Green Economy Industry Roadmap

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AWC Center for Quality Communities

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INTRODUCTION

Background and Report Objectives

Climate change, environmental degradation and resource mismanagement, if not adequately addressed, will increasingly impact societal wellbeing across the globe. Fortunately, many of the solutions to these problems are within reach and can be addressed through existing technological know-how, policy and industry expertise. Innovating solutions to these challenges presents a significant economic opportunity, particularly for Washington state businesses, organizations and communities. The “green economy” represents the intersection between these technologies and solutions and real economic opportunity.

The Association of Washington Cities Center for Quality Communities (CQC) is leading an effort to identify areas of growth and economic opportunity in the green economy in Washington state across four areas: energy, agriculture & forestry, building materials and water. As part of these efforts, the CQC has requested Communities Attributes Inc. develop an industry road map for each of these industries. Analysis includes a review of key trends, both globally and domestically, an asset inventory in Washington state and an opportunities assessment that maps these global trends and sources of demand with Washington state capabilities. Findings will be used by technical work groups for each industry to develop a set of actionable strategies for city-based green technology-focused economic development.

Methods and Data

A wide range of sources was used in the compilation and synthesis of this report. These include reports, news articles, data on industry trends when available from national and international organizations and 21 interviews with industry leaders, government agencies, investors and trade associations.

Organization of Report

The remainder of the report is organized as follows:

- **Green Economy Industries.** A review of each industry, including description of illustrative activities.
- **Energy.** A review of key trends in the clean energy industry, including sources of demand, research, innovation and key assets in Washington state.
- **Agriculture & forestry.** Analysis of global and domestic trends, research and key assets in Washington state.
• **Building materials.** Review of key trends in mass timber and its subset, cross-laminated timber, industry advancements, research and key assets in Washington state.

• **Water.** Major challenges in the access, management and sustainable use of potable and brown water sources, and key assets in Washington state.

**GREEN ECONOMY INDUSTRIES**

The industries identified by the CQC represent a wide range of activities and technologies. An initial set of interviews helped to narrow the focus of each industry to those activities and technologies that represent potential opportunities for Washington state businesses.

**Energy**

This report presents a global and national perspective on the clean energy industry, then focusing on subsectors relevant to Washington state such as alternative and renewable energy, particularly hydro and wind, smart grid technology, power storage, power grid management and efficient buildings.

Clean technology in the energy industry is the combination of programs and capital investments that result in energy-efficient facilities that save consumers energy and money, use low or no carbon emitting energy sources and have energy delivery systems that reduce waste and minimize impact on our air, water and natural environment.

**Agriculture & Forestry**

Agricultural & forestry clean technology encompasses many areas, such as crop optimization, consumer food sourcing and industrial biotechnology. All these areas involve hardware and software solutions aimed at improving yields and sustainability of agriculture and forestry while lowering environmental impact.

**Building Materials**

Green economy building materials refer specifically to:

- Mass timber and its subset, cross-laminated timber (CLT). Mass timber refers to “a category of framing styles typically characterized by the use of large solid wood panels for wall, floor and roof construction.”

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• Recycled materials, such as gypsum and particle board made from recycled woods and other materials.

Water

Water opportunities extend to numerous other sectors of the state economy, including natural resources, agriculture, industrial uses and energy. In this study, green technology applications in water include:

• **Potable water.** Growing stress on available water for human consumption due to population growth, competing uses and climate change.

• **Water treatment.** Improved methods for treating and reusing water, helping to address competing uses for water among residents, businesses and ecosystems.

• **Irrigation.** New methods and technologies for more efficiently using water, such as precision-based sprinkler systems and drip irrigation.

• **Surface water.** Including the growing need to manage stormwater runoff.
Energy

Key Target Opportunities

- Climate change will continue to necessitate the development of renewable energy and energy conservation solutions, though the rate of adoption will vary widely across the globe.
- Clean energy technologies are increasingly cost competitive.
- Some countries, notably China, have made vast investments in clean energy technologies and will be key sources of both demand and competition now and in the coming years.
- Much of the clean energy revolution entails the intersection of energy and information technology, such metering, efficiencies in use and distribution and energy management.

Leading Trends in Energy

Clean energy is generally used within the energy industry to refer to any source of power that does not pollute and harm the environment. Clean energy is often used as a synonym for renewables such as solar power, geothermal, wind energy, biomass, tidal power or hydropower. However, clean energy encompasses other industries such as energy efficiency, grid modernization and storage, renewable fuels and alternative transportation.

