump their fuel, for example.[13]



As extreme weather events hit communities with more frequency and ferocity, recognition is growing of the value of resilient energy systems that recover more quickly. Source: DOE Quadrennial Energy Review. U.S. Department of Energy.

Today's infrastructure systems have largely been designed to withstand extreme weather events, based on historic records and the assumption that climate is basically stationary. But 100-year floods and droughts appear to be coming more frequently, whether driven by natural variability or human-caused climate change. "Now that we can no longer use the weather record as a proxy for future conditions," says Steve Moddemeyer, a top infrastructure resilience expert with CollinsWoerman, "we need to place a value on flexible and adaptable systems."

10 The Regional Greenhouse Gas Initiative, "Investment of RGGI Proceeds Through 2013," April 2015.

11 Kayla Webley, "Hurricane Sandy By the Numbers: A Superstorm's Statistics, One Month Later," Time, November 2012

12 National Infrastructure Advisory Council, Critical Infrastructure Resilience Final Report and Recommendations, September 8, 2009.

13 "Resilient Power Project Webinars," Clean Energy Group, accessed December 16, 2015, http://www.cleanegroup.org/ceg-projects/resilient-power-project/webinars/.

A Vision for Our 2040 Energy System

CSI's inaugural report offered Five Big Goals for 2040, as a conversation starter. The Energy Goal was framed this way: "Renewable energy meets 95% of demand for all energy uses, efficiency gains reduce total energy demand per person by 60%, and sustainable solutions for heavy transportation have been adopted."

The conversations informing this new Energy paper bring forward a broadly similar picture of a world-class 2040 sustainable energy system for the Northwest, but one with many new facets and moving parts. Most thought leaders interviewed are optimistic that the rapid improvements in performance and cost for a wide wave of new clean technologies are good news. A sustainable energy infrastructure will be much more complex than today's, but it appears that a flexible, smart, super-efficient, clean system will likely be technically manageable, no more expensive, more resilient and less risky than maintaining and rebuilding today's system.

If it's true that we can have an energy system that performs better, for roughly the same or lower cost, and gives our kids clean air in the process – why wouldn't we build it?

This section paints a picture of a world-class 2040 energy system in the Northwest to show how the many new pieces together shape a very different system. Then it spotlights the key parts that are already getting market traction and drawing investment to propel their scale-up.

Window on the Future: How a 2040 Energy System Could Work

The Northwest energy system in 2040 will undoubtedly look and work much differently than today, as new technologies transform the options available to not only our utilities, but also residents, businesses, and industry. A world-class energy system for Oregon and Washington in 2040 will be more affordable, and much more sustainable, resilient, and integrated. And it will deliver a wide-range of co-benefits for the economy, public health, quality of life, equity, and environment of our communities.

Here's an overview of our potential 2040 energy system:

By 2040, electricity will do more in our economy, and every device and piece of equipment will apply energy much more precisely and efficiently. Energy consumption in our buildings will have dropped 50% or more as equipment gets much more efficient, existing buildings are retrofitted, and new buildings are designed much smarter.

Our electrical grid will serve not only the needs of today – to power lighting, appliances, computers, and other equipment small and large. It will also power the majority of our light-duty transportation vehicles, and increase its market share of space and water heating.

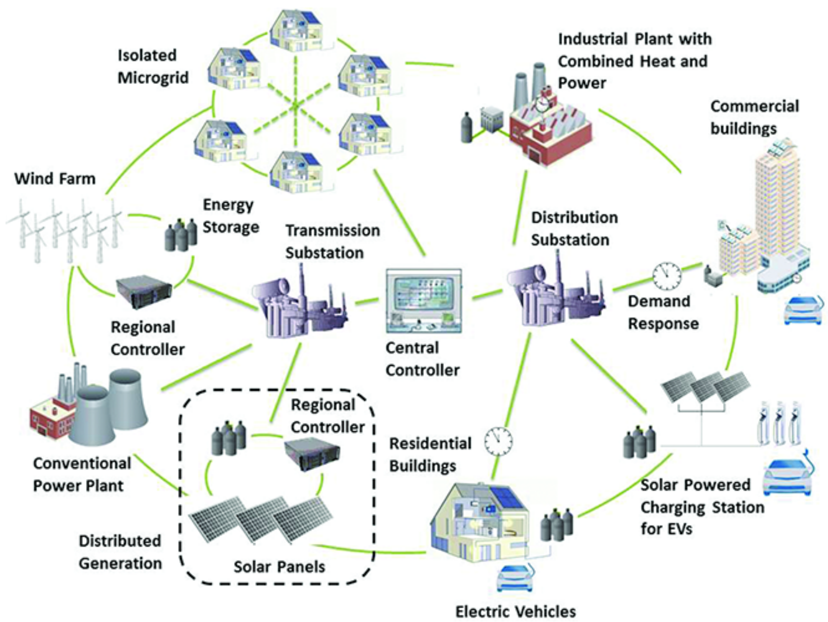
In 2040, most heating and cooling services for our homes and buildings, which by some estimates totaled over 40% of total U.S. energy use in 2015, will mostly be supplied by 'clean heat' resources. Solar heating and cooling systems will harness the sun's energy to directly heat water that is used to warm or cool homes and buildings, and to supply them with hot water. Alternatively, heating and cooling needs will be met by heat pump technologies that use electricity to efficiently pull heat from surrounding air. In the heart of our towns and cities, district systems will pull heat from sewer pipes, server farms, and other waste heat resources, or produce it from diverse local organic waste streams – such as wood waste, sewage, landscape trimmings, and food scraps – circulating it to local buildings very efficiently and affordably. Waste and wastewater utilities will collaborate to build facilities that optimize value by processing organic wastes.

By 2040, the electricity grid will have fully transitioned from the Edison era uni-directional system of large power plants sending electricity one way – out to millions of consumers. The basic physics of the power grid will still require electricity supply and demand to be balanced moment-to-moment. But our 2040 grid will do that through rich information streams and two-way communications. A variety of energy storage devices and facilities will be of tremendous value to the grid, storing power when it is abundant to use later when demand is higher. The grid will be far more complex, a smart grid which 'talks' to solar PV systems, commercial LED lighing and HVAC equipment, freezers, dryers, water heaters, batteries, and microgrids. It will respond flexibly to peaks in demand and supply to store power or dampen demand as needed with advanced grid management tools and price signals.

People, institutions, and businesses will be active participants in the energy system, equipped with tools that can produce, reduce, and manage energy. Customers will contract with systems operators to provide 'demand flexibility.' System operators will pay for this capacity because it enables seamless, mostly unnoticeable adjustments to customer energy use that helps 'flatten the peaks' in demand which are the most expensive to serve. Utilities will manage and operate this high tech system, perhaps with some regional functions managed by a non-profit Independent System Operator, strategically directing infrastructure investment to modernize aging infrastructure, build and transmit mass-scale renewable power, and support customer-side projects that benefit the larger system.

In 2040, nearly all the electricity supplied to the grid will be from pollution-free sources, anchored by our legacy hydroelectric facilities. Solar and wind generators, which vary widely in production daily and seasonally, will range in size and be widely distributed geographically, diluting the impact of cloudy or low wind days in any given location. When winds

A Vision for Our 2040 Energy System



Our electric grid is evolving from a relatively simple system delivering power from large central power plants, to an internet of energy that manages, controls, conditions, buys, sells, and stores power in a dynamic marketplace involving millions of participants.

Courtesy of Georgia Tech Climate and Energy Policy Laboratory: http://www.cepl.gatech.edu/drupal/node/43.

are up and the sun is shining, a diverse portfolio of energy storage facilities and units will absorb renewable power generated in excess of demand for release later when demand bumps back up. To further balance fluctuations in power generation and demand, the Northwest will swap even more renewable energy and 'flexibility resources' between neighboring grids and with California and other big regional grids, whenever it is mutually beneficial.

Within our communities, "microgrids" – local networks of neighborhood-scale energy resources, storage, and smart management tools – will nest throughout the Northwest system, able to detach and operate independently when disruptions hit. Some neighborhoods and communities will choose to collaborate with their local utility – or perhaps form their own utility – to take on a significant role in planning for the energy infrastructure where they live, even investing capital in 'community solar' and other shared facilities to help stabilize their rates and clean up their energy supply.

Most of our cars, buses, and delivery trucks will be powered by electricity, not petroleum, offering drivers superior performance, a much smaller carbon footprint, and billions of dollars in savings on fuel and maintenance costs. Collectively we will drive fewer miles, potentially much fewer, yet transport energy will still be an important new market for electric utilities. Nearly all big transportation vehicles, including long-haul trucks and shipping, airplanes, and trains, will be powered by – if not electricity – certified sustainable fuels.

Replacing fossil fuels imported from other regions with local energy resources and locally-deployed infrastructure will have nourished economic development in Oregon and Washington, keeping billions of energy dollars annually from draining out of the regional economy. To maximize the economic development benefits, both states have actively helped speed modernization by adopting a comprehensive state infrastructure strategy, with clear goals, strategic policies, and smart financial investment that draws in other public and private dollars to get vital work done.

For example, the states will have coordinated large-scale investment programs targeting critical components of a world-class systems where existing markets were unable to act with the needed speed or scale. State commitment will have been key to deep efficiency makeovers in thousands of state buildings, for example, and conversion of several large rail corridors to clean electricity. Our states developed into top R&D hubs in several key aspects of the new energy system such as smart grid, energy storage, clean heating and cooling, and electric grid cyber-security.

As a living laboratory for a world-class carbon-free energy system, the energy infrastructure workforce will be renewed from top to bottom with professionals skilled at planning, managing, and operating this new energy system, and at working collaboratively with community and partners. Programs to build the talent pipeline and create pathways out of poverty will have enabled tens of thousands of people from disadvantaged communities to develop family-supporting infrastructure careers.

The most successful utilities in 2040, as well as customer-centered energy companies will excel at 'bridging silos' to discover innovative whole system solutions. They'll work closely with local government in the communities they serve

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to support local goals and aspirations. And they will develop significant collaborative relationships with other infrastructure providers in the transportation, wastewater, water, and waste sectors to achieve efficiencies and deliver greater value to the community.

Spotlight on the Parts: Technologies Transforming the Energy System

A variety of technologies and market dynamics are converging to make a new energy system not only possible, but affordable – and cool.

Engineer Bethany Sparn measures energy consumption at NREL’s Automated Home Energy Laboratory which allows researchers to study the complex interactions of multiple appliances and devices with the broader distribution grid. Photo by Dennis Schroeder, NREL 20164.

One indicator of this coming affordable and cool revolution is that Silicon Valley investors and entrepreneurs, as well as heavyweights like Apple and Google, are joining the fray in a serious way. Eric Strid, founder and CEO for over two decades at Oregon’s Cascade Microtech, attended the 2014 World Innovation Forum. He found, “Driven entrepreneurs and their teams are willing to ‘eat glass’ as necessary to achieve their missions. Many of these people come from IT or semiconductors and expect exponential jumps in cost-performance.” Our infrastructure strategies should anticipate that technology entrepreneurs will transform many aspects of the energy marketplace in surprising ways.

“The thing that a lot of people in the industry miss is that for every technology there is a trajectory,” says Terry Oliver, Chief Innovation Officer at the Bonneville Power Administration (BPA). “In its first generations, every technology is extremely expensive, but cost can drop like a rock with economies of scale. Talk to the folks at Intel about technology development – there’s a spot at which you begin to try something, another where it becomes affordable, another where it becomes must-do. Think about 100% penetration of televisions.”

This section discusses an array of technologies that are only just beginning to scale-up for mass markets. At this early stage, investment pours in and, suddenly, thousands of smart people and dozens of companies are focused on improving cost and performance. That means, for technologies able to carve out market niches and some runway to grow, we may see many years of rapid progress, with continuous improvements that drive down costs and open up new applications, sometimes totally unforeseen, that expand customer value.

The technologies discussed next are each following their own technology pathway, market niches, and cost curves. But these technologies could work together to transform the energy system. Companies will uncover ways to combine

Smart meters enable two-way communication between energy user and utility, which helps the utility pinpoint inefficiencies and read energy usage remotely, reducing utility vehicle miles. (Posted to Flickr by Portland General Electric. Cropped. Creative Commons 2.0 Generic License (CC BY 2.0) https://creativecommons.org/licenses/by/2.0/legalcode.)

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technologies into novel new solution packages to serve more than one need and deliver multiple value streams, with less risk and more resilience than today's approaches. Smart phones have morphed so much that we hardly remember their original purpose was simply to make telephone calls on the move.

Among the most system-transforming are the suite of technologies now being called 'distributed energy resources' located locally, where consumers live, work, and play. People and businesses – passive consumers of energy up to now – are being invited into a rapidly expanding marketplace of attractive, exciting, and cost-saving offerings and opportunities to actively make or manage energy.

While people will make these purchases for their own reasons with their own resources, these energy tools can potentially be valuable for the larger community-scale systems we share. Ron Pernick of Clean Edge describes them as 'distributed assets' that can "dramatically reduce the need for energy, enable you to generate clean electrons and harvest heat, and allow you to distribute energy on demand."

For example, distributed assets can enable power grid managers to better integrate renewable power from solar and wind systems by accommodating their peaks and valleys in production. A range of new tools for grid operators will improve reliability, efficiency in moving power, and their capacity to manage a more complex system. And if that's not enough change for our energy infrastructure, other infrastructure sectors – transportation, water, wastewater, and waste – are undergoing transformative change in ways that affect energy.

'Smart home' technology and smart appliances allow customers to precisely track and manage their energy usage, and positions them to sell 'demand flexibility' to their utility – dialing down energy demand briefly at times when it helps the system operator keep supply and demand in balance. Source: Pacific Northwest National Laboratory.

An Agency of Transformation

The Northwest Energy Efficiency Alliance (NEEA) is a remarkably innovative institution, one of several that together make the region a global innovation hot spot for deploying advanced technology to use electricity more precisely and efficiently.

NEEA, an alliance of more than 140 utilities and energy efficiency organizations in Idaho, Montana, Oregon, and Washington, continuously scans the market for promising technologies that utilize electricity better. Leveraging the capabilities of this very broad partnership, NEEA develops markets for sustained adoption of emerging technologies that offer the most benefits for both the region and electricity customers.

Since 1997 NEEA's work is saving the Northwest enough electricity to power the cities of Portland, Boise and Seattle combined. NEEA's top achievements include helping to mainstream several technologies in the Northwest, such as:

- **Heat Pump Water Heaters** – NEEA helped accelerate market-readiness of heat pump water heaters for the Northwest climate, a technology that NEEA estimates can save the region enough electricity in the next 15 years to meet continuous demand for over 380,000 homes.
- **Ductless Heat Pumps** – For home heating, NEEA led efforts to expand the market's ability to deliver and install ductless heat pump technology. By 2013, these highly-efficient heating systems were installed in 19,000 Northwest homes through a network of nearly 1,000 contractors.
- **Energy Star TVs and Computers** – NEEA worked with manufacturers and government to bring super-efficient TVs and desktop computers to retail shelves, resulting in market transformation – today most TVs and computers sold in our region meet or exceed EPA Energy Star® standards.
- **Energy Efficient Homes and Buildings** – NEEA played a key role in adoption of energy codes for new homes and commercial buildings that, over the past five years, have cut electricity use in new Northwest buildings by 20 percent.

NEAA utilizes a technology and market savvy staff, its board and advisory groups that engage top innovators and experts in the utility industry, and the marketing capacity of its broad alliance, to strategically transform markets that help the Northwest use less electricity.

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Energy Tools in Customer Hands ~

"Up until now, the energy industry has changed very slowly," says Tugrul Daim at Portland State University. "But as technology companies insert themselves, change could happen much faster. When you put the power of consumer choice in people's hands that can really accelerate change."

Energy users – homes, companies, cities, and institutions – are quickly becoming energy producers and managers, too. The tools range from rooftop solar PV systems, to high-performance buildings, corporate and institutional clean energy buys, home energy systems, and neighborhood micro grids and community energy systems.

The Solar Rooftop Revolution

Distributed generation means, basically, a little power plant that fits on or in your house or local building. Solar power is the first and most important form of distributed generation to compete on price with retail electric power – not everywhere, but in rapidly expanding swaths of the country and world economy.

"I think that we'll see a far greater role for solar power than most people envision," says Denis Hayes of Seattle's Bullitt Foundation. "At the Bullitt Center, we produce 160% of the electricity that we use from rooftop solar. We have a tremendous amount of under-utilized rooftop space in cities like this one."

> The imperative for customer-facing companies is to develop home energy products that are intuitive and surprisingly cool. "A Nest thermostat is so cool you could give it as a gift for Christmas."
>
> *Tugrul Daim, Portland State University*

Solar is enjoying explosive growth and costs are declining rapidly. As costs drop, new and bigger markets open up, and with each jump in production costs drop further, and more bright minds focus on continuous cost and performance improvements. For well over a decade, "solar PV has shown 15-20% cost decline for every doubling of manufacturing capacity for the solar cells," points out solar entrepreneur Tim Ball.

The growth in the market for customer-side solar power is astonishing. In 2016, a new distributed solar PV system will be installed every 83 seconds in the United States, according to projections by GTM Research.[1] In February 2016, analysts expect 1 million American homes to be generating solar power, with another 3 million installations projected for the next five years. Of all new electricity generation capacity brought online in the U.S. in the first quarter of 2015, over half was solar power.[2]

Oregon and Washington, especially on the populous west side, will be among the last places to see the crossover point where solar PV can deliver unsubsidized electrons at a cost lower than that charged by the local utility. That's because retail power is among the nation's cheapest here, and the solar irradiance levels that determine solar productivity are relatively low.

But solar does work on the west side, and has a bright future across our two states. If solar PV costs continue to decline steadily as generally expected, and with the 30% federal solar tax credit extension passed by the U.S. Congress in December 2015, over 10,000 megawatts of solar PV capacity on homes and commercial buildings will reach 'grid parity' in Washington and Oregon by 2020, according to the interactive "Solar Grid Parity Map" developed by the Institute for Local Self-Reliance.[3]

At grid parity, customers can pay the same or less for solar power than they pay for kilowatts they buy retail from their utility. If 10,000 megawatts of grid-parity distributed solar systems were installed and produce at 20% of their maximum capacity – which is reasonable – they'd supply roughly 10% of the average electricity consumed across the broader four-state Northwest system, which totals 20,000 megawatts. Large-scale solar farms, discussed below, would be additional. However, the bulk of solar energy is produced when days are longer and sunnier, and Northwest electricity demand peaks in winter at 30,000 megawatts. To realize the full value of solar, we will also need cost-effective strategies to reduce peak demand and supply clean electricity in winter.

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1 Stephen Lacey, "A Solar System Is Installed in the US Every 4 Minutes," Greentech Media, August 20, 2013, http://www.greentechmedia.com/articles/read/america-installs-a-solar-system-every-four-minutes.

2 Chirinjeev Kathuria, "Musings on the Future of Energy: Residential Solar Panels Installations Reach Record High," accessed December 16, 2015, http://www.chirinjeevkathuria.org/2015/07/residential-solar-panels-installations-reach-record-high.html.

3 "How Much Unsubsidized Solar Power Is Possible?", Updated Solar Grid Parity Map, Institute for Local Self Reliance, accessed January 15, 2016, https://ilsr.org/newsolarparitymap/.

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As costs of solar PV modules have plummeted, the 'soft costs' of installing working systems make up a larger share of the cost of new installations. Permitting costs, for example, can be significant. "There's a big difference between installing solar PV systems in the U.S. versus Europe – it's narrowed, but it used to be a 30-50% difference," say Christy Holz and Tim Ball, leading solar entrepreneurs. "That's because permitting and standards are more difficult in the U.S.; it's not due to technology."

Solar will lead the way in distributed generation, but won't be the only tool in the energy customer's new toolkit. Nancy Hirsh, Executive Director of the NW Energy Coalition, believes "our buildings will be more full-cycle energy facilities and high efficiency, closer to 'net zero' buildings, generating power through solar, small wind, microhydro, and other micro-generation technologies." PSU's Tugrul Daim expects the military to innovate advancements in distributed generation because of its strong interest in readily accessible energy sources for mobile forces: "As we see military technologies transferred to the civilian economy, we'll see more distributed generation." Eric Moe, with district energy developer UMC Energy/Environment, foresees, "district energy utilities that can market both locally-produced power and thermal (heating and cooling energy) to neighborhoods – cleanly, affordably, and reliably."

With skilled, whole-building design, a growing number of new 'net zero' homes and buildings are proving capable of producing as much electricity in a year as they use.

High-Performance Homes and Buildings

The green building movement is catalyzing breathtaking innovations that are enabling builders to offer high-performance homes and commercial buildings that use strikingly little energy, even producing more energy on site than they use on a year-round basis.

The Northwest has a storied history at the forefront of groundbreaking commercial building design, capped by development of the Bullitt Center, renowned as the world's most sustainable building at its unveiling. But Northwest green building innovation is extending to the home building sector as well.

For example, the 47+7 apartment complex in Seattle leverages super-efficient design to shrink electricity demand to just 15% of other new multi-family buildings in the city. Designed by leading-edge firm CollinsWoerman, Principal Steve Moddemeyer explains that all the resident's hot water and space heating and cooling needs are supplied by solar hot water tubes with a natural gas booster.

Just as impressive, the zHome townhouse complex in Issaquah, Washington was designed to produce as much energy as it consumes, reduce water use 70%, use only low- and non-toxic materials, and recycle 90% of construction waste. Post-occupancy data shows that the complex is exceeding the net-zero design target, producing 3.5% more energy than it uses.[4]

Going Green: Corporations, Cities, and Institutions

The distributed energy story is not just about solar systems on the rooftops of our homes. Corporations and institutions seeking to control costs, shrink their carbon footprint, and burnish their green credentials are increasingly developing renewable energy on their buildings and/or signing agreements with utilities or developers to buy renewable energy. In the first half of 2015 alone, "Amazon signed a project for 150 megawatts, Apple signed for 130 megawatts, Kaiser Permanente signed for 153 megawatts, and Dow Chemical signed for 200 megawatts," according to Greentech Media.[5] Walmart, Costco, Kohl's, General Motors, Anheuser-Busch, IKEA, Microsoft, HP, Google, Intel and Yahoo, along with a

4 Built Green, accessed December 21, 2015, http://www.builtgreen.net/index.cfm?/NEWS-events--classes/Latest-News/page/Built-Green-Releases-White-Paper-on-zHome-First-US-Net-Zero-Townhomes.

5 Julia Pyper, "The World's Biggest Companies on Why They Buy Renewables: 'It's a Very Clear Economic Issue'," Greentech Media, October 30, 2015, http://www.greentechmedia.com/articles/read/How-to-Get-Corporate-Renewable-Energy-Deals-Done?utm_source=Daily&utm_medium=Newsletter&utm_campaign=GTMDaily.

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number of universities, and the U.S. Air Force and General Services Administration, have also built or signed agreements to buy renewable power and often with attractive returns on investment.[6]

John Savage, Oregon PUC Commissioner, points out, "They want to be 'green' companies. They all have renewable targets for their companies. They will meet their targets," says Savage. "This independent movement is saying that they are going to take responsibility for their power. These guys will be drivers of a lot of renewables."

Local governments are making bold clean energy commitments, too.[7] Vancouver, British Columbia, for example, has committed to supplying all the energy needs of residents, institutions and businesses with 100% green energy, across electricity, heating and cooling, and transportation.[8] The US EPA documents over 700 organizations now using green power to meet 100% of their electricity demand, "equivalent to the electricity use of nearly 1.5 million average American households each year."[9]

"Another driver is going to be the military – more so in Washington. I think that'll have a huge effect," says Oregon PUC Commissioner, John Savage. The U.S. Defense Department aims to consume 3,000 megawatts from renewable sources by 2025.[10] Jeff Johnson of the Washington State Labor Council says the state IBEW union is working toward a 20 acre solar farm on the Hanford Nuclear Reservation. "Their grand vision is to power the entire vitrification process to stabilize Hanford's nuclear waste with solar energy," says Johnson.

Personal Energy Tools

Tech giants including Apple, Google, and Samsung are also moving aggressively to provide 'smart home' tools that enable customers to conveniently save energy by controlling power use in appliances and devices. To sell to customers, homes especially, the imperative for these companies is to develop products that are intuitive and surprisingly cool.

Customers aren't necessarily buying energy tools only to save money. People don't buy the cheapest clothes or the cheapest car available, unless they have to. Part of a customer's decision may express their values, status, or image. PSU's Tugrul Daim, who previously managed a 300-person microprocessor development team at Intel, with revenues of more than $1 billion, tells an insightful story: "Intel was looking at a startup company's wirelessly controlled thermostat that could be managed remotely. But it was ugly and unappealing," says Daim. "We told them it has to be sexy and cool – then people will embrace it. Nest figured out how to do that, and sold the company to Google for a couple billion dollars. A Nest thermostat is so cool you could give it as a gift for Christmas."

Smart customer tools create the capacity to adjust energy demand appropriately in real time when either prices or supply are high. "I'm very excited about smart home and commercial equipment which enable radio control communication back-and-forth between your unit and the utility to control settings," says John Savage, the Oregon regulator. "The Nest thermostats are amazing, self-learning."

"Some utilities would love to own all the metering infrastructure, but there are a lot of competing business models right now," according to Fred Gordon of the Energy Trust of Oregon. "Nest wants to be the interface. Nest is saying, 'Pay us and we'll deliver measured savings to reduce peak demand.' ECOBEE wants utilities to pay them to run their utility programs through their thermostats and metering infrastructure. Alarm system and cable companies want to be the customer interface for energy and all home automation, too."

Microgrids, Neighborhood Systems, and Community Energy

Microgrids are local networks of neighborhood-scale 'distributed' resources and smart grid management tools able to detach and operate independently when disruptions hit the larger power grid. Microgrids could nest throughout the Northwest power grid to build system resiliency. "The military is big into micro-grids," says Oregon PUC's John Savage, "so I think you'll see more and more micro-grids for critical facilities. With microgrids, you can isolate and keep operating in the event of a catastrophe."

A variety of new technologies are making new local systems possible, especially in town centers and in cities. "Where you have urban density you are able to develop neighborhood scale systems where you have the electron, BTU, or therm generated very close to where it's used," says McKinstry's Megan Owen. "Far too much energy we currently generate is lost as waste heat, but we can productively capture and redistribute much of it to homes, businesses, and local economies."

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6 Herman K. Trabish, "The Other Death Spiral Utilities Are Beginning to Deal with," Utility Dive, August 6, 2015, http://www.utilitydive.com/news/the-other-death-spiral-utilities-are-beginning-to-deal-with/403286/.

7 "The Urban Clean Energy Revolution," Climate Solutions, November 30, 2015, http://www.climatesolutions.org/article/1448326289-urban-clean-energy-revolution.

8 Stephen Leahy, "Vancouver Commits to Run on 100% Renewable Energy," The Guardian, April 10, 2015, sec. Environment, http://www.theguardian.com/environment/2015/apr/10/vancouver-commits-to-run-on-100-renewable-energy.

9 US EPA, "Green Power Partnership," accessed December 16, 2015, http://www3.epa.gov/greenpower/toplists/partner100.htm.

10 Ken Silverstein, "U.S. Military Is Saving Lives by Allying with Clean Energy Developers," Forbes, September 1, 2015, http://www.forbes.com/sites/kensilverstein/2015/09/01/u-s-military-is-saving-lives-by-allying-with-clean-energy-developers/.

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Affordable and Sustainable Housing for Lopez Island

The Lopez Community Land Trust (LCLT) is a non-profit organization based out of Lopez Island, Washington whose goal is to serve residents by building a diverse, ecologically sound, and affordable community through the development of low-income housing and sustainable agriculture. Their first successful sustainable housing development, Morgantown, was approved for occupancy in 1992. Since then they have developed five additional neighborhoods – Coho, Innistown, Common Ground, Tierra Verde, and Salish Way – the most recent of which incorporated net zero energy techniques, meaning residents can potentially produce as much renewable electricity as they consume. During the past 26 years they have also been expanding their impact and building community by providing educational opportunities for first-time homebuyers and those interested in sustainable agriculture and green architecture.

The net-zero energy capable Common Ground housing development is one of their most ambitious undertakings yet. This neighborhood houses 11 mixed-income families and includes 2 additional studio rental units. It has received several green awards including a national award for best green housing, in part due to LCLT's published manual *Land, Water, Energy, Resource Use: A System's Approach*. The homes feature straw bale construction with earthen plaster, a rainwater catchment system, solar hot water, and a grid-tied solar electric system. Even more recently, the net-zero capable Tierra Verde and Salish Way developments provide homes to 7 additional families.

Most of the existing communities also make use of passive solar heating, rain gardens, and rain catchment tanks. Future and ongoing projects include an internship program to help educate students about sustainable practices and a plan to incorporate the use of wind energy to the grid. Through community engagement, volunteer work, and ongoing participation of community residents, the Land Trust is expanding their vision while at the same time striving toward attaining their goal of having a positive net impact on the environment.

By Terry Carroll Source: "Lopez Community Land Trust - Unleashing the Power of Community." Accessed January 16, 2016. http://www.lopezclt.org/.

The Lopez Community Land Trust has built six sustainable, affordable housing developments on Lopez Island, Washington. The two most recent are designed for net zero – to produce as much electricity as they consume. Copyright Mithun/Juan Hernandez.

Distributed energy resources open up new potentials for neighborhoods and communities to invest in local energy infrastructure in new ways. Pamela Morgan, a former utility executive with Portland General Electric, believes it is important to enable people to participate in their energy system. "Today people feel virtually no sense of connection to our energy system," says Morgan. "There are countless barriers between people and their energy. I reject all that. The goal is to get to the place where people can actually understand the system enough to feel they can get involved."

Jana Gastellum, Program Director for Climate at the Oregon Environmental Council, sees a growing "movement for people to have more control of their energy choices – the democratization of energy. I think the wave of the future is more local options, more local control."

Customers that want to invest in solar or other locally abundant energy resources, don't necessarily have to host the system on their home or building. Community and shared solar programs can also make the benefits of solar energy accessible to low- and moderate-income families that couldn't afford to build their own system. The Obama Administration rolled out a national solar initiative in July 2015 to accelerate availability of shared solar models to people of modest incomes.[11] Several Northwest utilities – Milton-Freewater, Tacoma Power, Seattle City Light, and Mason PUD #3, for example – are organizing opportunities for their customers to buy solar shares of a project built locally – on a school or over a parking lot, for example.

11 Derek Markham, "National Community Solar Partnership: 68 Cities, States, & Businesses To Expand Solar Access," CleanTechnica, November 23, 2015, http://cleantechnica.com/2015/11/23/national-community-solar-partnership-68-cities-states-businesses-to-expand-solar-access/.

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The Flexibility Revolution ~

Customers investing in energy tools represent a new source of capital investment in our energy infrastructure, but customers aren't necessarily buying these tools to strategically meet the needs of the power grid. New technologies, however, are giving grid managers the capability to manage a much more complex system and interact with customers to help balance fluctuating demand and supply.

"The architecture of the current grid provides lots of headroom, or excess capacity, so that during crises, the grid will still work reliably," says Terry Oliver of BPA. "We'll lose some of that headroom in the new system, but we'll have these new technologies enabling more flexibility between end users, distribution grids, and the bulk grid."

Energy Storage

The Northwest's vast hydropower system, much of it built in the 1930s – at great cost, it must be said, to the unparalleled salmon wealth and river systems of the region – is today not only producing 60% of the region's electricity. It's also serving as a huge battery bank that is enabling grid managers to integrate wide variations in wind and solar energy production, and keep the system in balance.

Virtually all thought leaders consulted by this project agreed that the hydro system will be a major asset in a virtually carbon-free energy system. But thought leaders also agree that a vast expansion of energy storage, of a range of sizes and types, is needed.

> "Energy storage is the key lynchpin for a distributed electricity grid with variable generation. It provides an energy bank to draw from to enable the match up of demand and supply that is governed by physics."
>
> *John Prescott, President of the Pacific Northwest Generating Co-op*

"A lot of it is based on physics," says John Prescott, President of the Pacific Northwest Generating Co-op. "Every two seconds you have to match demand and generation of electricity, and demand changes continually. That explains why we can get kind of nervous about intermittent renewables as that adds another degree of freedom to the balancing task," he says. "All that can be solved, though, and storage is a big part of it – energy storage is the key lynchpin for a distributed grid with variable generation. It provides an energy bank to draw from to enable the match up of demand and supply that is governed by physics." But, Prescott points out, the question of cost and environmental impact of energy storage systems remains.

Energy storage can take many forms and it is not yet clear which will emerge over the next decade as best in cost, performance, and reliability to meet different needs. But many thought leaders, and industry analysts, expect storage technologies to follow a trajectory similar to solar power of rapidly declining costs.

Different technologies store power for different lengths of time, or discharge power when needed at different rates, so they can occupy different segments of a grid manager's storage portfolio. An energy storage portfolio might include large-scale utility installations, lithium ion batteries in customers' homes and electric vehicles, and 'thermal storage' in electric hot water tanks and in chillers.

Thermal storage technologies add extra heating or cooling to a liquid or other medium when energy supply is abundant and cheap, which can be used to offset heating or cooling demand later when demand is up. Some 45 million electric water heaters in the U.S. could inexpensively balance 90,000 megawatts of variable renewables, according to energy economist Jim Lazar.[12] While lithium-ion battery companies are still not hitting cost-effective price points, the top companies providing cooled liquid storage – by making extra ice when power supplies are plentiful – are already proven and profitable in places, unlike the Northwest today, where transparent storage markets exist, "generally earning margins in the 25% to 30% range."[13]

Pratima Rangarajan, General Electric's GM of product development and marketing for energy storage, compares the coming growth of storage technology to the startling growth rates achieved by wind and solar power recently: "The next step for us is to scale. If we look at wind, when they went through a 5X (five-fold) drop in cost during the scale-up period, the number of annual installed megawatts went up 50X," she points out. "Solar was even faster. It was

12 Jim Lazar, "Thermal Energy Storage: The Lowest-Cost Option for Renewable Integration" (Regulatory Assistance Project, June 3, 2014).

13 Herman K. Trabish, "Ice, Ice Energy: The Hot Market for Cooled Liquid Energy Storage," Utility Dive, November 3, 2015, http://www.utilitydive.com/news/ice-ice-energy-the-hot-market-for-cooled-liquid-energy-storage/408356/.

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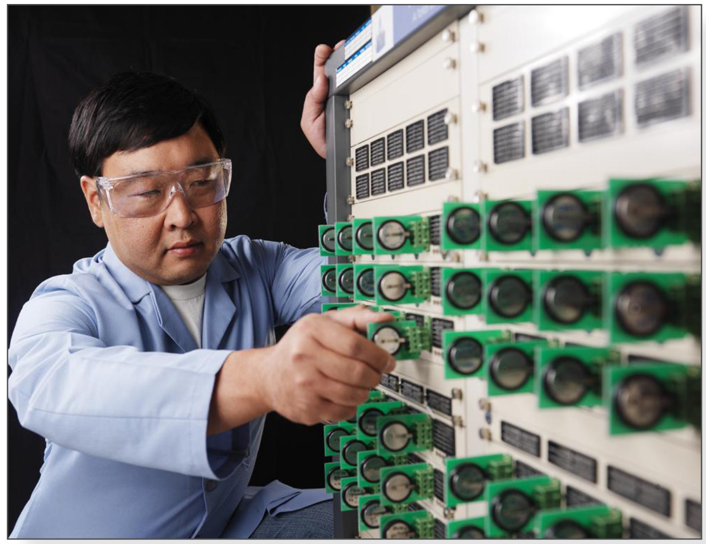
a 6X drop in cost with about a 70X increase in solar. I would even posit that energy storage will be faster than the two of them."[14]

Low-cost energy storage could transform the grid. Energy Trust's Fred Gordon believes, "If you can get the next halving of storage costs, you need a different grid, and maybe the transmission system does less and the distribution grid does more."

Energy storage, doesn't just store energy, according to GE's Rangarajan. "It can do so many things, it can provide so many services on the grid – services that we've been looking for an efficient way to deliver all these years." When evaluating the economics of energy storage, it is crucial to account for and stack the multiple value streams, which typical analyses don't currently do. According to Greentech Media, "stacking value streams can make storage a much more viable option for on-site applications. For example, this could mean using batteries to time-shift solar consumption, while also using them to provide frequency regulation services."

Meeting electricity demand in winter, when solar power production is lowest but regional demand is high, is a key challenge for the Northwest that will require special attention. Denis Hayes, CEO of the Bullitt Foundation, foresees batteries doing everything we need them to do "for short-term storage, but not seasonal." When longer term storage is needed, "it might be pumped hydro, pumped air storage, flywheels – it's hard to say."

Pumped hydro storage facilities pump water up, from a lower reservoir to a higher one, when winds are blowing hard and demand is down. When the energy is needed, the water is dropped from the upper to lower reservoir through a generator that pulls the power back out. EDF Renewable Energy is currently building a 400 megawatt pump storage facility near Klamath Falls.[15]



Research at Pacific Northwest National Laboratory (PNNL) includes development of materials and batteries for stationary energy storage applications. With growing interest in clean, sustainable energy, stationary energy storage will be vital to adding renewables to the power grid, and perhaps even to making the smart grid a reality.

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Demand Flexibility

While energy storage brings flexibility to power supplies, smart appliances and equipment can flex their demand without noticeably affecting the product user experience. Grid operators will pay for that flexibility because it can help them to ramp down demand – when aggregated across dozens of large or thousands of small units – when power supplies are short and prices high.

Flexible demand is also called demand response or demand management. In commercial buildings, "most new HVAC equipment is likely to be inverter-driven pretty soon, so that's got pretty broad implications," says Fred Gordon of Oregon's Energy Trust. Inverter technology uses a variable speed compressor motor that can speed up or slow down to precisely control temperature. "Most new efficient high bay LED lighting is now coming with communicating controls," notes Gordon. "People interested in demand response, voltage regulation, or energy efficiency will each have an interest in this equipment with built-in chips that enable control and communication. Truly distributed controls must be really cheap and do more than one thing."

Jeff Harris of the Northwest Energy Efficiency Alliance (NEEA) agrees. Heat pump water heaters are twice as efficient as old school electric water heaters, he points out. "And once you put all the intelligence into it, you can also turn it on to store wind power by heating water at times of low demand. It's just one great example of the types of technologies that enable a dynamic grid."

14 Eric Wesoff, "GE at ESNA 2015 : 'Energy Storage Is a Natural Extension to the Grid,'" Greentech Media, October 15, 2015, http://www.greentechmedia.com/articles/read/GE-at-ESNA-2015-Energy-Storage-is-a-Natural-Extension-to-the-Grid.

15 EDF Renewable Energy, accessed December 21, 2015, http://www.edf-re.com/projects/detail/swan_lake_north_pumped_storage_hydro_project/.

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Milton-Freewater: Small Town, Big Innovator

The City of Milton-Freewater, a community of 7,000 people in Umatilla County in Northeast Oregon, has participated in the Pacific Northwest Smart Grid Demonstration Project since 2011. The city's utility is the oldest in Oregon, in operation since 1889. They are finding smart grid technology can enhance use and delivery of power through intelligent two-way communication systems which allow utilities to monitor and adjust power requirements dynamically.

The Pacific Northwest Smart Grid Demonstration Project is 50% federally funded and involves 5 states and over 60,000 consumers. Milton-Freewater is the only public utility in Oregon that has chosen to take part in this project. The City was already a leader in the deployment of smart grid technology, having previously installed innovative demand response technology that can incentivize lower power usage during times of high wholesale market prices.

Milton-Freewater's utility installed two-way communication electric and water meters, which have cut outage response times from hours to minutes in many cases, saving money and frustration. The utility connected local water heaters and heating and cooling equipment to its flexible demand system to trim energy use when demand threatens to exceed supply. With just over 750 participating homes, businesses, churches, and other institutions, the utility uncovered capacity to reduce 3 megawatts of energy demand when needed as a last resort.

The City has also been testing Conservation Voltage Regulation (CVR) in order to determine if technology to optimize voltage can save money. They are testing the idea that voltage can be lowered by a small percentage throughout the day to deliver measurable energy savings.

Leadership in piloting and validating new technology is essential for the Northwest to develop a leading-edge energy system. Milton-Freewater is proving that a small community can have an outsized impact.

By Terry Carroll Sources: "Milton-Freewater: A Frontier for New Technology." September 5, 2014. https://www.bpa.gov/news/newsroom/Pages/Milton-Freewater-A-frontier-for-new-technology.aspx.

Harris sees next generation equipment that is not only smart, but very energy efficient. That efficiency can generate multiple value streams for grid managers. When lots of equipment is operating and electricity demand is high and expensive to supply, efficient equipment will deliver the most benefit, says Harris. "The region is realizing we'll have to invest in addressing the peaks;" says Harris. "What's the most cost-effective way to do that?"

Flexible demand is being pioneered in other regions where energy markets are more organized. "I think there's a lot more demand response than we're capturing," says John Savage. "We don't have markets for it yet, like they do in other areas." But Fred Gordon points out that, "We're just now seeing peak power price forecasts here that make demand response pretty attractive. There's now real value to be captured by reducing summer peak. As a result, demand management will mature here. You need a price signal and we're going to get it."

Grid operators can pay customers for cooperating in managing their energy demand to benefit the grid, but some customers won't necessarily be motivated by small payments. Eugene Water and Electric Board mapped 6 customer segments. Unlike lower-income customer segments, "for a wealthier customer $5 a month in savings may be meaningless," says General Manager Roger Gray. "But if we say to those customers, 'How about that $5 goes to your local school?' They're motivated. They're value-driven customers."

Energy Efficiency: The Next Frontier ~

Energy efficiency is the revered old silverback of sustainable energy infrastructure, and a remarkable success story. For 30 years the Northwest has been at the forefront of the energy efficiency revolution.

"Part of my job is to engage our staff and help them see they are part of something bigger that is achieving really important, amazing things," says NEEA's Jeff Harris. "We've effectively replaced four nuclear power plants with energy efficiency investments at a total societal cost lower than the operating cost of the one nuclear plant that actually got built. It's pretty darn inspirational to think about what could have been versus what we actually have done!"

"I think the Northwest has very good energy efficiency infrastructure that we need to sustain," says Oregon PUC's John Savage. "A world class system has world class EE infrastructure."