The pursuit of clean energy is at the heart of the world’s aspirations for a better future, as reflected in the 197 countries having signed the Paris Agreement on Climate Change. Moving from fossil fuels to renewable sources such as solar and wind is key to achieving social, economic and environmental development. The International Energy Agency outlines the outlook for this industry in their World Energy Outlook report:\(^2\)

- **Clean energy technologies are competing on price.** Clean energy technologies will continue to experience rapid deployment due to falling costs.
- **The share of electricity in the energy mix will continue to grow.** In 2016, spending by the world’s consumers on electricity approached parity with their spending on oil products.
- **China’s new economic strategy involves a shift to a more services-oriented economy.** Planning to become less reliant on heavy industry and coal, the country will impact its energy mix with implications for the global energy markets, as China remains the world’s largest energy consumer.
- **Shifting from being an energy-dependent importer, the United States is expected to become the global leader in oil and gas**

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despite lower prices. The shale oil and gas revolution in the United States continues, fueled by the remarkable ability of producers to unlock new resources in a cost-effective way. By 2030, the United States is expected to produce more than 30 million barrels of oil and gas a day, largely due to production from shale-rock formations.

Sources of Demand

Globally

Overall global investment in clean energy is up 3% from 2016 and at its second-highest point in history. The latest figures from Bloomberg New Energy Finance show that global clean energy investment was $335.5 billion in 2017, up from $324.6 billion in 2016 and only 7% short of 2015’s record investment of $360 billion (Exhibit 1).


China’s share of total global investment in clean energy technologies continues to increase, remaining the highest of all countries. Overall, Chinese investment in 2017 across all clean energy technologies was $132.6 billion, up 24% from $107 million in 2016. The United States is the second-largest investing country with $56.9 billion in 2017, followed by Japan (included in Other APAC in Exhibit 2) with $23.4 billion. Large wind and solar project financings pushed Australia up 150% to a record $9 billion, and Mexico up 516% to $6.2 billion.
On the downside, investment in the European Union plunged by more than half to 17% of the global total, or $57 billion in 2017, after peaking at $138 billion in 2011. As recently as 2010, Europe made up 45% of global clean energy investment. In the years after the global financial crisis, EU countries like Spain, the United Kingdom and Italy have cut incentives for renewable energy projects, citing efforts to reduce government spending and electricity rates during a period of economic turmoil. As a result, investors have been stirring away from an industry that offered the assurance of steady, government backed-profits (Exhibit 2).


*Note: Europe includes all EU countries and non-EU countries like Switzerland, Norway, Turkey and Russia. However, the majority of clean energy investment stems from the 28 EU members.*

**Solar leads the way in clean energy investment by industry and moves from third largest industry in 2006, behind wind and biofuels, to the largest industry by 2011 (Exhibit 3).** Global solar investment was $161 billion in 2017, an increase of 18% from 2016 despite reductions in cost. The two largest solar projects of all last year were both in the United Arab Emirates: the 1.2GW Marubeni JinkoSolar and Adwea Sweihan plant, at an estimated $899 million, and the 800MW Sheikh Mohammed Bin Rashid Al Maktoum III installation, at $968 million.

Wind comes second in terms of investment in 2017, at $107.2 billion. Although 2017 investment levels fell by 12%, there were record breaking projects financed both onshore and offshore. Offshore there were 13 Chinese-
financed wind projects with a total capacity of 3.7 GW. There was an estimated investment of $10.8 billion and one 1.4 GW project in the U.K. North Sea, at an estimated $4.8 billion. Onshore, American Electric Power stated it would back the 2GW Oklahoma Wind Catcher project in the U.S., at $2.9 billion excluding transmission.

Energy-smart technologies come in third with investment in digital energy, smart grids, power storage, hydrogen and fuel cells, advanced transportation and energy efficiency reaching roughly $49 billion in 2017.


Note: “Other” includes Biomass & Waste, Biofuels, Geothermal, Small hydro, Marine and Low carbon services and support. The clean energy investment total excludes hydroelectric projects of more than 50MW. However, for comparison, final investment decisions in large hydro were likely to have been worth $40 to $50 billion in 2017.