The Northwest's energy efficiency resource is not nearly exhausted. The landmark 7th Power Plan, released in draft form in late 2015 by the Northwest Power and Conservation Council (NWPCC), is a world-class 'least cost planning' analysis for the regional electric system. Looking ahead for

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20 years, it found energy efficiency "proved the least expensive and least economically risky resource" for meeting electricity demand. "In more than 90 percent of future conditions (modelled), cost-effective efficiency met all electricity load growth through 2035."[16]

Globally, investment in energy efficiency in 2012 reached $375 billion, according to HSBC, the London-based global banking and financial services company, as much as was invested in producing electricity from fossil fuels and 50% more than was invested in renewable energy sources.[17]

In September 2015, U.S. Energy Secretary Ernest Moniz unveiled a strategic plan to double "the economic value created per unit of energy used" in the U.S. economy by 2030 – essentially, using energy twice as efficiently as today. This ambitious target for economy-wide improvement in energy productivity is based on "demonstrated, proven opportunities," according to the U.S. Department of Energy, and will deliver very substantial economic benefits to the nation, increasing GDP in 2030 by over $900 billion.[18]

In the Northwest, "we're spending in total $400M a year on energy efficiency – can we get more bang for the buck?," asks Jeff Harris. "It's very important that we lift our eyes off the immediate work to the 5-10 year time horizon to catch the flow of innovation to get where we want to go." Fred Gordon adds, "these new control opportunities are good interface points for at least three goals: efficiency, demand management, and voltage regulation. It's cheaper, and more practical, to build a single interface to control load for multiple purposes than to pursue each goal separately."

The next frontier in energy efficiency will do more than conserve energy; it will at the same time add flexibility to the grid. In addition, the next frontier will reward whole building design and retrofits to achieve deep efficiencies. "A lot of people assume end use loads will be similar in the future to today's, not recognizing that buildings can be consuming half the energy," says Harris. "The Bullitt Center uses 25% of the energy per square foot of a comparable downtown Seattle building."

Denis Hayes, the driving force behind the world-class Bullitt Center building, says, "With really smart use of design and modest behavioral changes, we can reduce the amount of energy required throughout the economy. We're a couple of generations away from chips that require ridiculously little amounts of power," he says. "On efficiency, to go in and do the kinds of things that need to be done, there are no utilities that are really supporting that yet."

Rob Harmon believes prevailing energy efficiency policies actually encourage building owners to 'skim off the cream' by, "implementing measures that have short-term paybacks while leaving the longer-term opportunities unaddressed. We need a new set of policies that truly capture all the energy efficiency available in the building that's cost-effective over the lifespan of the measure, not just the measures that pay back in two or three years," says Harmon. "Once you've stripped those short-term measures from the building, it's substantially more difficult to recover the costs of going back and getting the rest of the savings. We have done tremendous work getting those short-term savings but that outcome is no longer sufficient – we have the technology to do much better."

Building right from the outset is often easier than retrofitting later. Nancy Hirsh of the NW Energy Coalition says Washington State's new building code will require new buildings – and major retrofits – to use 70% less off-site energy by 2030. "They are starting to look at 'whole energy building use', output-based, performance-based codes," says Hirsh. "They are giving designers and engineers clear targets, but they can get there however they want."

Transmission Flexibility ~

New technologies are coming that increase efficiency of the big electricity transmission lines, opening capacity to carry more energy, and that give grid managers more flexibility to handle real-time fluctuations in power supply and demand. But it gets wonky fast.

Transmission engineers are abuzz about the potentials of such cutting-edge capabilities as transactive energy, dynamic transfer, synchrophasors, and conservation voltage regulation. The rest of us can't relate, but the important thing is that these technologies, as they mature, will cut costs, free up capacity, and increase flexibility on the big grid to manage peaks and integrate renewable energy resources.

"Today's grid is hierarchical, rigid, and centrally controlled, and it depends on physical capacity to allow headroom and flexibility against dynamics that can disrupt the grid," points out BPA's Terry Oliver. "What happens on the bulk grid matters for the distribution grid and vice versa, in a very tight way. The grid of the future will be much more loosely coupled with much more flexibility."

One shorthand for the grid of the future is 'smart grid.' "There's a lot of important progress to be made in smart

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16 Northwest Power and Conservation Council, "Draft Seventh Northwest Conservation and Electric Power Plan: Summary Brochure," October 2015.

17 Giles Parkinson, "Why Solar May Not Be Biggest Threat to Energy Utilities," RenewEconomy, August 12, 2014; http://reneweconomy.com.

18 U.S. Department of Energy. (2015). Accelerate Energy Productivity 2030: A Strategic Roadmap for American Energy Innovation, Economic Growth, and Competitiveness. Prepared by Keyser, D.; Mayernik, J., M.; McMillan, C. of National Renewable Energy Laboratory; Agan, J.; Kempkey, N.; Zweig, J. of U.S. Department of Energy.

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grid technology," says Oliver. "When you have a lot of wiggly (variable) generation on the bulk grid and at the end use (like wind farms and rooftop solar, respectively)… in some cases those wigglies balance each other," he says, "a lot of the time, they don't. But there are technologies, some available now, some yet to be invented, that provide grid operators flexibility."

"The smart grid will be the energy backbone for the low-carbon world," says Patrick Mazza, principal at MROC. "It will use digital technology to connect devices from solar panels and wind turbines to electric vehicles and smart building controls. The smart grid will provide connective tissue that lets a range of energy devices 'talk' to each other and balance each other's operations. It will optimize the entire power system from generation to delivery to end use. But we still need to overcome obstacles."

With mobile onsite data collection, 3D data visualization, and advanced computer modeling, the simuwatt Energy Auditor helps professionals more quickly identify greater opportunities for energy savings in buildings. Photo by Dennis Schroeder, NREL 24505.

Powering Up the Smart Grid, a 2005 Climate Solutions report authored by Mazza based on a stakeholder consensus process engaging 54 Northwest and national organizations, noted, "The smart grid still faces hurdles, in particular the need for extensive field testing to prove new energy systems and regulatory reform to remove financial disincentives to adopting new technologies."[19]

The 'Powering Up' process aimed at spurring a major regional smart grid demonstration. That became a reality when the region secured the largest smart grid project funded through the 2009 economic stimulus package. The Pacific Northwest Smart Grid Demonstration drew $178 million in federal and matching funds. It tested smart grid technologies deployed to 60,000 customers and 11 utilities across 5 states. It was based on an earlier pilot, the Olympic Peninsula Gridwise Demonstration, which tested smart grid capabilities with 100 customers. The region is very much a smart grid 'living laboratory.'

According to BPA's Terry Oliver, who has been at the center of all these efforts, "In the wake of our work in the Northwest a key concept – transactive energy – is being explored around the world," from New York's 'Reforming the Energy Vision' process to Bornholm's EcoGrid in Denmark and many other efforts. "It's spreading like wildfire," he says.

Further, transmission flexibility is a resource that can actually be shared between regions. "I think we've got a tremendous amount of storage in the system itself; we just don't have the market tools to access it," says Rachel Shimshak of Renewable Northwest. "Most regions have coordination among and between utility systems. We really don't – we mostly have bilateral agreements which are clunky and not very nimble," points out Shimshak. "Today, we have 38 balancing areas in the western U.S. system, each of which needs to be independently in balance. What we want is for each balancing area to be able to share flexible capacity with their neighbors."

Bulk Power: Sun, Wind, and Water ~

Even if we get really efficient and precise in our use of electricity, and aggressively develop distributed systems, nearly all the thought leaders interviewed for this project see large-scale, central energy production facilities – mostly solar and wind farms and hydroelectric dams – as essential to get to a virtually carbon-free grid in 2040.

Solar isn't just small scale. Modern solar farms are producing at larger scales and lower costs. The costs for installed solar electric power have dropped dramatically – by 6-8% per year on average, each year since 1998,[20] with more cost declines to come.

Wind power has already gone mainstream, supplying a rapidly growing share of bulk power to the grid. Buoyed by steadily declining costs and its ability to come online in small increments, yearly additions of new wind resources grew from less than 4,000 megawatts in 2000 globally to almost 40,000 megawatts a year on average for the past 5 years.

19 Patrick Mazza, "Powering Up the Smart Grid: A Northwest Initiative for Job Creation, Energy Security and Clean, Affordable Energy, Climate Solutions", 2005, p. 2-3.

20 Weaver, Barbose and Naim Darghouth, "Benchmarking the Declining Cost of Solar," Solar Today, January 27, 2015, http://solartoday.org/2015/01/benchmarking-the-declining-cost-of-solar/.

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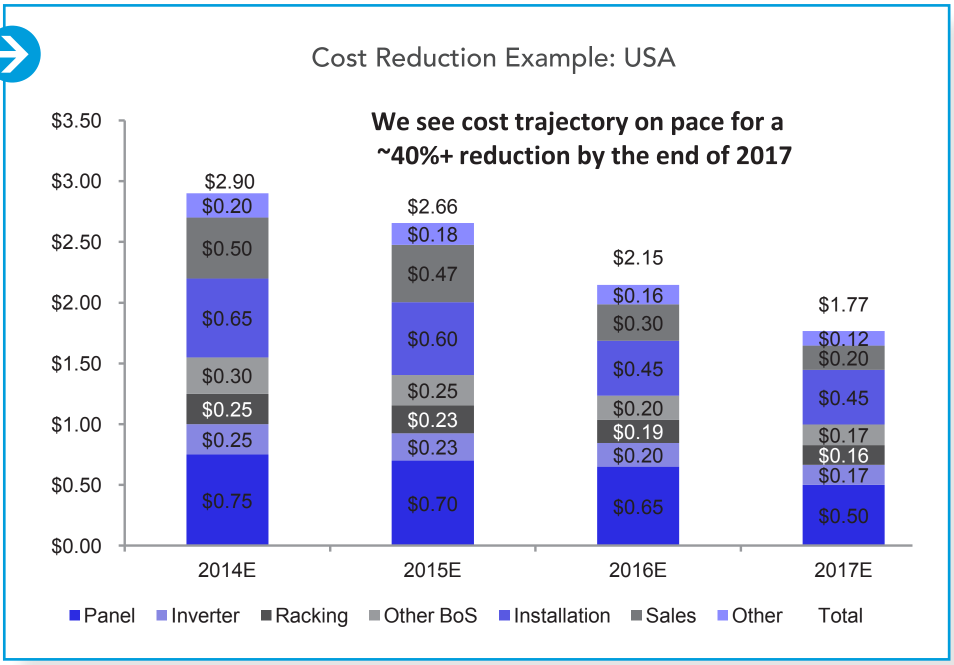

A recent Deutsche Bank report projects solar PV costs to drop another 40% in 4 years from 2014-2017, continuing a long-term trend of sharp and continuous cost declines. Source: Deutsche Bank.

In Oregon and Washington, about 6,000 megawatts of wind generating capacity have been installed so far. In-state wind farms are supplying over 12% of the electricity Oregon uses, and over 6% in Washington. Idaho produces 18% of its electricity from wind.[21] The recently passed 5-year extension of federal tax credits for renewable energy will provide a massive boost to the industry. In the next five years, the extension will add 20,000 megawatts of solar in the U.S., as much as all the solar installed prior to 2015, and 19,000 megawatts of wind power – combined enough to power 8 million homes, according to Bloomberg New Energy Finance, and stimulate $79 billion in additional investment.[22]

Renewable energy farms bring vital economic development to rural communities, generating tens of thousands of dollars in annual revenues for landowners that host wind and solar farms. Local tax revenues are boosted, too, while good-paying construction, operations and maintenance jobs are created in rural communities. *(See Blowing Winds Boost Rural Economies, page 40).*

The hydroelectric power plants in the Columbia River Basin represent over one-third of the hydropower capacity in the U.S., and provide over half the electricity in the Pacific Northwest. Hydropower production varies year-to-year and it may be impacted by changing climate – the most recent national climate assessment suggests a 20% decline in the Northwest for later in the century.[23]

Because hydropower dams can hold water back when wind and solar power production is high, and release it later when needed, the hydro system acts like a giant battery bank for the Northwest's power grid, as long as fish and wildlife and cultural constraints are honored. "If we're looking towards a carbon-free future, we've got to support the hydro system and recognize it as the backbone of a carbon-free system," says John Prescott of the Pacific Northwest Generating Co-op. "If there's continual war against the hydro system, it's going to be harder to get to any clean energy goal. Our region is truly blessed with this resource and as long as the environmental and cultural impacts are mitigated, the hydro system should be the centerpiece of a clean energy future."

Nearly all thought leaders interviewed for this project appear to agree that our hydro system is a tremendous asset that can be pivotal in our ability to reach a carbon-free future. The coming rapid advances in energy storage and grid flexibility technologies may help take pressure off the hydro system and enable better sharing among the competing needs of irrigators and fish.

Are there other carbon-free bulk power sources that could be important to the Northwest's energy system in 2040? Denis Hayes says, "I'd bet on geothermal, for this region and globally. We may learn from the fracking industry. Deep geothermal may make economic sense – it can be clean, and it can be baseload, and it can also be ramped up and down." While several of our thought leaders are skeptical, others believe next-generation nuclear power could play a role: "Nuclear is always looked at as a bad child," says PSU's Tugrul Daim. "But in 25 years, we could see technological developments that will make the half-life of the waste much shorter. Look what's happened with oil extraction – technology has overturned the forecasts of 10 years ago of oil scarcity."

21 Wind Energy State Facts, American Wind Energy Association, accessed January 30, 2016, www.awea.org/resources/statefactsheets.aspx?itemnumber=890.

22 Tom Randall, "What Just Happened in Solar Is a Bigger Deal than Oil Exports," Bloomberg.com, December 17, 2015, http://www.bloomberg.com/news/articles/2015-12-17/what-just-happened-to-solar-and-wind-is-a-really-big-deal.

23 Cassandra Profita, "Report: Climate Change Likely to Reduce Hydropower in the Northwest," OPB, May 6, 2014, http://www.opb.org/news/article/report-climate-change-likely-to-reduce-hydropower-/.

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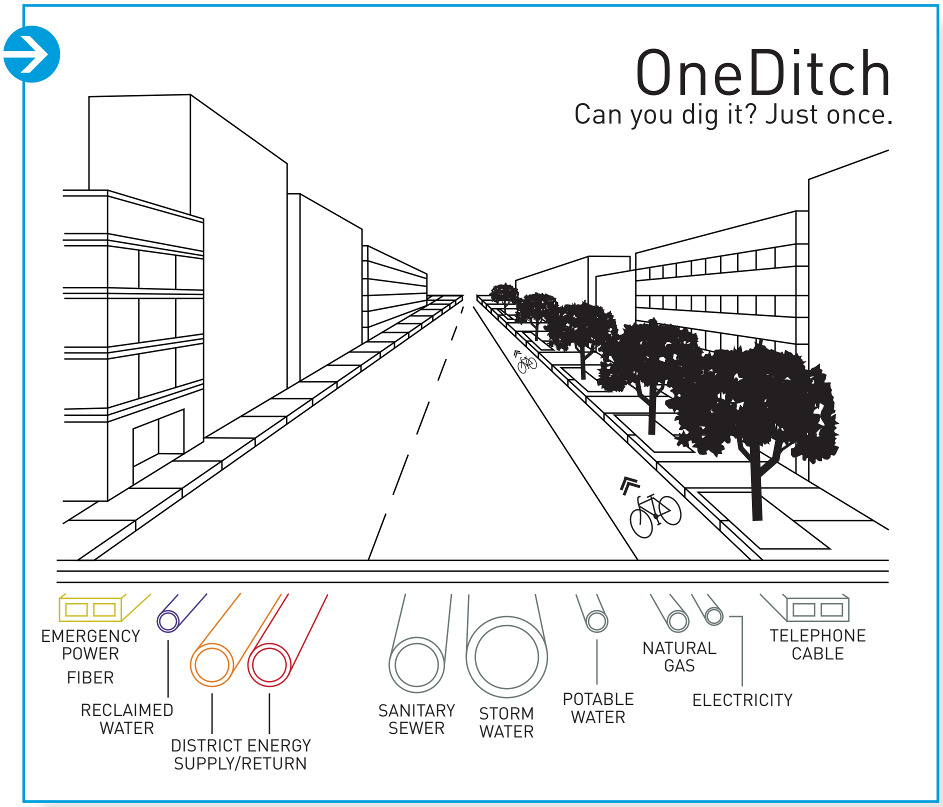
Integrated, Silo-Bridging Solutions

Advancing technology and the imperative for clean energy are opening up innovative energy opportunities that bridge the infrastructure silos of electricity, heating and cooling, transportation, waste management and water. Though today's energy institutions and utilities are not organized to pursue integrated solutions, to build a world-class 2040 energy system will require us to rethink and repurpose these organizations to pursue these opportunities when they yield superior benefits to our communities.

Integrated solutions benefit more than one infrastructure system and, at the same time, deliver a generous range of other economic, social and environmental benefits. Integrated solutions take many forms. "We have a generational imperative to reimagine our infrastructure systems," says Nan McKay, former Chair of the Puget Sound Action Team. "We've got to break through institutional silos and find innovative solutions that connect systems for the greatest community-wide benefit for the long-term."



Rather than digging up streets multiple times, utilities and companies managing different systems in the public right-of-way can reduce costly economic disruptions by coordinating repair and improvement strategies. © University Mechanical Contractors, Inc. | UMC Energy & Environment.

Rachel Shimshak of Renewable Northwest agrees: "You can't think in stovepipes anymore – you have to think integrated. It's more challenging and you have a lot of moving parts. But I think ultimately it'll be a lot more stable. People have to get out of their silos and think about how all these things work together."

Innovators are beginning to do just that, pioneering new solutions that integrate across traditional silos. "We're now thinking differently as we modernize the infrastructure," says Roger Woodworth, President of Avista Development. "Now we ask, 'Can it be modernized in a way that helps improve performance across the full range of things that a city needs?' With the collapse of the cost of sensing and the increase in data science tools, we could discover better value across diverse fields of interest – water, gas, electricity, waste, traffic, parking, security, pedestrian safety, air quality, and even human health."

Next we'll look at two big areas where the current Northwest energy system relies heavily on fossil fuels – transportation and heat – and new technologies are poised to blur the boundaries we're accustomed to. Then this section will conclude by highlighting ways that the future of water and waste infrastructures are aligning with the future of sustainable energy.

Driving Clean ~

Over 25% of all the energy consumed in the U.S. is utilized to move vehicles from place to place.[24] "When you think about it, the biggest 'power plant' most people have is not their share of their local electric utility," says Roger Gray, EWEB's General Manager. "It's their car."

For a century, the internal combustion engine powered by fossil fuel has dominated transportation. But in the next decade, we may see the beginnings of a dramatic shift from internal combustion to electric. This represents a tremendous opportunity to reduce carbon emissions. "There is no way California can reach its ambitious carbon reduction goals without the conversion from fossil fuel vehicles to electric," says Gray.

24 "How We Use Energy, Transportation," National Academies of Sciences, Engineering, and Medicine, accessed December 21, 2015, http://needtoknow.nas.edu/energy/energy-use/transportation/.

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Led by upstart Tesla Motors and its brash CEO Elon Musk – founder as well of PayPal and Space X – market competition is now driving a race to lead in mainstreaming electric vehicles (EVs). Incumbent automakers – including BMW, Mercedes, GM, Ford, Toyota, Honda, Nissan, Renault and Kia – are competing with Tesla to bring affordable EVs to a mass market.[25]

Musk recently told investors he's confident EVs will match or beat the price of comparable petroleum-powered cars within 10 years. Crucial to success will be driving down the cost of these cars' battery banks. Tesla has teamed with Panasonic to build a 'gigafactory' near Reno, Nevada to produce batteries on a scale not yet seen. Current Tesla batteries cost $250 per kilowatt hour (kWh) of storage; for EVs to have a clear price advantage, those costs must drop to $100/kWh. Musk told investors he'd be 'disappointed' if Tesla batteries didn't hit that target within 10 years. "It's heading to a place of no contest with gasoline," said Musk.[26]

Tesla advertises its 2016 electric Model X as the 'safest, fastest, and most capable SUV in history,' and reportedly plans $30,000 mass market electric cars by 2018. (Posted to Flickr by Steve Jurvetson. Cropped. Creative Commons 2.0 Generic License (CC BY 2.0) https://creative commons.org/licenses/by/2.0/legalcode.)

EVs have a tremendous advantage in performance – in 'audacious mode' a Tesla goes 0-60 mph in half the time of a typical gas-powered car. Maintenance on EVs will also be much simpler and less expensive. But a major transition to EVs will depend, too, on how EVs overcome their current disadvantage in range and refueling convenience. Already, Tesla's Model S sedan goes 300 miles on a full charge, comparable to many cars on today's roads. But fast charging stations need to be ubiquitous. "When I go to fill up at the gas station, I'm there for maybe 4 minutes, while equivalent charging would take maybe an hour," points out Tom Potiowsky, Chair of the Economics Department at Portland State University. "If the technology can get that charge time a lot shorter and you can go further on a single charge, the transition to EVs will go a lot faster."

America's elite software, electrical, and automotive engineers are being set loose on the challenge to improve cost, performance, and convenience. Google and Apple are leaning into the challenge, for example. "There are an awful lot of companies right now playing with electric cars and… self-driving cars. This is the future and it might be huge…and it is perfect territory for a company like Apple," says Apple co-founder Steve Wozniak.[27]

How much of our transportation demand could shift to electric by 2040? "It's a fascinating conversation right now," says Scott Bolton, Vice President of External Affairs at PacifiCorp. "A prudent view would be there'll be a pretty moderate adoption, maybe 25-40%, but who knows? Tech adoption and consumer pickup has been extremely dynamic – it's not unimaginable that we could be at nearly 100% adoption by 2040." Could electric utilities actively help the region make this transition? "There's been such an emphasis on conservation and reducing demand for electricity in the region," says Bolton, "that it'd be a paradigm-shift to promote demand. But if we can find broad-based agreement that it is in the public interest, it's in our business interest. It's an alignment we don't often see."

To truly benefit the public interest, EVs need to draw power from a clean electricity grid. Angus Duncan, Chair of the Oregon Global Warming Commission, notes: "If you plug an EV into Seattle's mostly clean electric system, you get over 100 mpg carbon-equivalent. On Portland General Electric's grid, you'll get 50-60 mpg carbon equivalent, after the Boardman coal plant shuts down. Plug it into the PacifiCorp system, and you're getting 35 mpg."

"Energy and transportation are a system that, when thought of in concert, can be made more profitable and more resilient, and better for humanity in general," says Avista's Roger Woodworth. "But you have to think of transportation as a system – not just cars and roads, but how the design, development, and maintenance of each work in concert." To uncover the best solutions, integrated thinking is key. "Resilience is derived in large part from how we organize to meet our needs – not so much in silos, but looking at how the different parts work as a whole," says Woodworth.

25 "How Tesla Fares Against Upcoming Electric Cars," iStockAnalyst, November 19, 2013; www.istockanalyst.com.

26 Julie Pyper, E&E Reporter, "Tesla chief predicts price parity with gasoline-powered cars within 10 years," Climatewire, August 14, 2014.

27 Paul Smith, "Apple Co-Founder Steve Wozniak on the Apple Watch, Electric Cars and the Surpassing of Humanity," Financial Review, March 23, 2015.

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Sharing More, Paying Less

Cars are quickly becoming computers-on-wheels, with big implications for the future of our transportation infrastructure. In the past year, the concept of 'driverless' cars moved quickly from the futuristic fringe to something we should expect to see beginning in the next decade or so. With 360 degree sensors, self-driving cars should be able to safely drive much closer together, enabling far more cars to fill existing road space. "A massive efficiency gain for our road infrastructure," says Daniel Malarkey, former Deputy Director of Washington State's Department of Commerce.

"In Google's vision, you'll be able to summon a driverless vehicle whenever you need it," says Chris Taylor, City Manager for Google Fiber. "The car would pick you up, take you where you need to go, then go pick up someone else, so these cars essentially don't need parking. The current paradigm is that we all need a gas-powered car and a place to park it;" says Taylor. "That may not be the future."

Indeed, the emerging 'sharing economy' means people will own fewer cars and drive less. Car sharing clubs, which enable members to rent cars by the hour, are growing rapidly, from 1.3 million members in 2010 to 3.3 million in 2013. Frost & Sullivan projects 26 million members by 2020, with each car share vehicle reducing the number of cars on our streets by seven to nine. Members typically save about $3,000 a year over car ownership, making this a particularly attractive option for tech-savvy young people. Major automakers are beginning to adapt by repositioning themselves into "service providers offering integrated mobility solutions." Daimler, for example, expects to generate over $130 million from its mobility services in 2014 and is aiming for 10 times that by 2020.[28]

Powering Bigger Rigs

All-electric vehicles in the coming decade will begin to expand from small passenger cars to larger vehicles, from delivery vans to full-sized transit buses. Washington's Department of Transportation recently awarded contracts for the biggest mass purchase of all-electric buses in U.S. history, "a visionary move by Washington State" according to analysts. The contract is for 800 heavy duty buses for highway and in-town applications, and any transit agency in Washington, as well as Oregon, can buy buses under the procurement contract.[29]

Could renewable electricity power trains in the Northwest? Belgium's rail infrastructure manager recently flipped the switch on a project to supply wind power for 5% of the electricity to power three rail lines which move 170 trains a day.[30] Meanwhile, the Dutch rail network, which handles 1.2 million passenger trips per day, has signed a contract to supply 100% of its electricity from wind power by 2018. It's a staggering amount of electricity, equivalent to consumption by all the households in the country.[31]

By 2018 the Dutch rail network will use electricity produced from 100% wind power to move its 1.2 million passengers a day. In the U.S. proposals to electrify rail corridors are beginning to emerge. Photo courtesy of Ad Meskens.

In the U.S., where trains predominantly are powered by diesel fuel, proposals to convert the train fleet and electrify rail corridors are beginning to emerge. Solutionary Rail, for example, envisions a national push to electrify rail, beginning with the BNSF Northern Transcon connecting Seattle and Chicago.[32]

For other forms of heavy transportation – chiefly airplanes, heavy trucks, and shipping – electricity may not be viable. But if liquid fuels are going to be required for these uses long-term, can those fuels be produced sustainably?

The Northwest has been a leader in the challenging effort to develop biofuels that can meet rigorous sustainability standards and achieve commercial viability.[33] "The latest thinking is still that heavy transportation, like aviation, are going to be the hardest to decarbonize," says Ross Macfarlane of

28 Sarwant Singh, "Future of Personal Mobility – Life With or Without Ownership of Cars," Forbes, April 23, 2014.

29 "BYD Motors Wins America's Largest Electric Bus Order," PR Newswire, accessed December 17, 2015, http://www.prnewswire.com/news-releases/byd-motors-wins-americas-largest-electric-bus-order-300138125.html.

30 Jan Dodd, "Belgian Trains Powered by Wind," Wind Power Monthly, October 27, 2015, http://www.windpowermonthly.com/article/1370069.

31 Jan Dodd, "Belgian Trains Powered by Wind," Wind Power Monthly, October 27, 2015, http://www.windpowermonthly.com/article/1370069.

32 "Solutionary Rail," accessed December 21, 2015, http://www.solutionaryrail.org/.

33 "Toward Sustainable Aviation Fuels" (Climate Solutions, October 2015).

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Climate Solutions. "These will be the sectors that most need low-carbon sustainable biofuels." Boeing, in particular, is working with the non-profit Climate Solutions and a range of other Northwest partners to find optimal sustainable pathways to power airplanes and other heavy transportation vehicles.[34] The Northwest Advanced Renewables Alliance, led by Washington State University and including the University of Washington, U.S. Forest Service, Weyerhaeuser, University of Idaho, and Oregon State University, aims to build a sustainable supply chain to produce jet fuel from woody waste materials in the Northwest.[35]

The Eugene Water and Electric Board is an early adopter. It has moved to 100% 'renewable diesel'. "We don't see an operational concern and the cost is very small compared to the normal swing in fossil fuel costs we experience," says General Manager Roger Gray. At the same time, EWEB is working with Amtrak to connect their trains to electric power overnight, rather than idling on diesel.

Clean Heat ~

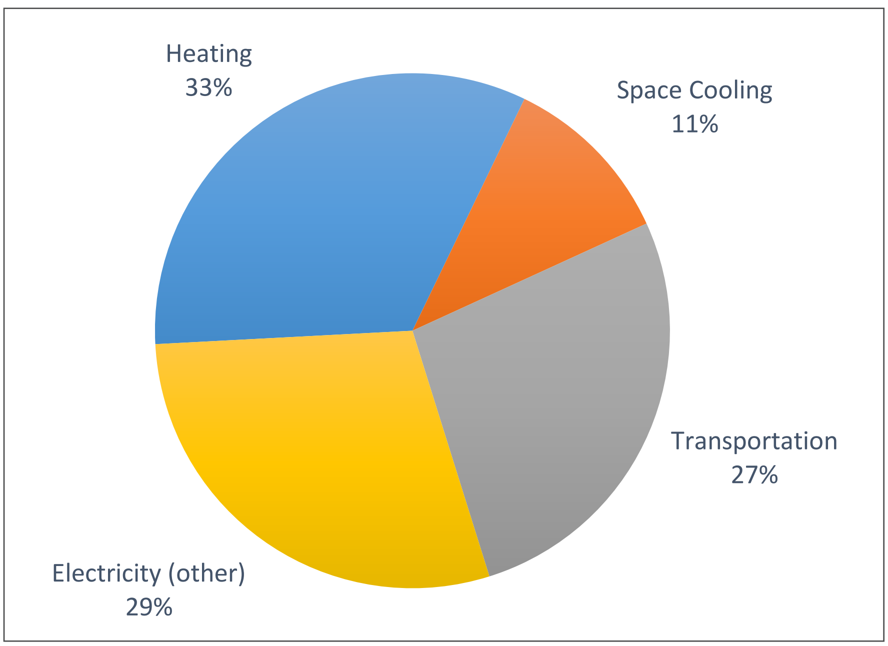
Heating, along with cooling, to keep our homes and buildings comfortable and to supply us hot water, is a major component of the region's energy demand, accounting for over 40% of all the energy used in the U.S. by some estimates.[36] Innovation opportunities for clean and efficient heat abound.

But while the Northwest has made tremendous progress in advancing efficient electricity, we still heat most of our homes and facilities today with equipment that burns carbon-based fuel, or that uses electricity inefficiently. Compared to our excellence in electricity planning, the region is sorely lacking in strategic intelligence and decision-making for heating and cooling. We just don't pay systematic attention to opportunities to make heat energy much more efficient and sustainable.

Electricity is a very high-grade form of energy, and heat can be low grade. Heat pump technology is interesting because it very efficiently applies electricity to pump heat that exists in the surrounding air to warm the space in a home or building, or to heat a tank of water. Rather than using energy to generate heat, heat pumps simply work like a refrigerator in reverse to move heat that already exists in the environment, directing it where we need it.

With an electricity grid that is over 90% powered by sun, wind and water, the Northwest can shrink its carbon footprint by using heat pump technology to replace natural gas-powered or inefficient electric heating units. According to US EPA, "Heat pump water heaters…can be two to three times more energy efficient than conventional electric resistance water heaters."[37]

Heating and Cooling: The Nearly One-Half of Energy Use We Don't Plan For



Heating and cooling, together, make up the largest expenditure of energy in the U.S., greater than either transportation or all other electricity uses combined. Northwest electricity planning is world-class, but to invest smarter we need to plan for the whole, integrated system. Source: Solar Heating & Cooling: Energy for a Secure Future, SEIA.

34 Nancy Owano, "Wind-Powered Train Travel Is on Dutch Rail Schedule," Tech Xplore, August 28, 2015, http://techxplore.com/news/2015-08-wind-powered-dutch-rail.html.

35 "Sustainable Aviation Fuels Northwest," Climate Solutions, http://www.climatesolutions.org.

36 "Solar Heating & Cooling: Energy for a Secure Future," SEIA, accessed December 21, 2015, http://www.seia.org/research-resources/solar-heating-cooling-energy-secure-future.

37 "Heat Pump Water Heaters: Department of Energy," Energy.gov Energy Saver, accessed December 17, 2015, http://energy.gov/energysaver/heat-pump-water-heaters.

A Vision for Our 2040 Energy System

For water heating, a typical natural gas tank system may have an energy factor up to 0.7, meaning 70% of the burned gas heats water and 30% is wasted. An Energy Star® tankless, on-demand gas water heater has an energy factor over 0.9. Heat pump water heaters, by contrast, have an energy factor of 2.0 or more, which means at least two units of heat are fed into the water for each unit of energy consumed to do it.[38] Where electricity is generated mostly from renewable sources, the carbon profile for heating water with electricity at 200% efficiency looks a lot better than heating it with fossil-based natural gas, even at 90% efficiency.

A roof-top installation of flat-plate solar thermal collectors. The system captures medium-temperature heat and circulates it to residential or commercial buildings to meet demand for space heat and hot water.

Heat pumps work more efficiently in a warmer climate, so the Northwest's relatively mild climate will be more heat pump-friendly than colder climates. Smart energy infrastructure investments do more than one thing, and heat pump water heaters can also "reduce peak demand or provide energy storage services to the grid" according to a 2014 study by the Northwest Energy Efficiency Alliance.[39]

Heat pump technology can also be used to pump heat out of our sewers (discussed in the next section), or from other industrial, data, or power facilities that throw off concentrated waste heat. Recycling heat that would otherwise go to waste essentially uses clean electricity to harvest two or three times as much energy to heat buildings and water.

District energy systems – for places that have a concentration of active buildings in close proximity – can deliver heat through a network of underground pipes to multiple buildings, very affordably and efficiently. In summer, a district energy system can cool buildings. As a result, district energy systems displace the need for each building owner to install and maintain their own heating, cooling, and hot water systems. "A colossal amount of money could go into any given building to provide heat with renewable energy," suggests district energy expert Eric Moe of UMC Energy/Environment, "but those same resources shared over a broader neighborhood through district energy infrastructure at scale may deliver substantially more bang for the buck."

The most efficient and sustainable heating and cooling source may be great building design. 'Passive house' buildings, according to Steve Moddemeyer of CollinsWoerman, "use super insulation and air-tight construction, coupled with air-to-air heat exchangers that also supply constant fresh air, to achieve 90%+ reductions in heat demand."

Solar hot water collectors are another clean heat tool, different than solar PV because these systems don't generate electricity, instead gathering the sun's energy to heat water. That hot water can be used directly by building occupants, and circulated through radiators or radiant floor systems to heat rooms. The 47+7 Apartments in Seattle, designed by CollinsWoerman, use solar collectors on the roof to heat water to meet residents' entire space heating and hot water needs for fully 9 months of the year.[40]

Waste, Water, Wastewater, and Energy ~

Today, for the most part, we manage solid waste, water supply, stormwater, sewage and wastewater, as well as energy, through separate utilities and agencies. In a sustainable energy future, these utilities will partner to use, produce, and manage energy smarter, in ways that save everyone money and generate more value for the community.

Drinking water and wastewater facilities alone account for 3-4% of all energy use in the U.S., resulting in 45 million tons of greenhouse gas emissions per year, according to the US EPA. Powering these facilities may consume 30-40% of the local government's energy budget. But 'readily available' energy efficiency measures with payback periods of only a few months to a few years can cut energy demand of these

38 "Energy Star Water Heaters" accessed December 21, 2015, http://www.hotwater.com/resources/energy-star-qualified-products/.

39 Broad, Spielman and Ken Dragoon, "Heat Pump Water Heaters for Demand Response and Energy Storage" (Northwest Energy Efficiency Alliance, 2014).

40 "47+7-Seattle: Features," accessed December 17, 2015, http://www.47and7.com/Apartments/module/amenities/property%5Bid%5D/118849/.

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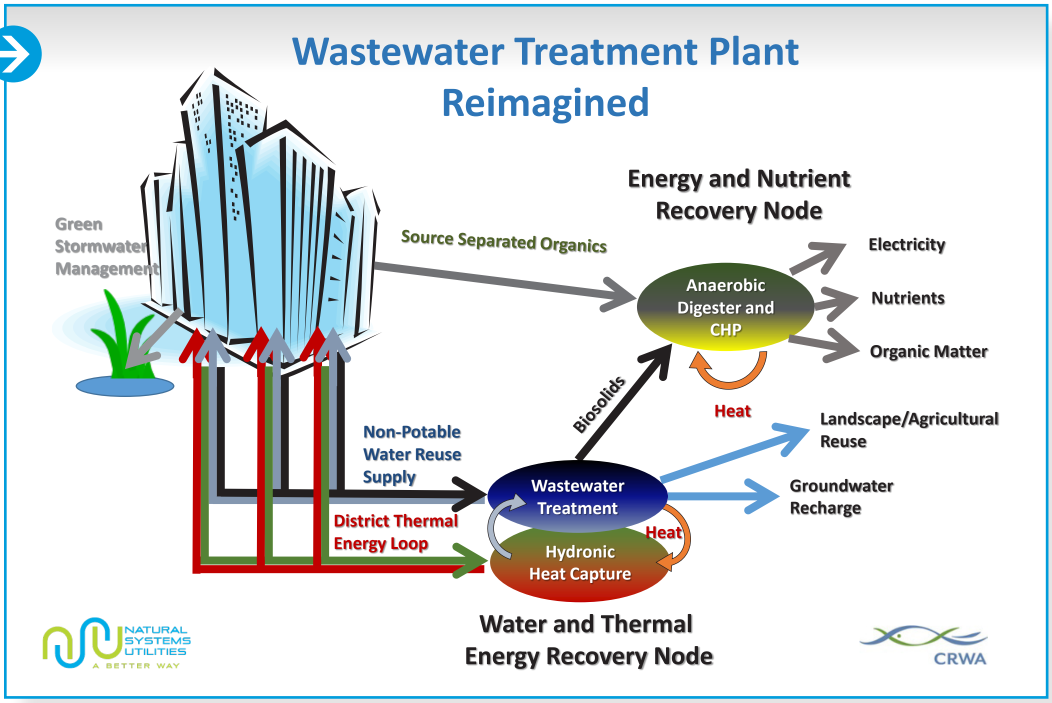

Wastewater treatment plants in the years ahead can become integrated community economic hubs that produce and distribute a variety of valuable clean products including not just water but clean power and heat, as well as nutrients and rich soils. Source: Natural Systems Utilities and CRWA.

facilities by 15-30 percent.[41] Much deeper efficiencies may well be possible with a 10 year payback schedule.

These facilities can not only use energy much more efficiently, but they can produce clean energy. For example, one of the richest, largely untapped sources of clean heat energy is in our sewers. We feed heat into our sewers from our showers, clothes washers, kitchens and dishwashers. By one estimate, some 350 billion kilowatt-hours of energy are poured into U.S. sewers each year—roughly enough to power 30 million homes.[42] Sewer heat recovery systems use heat pumps to pull waste heat out of the sewers to heat water and space in our buildings. Vancouver, BC is a North American leader in sewer heat recovery.

Wastewater utilities are also increasingly harnessing the methane (renewable natural gas) generated at their treatment plants to produce energy, while transforming the carbon and nutrient-rich solids that are left over after the treatment process into a marketable, biologically-rich soil amendment.

The Association of Oregon Clean Water Agencies is convinced that the state's wastewater utilities can become energy independent – eliminating purchased electricity through energy efficiency, use of digester gas, and renewable energy sources like solar and gravity-based hydro.[43]

In Oregon, the City of Gresham's wastewater treatment plant, serving over 100,000 people, was city government's biggest energy consumer 10 years ago with energy costs of $50,000 a month. Today the plant produces as much energy as it consumes and has zeroed out its energy costs. The plant is energy efficient, and it produces 92% of the energy it uses from biogas, tapping the methane generated by the organic matter in sewage, as well as fats, oils, and grease that it collects from Portland-area restaurants and food establishments. The remaining 8% of the plant's energy demand is supplied by one of the Pacific Northwest's largest solar arrays. Leveraging funding from the Energy Trust of Oregon and the State's Department of Energy, the sustainable energy retrofits are expected to repay the capital costs in 8 years, and then generate net profit for many years to come.[44]

Wastewater treatment systems may be in the early stages of a wholesale reimagining of their role in a sustainable community infrastructure. For example, Joshua Proudfoot, Principal at Good Company, says wastewater plants "have the potential to grow poplars and make that the hub of an integrated, symbiotic natural materials industrial complex." Proudfoot says Clean Water Services, based in Hillsboro, is at the forefront. "They are doing joint ventures with fertilizer companies, and exploring ethanol production in partnership with a soda company using expired soda," he says. "They are breaking down every wastewater source that could drive them to have to expand capacity and

41 "Energy Efficiency in Water and Wastewater Facilities," U.S. Environmental Protection Agency, State and Local Climate and Energy Program, 2013.

42 Rachel Kaufman, "Waste Wattage: Cities Aim to Flush Heat Energy Out of Sewers," National Geographic News, December 11, 2012, http://news.nationalgeographic.com/news/energy/2012/12/121211-sewage-heat-recovery/.

43 Oregon Association of Clean Water Agencies, accessed December 20, 2015, http://www.orawa.org.

44 Planet Veolia North America, "Energy Independence: How the City of Gresham Uses Biogas and Solar Energy to Fuel Wastewater Operations," April 21, 2015.

A Vision for Our 2040 Energy System

looking for ways to convert it into a marginal revenue stream. It's really about striking the right business opportunity with the right partner."

According to Steve Moddemeyer, principal at CollinsWoerman, "For every 10 calories of energy in the wastewater, it takes just 1 calorie to treat the equivalent quantity of water. So we can turn wastewater plants into clean energy and water factories. They will be harvesting metals, producing struvite for fertilizer plants, and turning organics into soil amendments."

Not only can wastewater treatment plants produce clean water and energy, says Moddemeyer. "The sewer collection system is also a huge district energy system – you can pull heat out at any point along it and you can also pour heat into it when you need a cooling system."

Because water and wastewater systems have storage capacity, "they may also be some of the best candidates to shift energy consumption patterns to provide valuable demand flexibility for the electricity system," points out EWEB's Roger Gray.

Teaming with solid waste utilities, wastewater treatment plants can become integrated 'energy and water factories', optimized for local organic waste resource flows, to produce a range of valuable products, including renewable biogas, district and industrial heating and cooling, flexible demand and energy storage services for electric utilities, fertilizer, clean soil, and more.