United States

The 2018 Sustainable Energy in America Factbook published by Bloomberg New Energy Finance (BNEF) and the Business Council for Sustainable Energy (BCSE) identifies three main growth industries of the U.S. energy economy in 2017: energy efficiency, natural gas and renewable energy. Key trends in the clean energy industry include:

- Natural gas and renewable energy industries employed roughly 3 million jobs in 2016.
• Energy efficiency was the top employer within the sustainable energy industries, and solar was the fastest growing job-creator among all electricity generation technologies.
• Household expenses on energy costs were at 4%, near an all-time low, while industrial prices also remained low, giving the U.S. a global competitive advantage for energy-intensive industries.
• New U.S. investments in clean energy tracked 2016 levels at $57 billion, but there was a shift in capital deployment towards wind and energy-smart technologies (Exhibit 4).
• Renewable generation increased from 15% to 18% of the total electricity mix in 2017, more than twice their concentration a decade ago. The expansion mainly owes to a rebound in hydro and an increasing number of wind and solar built in 2016 that had their first year of operation in 2017.
• The U.S. was for the first time a net exporter of liquified natural gas in every month of 2017.
• The role of corporations in the energy transformation industry is becoming more important, as more companies look to capture the benefits of energy efficiency and the federal government backtracks from national and international engagement on climate change issues.


Research

Every year, the Energy Department’s Office of Energy and Efficiency and Renewable Energy publishes Revolution Now, a report that documents the
accelerated deployment of clean energy technologies with significant impacts to the U.S. market. In 2016, Revolution Now focused on five clean energy technologies that already provide benefits and are easily visible in our daily lives.³

Wind Power

In 2015, wind power accounted for 41% of all new generation capacity built in the United States and there were nearly 74,000 megawatts (MW) of utility-scale wind power deployed across 41 states.

The success of wind deployment is owed in part to the recent decrease in wind prices from 7 cents/kilowatt-hour (kWh) in 2009 to an average of 2 cents/kWh today in some parts of the United States. Government investment, infrastructure development and federal and state incentives have also contributed to the increase in deployment. The Department of Energy alone has invested $2.4 billion in wind research and development between 1976 and 2014. Finally, state policies like state renewable portfolio standards and federal policies like the production tax credit (PTC) have played essential roles in driving continued deployment of wind.

Revolution Now outlines some areas in which innovation is expected to further expand the market for wind power and increase its competitiveness:

- Taller towers and longer blades could allow access to stronger and more consistent winds. This could lead to the development of more projects in areas like the Southeastern U.S., where historically there has not been significant wind development.
- Offshore wind holds enormous potential as a future source of clean electricity for the nation. The 30 MW Block Island project, located off the shore of Rhode Island, is the first commercial offshore wind power plant to operate in the U.S.
- Private corporations across a range of industries are purchasing more wind power—from roughly 100 MW in 2011 to nearly 2,000 MW in 2015.

Photovoltaic Power

Utility-scale solar PV costs have dropped by more than 64% since 2008, expanding deployment of the technology. Total capacity grew by 43% in 2015, reaching nearly 14,000 MW. Falling prices have led to the expansion of utility-scale PV to areas beyond sun-drenched Southwestern markets, such as

east of the Rocky Mountains, including Texas and Southeastern and Midwestern parts of the country.

Like wind power, utility-scale PV is purchased by both non-utility consumers and, increasingly, the federal government. As of mid-2016, there were more than 21,000 MW of utility-scale solar projects under development, with 8,400 MW of that total already under construction.

Distributed PV systems have experienced similar trends, with rises in installation partly due to a 54% reduction in installed costs since 2008. The federal investment tax credit (ITC) and net energy metering policies at the state level have also been conducive to cost reductions. Finally, growth in the solar market has been supported by initiatives such as:

- Clean Energy Savings for All, which intends to bring 1 gigawatt (GW) of solar power to low- and moderate-income families by 2020.
- National Community Solar Partnership, which expands solar access to new demographic and geographic markets and convenes relevant stakeholders to assess market barriers and catalyze deployment in low- and moderate-income communities.

**LED Light Bulbs**

A-type LED installations surpassed 200 million in 2015, more than doubling the previous year’s figure. According to the Department of Energy (DOE) *Revolution Now* report, A-type LED bulb costs are around 94% lower than in 2008. Switching entirely to LED lights in the next two decades could generate $250 billion in energy savings in the U.S. Ongoing technology research and development (R&D) improvements will continue to lower costs and improve the efficiency and performance of LEDs.

**Electric Vehicles (EV)**

More than 490,000 electric vehicles have been sold in the United States as of August 2016. Battery technology is a key factor that impacts the cost of EV ownership, and both private and public organizations have invested in battery R&D. Between 1992 and 2012, the DOE invested $1 billion in battery R&D, which advanced the state-of-the-art by six years and created $3.5 billion of economic value.

Another important factor of maintaining the momentum for EVs is improved and expanded infrastructure. Today, there are more than 35,000 public and private charging outlets in the United States. The DOE plans to collaborate with utilities in accelerating EV charging infrastructure deployment. Other support for EV adoption includes drivetrain improvements, tax credits and other incentives and public and private investment in domestic EV manufacturing capacity.
Emerging Technologies

In addition to the five clean energy technologies mentioned above, the DOE’s *Revolution Now* report also mentions emerging technologies expected to transform the energy industry over the next five to ten years. These include fuel-efficient long-haul trucks, smart buildings, vehicle lightweighting materials, fuel cells, grid-connected batteries and big area additive manufacturing, commonly known as 3-D printing. The DOE continues to invest in the R&D of these technologies. For example:

- SuperTruck Initiative has led to commercialization of 21 new transportation technologies to date, including breakthroughs in the areas of aerodynamics and engine/drivetrain integration.
- Smart Energy Analytics Campaign provides technical support and recognition for owners in their use of a wide variety of commercially available Energy Management and Information Systems (EMIS) technologies.
- SunShot program awarded $18 million in 2016 to develop energy storage solutions for solar power using battery and other technologies, with the goal of developing projects to enable essentially “on-demand” solar power.

Cleantech Patents

According to a study by the Brookings Institution, the total number of granted patents in the clean technology industry has more than doubled between 2001 and 2014. However, it has since fallen by 9 percent from 35,300 patents to roughly 32,000 (*Exhibit 5*). The patents in clean energy related technology areas, which represent almost 50% of total patents granted in the country in 2016, have followed a similar trend.4

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4 [https://www.brookings.edu/blog/the-avenue/2017/04/26/patenting-invention-five-clean-energy-innovation-trends/](https://www.brookings.edu/blog/the-avenue/2017/04/26/patenting-invention-five-clean-energy-innovation-trends/)
U.S. cleantech patenting is concentrated in relatively few technology categories. Advanced green materials, energy efficiency and transportation each accounted for 18 percent of total cleantech patenting between 2011 and 2016 (Exhibit 6), while energy storage accounted for 15 percent. Far fewer patents are granted in areas such as geothermal energy, hydro & marine power and nuclear generation.
Key Assets and Strengths in Washington State

Energy Industry Overview in Washington State

Due to the low price and abundant supply of hydropower, the development of other renewable technologies (wind and solar) has been slow in a regulatory environment that mandates lowest cost supplies until recent price declines have made the technologies cost competitive. However, in recent years, Washington state has pushed forward with an ambitious agenda to become a global leader in the clean energy industry, owing in part to a unique intersection of some of Washington’s leading industries—aerospace, information & communication technology (ICT) and agriculture—with the energy industry.

Washington state’s electricity industry powers nearly 2 million households and more than 200,000 businesses. Technology plays a critical role throughout the state in power generation, transmission, distribution and consumption. Ninety percent of Washington’s electricity comes from hydropower, solar and wind, compared to only 11 percent nationwide. Washington is second in the nation only to California for electricity generated from renewable resources.

Sources: IP Checkups Cleantech PatentEdge database, 2018; Community Attributes Inc., 2018.
According to the 2018 U.S. Energy and Employment Report (USEER), Washington state employs roughly 150,000 people in energy jobs. Over 54,500 of these are ‘traditional’ energy workers. Another 62,500 are energy efficiency jobs, accounting for 2.8% of all U.S. energy efficiency jobs, making Washington a national leader in the industry (Exhibit 7). The largest number of energy efficiency employees work in traditional HVAC firms, followed by Energy Star & Efficient Lighting. The remaining 32,000 jobs are found in the motor vehicles industry.

Exhibit 7. Employment by Major Energy Technology Application, Washington State, 2017


Overview of Washington’s Key Strengths in Clean Energy

Washington state is a prominent pioneer in the global clean tech industry, boasting the largest state trade association of cleantech businesses in the country (Washington CleanTech Alliance), the world’s greenest building (Bullitt Center) and a #1 ranking for hydroelectricity production in the nation. According to the state’s Department of Commerce 2017-2019 Proposed Strategic Plan for the clean technology industry, Washington has

competitive advantages in several energy industries: energy generation, energy storage, energy infrastructure, energy efficiency and transportation.

**Resources.** The state’s hydropower system has set Washington on the path to becoming a leader in the clean energy industry. Washington also benefits from other resources, like geothermal, strong tides, wind, solar (in the east), biofeed-stocks and cooling water.

**Education and R&D Cluster.** The state benefits from a strong network of educational and research institutions supporting clean energy, such as the Pacific Northwest National Laboratory, University of Washington, Washington State University and important trade and industry organizations, including the Washington Clean Technology Alliance, Washington Technology Industry Association and Northwest Energy Efficiency Council.