The infrastructure to deliver clean water to our homes and businesses also consumes a lot of energy, but it too can be tapped for energy. For example, wherever water flows downhill through pipes there is potential energy, and in-pipe turbine technology could make it profitable for water utilities to tap it. In January 2015, Lucid Energy installed the nation's first such project in a 42-inch water pipe in Portland, Oregon at no cost to the City because Lucid has signed a 20 year power purchase agreement with the local electric utility.[45] Rainwater harvesting, if done at scale to reduce water supply and stormwater costs, can also save energy for communities whose water supplies are pumped long distances.

Irrigation canals are another source of potential renewable energy, tapping the power of water running downslope. The Hood River, Oregon-based Farmers Conservation Alliance invented breakthrough screening technology that screens out both debris and fish at points where water is diverted into canals. For the small hydropower facilities on these canals, the FCA screen technology cuts O&M costs dramatically, while simultaneously protecting fish and increasing reliability of water delivery at critical times for farmers. This is another illustration that the best sustainable infrastructure investments do more than one thing well.

45 David Russell Schilling, "In-Pipe Hydropower: Electric Generators in Water Pipeline Infrastructure," Industry Tap, July 31, 2015, http://www.industrytap.com/pipe-hydropower-electric-generators-water-pipeline-infrastructure/30355.

"We can turn wastewater treatment plants into clean energy and water factories, that also harvest metals, produce struvite for fertilizer plants, and turn organics into soil amendments."

Steve Moddemeyer, CollinsWoerman

World Class by 2040: Is It Feasible and Affordable for the Northwest?

This section reflects on the threshold questions about the integrated 2040 energy system we're envisioning. That system is high tech, interactive, and flexible. It connects a highly participatory web of diverse energy systems and owners to deliver hyper-efficient and clean energy services to power our vital needs for electricity, heat, and transportation.

Is such a system actually operable? Can we deliver energy in this system to everyone, when and where they need it, reliably and affordably?

Is This Technically Feasible?

Can an interactive and flexible electric grid, rich in two-way communications, integrating highly variable renewable energy sources, really work?

In our emerging 2040 energy vision, the most difficult questions about technical feasibility of a world-class energy system focus on the power grid.

Several thought leaders interviewed for this project believe that we already have the technology to develop an advanced energy system. The challenge is not technological, they argue, though each has a bit different way of framing the true challenge to accelerate progress: "We need the vision!" "It's a deployment exercise." "It's really about fixing the transaction structure."

Can a Renewable Power Grid Work in the Northwest? ~

California has marshalled a few hundred thousand dollars, and many top-notch minds, to take a first cut at the question of whether a flexible, interactive, renewables-rich power grid can work in that enormous state, looking 15 years ahead. The California 2030 Low-Carbon Grid Study[1] looks primarily at the power grid, not a comprehensive, integrated picture that also encompasses transportation and heat energy. But the Northwest can nevertheless leverage the intellectual horsepower mobilized for this study to help inform our energy infrastructure planning.

"Imagine a system that's organized around variable resources. Currently, wind and solar power are jammed into an existing system that wasn't designed for it," says Virinder Singh, Director of Regulatory and Legislature Affairs for EDF Renewable Energy. "The Low-Carbon Grid Study reverses that and flips it to consider a system designed for renewable energy."

The growth of utility-scale wind and solar farms are driving grid managers to adopt new tools for managing a more dynamic power supply. Photo by U.S. Air Force photo/Airman 1st Class Nadine Y. Barclay [Public domain], via Wikimedia Commons.

Singh, who was a driving force in galvanizing the partnerships to fund this extensively peer-reviewed study, says the core question it addresses is, *"How do we get to an affordable, reliable, low-carbon grid in 2030?"* It "looks at a completely different mix of resources: retrofitting natural gas to be more flexible; energy efficiency; energy storage; demand management; a smart mix of renewable energy – wind and solar farms, rooftop solar, some geothermal, and geographic diversity," he says. "Plus resource sharing and coordination between neighboring grid systems."

Key conclusions of the study: California can reduce carbon emissions from the electricity sector more than 50% below 2012 levels without additional costs to ratepayers, even factoring in $58 billion in new infrastructure investment. About 80% of that investment will occur in California, acting as a powerful stimulus for the state economy.

The Northwest may be well-positioned to go even further toward a world-class power grid than California. "Fundamentally we've got the pieces in place to go carbon-free, starting with a huge hydro system that provides some reasonable flexibility," says Terry Oliver, BPA's Chief Innovation Officer. "Our wind resource is perhaps 30% built out – there's still a great deal of wind potential and the very best areas haven't been tapped because they don't yet have transmission. We've only barely begun to adopt solar photovoltaic."

PayPal and Tesla founder Elon Musk believes strong climate policy could accelerate the global transition to clean energy from a 40-50 year time frame to 15-20 years. "We could probably cut it in half and that would have a huge impact on

1 "The Low Carbon Grid Study -," California 2030 Low Carbon Grid Study, accessed December 17, 2015, http://lowcarbongrid2030.org/.

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the welfare of the world. It really matters whether we do this transition sooner or later."[2]

In 2012, the National Renewable Energy Laboratory (NREL) first tackled the question of whether a grid powered mostly by renewable energy can work. Looking state-by-state, the *Renewable Electricity Futures* study also involved the Massachusetts Institute for Technology and the Lawrence Livermore and Pacific Northwest national labs. The study's central conclusion: "Renewable electricity generation from technologies that are commercially available today, in combination with a more flexible electric system, is more than adequate to supply 80% of total U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the United States."[3]

More recently, a groundbreaking study specific to Washington state tests a much bolder proposition, that all the energy Washingtonians use can be provided by renewable energy by 2050. *"A 100% wind, water, sunlight (WWS) all-sector energy plan for Washington State"*[4] is especially important because it looks at – not just the electricity grid, as the California and NREL studies do, as does the Northwest Power and Conservation Council's 7th Plan – but the energy system as a whole, including electricity, heating/cooling, transportation and industry.

The study, produced by a team led by Mark Jacobson of Stanford University, is the first of its kind to look across energy silos to the whole system so it can undoubtedly be improved upon. But it reached a couple striking conclusions:

- *The state possesses more than enough renewable energy to meet its total energy demand across systems and all uses of energy.* That conclusion may be conservative because of two study assumptions – only modest energy efficiency improvements (just 7.4%), and no purchase of renewable energy from other states, such as wind from Montana or solar from Arizona.
- *Implementing the plan would slash total statewide energy consumption, across the various uses, by 40%*, in spite of modest efficiency improvements. Electricity consumption in the plan increases, but overall energy consumption goes down because electric vehicles, industrial motors, and heating devices require far less energy to operate than engines and furnaces that burn fuel.

2 Lenore Taylor, "Elon Musk Says Robust Carbon Tax Would Speed Global Clean Energy Transition," The Guardian, December 2, 2015, sec. Environment, http://www.theguardian.com/environment/2015/dec/03/elon-musk-says-robust-carbon-tax-would-speed-global-clean-energy-transition.

3 "NREL: Energy Analysis - Renewable Electricity Futures Study," National Renewable Energy Laboratory, accessed December 17, 2015, http://www.nrel.gov/analysis/re_futures/.

4 Mark Z. Jacobson et al., "A 100% Wind, Water, Sunlight (WWS) All-Sector Energy Plan for Washington State," Renewable Energy 86, no. C (2016): 75–88.

The Northwest Power and Conservation Council identifies the wintertime peaks in electricity demand, to supply heat and lighting during the cold and dark months, as a critical chokepoint for renewable energy because solar production is low in winter. While the wider Northwest electricity system consumes about 20,000 average megawatts, during winter demand reaches 50 percent higher.[5]

The Stanford analysts developed a model to test the quantity and quality of energy storage devices needed to ensure electricity supply and demand can be matched year round and moment-to-moment in their plan. A variety of energy storage assets are deployed, including a continued large role for the region's hydroelectric dams, to enable grid operators to "match load without loss every 30 seconds for 6 years (2050 to 2055) while accounting for the variability and uncertainty of WWS resources."

Cutting electricity demand substantially in winter, when lighting and heat demand on the system are high but solar power production is low, will be a key challenge for the Northwest. A range of money-saving, sustainable, silo-busting solutions can help damp down winter demand. High performance buildings use both light and heat very efficiently. District systems can efficiently and affordably deliver heating and cooling services to concentrations of people, businesses and institutions. Weatherizing homes and modernizing their heating systems and lighting will cut winter demand, while benefiting lower-income people who disproportionately live in inefficient homes.

Is a Flexible, Smart Grid Actually Workable? ~

Key regulators are optimistic that a power grid tapping renewable energy sources on a much larger scale can be done successfully. "Research is saying that we'll be able to manage a very high penetration of wind and solar," says Oregon PUC Commissioner John Savage. "We'll need energy storage and bigger and faster markets over wider geographies. The emerging 'Energy Imbalance Market' – which enables our grids to share with their neighbors – is very valuable – it's a really good thing."

Rachel Shimshak of Renewable Northwest sees a broadly similar picture. "The key is going to be flexibility – a close fit between demand and supply side strategies to accommodate customer needs at reasonable cost and next to no environmental impact," she says. "To me, that means a

5 Charlie Black, "Memorandum to Power Committee: PNUCC Northwest Regional Forecast" (Northwest Power and Conservation Council, April 29, 2014). https://www.nwcouncil.org/media/7073133/p3.pdf.

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combination of clean energy resources and strategies – energy efficiency, demand management, market improvements that will supply storage opportunities, and storage widgets themselves."

While this project's thought leaders are generally optimistic that a flexible, interactive smart grid can work, innovation in the market is a new frontier with unproven tools and technologies. "An important step, to develop a smart grid capable of incorporating all that we need it to, is the ability for two-way communication, so electrons can pass to and from a consumer reliably and efficiently.," says Megan Owen, McKinstry's Director of Strategic Market Development. "Another challenge is the sheer volume of data we have the ability to collect. The industry is in the process of identifying new methods, tools, and analytical capabilities to sort and analyze the right streams of energy and usage data that would enhance the overall network."

Fred Gordon of Energy Trust agrees: "At the macro-level, we'll have masses of data from all these individual lighting fixture and HVAC units that are reporting. The questions that need resolving include: who owns the data, what are the agreements for access to it, what are the standards for quality, what are the verification protocols for energy savings. This is the key intellectual infrastructure," says Gordon. "There's a lot of noise in whole building data streams. There is a whole raft of things that we need to learn how to do that are pretty new to us."

"Right now, faced with an overwhelming amount of information, alarms, and reports coming at them, a facility manager too often opts to turn off the data flow and revert back their old patterns of operating," points out Megan Owen. "It is critical that we keep those charged with operating complex systems front of mind, and use technology to enable better performance and productivity and present it in a visual and intuitive way. Technology is a tool to an end result, it is not the end result."

While the tools to effectively operate a flexible, smart grid are evolving rapidly, a number of tools are already poised to deliver real value. A key challenge for mass adoption of renewable energy, for example, is that on sunny afternoons solar power can ramp up dramatically, but a few hours too soon to meet the evening ramp up in demand. Leading regional energy economist Jim Lazar has identified ten existing carbon-free strategies and tools that can be implemented quickly, each making a small contribution, to solve the problem within a few years, and actually make the grid easier to operate than it would be without renewables.[6]

6 Jim Lazar, "Teach the Duck to Fly: Integrating Renewable Energy," Regulatory Assistance Project, Jaunuary 2014, http://www.raponline.org/featured-work/teach-the-duck-to-fly-integrating-renewable-energy.

For well over a decade, the Pacific Northwest has been a national pioneer in smart grid research, development, and field deployment. The Pacific Northwest Smart Grid Demonstration Project, completed in 2015, is the nation's largest, most comprehensive, and ambitious smart grid deployment project yet, engaging 60,000 customers and 11 utilities across five states. The project installed technology and equipment worth $80 million to test the ability of smart grid applications to deliver a number of value streams, including improved reliability, energy efficiency, and demand flexibility. The Project's final report noted that, "The demonstration developed and deployed an innovative transactive system, unique in the world…This region-wide connection from the transmission system down to equipment in individual premises was one of the major successes of the project."[7]

Is the Smart Grid Hackable? ~

To build a flexible, interactive power grid, "We really need to advance IT throughout the grid," says Virinder Singh. "I think we've accepted that technology evolves remarkably. But cyber-security still is a serious challenge." John Savage agrees: "The more that we rely on two-way communication and the Internet of Things, the more entry points for cyber-attacks we're creating."

Cyber-security is a mission-critical challenge for utilities as they manage an increasingly connected smart grid. (Posted to Flickr by Yuri Somoilov. Cropped. Creative Commons 2.0 Generic License (CC BY 2.0) https://creativecommons.org/licenses/by/2.0/legalcode.)

7 Battelle Memorial Institute, "Pacific Northwest Smart Grid Demonstration Project Technology Performance Report," Volume 1: Technology Performance," Smartgrid.gov, June 2015, https://www.smartgrid.gov/document/Pacific_Northwest_Smart_Grid_Technology_Performance.html.

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Steve Moddemeyer believes "it's a mistake to have all things Internet of Things'd together. They should be componentized. For example, if you have a building, you want to keep as much internalized as possible and interact with the grid only to the extent necessary," he says. "The transfer point between the two could be hackable and that's where you focus your cyber-security measures. When these systems break, they need to break closed. Think of them as modular systems that link together rather than being all hyper-connected." When linked systems do go down, neighborhood or building systems need to "default to a state where they still perform essential services in 'analogue', non-digital mode," says Moddemeyer.

Others believe that the hyper-connected Internet of Things is inescapable. "It's coming – deal with it," says Terry Oliver, BPA's Chief Innovation Officer. "The hack-ability is pretty easy now," says Denis Hayes. "The average luxury automobile has 100 million lines of code in it – more than the Hadron Collider! When you've got all of that, a few malicious lines of code buried in there creates real risks." But Hayes envisions the Pacific Northwest "getting out there first to solve those problems. With the technical expertise we have in this region, we can deliver real solutions to benefit the world."

Imported coal energy makes up a share of Washington and Oregon's electricity mix. By phasing out coal, we can free up capacity on the bulk transmission power lines and tap big reservoirs of Montana wind or Southwest solar power more affordably.

Can We Live Without Coal? ~

This project's thought leaders predominantly agree with Dave Danner, Chair of Washington's Utilities and Transportation Commission (UTC), who said, "I believe that by 2040 the few straggler coal plants remaining after the EPA Clean Power Plan is implemented will have reached the end of their useful life – they'll either be closed or they'll have some kind of carbon capture."

When coal plants shut down, a valuable resource – capacity on the bulk transmission power lines – can open up for renewable energy. "The beauty of retiring those coal plants is that you can repurpose the associated transmission infrastructure to move new renewable energy," points out Rachel Shimshak. "For example, Montana has an enormous amount of wind but no way to get it to markets. Right now, transmission lines are filled up with Colstrip coal power, but when these bulk lines are freed up, with some modest investment in new lines, Montana can develop a lot of wind."

A significant amount of additional coal-fired electricity is now being delivered to Northwest consumers from nine coal plants in Wyoming, Utah, Colorado, and Arizona, according to the NW Energy Coalition, but current modeling by the Northwest Power and Conservation Council does not quantify or include this imported electricity.[8] To shrink the region's carbon footprint will require that we ensure these imports are visible, managed, and replaced, to the extent feasible, with renewable energy.

Will the Grid Need Natural Gas? ~

Scott Bolton of PacifiCorp argues that fossil resources may be necessary in the 2040 energy system to ensure resiliency. "There's probably a good case for affordability and resiliency to have fossil resources in the portfolio," he says. "For example, what happens in the case of extreme drought? With hydropower squeezed, renewables can't provide base-load – so you'll still need some coal and natural gas."

Geoff Brown of NRG Energy argues that cutting the carbon footprint of "our electricity system to 10% of our current carbon usage would be a great outcome." He says, "Fossil fuels are an incredibly versatile and dense energy source and I don't think we have to replace 100% of it. Replacing that last 10% while maintaining high reliability is tough – that's a cloudy day in winter without the wind blowing where you are producing just 5% of your load for three days."

8 "Coalition Analysis: 7th Power Plan Model Minimizes Looming Coal Plant Costs, Ignores out-of-Region Generators," NW Energy Coalition, July 16, 2015, http://www.nwenergy.org/news/coalition-analysis-7th-power-plan-model-minimizes-looming-coal-plant-costs-ignores-out-of-region-generators/.

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John Prescott of the Pacific Northwest Generating Co-op agrees that "we have to embrace natural gas as a bridging strategy, as much as I am concerned by carbon emissions and the volatility of price." The advantages Prescott sees are that natural gas is proven technology that is quick to build and low cost, it can ramp up and down quickly to meet demand fluctuations and to help integrate variable energy resources like wind and solar, and it is cleaner than coal. On the other hand, he notes some key disadvantages: the fuel price is volatile, there can be pipeline bottlenecks, and it is a carbon-based fossil fuel.

Natural gas is generally considered an attractive substitute for coal energy because it burns significantly cleaner, with lower emissions of carbon dioxide. But calculating the lifecycle climate impact of natural gas is difficult and very sensitive to methane leaks. In fact, Cornell researchers calculate a higher greenhouse gas emission profile for natural gas than for coal or oil.[9] "When you really look at the full life cycle, I'm not sure gas is really much better than coal for power generation," says Eileen Quigley of Climate Solutions. "The new research is showing there is significant methane leaking throughout the supply chain. As you get closer to the tipping points on climate, these gas plants may really be too much of a pollutant."

On the other hand, renewable gas – biogas produced from food, sewage, and other organic wastes – can fuel the flexible, gas-fired 'peaker plants,' but the size of this renewable resource in the Northwest is not well understood.

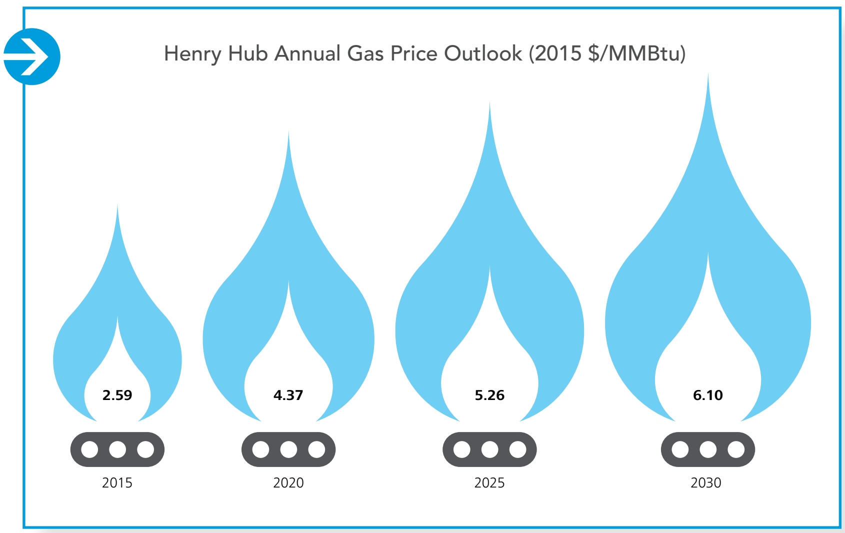
Oregon's Global Warming Commission developed a low carbon scenario for the 2050 power grid that cuts emissions at least 75% below 1990 levels. Commission chair Angus Duncan says a world-class system will go further – reaching closer to 90% lower. In the 75% scenario, says Duncan, "We're meeting all growth with efficiency, and supplying 50% of baseload power from hydro, and 30% from variable renewables – very geographically diverse, and mainly wind and solar PV, probably with some biomass energy." The other 20% of the power, says Duncan, is "wind-chaser" gas which is used to integrate variations in wind and solar power production.

To get to a 90%+ carbon-free grid, Duncan sees energy storage as key. "We could get to crossover price points where energy storage becomes cheaper than wind-chaser gas in the next 25 years. Already, there are some pump storage projects that could be cost-effective today."

The former head of the Federal Energy Regulatory Commission, Jon Wellinghoff, warns that if energy storage costs continue their steady decline, utility investment in natural gas plants could be at risk. "These utilities are taking a risk that these will be stranded assets that ultimately their shareholders will have to pay off," Wellinghoff recently told reporters. "We will see regulators being more critical of these asset decisions as prices of renewables continue to go down."[10]

Washington's top utility regulator, Dave Danner, chair of the Washington UTC, is concerned about natural gas as a bridge fuel to replace coal plants. "You're looking at a generation of infrastructure that will be on the books for decades. Do you want to go with the bridge fuel or will you be saddled with their high cost and will that bridge fuel investment delay other innovative solutions?" He expects, however, that, "we'll be saddled with some natural gas plants because we don't have alternatives ready in 2016."

Nancy Hirsh of the NW Energy Coalition echoes Danner's concern. "The investments we make in the next 5 years – this is very important for 30-40 years out. Are natural gas plants really cheaper if we have to pay for it for decades to come?" On the other hand, she says, gas plants are less expensive at $200 million to $500 million, so if we lose $100 million in value in the out years when these plants become obsolete, maybe that's not a huge problem."



Solar and wind resources must compete on price with natural gas. Unlike wind and solar, natural gas prices aren't stable, and some analysts forecast price doubling by 2030. Source: Deloitte Center for Energy Solutions. "Journey to Grid Parity," 2015. http://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-pu-journey-to-grid-parity-report.pdf.