**Strong Policy and Government Support.** Washington’s clean tech industry benefits from strong public support through policy measures that aim to create a thriving innovation and entrepreneurship ecosystem. To attract investment, Washington state offers businesses a range of incentives including business and occupation (B&O) tax reductions for manufacturers of solar energy systems, sales and tax credits for equipment that generates electricity using renewables and others.

**Talented Workforce.** Washington state offers employers a highly talented and trained workforce. The presence of strong Information, Technology and Communications (ICT) and Aerospace clusters, as well as world-class education institutions, has attracted an expert workforce that gives the state a competitive edge.

**Leading Companies and Associated Technologies**

The Washington State Department of Commerce estimates that the clean tech industry in the state employs roughly 57,000 workers and is supported by more than $1 billion in venture capital. The clean tech industry in Washington has over 900 companies serving more than 12 different industries and possessing over 195 clean technology patents. **Exhibit 8** summarizes illustrative businesses in the clean energy industry in Washington state.
### Exhibit 8. Leading Private Sector Clean Energy Companies, Washington State

<table>
<thead>
<tr>
<th>Technology/Capability</th>
<th>Illustrative Companies</th>
<th>Description of Tech</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Renewables - Wind</strong></td>
<td>Oscilla Power</td>
<td>Wave energy converter</td>
</tr>
<tr>
<td></td>
<td>Trident Winds</td>
<td>Commercial-scale offshore wind farm</td>
</tr>
<tr>
<td><strong>Renewables - Solar</strong></td>
<td>Itek Energy</td>
<td>Solar modules</td>
</tr>
<tr>
<td><strong>Energy storage and batteries</strong></td>
<td>UniEnergy Technologies (UET)</td>
<td>Large-scale energy storage systems using advanced vanadium flow battery</td>
</tr>
<tr>
<td></td>
<td>Demand Energy (Enel Group company)</td>
<td>Battery storage optimization systems and software (Distributed Energy Network Optimization System)</td>
</tr>
<tr>
<td></td>
<td>EnerG2</td>
<td>Commercial-scale production of carbon materials for energy storage devices</td>
</tr>
<tr>
<td></td>
<td>Group14 Technologies</td>
<td>New-low cost approach to nano-scale silicon production for use in lithium ion batteries</td>
</tr>
<tr>
<td><strong>Energy efficiency</strong></td>
<td>Engie Insight (former Ecova)</td>
<td>Energy supply management technologies</td>
</tr>
<tr>
<td></td>
<td>McKinstry</td>
<td>Energy-smart building systems</td>
</tr>
<tr>
<td><strong>Grid technology</strong></td>
<td>Itron</td>
<td>Smart grid</td>
</tr>
<tr>
<td></td>
<td>1Energy Systems (Doosan GridTech company)</td>
<td>Software for grid-connected energy storage systems (ESS)</td>
</tr>
<tr>
<td></td>
<td>Avista Seattle City Light, Orcas Power and Light, Snohomish County PUD, Energy Northwest</td>
<td>Grid modernization</td>
</tr>
<tr>
<td></td>
<td>Schweitzer Engineering</td>
<td>Hardware and software for the grid</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td>SGL Automotive Carbon Fibers</td>
<td>Carbon-based products for electric cars</td>
</tr>
</tbody>
</table>
**Innovation and Research**

Washington is home to many research entities committed to the mission of biofuels and bioproducts. A number of these are included in Exhibit 9.

**Exhibit 9. Biofuel and Bioproduct Research Entities in Washington State**

<table>
<thead>
<tr>
<th>Illustrative Companies</th>
<th>Description of Tech</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSU Center of Excellence for Alternative Jet Fuels and the Environment</td>
<td>Alternative jet fuels</td>
</tr>
<tr>
<td>WSU Northwest Advanced Renewables Alliance (NARA)</td>
<td>Aviation biofuels and co-products from feedstocks as diverse as forest residues and construction waste</td>
</tr>
<tr>
<td>WSU Office of Clean Technology</td>
<td>Technologies to convert feedstocks to aviation biofuels, fuel cell systems that directly convert bio-based jet fuels to electricity</td>
</tr>
<tr>
<td>WSU Bioproducts, Sciences, and Engineering Laboratory (BSEL)</td>
<td>Bioproducts, bioprocesses and bioenergy</td>
</tr>
<tr>
<td>WSU Energy Systems Innovation Center</td>
<td>Smart grid</td>
</tr>
<tr>
<td>University of Washington Clean Energy Institute</td>
<td>Solar energy and battery materials and devices</td>
</tr>
<tr>
<td>University of Washington</td>
<td>CAMCET building</td>
</tr>
<tr>
<td>PNNL Analytical Resources</td>
<td>McKinstry Innovation Center</td>
</tr>
</tbody>
</table>

**Workforce Training and Educational Institutions**

The Pacific Northwest Center of Excellence for Clean Energy has served the region for the past 12 years by representing the needs and interests of the energy industry and labor partners. It is charged with narrowing the gap between employers’ demands for a highly skilled workforce and the ability of community colleges to supply work-ready graduates.

Demand for energy workforce training at colleges across Washington state is continuing to grow. In the last 10 years, the number of workforce training programs in the state has quadrupled, from 5 to 20. Enrollment in training in key clean energy industries like wind, solar, sustainability and smart buildings is growing at twice that rate, with growth of almost 12 percent.

Growth is occurring even faster in new technology areas like smart buildings, where demand for training at South Seattle College has grown 33 percent since the program started in 2013.
In addition to the programs at the community college level, Western Washington University established the Institute for Energy Studies in 2012. The Institute for Energy Studies is one of the only bachelor's degree programs in the country to combine technology, economics, business and public policy at the undergraduate level to prepare students for jobs in the new energy economy. Over the last three years, enrollment in the Institute for Energy Studies has more than doubled.

Western Washington University also works in partnership with community and technical colleges to develop curricular programs and streamline pathways to degrees in energy-related studies for students who would like to continue their education.

**Policy and Government Support**

The growth of the clean energy industry is reliant on coherent long-term energy policies, government-led incentives and government commitment to investments in clean tech R&D, energy innovation and the clean technology business ecosystem. State policies and incentives can make investments in clean energy more attractive by reducing cost barriers, lowering risk and reducing regulatory compliance costs.

As established by the Washington State Legislature (RCW 43.21F.010), Washington has three energy strategy goals:

- Maintain competitive energy prices that are fair and reasonable for consumers and businesses and that support the state's continued economic success;
- Increase competitiveness by fostering a clean energy economy and jobs through business and workforce development; and
- Meet the state's obligations to reduce greenhouse gas emissions.

With the passage of Initiative 937 in 2006, enacted as the Energy Independence Act (EIA), Washington state became the second state after Colorado to pass a renewable energy standard which mandated that 15% of the state’s electricity come from renewable energy sources other than hydro by 2020. Currently 18 utilities are subject to Initiative 937, which provide 80% of the electricity sold to Washington retail customers. As result of the EIA, the state now has over 3000MW of installed wind capacity and it has the utility with the largest wind portfolio in the United States.

Washington state also offers tax credits, rebates, performance payments, property and sales tax exemptions to help create conditions for long-term market development and growth.

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6 [https://app.leg.wa.gov/rcw/default.aspx?cite=43.21F.010](https://app.leg.wa.gov/rcw/default.aspx?cite=43.21F.010)
For example, since 2006, Washington state has been offering incentives to individuals, businesses and local governments for generating electricity from solar power, wind power or anaerobic digesters. This program has encouraged over 7,000 residents and businesses to invest in and install solar in their communities. On July 1st, 2017, the Washington State Legislature passed Senate Bill 5939, which revised and extended this incentive program. The program provides additional incentives for using equipment made in Washington State.

In 2013, the state established the Clean Energy Fund through a $36 million investment. The purpose of the Clean Energy Fund is to expand clean energy projects and technologies statewide. The initial investment attracted an additional $60.5 million in outside funding. The fund was designed to “provide a benefit to the public through development, demonstration and deployment of clean energy technologies that save energy and reduce energy costs, reduce harmful air emissions or otherwise increase energy independence for the state.” The Clean Energy Fund is focused on grid modernization, electrification of transportation, R&D and demonstration and solar programs.

AGRICULTURE & FORESTRY

Key Target Opportunities

- More efficient uses of resources and improved yields. Demand for higher yield food production, facing a growing population, and for more protein as countries develop and competition for labor increases.
- Agriculture globally needs to become cleaner, convert to a more environmentally sustainable model and produce less greenhouse gas emissions.
- Sustaining or enhancing profitability in the agriculture sector.
- Reduced ecological impact and associated social costs.

Leading Trends in Agriculture & Forestry

In a new report on agricultural cleantech, Kachan, an analysis and consulting company, uses the following criteria to differentiate cleantech developments from generic agricultural innovations:

- A cleantech development has more efficient use of resources;
- Reduced ecological impact and social costs;
- Smaller carbon footprint; and
- Sustained or enhanced profitability.