9 R.W. Howarth, "A Bridge to Nowhere: Methane Emissions and the Greenhouse Gas Footprint of Natural Gas," Energy Science & Engineering. 2(2): 47-60, 2014.

10 Robert Walton, "Former FERC Chair Wellinghoff: Utility Gas Investments Risky as Energy Storage Prices Fall," Utility Dive, November 13, 2015, http://www.utilitydive.com/news/former-ferc-chair-wellinghoff-utility-gas-investments-risky-as-energy-stor/409157/.

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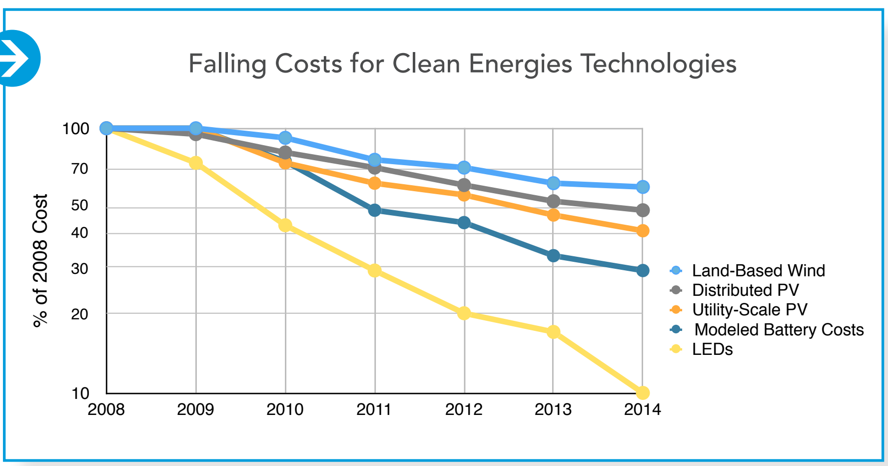
Is This Affordable?

Is it reasonable to believe that the investments needed to build a world-class energy system in the Northwest can outperform the investment needed to sustain the current system on a life cycle cost-value basis?

To answer this question, we have to evaluate affordability in new ways. Thinking about affordability has to start from the perspective of the people, institutions, and businesses who use and pay for energy to stay warm or cool, power devices, get where they need to go, and wield energy to do work. Whether people pay a particular utility, gas station, or private company for energy services may matter less to them than the cost, quality, reliability, and value of the services they can purchase to meet their needs.

For utility-based and other shared systems, investing for affordability is not just about the upfront capital costs to build a particular project – it also includes operating and maintenance cost for the life of the investment (e.g. 25 years). And risk must be factored in, such as the risk that technology or policy changes will make past projects obsolete before they've been paid off.



Costs for many clean energy technologies dropped by half since 2008, with no clear end in sight for plummeting costs. Source: U.S. Department of Energy "Revolution Now: The Future Arrives for Five Clean Energy Technologies–2015 Update". Logarithmic chart by Eric Strid.

Another challenge for forecasting affordability through 2040 is that so many key technologies and systems – energy storage, demand flexibility, solar PV and wind, deep efficiency, and electric vehicles – are still in the thick of innovation cycles and declining cost curves. We don't know exactly what advancements will be made or what these technologies will cost in 5, 10, or 20 years. This makes assessing affordability challenging. But the future is bright for these technologies, global demand will be robust, and further improvements in cost and performance are inevitable. Together this portfolio of new technologies and systems could enable a substantially more affordable, sustainable and resilient energy system for the Northwest.

Whole System Savings ~

To think about affordability in a new way, we must also take a whole system perspective to consider both what energy users' pay for all their energy services, and the soup-to-nuts, lifecycle costs for operators of our shared systems.

For energy users, switching from one type of energy provider to an entirely different one can be economically beneficial. For example, switching from a petroleum-powered car to an electric car can save a lot of money. A recent analysis by NerdWallet spanning 27 cities found that switching to an electric car can save the average driver 36% in fuel and maintenance, totaling over $10,000 in five years.[11] In that case, the customer likely cares more about superior quality and lower cost of the energy service than about whether they pay an electric utility instead of a gas station (and repair shop).

For system operators, a project that does more than one thing to benefit the broader system will generate additional value streams compared to a single purpose project. What is needed is an investment policy for utilities that supports strategies that do more than one thing to provide multiple whole-system value streams.

The Stanford study that offered a 100% renewable plan for all energy uses across electricity, heat, transportation and industry concluded that, rather than costing Washingtonians more money, the plan would actually reduce energy costs modestly – by a bit over $300 a year on average for a family of four. Researchers further estimated that eliminating most energy-related air pollution will save Washingtonians 10 times as much on health care and other costs, over $10 billion a year.

For wastewater utilities, investments in efficiency and on-site renewable energy production are apparently not just affordable, but profitable. In Gresham, for example, the set of investments needed to zero out their energy purchases, leveraging grant funding, will pay back in 8 years and then

11 Jeffrey Chu, "Electric Vehicle vs. Gas vs. Hybrid Cars: A Comparison of Maintenance, Fuel, Insurance and Other Costs - NerdWallet," NerdWallet Credit Card Blog, September 15, 2015, https://www.nerdwallet.com/blog/insurance/auto/electric-hybrid-gas-how-they-compare-costs-2015/.

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Sharing Benefits and Prosperity Broadly

Millions of families in the Northwest, as well as small businesses, are struggling economically, in both our rural and urban communities. In Washington State, for example, 1 in 7 people are living below the federal poverty line and 40% of children live in families that struggle to make ends meet. Energy costs can gobble up a painful chunk of these families' limited resources. At a minimum a world-class energy system needs to share the benefits of advanced technology with families and businesses in the form of affordable prices for energy.

"Right now, there are a lot of people living one pink slip or medical crisis from not being able to pay their electric bills," points out Bob Jenks, Executive Director of Oregon's Citizen Utility Board. "The renewable energy we're investing in today – as we pay down the capital costs on those facilities – will become more valuable because they have no fuel costs. The last half of their capital life will be the most economical to the system. That will help protect people who are struggling." Jenks also points out that low income families disproportionately live in poorly insulated homes with inefficient heating, "so we ought to be helping folks insulate and get more efficient furnaces."

But there is more to broadly sharing the benefits of the new energy system than affordable energy prices. For example, higher income people and larger businesses are the early adopters of cool new energy tools. To give low-income customers access, too, Rocky Mountain Institute's eLab has launched a new program – piloted first in New York – called Leap. The program offers low-income customers and organizations "an important seat at the table in electricity system transformation, to find common ground and build a shared understanding of customer's needs and concerns, and co-create, replicate, and scale solutions that take these needs into account."

Community energy models, such as the community solar programs at Spokane's Inland Power and Light and at Seattle City Light, can also create participation opportunities for lower-income households. "This is key to allowing renters, low-income people, and the roughly 75% of homeowners without good solar access to participate," says Seattle-based energy researcher Patrick Mazza.

On a bigger scale, in California a quarter of the revenues generated by the state's carbon cap-and-trade program are directed toward projects that benefit disadvantaged communities, with 10% spent on projects located within those communities. "It's gigantic! This is the best model I know of – it's really exciting," says Aiko Schaeffer, a strategic consultant on environmental equity at the University of Washington.

Rural communities, in particular, tend to have higher poverty rates in our states. Renewable energy infrastructure development can bring vitally needed rural jobs, investment, and tax revenues. In Tokeland, Washington, the Coastal Community Action Project developed its own 6 megawatt wind farm that is generating $400,000 a year in net revenue for the non-profit to support the direct services it provides to low-income households in the community.

A bold and sustained program to upgrade our region's energy infrastructure can create jobs and build pathways out of poverty. Many infrastructure jobs are low-barrier-to-entry, meaning they don't require an advanced degree. Instead technical colleges and union apprenticeship programs can rapidly train workers to install and operate new systems. "I regularly go out and talk to classes of apprentices and these are hungry people that want to do good work," says Jeff Johnson, President of the Washington State Labor Council. "And it just breaks your heart to see them on the sidelines. I'd like to see pipelines for bringing new people in, including disadvantaged populations, people of color, and women."

Sources: Washington State Budget and Policy Center, Poverty Fact Sheet, September 2015, http://budgetandpolicy.org; Rocky Mountain Institute, eLab, http://www.rmi.org/elab_leap; CalEPA, Greenhouse Gas-Reduction Investments to Benefit Disadvantaged Communities, www.calepa.ca.gov; CDFI Fund, Capacity Building Initiative, Impact Report on Coastal Energy Project.

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save $50,000 in energy costs per month for years. Going further, wastewater utilities can expand their services from clean water to clean energy, too, supplying money-saving district heating and cooling to local buildings and industry. Natural gas utilities could be strategic partners, morphing their business model to center on clean heat solutions that help customers to save money and the region to reduce its carbon footprint.

Smarter Investment for a Flexible, Renewable System ~

The Northwest has developed sophisticated and startlingly valuable tools for 'least-cost planning' in the electricity sector that have saved Northwest electricity consumers billions of dollars. Led by the Northwest Power and Conservation Council, profitable planning for the region's electricity system looks at just one very important slice of the Northwest's energy pie. But the tools and insights are transferable. For example, the most valuable and affordable investments do more than one thing. Infrastructure planners typically calculate the costs and benefits of a project based on a single value stream, but smart energy infrastructure investment will deliver multiple system benefits, freeing capacity on distribution systems, increasing system operators' flexibility to manage peaks and valleys in demand and supply, reducing reliance on carbon-based fuels, and building resilient, 'self-healing' systems.

> In Washington and Oregon, we spend over $30 billion a year on imported fossil fuels. With a clean grid, electric vehicles, and clean heat, several billion dollars now draining from our state economies can be redirected to in-state infrastructure that pays local wages and taxes.

Looking at the edges of the electric grid, customers will invest billions of dollars in devices that can produce, reduce, and manage energy. These purchases may benefit the larger system, add complexity, or both. Customer-side purchases can potentially bring substantial value to the grid. Utilities and governments can cost-effectively incentivize consumer purchases that benefit the larger system, or contract with them to pay for benefits delivered to the grid. For private investment to best benefit the system, a key challenge is to evolve better tools to calculate the various value streams that independent investments offer the system, which can vary based on location and the specific needs of local systems.

For example, one key frontier for cost-effective efficiency investment is to target measures that do more than one thing and thereby generate additional value streams. "Right now, utilities are making capital investments to shore up the grid, to support voltage and capacity requirements on the local distribution wires," says the Northwest Energy Efficiency Alliance's Jeff Harris. "They're investing in fossil fuel combustion turbines that can turn on and off quickly. If you're only looking two years out, it kind of makes sense. But if you have the long-run outlook," says Harris, "you'd consider the sunk capital and fuel costs for 20 years and compare that to investing in energy efficient equipment with demand management capabilities."

For utilities, the switch to a flexible, renewable system can be politically risky, at least in the short-term. "EWEB moved forward to pursue a strategy of 100% renewables and conservation," notes Roger Gray, manager of the Eugene-based water and electric utility. "But it started to move our rates toward the highest in the Northwest… The short-term and political costs are real." Successful innovation models will prove cost-effective both for the short-term and over the multi-decade lifecycle.

Deep Efficiency ~

Energy efficiency has proven to be an extraordinarily affordable investment. "The efficiency we've captured over the last 30 years is now double the amount we generate annually from the Grand Coulee dam – and its cost is one-third the cost of power from a new fossil-fuel power plant," says Angus Duncan. What's more, he says, we can expect another three Grand Coulee's worth of efficiency savings in the next 20 years.

One caution: Pursuing the cheapest layer of energy efficiency first, can make it harder and more expensive to go deep and capture all the energy savings that are profitable over a longer time horizon in a given home or building. Already today an increasing number of homes and buildings are so efficient they are able to produce all or most of the energy they require. Because most utility infrastructure is financed over decades, capturing the deep efficiency potential for retrofitting buildings – rather than 'skimming the cream' – should in theory be achievable and affordable. But the region has yet to develop and scale strategies for utilities to benefit by incentivizing whole building deep efficiency approaches.

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Existing homes are much more challenging to retrofit for energy efficiency than designing super-efficient new homes. But Clean Energy Works, a non-profit public-private partnership recently rebranded as Enhabit, has pioneered a successful model and now operates throughout much of Oregon as well as in some Washington communities. In six years, Enhabit "has grown from a 500-home City of Portland pilot project to the region's largest home renewal service, completing more than 4500 projects and generating over $90 million in local economic activity," the group reported recently.[12]

A Portland homeowner finds peace of mind in an energy-efficient home, with solar panels and a seismic retrofit, thanks to Enhabit. Photo courtesy of Enhabit.

Can We Afford to Replace Fossils with Renewables? ~

The integrated Washington state energy plan developed by the Stanford group found that the entire state's energy need – including electricity, transportation, heat, and industry can be supplied by renewable energy at a small net savings per person.

In contrast, the draft 7th Power Plan produced by the Northwest Power and Conservation Council looks at the regional electricity system in isolation. But deploying some of the most advanced planning models in the world, the 7th Plan finds the most cost-effective resource to meet growing demand in the region is conservation, with little or no need to develop new power generating resources in the next 20 years. As a result, little renewable energy, beyond what is already required by state law, is developed in the Council's plan. The Council developed two "Maximum Carbon Reduction" scenarios that reduce emissions 80-90% from today, but found the cost to be quite high. That may reflect their models' failure to properly anticipate technology cost and performance trajectories, which are largely new to the electricity industry. But the 7th Plan is in draft form as of this writing and the final may address such criticisms.

Economy-Wide Benefits ~

In Washington and Oregon, we collectively spend over $30 billion a year on fossil fuels, according to the Sightline Institute. Since our states do not produce these fuels, two-thirds to three-quarters of that money drains directly out of our state economies to pay producers elsewhere.[13] With a clean grid, electric vehicles, and full-scale efforts to convert to clean heat, fossil fuel imports can be dramatically reduced. Several billion dollars now draining from our state economies can be redirected to in-state infrastructure that pays local wages and taxes which will recirculate in local economies statewide.

Eliminating air pollution can save billions, too, with the Stanford study estimating 100% renewable energy would deliver health and related savings of $10 billion a year in Washington alone. To the extent that disadvantaged communities and low-income families are disproportionately impacted by air pollution, eliminating this pollution will make the Northwest energy system more equitable.

One value stream that we haven't yet evolved good tools to monetize is the value of resilient, 'self-healing' grid systems. John Savage, Oregon PUC Commissioner, says, "Most of our outages or blips are problems at the distribution system level. When I have a break in the distribution system, like a circuit gets cut, can I route around it to get power to end users? Self-healing systems can figure out how to route power instantaneously via computer systems – that's very valuable for resilience, but very hard to quantify."

Jeff Harris illustrates: "The old standard grid trips off when an incident happens; the triggers are set to a low level problem to contain the impact, but still a fairly large area will often be down for hours." But the Spokane-based utility Avista is a leader in demonstrating smart grid technology. "With Avista's intelligent systems, a truck backed into a power pole and the system was able to identify the exact place where the incident occurred, isolate it to a very precise area, and bring it all back online quickly," says Harris. "What is the economic value of a neighborhood being blacked out for just minutes instead of hours?"

12 "Enhabit," accessed December 21, 2015, https://enhabit.org/news/new-name-expanded-offering-welcome-enhabit-formerly-clean-energy-works/.

13 Kristin Eberhard, "How Much Do We Spend on Fossil Fuels?," Sightline Institute, December 29, 2014, http://www.sightline.org/2014/12/29/how-much-do-we-spend-on-fossil-fuels/.

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Blowing Winds Boost Rural Economies

By late 2013, Oregon reached fifth place among U.S. states for wind power capacity with 3.2 gigawatts in place. Mostly located in rural communities, this wind generation infrastructure brought $7 billion in capital investment spread over 29 projects in four Oregon counties along the Columbia Gorge. The investment created 2,000 jobs during construction, and over 180 permanent jobs, helping bring robust economic growth to these rural counties while much of Oregon struggled through recession.

Wind development also generates much needed support for local government services. Through 2013 wind in Oregon pumped more than $110 million dollars in taxes into local and state government coffers. Oregon's farmers, ranchers, and rural landowners are benefitting, too, by leasing small portions of their land to host wind projects, collecting an estimated $7.5 million a year in lease payments.

Gilliam County judge Steve Shaffer testified in an opinion piece written for *The Oregonian*, "As a county official who shares responsibility for maintaining rural roads, funding social services and ensuring public safety, I assure you this kind of economic development would be welcome anytime. Coming, as it did, during troubled economic times, the investment has been a godsend. Wind energy is generating a brighter future for our communities."

Source: "What is Oregon's Long-Term Outlook," North American WindPower, vol 10, #10, November 2013.

Renewable energy has already become an economic anchor in several rural counties in Washington and Oregon. (Posted to Flickr by Loco Steve. Cropped. Creative Commons Attribution 2.0 Generic (CC BY 2.0) https://creativecommons.org/licenses/by/2.0/legalcode.)

Stranded Assets ~

For an energy system plunging into a period of rapid technological transformation, making smart long-term infrastructure investments gets much more challenging. "We see utilities spending a lot of capital now on assets that may not make sense in 10-15 years because the rate of technology change is so fast or their model will have shifted from the business we know today," says Megan Owen.

"What could make utilities go broke is stranded assets," says Jack Speer, "where they have to continue to pay off investments to build power plants that were approved by regulators but are no longer needed." That is a risk not only for the utilities, but their customers. "I represent the customers," says Bob Jenks, Executive Director of the Oregon Citizens Utility Board. "The worst outcome for them is where you make bad capital investments where you either have to retire the assets before their useful lifespan, or you have to make redundant investment," he says.

"This stranded assets piece is crucial to really understand and wrestle with," says Scott Bolton of PacifiCorp. "If we want to get to really high levels of renewables in the 2040 time frame, we'll have to work through the challenges of figuring out how to deal with all the stuff that will have to be retired or closed down prematurely."

New investment in carbon fuel infrastructure may well be risky. "Over the next 50 years of an investment we can expect most of that will be under a carbon regulatory structure – we know the rules are going to come, but we don't know what they will be," says Bob Jenks, Executive Director of the Oregon Citizens Utility Board. "The key for long term affordable infrastructure is making the right decision; that's also the key to sustainability. We have to think about whether we're making the right investments not just for today, but for 30, 40, 50 years forward."

Rob Harmon argues that, "We need a plan to decommission the existing fossil plants in a way that's equitable across society. It's not equitable to force only the customers of specific utilities to pay all of those costs if we are closing the plants to benefit the public at large. It will benefit everyone, so we should have the conversation about how to share those costs."

Rethinking Energy Infrastructure Investment

Much of our energy infrastructure was built out several decades ago, and in the Northwest we'll spend many billions of dollars in the decades ahead restoring, replacing, and renewing our energy systems. The multi-billion dollar question for the Northwest: *How do we generate the most long-term value from these investments?*

This section explores the strategies for rethinking our energy infrastructure investments to get world-class sustainable, resilient, affordable and equitable outcomes. It begins with the foundational value of a shared long-term vision, and offers a set of system-wide goals and innovation principles for the Northwest to achieve it. It then suggests a set of big-picture changes to get us on the right trajectory: a new statewide infrastructure strategy for policymakers; a new infrastructure investment discipline for utilities and state programs; and a new 'utility compact' to reform the utility business model.

Vision, System-Wide Goals, and Principles for Innovation

Aligning on a long-term vision for our 2040 energy system can make a pivotal difference for determining our smartest investment pathways. If we're on a long-term path toward an energy system much like today's, the economically smartest project can be very different than the best investments to build a world-class sustainable, resilient and affordable system. For the former, investing $500 million to install air pollution scrubbers to prevent shutdown of coal factories in Wyoming could be a smart and justifiable investment. But for a world-class integrated system, like the one described earlier (see 'Window on the Future'), that same $500 million might better – more 'profitably' – be deployed for a smart combination of grid modernization, deep efficiency and flexible demand, electric vehicle infrastructure, renewable energy, and clean heat investments.

The purpose of this inquiry is to develop an achievable vision of excellence – measured by affordability, sustainability, resilience, and rich community co-benefits – for an integrated Northwest energy system in 2040 that will supply the electricity, transportation, and heat that we need.

The CSI inaugural report from November 2014 offered as a conversation starter the following short-hand for a 2040 Energy Goal, to be tested and probed by this, the first project of the Five Big Goals research program:

> *"Renewable energy meets 95% of demand for all energy uses, efficiency gains reduce total energy demand per person by 60%, and sustainable solutions for heavy transportation have been adopted."*

System-Wide Goals ~

The vision for excellence that has emerged from nearly three dozen thought leader conversations for this project is difficult to streamline into a single goal for a complex, integrated energy system. There is plenty of room to quibble on details, and our thought leaders naturally brought a wide range of views to the table.

That said, these specific system-wide goals reflect our best synthesis of the prevailing picture of the sustainable, resilient, equitable and affordable 2040 energy system for the Northwest that emerges from the thought leader conversations:

- Electricity will be the leading energy medium to meet the range of our energy needs, replacing most fossil fuels with power produced from at least 90% carbon-free sun, wind, waste, and water resources.
- At least 80% of the heating, cooling, and hot water for our homes, buildings and industry will be supplied by clean heat systems, efficiently tapping waste and sewer heat, heat pump technologies, organic waste, and renewable resources.
- We'll use electricity at least 50% more efficiently, and the transition will be complete from a one-way electric grid to a multi-directional, multi-scale, smart and resilient grid, with energy customers integral in many ways.
- Fluctuating supply and demand for electricity, locally and across the system, will be seamlessly balanced at low cost with networks of energy storage and flexible demand, making most fast-ramp natural gas plants potentially obsolete.
- Electricity will power a strong majority of transportation miles for cars, buses, short-haul trucks, and trains and virtually all new vehicle purchases and infrastructure investments are for electric.
- For heavy transportation – shipping, freight trucks, airplanes – that can't practically go electric, the fuels for these market segments are all certified sustainable.

Achieving this ambitious and integrated energy vision means our systems will be affordable, sustainable, and resilient. But a range of other important, indeed enormous region-wide co-benefits for our health, economy, quality of life, and environment will also flow out from the transition to this energy system.

Rethinking Energy Infrastructure Investment

Principles for Innovation ~

CSI's inaugural report, *Infrastructure Crisis, Sustainable Solutions: Rethinking Our Infrastructure Investment Strategies*, offered agency leaders, elected officials, and community planners a set of principles to provide guide-posts for smarter investment decision-making.

Here are highlights most relevant to energy infrastructure development:

Go for the Triple Crown: Fiscally Sound, Resilient, and Sustainable

The good news is that there are a rich array of opportunities and new infrastructure strategies that offer strong and simultaneous affordability, resilience, and sustainability benefits. The best infrastructure investments do more than one thing and create multiple value streams.

Consider Broader Alternatives

Before committing real money to business-as-usual infrastructure projects and programs, smart public decision-makers consider it a wise investment to draw on the best innovations out there to thoroughly compare a portfolio of options that provide the most lifecycle value for the cost. Instead of the typical 1-2% for pre-development project planning, a thorough analysis may require 5% to uncover and design solutions that can yield much larger return on investment.

Build a Better Business Case

Once infrastructure planners narrow the project options to the top few, it's crucial to weigh the full benefits and costs, and to do it on a life-cycle basis – meaning for not only construction but also operation and maintenance over time. But benefits, costs, and risks should not be limited to the department or utility managing just one infrastructure system. Smart investments will also save money, manage risk, and accrue benefits to other departments, and serve broader community goals. The full range of lifecycle benefits, costs and risks – to the department, to government as a whole, and also to the broader community – need to be carefully evaluated and documented with well-designed business cases to compare investment options one against the other.

Seattle Public Utilities: Inventing the New Investment Discipline

Seattle Public Utilities (SPU) is responsible for maintaining drinking water, sewer and drainage systems, as well as solid waste disposal throughout Seattle. SPU has pioneered a new infrastructure investment discipline that costs a little more up front, but is saving ratepayers many millions of dollars more and delivering projects with lower risk and better environmental and equity performance.

The key to their approach is that, before committing to a standard solution to a specific problem, SPU assembles an interdisciplinary team to brainstorm alternative solutions, and evaluate business cases for the most promising options, based on lifecycle cost and performance.

The interdisciplinary teams "include people not close to the issue that often come up with novel options or just ask 'dumb questions' that get people thinking differently," says Jenny Bagby, SPU's Director of Corporate Services. "We have many examples where this has happened."

Bagby shares one example, exemplifying why framing the problem correctly is essential. The project was originally framed as the 'Phinney Ridge Pump Station,' based on a consultant recommendation to build a new pump station with water mains at a cost of $4-5 million. But the interdisciplinary team reframed the problem more accurately as 'Phinney Ridge Low Pressure,' affecting about 140 homes, and found that individual booster pumps for people's homes or installed in the sidewalk could address the low pressure problem for under $1 million.

SPU economists evaluate the most promising options identified by the team, monetizing the full range of benefits and risks over the project lifecycle. Where monetizing benefits is too time consuming or expensive, SPU compares options through a Multi Criteria Decision Analysis Method that ensures cost, risk, environment, and equity performance are considered. SPU is proving that taking the time to consider broader alternatives before committing to the standard solution can pay tremendous economic, environmental and community dividends.

Source: "Maximizing Value Using Project Stage Gates, Economic Analyses, & Willingness to Pay Surveys," Jenny Bagby, PhD, Director of Corporate Services, Seattle Public Utilities, slide presentation, August 28, 2015.

Rethinking Energy Infrastructure Investment

Encourage Silo Busting

Virtually all our communities are heavily invested in multiple infrastructures – everything from streets and bridges, to electricity, natural gas and heating services, water supply, sewers and stormwater, and waste collection, recycling and disposal. Very often planning and investment for these systems are compartmentalized, which can lead to missed opportunities for multiple benefits and increased overall value.

Educate, Engage, Empower and Inspire

Infrastructure systems are the most costly and enduring capital assets any community invests in. Support from the people and businesses paying for these infrastructure investments is increasingly crucial, even more so when these same people are emerging as active participants in the energy system. Earning their support requires effective communication and public engagement, which in turn must rest firmly upon a compelling vision of where we are going, why it's so important, and why the strategy is smarter and more cost-effective than the standard way of doing business.

Build Community Prosperity

Infrastructure spending is paid by and benefits the whole community. It is widely recognized as a job generator, important to local business and economic vitality. The retirement wave is urgent and we need to inspire, attract and equip the next generation of energy technicians, operators, engineers, planners, managers, and leaders. Dovetailing both infrastructure investment and workforce recruitment strategies with local economic development goals can reveal opportunities and strategies to in-source infrastructure jobs and lift up segments of the community too often left out. Higher education, technical colleges, and apprenticeship programs can build the critical pipeline of local talent.

Choose for a Changing World

Infrastructure decision-makers must increasingly be future-casters. Capital projects this year will often be paid for over decades and in operation even longer. It's vital to make sure we are building infrastructure systems well-adapted to our changing world – from technology revolutions to major environmental stresses, from shifting living patterns to changing lifestyles and demographics.

Pullman, Washington: A Northwest Smart Grid Pioneer

Profiled in our inaugural report, the City of Pullman, home to Washington State University, may still be the region's most advanced smart grid community.

Pullman was a leader in the recently completed Pacific Northwest Smart Grid Demonstration Project, which over its five years installed $80 million in technology and equipment. This demonstration deployed a variety of smart technologies that could prove key to a clean power system by improving efficiencies and the capacity of grid operators to manage demand peaks and variable output from renewable energy. Importantly, the project advanced state-of-the-art tools to measure and validate cost and performance for the technologies in field conditions.

Spokane-based Avista, an investor-owned utility, upgraded many aspects of its electricity distribution system in Pullman, for example, by installing some 13,000 electric and 5,000 gas smart meters. These meters provide the utility with instant alerts should any problems arise, allowing quicker and better informed response. Avista's deployment of smart voltage controls on key power distribution corridors in Pullman showed energy savings of 2.1%, prompting the utility to plan wider deployment which they estimate could save $500,000 a year on the Pullman system.

Avista also piloted smart home thermostats to Pullman customers. The thermostats receive signals from the grid communicating moment-to-moment supply and demand balance and enabling real-time response. Though marketing for this program showed disappointing results, the technology remains promising. When mature, for example, it will produce 'incentive signals' which indicate the price of delivering power to a given location at a particular time. Customers who choose to allow subtle, override-able, and largely unnoticeable adjustments to power demand on smart equipment will save on their power bill, while helping utilities keep the broader system in balance.

One key objective of the smart grid demonstration was to "create the foundation of a sustainable regional smart grid that continues to grow following the completion of the project." Pullman, with leading-edge smart grid R&D programs and a committed partner at Avista, along with motivated citizens, companies, and elected officials, is certainly a place to watch for continued smart grid leadership.

By Terry Carroll Source: Battelle Memorial Institute, "Pacific Northwest Smart Grid Demonstration Project Technology Performance Report: Highlights" June 2015. Accessed January 13, 2016 at http://www.pnwsmartgrid.org/docs/PNW_SGDP_AnnualReport.

Rethinking Energy Infrastructure Investment

A New Statewide Infrastructure Strategy

Northwesterners will collectively invest billions of dollars on energy and other infrastructure, year-in and year-out, in the next decade. Much of this investment will be directed by a wide array of public and private utilities and agencies, but a state infrastructure strategy's core goal should be to help generate the most community value we can from our infrastructure spending. This requires a top-to-bottom rethinking of how we incentivize, manage, maintain and invest in infrastructure.

State leaders can drive this rethinking toward optimal, integrated solutions from a vantage point above the silos of electricity, transportation, heat, and industry. State policymakers need to adopt a clear vision and overarching goals that will provide the touchstone for policies, rules, standards, and spending. The core focus of a comprehensive State Infrastructure Strategy should be on quality-of-life for everyone, to build healthy, prosperous, sustainable, resilient, and inclusive communities of all sizes, throughout the Northwest.

To get better outcomes from the money we spend on infrastructure, our state governments should focus on doing these things:

1. Set clear, high level and system-wide goals for the integrated energy system, like those outlined on page 41, and define performance metrics.
2. Rethink the utility compact and the layers of inherited regulations, policies, and processes which now govern how utilities – especially investor-owned but publicly regulated utilities – spend money on our behalf to better align with the integrated statewide goals and reward measured progress on performance metrics.
3. Remove barriers to investment in energy systems by families, businesses, and institutions that aligns with system-wide goals, and ensure utilities pay-for-performance based on agreed measures of actual value streams these private systems contribute to the larger system.
4. Encourage innovation in capital formation to develop integrated energy infrastructure projects, including joint ventures by utilities, community and grassroots-driven projects, and public-private partnerships.

Our communities are heavily invested in many infrastructure systems but for the most part they are managed separately and are uncoordinated. Courtesy of CollinsWoerman.

5. Advocate federal policy changes needed to better support the system-wide goals, and adapt lean management principles for coordination between regulatory agencies to enable more efficient permitting pipelines for world-class projects.
6. Rethink state clean energy spending to maximize whole system value, and target strategic initiatives to build crucial components needed for the 2040 energy system where existing markets are failing or moving too slow. (See Two More Audacious Ideas, page 50).
7. Tackle the coming retirement wave by developing the coordinated ecosystem of training and education pathways spanning apprenticeship, technical college, certification, and four-year institutions to attract and equip the next generation infrastructure workforce.

A serious and sustained commitment to a state infrastructure strategy will create a platform to consider whole systems and identify integrated solutions that deliver benefits across silos. Wide deployment of heat pumps and electric vehicles, for example, may increase demand on the electricity system, but will save money, create jobs, and reduce fossil fuels for the Northwest as a whole.

Also at the heart of the state strategy should be continuous improvement of the infrastructure systems of our communities, with transparent performance baselining and dashboarding that clearly communicates real-time results gained from our infrastructure investments. Washington's

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Transportation Improvement Board is a national model for this. States should replicate TIB's 'Lean Government' approach and continuous improvement processes within and among all state infrastructure entities and programs. The intent: maximize results on each dollar of spending, ensure strategic alignment of each program's objectives with state-wide goals, and track performance progress transparently.

The state must also recognize that infrastructure is provided by a myriad of local government agencies, both large and small, including utilities (many public, others owned by investors), ports, and other special purpose districts, as well as the federal government. The state should encourage and help local agencies to achieve the strategy's goals, particularly smaller agencies with limited resources.

A state infrastructure strategy can also help ensure that customer and private investment, which is growing in importance for our energy system, advances system-wide goals. "Having a state energy policy which is clear and consistent, and which defines the long term goals and incentives, is critical to facilitating the private sector investments which are going to be required," says solar entrepreneur Tim Ball.

Our state governments are also the best guardians to ensure an equitable and fair energy system that benefits all Washingtonians and Oregonians. For example, states are best positioned to ensure energy changes don't harm disadvantaged rural and urban communities, but instead share new benefits and opportunity with everyone. "You want to give people the right price signals, but you don't want to harm people with lower incomes by doing that," says Aiko Schaefer, an environmental equity consultant at the University of Washington. "At a minimum, whatever policies we implement, shouldn't make people poorer."

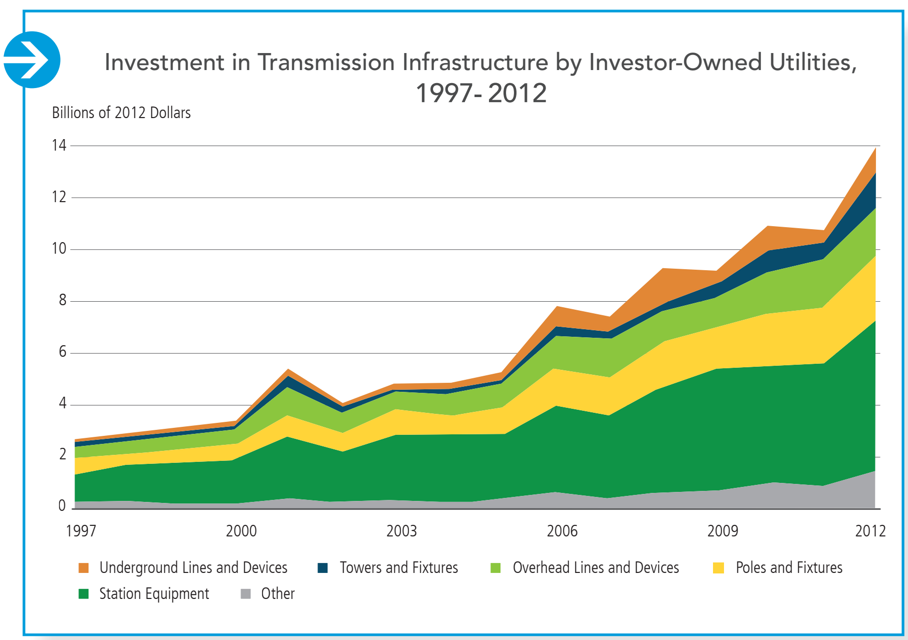
At the community level, local government can become a focal point for planning integrated sustainable infrastructure that maximizes local benefits. Local governments should consider developing a 20 year *Sustainable Infrastructure Strategic Plan* for the community that encompasses the various infrastructure systems, and that aligns with and advances other local plans for economic development, fiscal health, equity, land use, and quality of life. The local infrastructure plan can also provide a platform for the agencies and utilities managing different infrastructure systems, both local and regional, to harmonize their plans with the community's goals and aspirations.

A New Infrastructure Investment Discipline

Northwest electric utilities alone will spend billions of dollars on generation, distribution, and transmission infrastructure in the years ahead. Public energy programs will spend billions more to advance positive environmental, social, and economic outcomes.

To maximize the return on investment (ROI) of state, federal utility, and customer dollars, we need a new investment discipline for major spending decisions. Key to this discipline – before locking into a particular approach – is to systematically evaluate a broader set of innovative options, and a broader set of costs, risks, and benefits. Investing more time and resources in this upfront work will yield superior return for the much larger dollars invested on actual infrastructure projects.

For utility and infrastructure managers, the disciplined practices of *Sustainable* Asset Management provide a framework to implement a smarter investment approach. Standard asset management tools are improving utility management by uncovering investments that control the total cost of ownership over the lifecycle of the infrastructure system's various assets. Sustainable Asset Management adds two crucial elements to the discipline: integrated strategies that reveal solutions benefiting more than one infrastructure system, and 'Triple Bottom Line' metrics that measure not only financial factors, but also important social and environmental considerations.



Utility investment in electricity transmission has climbed sharply in the past 20 years. A new investment discipline will help ensure the next waves of investment yield better long-term, system-wide benefits and returns. Source: U.S. Department of Energy "Quadrennial Energy Review" 2015.

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Also critical is robust scenario planning that factors in risk of technology, climate, and other changes to develop a system that is flexible and adaptable for a range of plausible futures. For smaller communities, where the resources and capacity of local utilities and agencies are limited, states should fund the capacity needed for the robust local and pre-design planning to uncover infrastructure pathways with the greatest ROI.

In 2012, Oregon Governor John Kitzhaber released a 10 year energy plan for the state. A recent study analyzed the state's energy expenditures, "in order to track how well Oregon's current spending is setting the state up to meet future goals." It found that state spending totals over $400 million a year, but concluded that, "funding decisions are undertaken in isolation without a sense of the broader policy goals. Each program uses funds to achieve their stated goal, but there could be a greater level of coordination across energy-spending categories."[1]

The Northwest boasts an extraordinary resource to inform infrastructure planning and investment for our electricity – the Northwest Power and Conservation Council. The value of this intellectual firepower should not be underestimated. But as we enter a new era of integrated energy solutions and technologies that dissolve the boundaries between electricity, transportation, and heating silos, we may need to update the mandate of the Power Council.

The federal Northwest Power Act of 1980 established the Council and its mandate to focus specifically on developing a better electricity system. But a third of a century later, our Congressional delegation should consider expanding the Council mandate to apply its advanced analytical tools to plan for the energy system as a whole across electricity, transportation and heat. Alternatively, our states could establish a new agency, modelled on and collaborating closely with the Power Council, that is dedicated to optimizing sustainability, resilience, affordability, and equity of the whole, integrated Northwest energy system.

Toward a New Utility Compact

Last century, most of the gas and electric utilities were formed that still serve the Northwest today. They were granted monopolies over specific territories with a mandate to supply all the people living and working there with reliable and affordable power.

Utilities are like democratic governments, formed among people to pursue shared ends that we can pursue better together than alone. But to work properly, these institutions need to be accountable to the people they serve, and to change and evolve as technology and the needs and priorities of people change.

"The 20th century electricity model was about a shared system that created huge public benefit," says EWEB General Manager Roger Gray. "I think that the challenge of the 21st century is to figure out how to keep the best of the 20th century (shared and public benefit) and make it clean and more resilient….How do we ensure continued wide distribution and sharing of the benefits and costs?"

As successful as utilities have been at providing affordable energy to power the U.S. economy in the past, new technologies are declining in cost and improving performance to

A Revolutionary Idea: Pay-for-Performance

A real key to ensuring energy infrastructure investments are affordable is to upend how utilities are rewarded. "Utilities are incentivized in this system to make money on how much they spend on capital assets," says Rachel Shimshak. "I think instead it should be based on performance." In fact, paying for performance "is one of the revolutionary ideas that will enable us to not have to build peaking plants, but instead be able to assemble resource mixes in a very different way than today," according to McKinstry's Megan Owen.

Shimshak says, "We should get together to decide what the performance metrics that matter are, then utility commissions can base profits on whether utilities exceed or fall short on their performance metrics – everything from carbon profile to customer response time. We just need to break this link between profit and capital spending."

"What we need are relationships between utilities, building owners, investors, and distributed resource companies that share the long-term benefits of the new, distributed energy economy," says Rob Harmon. One pay-for-performance example of this is the Metered Energy Efficiency Transaction Structure (MEETS) approach that was set up between Seattle City Light and the Bullitt Center, where the utility pays the building owner, not for particular measures, but instead for the actual measured energy savings the building delivers year-by-year.

Source: "Pilot Projects," MEETS Coalition, accessed December 21, 2015, http://www.meetscoalition.org?p=38.

1 "Oregon Public Energy Expenditures: 2010-2013" (Northwest Economic Research Center, August 2014).

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enable customers to not only use less, but to also generate, store, and manage electricity. The result is that many utilities are starting to see their electricity revenues, which are tied to the quantity of energy they sell to customers, decline. Without fundamental changes in the historic utility business model, this erosion of revenue could become more widespread and intensify with time, creating serious challenges for utilities' balance sheets.

On the other hand, expanding opportunities for customers to produce and manage energy can ultimately contribute to a more affordable, sustainable and resilient energy system.

One challenge for utilities is to better anticipate change. "A regulated utility's speed of decision-making is increasingly incompatible with rapid technology change," says Eric Strid, co-founder and retired CEO of Cascade Microtech. "A significant policy change for a regulated utility may take two years – that's long enough for a whole technology generation in semiconductors. In this technology environment, we need our utilities to be much more nimble."

"Utilities can be the Great Enabler of the future we want," says Rob Harmon. "Or they can be the Roadkill on the future we're going to get anyway."

National Renewable Energy Lab engineers Julieta Giraldez and Annabelle Pratt review data at a test area near the Energy Systems Integration Facility, where researchers find grid solutions for high levels of renewables. Photo by Dennis Schroeder, NREL 31538.

Is this private investment at the edges of the grid a wonderful source of new infrastructure capital or is it a threat to the wide and inclusive sharing of the benefits and costs of our energy systems?

Utilities are important to the future of affordable, sustainable and resilient energy, according to Rocky Mountain Institute's Electricity Innovation Lab (eLab): "The historical role of the utility to coordinate operations and planning does not fade away but rather grows in importance as distributed resources proliferate." For utilities to realize the opportunity to step into the critical role of coordinating deployment and integration of distributed resources, though, "may require transformative changes to existing utility business models," says eLab.[2]

Today's utility operating environment and business model have a number of other problems that suggest a new utility compact may be needed:

- Regulated utilities make money on investments in capital assets which may or may not be the optimal investment pathway to get to a sustainable, resilient and affordable system, and may be vulnerable to becoming stranded in a decade or two.
- State laws, such as Renewable Portfolio Standards and net metering, have been grafted onto the existing system to essentially force utilities to buy new renewable energy – a reflection of the strong popular support for clean energy that have indeed proven effective in increasing renewable energy development. But these policy mechanisms may not be the most effective way to get the desired results affordably.
- Both customer-side and utility infrastructure spending are not coordinated or incentivized to serve a coherent set of statewide or regional goals.
- For many utilities, inertia from the past can be a barrier to innovation, from the utility's organizational culture, to the experience, skill sets, and tools of its leaders and staff.
- Our planning institutions are not mandated to address energy holistically, to uncover optimal pathways to meet our needs for affordable, sustainable and resilient energy services for electricity, transportation, heating and cooling.