7 [http://www.kachan.com/content/agricultural-cleantech-agtech-report](http://www.kachan.com/content/agricultural-cleantech-agtech-report)
The agriculture sector is one of the world’s largest economic sectors. Net farm income, a broad measure of profits, is around $120 billion and farm assets are roughly estimated at $2 trillion. However, compared to other industries like energy, agriculture has seen relatively less investment in clean technologies over time, and even where investment occurred, there has been a slow adoption of new digital technologies.

In more recent years, investment in agriculture and the food sector has picked up, with figures since 2014 consistently doubling the value amount of investments of previous years. The sub-sectors driving the growth are technological advancements in automation such as drone technologies, data and the Internet of Things (IoT), sustainable proteins and genetic engineering of crops in agricultural biotech. These combined have contributed to more than $1 billion in investment in 2016 to the agriculture and food industries (Exhibit 10).

Exhibit 10. Agriculture & Food Sector Global Investment, 2010 - 2016

<table>
<thead>
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<th>Year</th>
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<th>Total Deal Volume</th>
</tr>
</thead>
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<td>2013</td>
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<tr>
<td>2016</td>
<td>$1,084.4</td>
<td>152</td>
</tr>
</tbody>
</table>

Source: Cleantech Group, Quarterly Investment Monitor, 2018; Community Attributes, 2018.

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8 Dutia, G. Suren. AgTech: Challenges and Opportunities for Sustainable Growth. Ewing Marion Kauffman Foundation, April 2014.
A summary provided by Cleantech Group on the 2018 Cleantech Forum in San Francisco emphasizes some of the current challenges the industry faces and some potential solutions for overcoming them:

- Digital technologies add complexity for farmers and turn agronomy into a science rather than an art, as many practitioners view it. This makes a data-driven approach difficult to implement.
- Additionally, digital technologies can have a disruptive effect on crop insurance because they provide insurance companies with a data-driven approach to distinguish between externalities like bad weather and erroneous farming processes. Farmers then risk losing their insurance benefits unless they adopt a more scientific-based approach.
- Corporate strategic partnerships are required to ensure a sustainable food system, with investors committing for the long term to truly add value to the ecosystem. Corporate partnership is also a key attribute in de-risking new technology.
- The success of agricultural biotechnology is dependent on public adoption and acceptance of new technologies, like gene editing.
- Farmers are increasingly concerned about who owns the data collected on their farm by sensors, drones or software. Clear guidelines are needed to make growers feel confident in the security of their data.

Sources of Demand
Agriculture will play a crucial role in addressing the planet’s future needs related to food production, health and the preservation of the environment. Transforming the global agricultural model could be the greatest challenge of all. While agriculture should be an integral part of the solutions for the 2030 United Nations Agenda for Sustainable Development and contribute towards SDG 1, 2, 3 (no poverty, zero hunger, good health and well-being), it must also support SDG 12, 13, 14 and 15 (responsible consumption and production, climate action, life below water, life on land).

High-input, resource-intensive farming systems, which have led to massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions, cannot deliver sustainable food and agricultural production. More innovative systems are needed to protect and enhance the natural resource base while increasing productivity. Adoption of clean technology in the agriculture and forestry sector can help overcome some of the challenges that the sector is facing. This section of the report discusses key main drivers for production and adoption of clean technology in agriculture and forestry.

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Growth in Demand

The Food and Agriculture Organization (FAO) of the United Nations forecasts that demand for food and other agricultural products will increase by 50% between 2012 and 2050. Population growth is one of the key drivers of food demand and while, in general, world population is slowing down, some parts of the world like Africa and Asia will still see a large population expansion well beyond 2050.

Population dynamics also have an impact on food demand and on food systems, with more people now living in the cities. Urbanization has been accompanied by a change in food consumption patterns with a shift towards processed foods and food products that have more labor embedded in them, for example, fast food or store-bought convenient foods, and an increase in kilocalories per day within developing regions (Exhibit 11).

Exhibit 11. Food Supply by Region in Kilocalories per Person per Day, 1961 - 2013

Source: UN Food and Agricultural Organization (FAO), 2018; Community Attributes, 2018.

Finally, an increasingly important source of the food demand increase is per capita increases in income. Since the proportion of income spending on food decreases as incomes rise, growth in global food demand will be greater if incomes grow faster in developing countries than in high-income countries. Such a pattern of income convergence has become established in recent years with implications for food demand and supply.
Resource Availability

Competition for natural resources is intensifying due to changes in consumption patterns driven mainly by population growth, industrial development, urbanization and climate change. Intensified competition leads to overexploitation of the resource base, harming the environment and creating a continuous loop where more degradation leads to more fierce competition for resources.