2 "eLab: New Business Models for the Distribution Edge," accessed December 19, 2015, http://www.rmi.org/New_Business_Models.

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To overcome this complex of challenges and problems with the current utility operating environment, we will need to re-imagine and redesign the relationship between utilities, policymakers, technology providers, and the families, businesses, institutions, and industry that utilize energy. Energy storage, for example, can provide valuable services to the grid, but "to enable that, developers need to get paid to store power at a level that provides a real incentive to build," points out Google's Chris Taylor. "Klickitat PUD wants to build a pumped hydro storage system to store renewable energy, but there is not yet a transparent market for that kind of service."

The Northwest can learn from pioneering work in California and New York, in particular, as well as at the RMI eLab, to rethink the utility compact and design new business models for the utility sector to value and invest in distributed assets that are a key component of a sustainable power grid. A new utility compact will:

- Reward utilities for performance on statewide goals, so they are strongly incentivized to deliver the right results.
- Treat energy efficiency, distributed generation and demand response as co-equal resources throughout the utility system.
- Rethink renewable energy mandates and incentives to balance key objectives: ensure fairness among utility customers, open opportunity to lower-income people, encourage and optimize the value of private investment, and sustain the market for new renewable energy development.
- Require utilities to implement sustainable asset management and the new investment discipline.
- Encourage utilities to change, cooperate with regional systems, form joint ventures, take on silo-bridging projects – and enable new utilities to form – to better achieve whole system solutions that optimize customer and community benefits.

Our state governments need to play the chief convener role, bringing all the key stakeholders together to help bring our energy and utility policy structures into the new era of energy technology transformation. The most crucial conversations that state government needs to convene are:

1) To craft the statewide goals and performance metrics, that can put us onto the trajectory for a world-class system; and

2) To reimagine and redesign the utility compact. Getting alignment from a broad range of stakeholders with different interests is a difficult proposition; states may want to enlist the help of the RMI's eLab Accelerator project, or a similar organization with proven skill at creating collaborative processes that can get people of very different perspectives working constructively together.

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Key Conclusions

This report offers a bold vision for the Northwest to develop one of the world's most sustainable, resilient, affordable, and well-integrated energy systems by 2040. The system envisioned here is high tech, interactive, and flexible. It dramatically reduces air pollution and carbon emissions, and it appears likely to be both technically manageable and affordable. It connects a highly participatory web of diverse energy systems and owners to deliver clean and hyper-efficient energy services to power our vital needs for electricity, heat, and transportation. And it offers a host of rich economic, public health, and environmental co-benefits throughout Oregon and Washington.

Other major conclusions of this report include:

Technology and market change drivers will transform the energy sector in the decades ahead.

Rapidly declining costs and improving performance for several technologies and systems – from solar PV and wind to energy storage, electric vehicles, flexible demand, heat pumps, microgrids, and next-generation energy efficiency – will reshape the sector and alter utility business models. New tools for customers to produce, manage, and use less energy are already enabling people, companies, institutions, and communities to affordably shrink their carbon footprint. This trend is accelerating as technology performance improves, costs decline, and attractive marketplace offerings proliferate. As customers shift from passive energy consumers to more active participants and investors, their relationship with their utilities changes significantly.

It's not just about electricity; transportation and heating are huge, too.

The Northwest boasts one of the world's most sophisticated planning capacities for efficient investment in electricity infrastructure. But to optimize our investments, we need to de-silo our institutions. Electricity is only one component of the region's energy system, albeit one that will grow in importance in the decades ahead. Transportation, which will be powered to a much greater extent by electricity in the future, represents over 25% of U.S. energy consumption today. Heating and cooling consumes even more – over 40% of U.S. energy by some estimates. Heat pump technology, district energy systems, and smart building design could dramatically reshape the efficiency, cost, and carbon footprint of our heating and cooling infrastructure.

It's time to begin reimagining our utilities – electric, natural gas, and wastewater.

In the years ahead, customers will be able to affordably invest in power generation and efficiency systems that significantly reduce the amount of energy they buy, thus reducing utility revenue. This means the old utility business models will need to be rethought and redesigned. And as the boundaries blur between the electricity, transportation, and heating silos, these silos will increasingly hinder optimal solutions. In the future, for example, natural gas utilities may need to morph into heating and cooling utilities, perhaps partnering with wastewater treatment facilities which possess extensive piping systems, rich in cheap thermal energy, throughout many of our communities.

Customers will bring billions of dollars in new investment to our energy infrastructure.

Technology companies will bring ever-more attractive and better-performing energy tools to customers in the years ahead that enable them to produce, reduce, and manage energy. People, businesses, governments and institutions will be motivated to buy for various reasons – to save money, shrink their carbon footprint, or to own cool and great performing products. Billions of dollars in new customer-side purchases and other private investment in energy efficiency, flexible demand, and clean generation will bring substantial value to our shared energy systems. With better tools to calculate the various value streams that private investment projects actually bring, utilities and governments can incentivize or contract with customers to help pay for and steer their purchases to maximize the system-wide benefits.

State leadership is key to steering energy system change to optimize value and benefits for everyone.

State leaders, serving the interests of everyone and from a vantage point above the silos of electricity, transportation, and heat, are in the best position to coordinate the process of revamping energy and utility policies, rules, standards, and spending. State policymakers need to establish a clear vision, overarching goals, and performance metrics to support an integrated energy system that best benefits quality-of-life and prosperity for all. States need to play the chief convener role to bring together the range of key stakeholders to shape a new State Infrastructure Strategy and utility compact that aligns state policy with statewide goals. Special attention needs to be paid to regional collaboration that advances the Northwest vision, and to supporting and incentivizing local planning capacity to enable smarter investment decisions. States should also support energy research and development, invest in building the next generation energy workforce, and target strategic initiatives where gaps persist to ensure all the critical pieces are put in place to develop the 2040 energy system.

Two More Audacious Ideas

The primary purpose of this report is to outline how the Northwest can achieve an audacious proposition: *that Oregon and Washington can develop one of the world's most sustainable, resilient, affordable, and inclusive energy systems by 2040, meeting the electricity, transportation, heating and cooling needs of a vibrant economy with very low-carbon energy.*

Achieving this vision cost-effectively can deliver wide-ranging economic development, affordability, public health, equity, and environmental co-benefits for the region's people. This section offers two more audacious and complementary ideas for deepening and accelerating this positive transition for our Northwest energy system.

1 Infrastructure Renewal for Sustainable Jobs

This audacious idea proposes that our states launch two sustained and complementary campaigns to create jobs and maximize the economic benefits from renewing our energy infrastructure: First, strategic initiatives to invest in crucial energy system components in ways that fuel local economic development and, second, large-scale, coordinated efforts to train and equip the next generation infrastructure workforce.

Infrastructure is widely and correctly recognized as a cornerstone of our economy. In 2012, according to a Brookings study,[1] over 14 million U.S. workers were employed in infrastructure jobs, accounting for 11% of national employment. In general, infrastructure jobs are good quality, family-supporting jobs that aren't easily outsourced.

Renewing the Northwest's energy infrastructure could create tens of thousands of new sustainable jobs as money now spent on fossil fuels produced in other states is redirected toward in-state resources and systems. The California Low-Carbon Grid Study, for example, found the state can cut carbon emissions from electricity in half by 2030 by investing $58 billion – which will be completely offset by savings from efficiency gains and reduced fuel costs. Of that $58 billion in new infrastructure investment, 80% would be spent in California, a significant stimulus for job creation and economic development.

Deploying advanced energy infrastructure in the Northwest will generate lots of local installation and operations jobs. But it can also help position Northwest companies to market world-class products and services nationwide and globally. The key to building successful business clusters, according to technology entrepreneur Eric Strid, is to pursue unique value where our companies can design superior technology solutions and business models, rather than simply competing to sell commodities like solar panels or electric cars.

Our states should target energy infrastructure investments toward strategic components where markets are not acting at the necessary scale or speed, marshalling low-cost capital through public bonds, or perhaps a state infrastructure bank of some sort. This targeted investment toward under-realized energy system components could focus on several priorities, such as high-performance retrofits for tenant-occupied commercial buildings and homes; high speed rail corridors powered by clean electricity for passengers and freight; electric vehicle infrastructure; transmission and energy storage to tap large renewable energy resources; district heating and cooling systems; and microgrids to improve resiliency in the event of a major earthquake.

Sustained investment in energy infrastructure renewal in our states can stem the loss of billions of dollars to buy fossil fuels, power sustainable job creation, and help attract and equip bright new minds to thrive in this field for the future.

1 Beyond Shovel-Ready: The Extent and Impact of U.S. Infrastructure Jobs, Brookings, May 8, 2014.

Two More Audacious Ideas

Where local communities face loss of an important employer, the state can support a 'just transition' to new sustainable infrastructure-related jobs. Jeff Johnson, President of the Washington State Labor Council, offers an example from Denmark. "They took their Port workforces and converted them to wind power and got the manufacturers to locate right on port sites. The whole Port workforce went from maritime to getting reskilled in wind manufacturing," recounts Johnson. "They did a just transition so that the community and its labor force remained whole. You look at that and say, 'Of course it can be done!'"

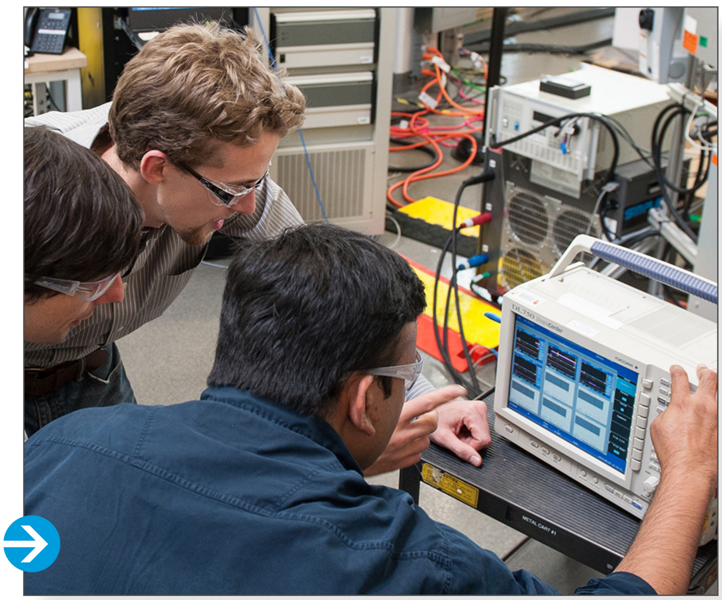
While infrastructure jobs are a major component of the economy, a great retirement wave is coming that threatens to deplete the infrastructure workforce. To build the talent pipeline for a new generation of energy technicians, operators, engineers, planners, managers, and leaders, a coordinated approach will be required that builds training and education pathways appropriate for all major job categories. Technical college offerings should be closely coordinated with union apprenticeship programs. Masters, PhD, and other advanced training programs need to equip candidates with the skill sets needed to plan, design, finance, and manage the integrated, high tech, sustainable, and resilient energy systems of the future.

Roger Gray, General Manager of the Eugene Water and Electric Board, suggests that old and new infrastructure will exist side-by-side for many years, but even old job classes are getting more high tech. "A water treatment plant operator requires 8 years of training. You might call it a trade-type job, but it requires the equivalent of 4 years of college and a lot of technical training on top of that," says Gray. "More and more jobs have to be computer literate on top of their historic capabilities; I think it's an opportunity for education and industry to work together." More technical and vocational training will be needed, he argues. "We need some big thinking around that."

Josh Bratt of the Oregon Talent Council says that in our increasingly high tech, information-rich economy, cultivating talented and tech savvy people for the infrastructure professions is now a crucial component of smart infrastructure investment. "Investment in talent will be most effective when it is based on understanding employer demand, on industry-verified data, that identifies immediate and future skill and occupation gaps," says Bratt. The Talent Council is charged with developing a statewide Talent Plan to guide workforce, education and STEM investments, and to catalyze targeted efforts to invest in critical talent gaps. "Our clean energy policies and spending will be optimized," according to Bratt, "if we invest in building the pipeline of talented people with the right skill sets to develop and operate 21st century energy infrastructure."

2 Living Laboratory: Scaling Up the Northwest's World-Class R&D Program

This audacious idea proposes that the region significantly ramp up research and development (R&D) in key focus areas where the Northwest has special expertise and capacity to make world-class energy system advancements. Our region has a golden opportunity to leverage a major new federal clean energy R&D commitment that is complemented by private investors who will invest in commercializing the best technologies that emerge from the R&D pipeline.



Northwest researchers are well-positioned to carve out cutting-edge roles in energy R&D in several focus areas crucial to development of dynamic, integrated, and sustainable systems. Photo by Dennis Schroeder, NREL 31551.

In late 2015, the U.S. joined the 'Mission Innovation' coalition of 20 countries in pledging to double energy R&D investment over the next 5 years.[2] Simultaneously, a group of private investors led by Bill Gates called the Breakthrough Energy Coalition[3] announced its commitment to invest in early stage energy companies to help them move from lab to market. The Northwest needs to leverage this opportunity to scale up R&D by demonstrating the region is serious about world-class energy R&D: investing in our labs and universities, and incentivizing our utilities and companies, so that Northwest institutions can effectively compete for new federal R&D investment.

2 "Fact Sheet: Mission Innovation." Whitehouse.gov. Accessed January 16, 2016. https://www.whitehouse.gov/the-press-office/2015/11/29/fact-sheet-mission-innovation.

3 "Introducing the Breakthrough Energy Coalition." Accessed January 16, 2016. http://www.breakthroughenergycoalition.com/en/.

Two More Audacious Ideas

There are a number of strong candidates for energy R&D focus areas where the Northwest could deliver near-term value and stake out territory at the cutting-edge of energy innovation. These include smart grid, energy storage (including seasonal storage), bioenergy, infrastructure, super-efficient buildings, pay-for-performance EV project models, clean heating and cooling, microgrids, carbon fiber materials, cyber-security and disaster recovery.

Many of the region's most influential and valuable energy R&D work to date has emanated from the Pacific Northwest National Laboratory (PNNL) and the Portland-based federal power agency, the Bonneville Power Administration (BPA). Terry Oliver, BPA's chief technology innovation officer, led creation of a research discipline unique to the electric utility industry, pioneering an approach that ensures the agency is making shrewd investments in technology research. "Our approach centers on disciplined risk taking drawing on best research management practices from private industry, including Boeing, Intel, 3M, Verizon, Battelle, IBM, and Lockheed Martin," says Oliver. "That helps ground our R&D spending and practices on disciplined achievements that generate outcomes that are useful and valuable to BPA."

> "Our approach centers on disciplined risk taking drawing on best research management practices from private industry, including Boeing, Intel, 3M, Verizon, Battelle, IBM, and Lockheed Martin."
>
> *Terry Oliver,*
> *Chief Technology Innovation Officer*
> *of Bonneville Power Administration*

BPA ensures its R&D delivers value more broadly by partnering with a wide range of utility, academic, and industry participants, as exemplified by the Pacific Northwest Smart Grid Demonstration Project, the nation's largest, most comprehensive and successful smart grid deployment project involving 60,000 customers and 11 utilities in 5 states.

There is a range of R&D happening in the region. Oliver says, "We work with Portland State University to develop priority technology roadmaps. University of Washington has a whole pile of energy-related and climate research, and WSU has electric grid and power systems. PNNL is working on biofuels, battery chemistry, fuel cells, and smart grid," he says. The Energy Trust of Oregon and Washington's Clean Energy Fund support clean energy deployment projects, "and some utilities, like Avista, PGE, and Snohomish PUD are doing R&D," Oliver points out. "But if we were really going to advance this, we may need to map an integrated research agenda across all the various actors and needs."

R&D does deserve greater investment, according to John Prescott, President of the Pacific Northwest Generating Co-op, a consortium of consumer-owned utilities. "R&D is fundamental to a clean energy future" he says, "and utilities need to support and be directly involved in targeted R&D projects. I think our industry has drifted away from supporting R&D, for some valid reasons," says Prescott, "but I believe we need to partner with federal and state R&D efforts to validate new energy technologies and methods."

Regulated utilities can be hamstrung when it comes to investing in R&D, however. Dave Danner, chief utility regulator in Washington State, explains that, "by statute our commission is an *economic* regulator, so we're always looking at 'Least Cost.' That can make it hard for companies developing new technologies to break in, because their technology has to basically be proven and cost-effective before a regulated utility will put it in its portfolio," he says. To overcome that barrier requires clear legislative direction, according to Danner.

Energy technology companies could be major players in regional R&D, too, and state tax incentives could spur these companies to invest more in R&D. Seattle Mayor Ed Murray argues that Washington state tax incentives for R&D by tech companies (information and life sciences), enacted in 1995 but allowed to expire in 2014, had spectacular economic results. He cites tech sector job growth far outpacing the rest of the state's economy, a climb from 20th to 5th place nationwide in new patents, and tax revenue of $3 billion each year – three times more than the total value of the tax incentive over its entire 20 years. The key, according to Murray, was to structure the incentives to allow companies of all sizes to benefit, but "with smaller firms receiving a proportionally larger benefit. A startup firm with little revenue might offset its entire B&O tax liability," Murray explains, "while larger, more established companies qualifying for the maximum credit would still pay taxes that were many times the total credit."[4]

4 "How to create more jobs in the state's tech sector," Opinion, by Ed Murray and Eric Pettigrew, The Seattle Times, March 2, 2014.

Acknowledgments

Pacific Northwest Infrastructure Innovators and Thought Leaders

During summer 2015, the Center for Sustainable Infrastructure interviewed the following Northwest energy thought leaders. Each contributed important insights to the project. As author, I maintain responsibility for the report's entire content, and any errors and shortcomings. This is not meant as a consensus document – as individuals will undoubtedly find points to disagree with – but instead represents my best effort to distill from the wide-range of expert views a coherent vision for the Northwest to develop a world-class sustainable energy infrastructure. — Rhys Roth
(*) Also contributed by serving on the Executive Review Team.

Tim Ball*, Solar Investor and Entrepreneur

Scott Bolton, Vice President, External Affairs, Pacific Power

Geoff Brown, Director, Microgrids, NRG Energy

Tugrul Daim*, Professor and Ph.D. Program Director, Dept. of Engineering and Technology Management, Portland State University

Dave Danner, Chair, Washington Utilities and Transportation Commission

Angus Duncan, President, Bonneville Environmental Foundation

Jana Gastellum, Program Manager for Climate, Oregon Environmental Council

Fred Gordon*, Director of Planning and Evaluation, Energy Trust of Oregon

Roger Gray*, General Manager, Eugene Water and Electric Board

Rob Harmon*, Principal, Robert K. Harmon & Company LLC

Jeff Harris*, Chief Transformation Officer, Northwest Energy Efficiency Alliance

Denis Hayes, President, The Bullitt Foundation

Nancy Hirsh*, Executive Director, NW Energy Coalition

Christy Holz, Solar Investor and Entrepreneur

Bob Jenks, Executive Director, Oregon Citizens Utility Board

Jeff Johnson, President, Washington State Labor Council

Tom Karier, Councilmember, Northwest Power and Conservation Council

Ross Macfarlane, Senior Advisor, Business Partnerships, Climate Solutions

Steve Moddemeyer*, Principal, CollinsWoerman

Pamela Morgan*, Interim Director, PECI

Terry Oliver*, Chief Innovation Officer, Bonneville Power Administration

Megan Owen*, Director, Strategic Market Development, McKinstry

Ron Pernick, Founder and Managing Director, Clean Edge, Inc.

Thomas Potiowsky, Chair, Economics Department, Portland State University

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John Savage, Commissioner, Oregon Public Utilities Commission

Aiko Schaefer*, Strategic Consultant on Environmental Equity, University of Washington

Rachel Shimshak, Executive Director, Renewable Northwest

Virinder Singh, Director of Regulatory and Legislative Affairs, EDF Renewable Energy

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Chris Taylor, City Manager, Google Fiber

Roger Woodworth, President, Avista Development

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I am deeply indebted to the many innovators, thought leaders, and experts who took valuable time from their busy schedules to patiently coach me on the intricacies and challenges of rethinking our energy infrastructure investment strategies.

Rewiring the Northwest's Energy Infrastructure is the first in the Center for Sustainable Infrastructure's "Five Big Goals for 2040" research series. The series engages leading thinkers and innovative practitioners in mapping the path to achieve a transformative 2040 infrastructure vision in the Pacific Northwest.

Infrastructure investments across our energy, water, transportation, and waste management systems add up to a generational legacy. The billions we spend in Oregon and Washington year-upon-year, much of it for projects designed to last 25 years or more, will – for good or ill – fundamentally reshape our infrastructure systems and our built environment. The *Five Big Goals* reports will help build alignment around a vision for how our infrastructure systems will work in 2040, and show how we can rethink near-term investments to get where we want to go in the longer-term.

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– *Rhys Roth*

FIVE BIG GOALS FOR 2040

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