FAO estimates that 33% of the world’s farmland is moderately to highly degraded and forest losses due to expansion of agricultural land have amounted to just under 100 million ha. In addition, available farmland is concentrated in only a few countries and in some regions is not readily accessible, due to the lack of infrastructure, physical remoteness or vulnerability to disease outbreaks.

Water scarcity is also expected to become a constraint as more than 40% of the world’s rural population lives in river basins that are classified as water scarce. Climate changes resulting in higher temperatures and lower levels of precipitation will drive further stress on the availability of water resources.

Resource availability constraints imply that increases in agricultural output have to come from increases in productivity and more efficient use of the natural resource base. This drives the demand for technological progress, social innovation and new business models for agriculture and forestry.

Climate Change

Agriculture is one of the most significant sectors in terms of climate and energy consumption. Globally, agriculture contributes 10%–12% of total anthropogenic greenhouse gas (GHG) emissions and 56% of the non-CO₂ GHG emissions, mainly due to nitrous oxide emissions from soils and methane emissions from cattle.¹¹ In addition to greenhouse gas emissions and energy consumption, agriculture is the single largest consumer of water in most countries and is accordingly a significant source of water pollution. These negative externalities force agriculture to improve its production and become cleaner by using fewer resources and causing fewer emissions.

Policy

The need for technological development in agriculture to achieve "sustainable intensification" is on the agenda of governments and international bodies. For example, in Europe, innovation is at the center of the EU2020 strategy. New technologies and their adoption by EU farmers are key drivers in

maintaining European agriculture competitive in a global world. The EU nearly doubled its efforts with an unprecedented budget of nearly 4 billion euros allocated to Horizon 2020's Societal Challenge 2 “Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy [sic].”12

Agriculture & Forestry R&D

Sustainable Food Systems
A sustainable food system has certain characteristics which enhance environmental, economic and social well-being: secure, reliable and resilient to change, accessible and affordable, energy efficient, economic generator for farmers, whole communities and regions and environmentally beneficial. The clean technologies listed below are good examples of where we are currently seeing innovation in improving sustainability of food systems and address concerns related to food access, food security and availability.

Vertical Farming
Vertical farming involves growing crops in vertically stacked layers which enables an increase in crop yield without increasing the land area for crops. It is associated with city farming and urban farming and aims to bring food production close to areas with high population concentrations. Vertical farming also has the potential to reduce the environmental footprint of food transport. Energy is the great limiting factor for this technology, as plants need a lot of light for photosynthesis. AeroFarms is working on a technology called aeroponics that can grow crops in vertical stacks of plant beds, without soil, sunlight or water. The company raised $34 million in 2017 only and is currently on the 10th or more iteration of production facilities. Other businesses that are on a mission to build large scale vertical farms near urban cities include Plenty, AeroFarms and Bowery.

Alternative Food Sources
Alternative protein sources include plant or insect-based alternatives, or cultured products grown in a cell structure outside of the animal. These alternatives aim to be indistinguishable from animal products and contribute to the global food supply by ensuring sufficient access to safe and nutritious food for a growing population.

Beyond Meat is an example of a company that processes plant proteins to chemically recreate the structure of meat. Impossible Foods wants to completely replace animals as a food production technology by 2035, cut greenhouse gas emissions generated by the meat and dairy industry in its

12 https://ec.europa.eu/agriculture/research-innovation_en
current form and solve food security problems. Finless Foods is a developer of cultured products that wants to produce sustainable seafood without having to farm or harvest live fish from the oceans.

In the insect-based alternatives category, while insect use in the human food chain is not expected to take a great leap forward, insect alternatives to animal and fish proteins used in animal feed and other industries is experiencing a period of growth. Tiny Farm is an example of an innovator in this category that is developing technology for industrial-scale insect farming. Other examples include AgriProtein Technologies, developer of an alternative protein feed product from organic waste and Ynsect, a producer of high-quality, premium natural ingredients for aquaculture and pet nutrition from insects.

**Aquaculture**

Aquaculture is one of the fastest growing food-producing industries and currently accounts for 50% of the world’s fish that is used for food.\(^\text{13}\) The industry has been making a significant contribution to food security however there are certain challenges that the sector is facing. Large scale aquaculture can generate a lot of waste and fish farms can become breeding grounds for diseases that infect wild fish nearby. Moreover, feeding the fish on the marine farms has led to overfishing of species caught for feed. Finally, overuse of antibiotics and lack of wastewater treatment are also concerns.

Across the world, companies are investing to incorporate existing clean technologies into this sector to make fish farming totally clean and green:

Canada launched the Fisheries and Aquaculture Clean Technology Adoption Program last year that will provide up to $20 million over four years to fisheries and aquaculture businesses to improve their environmental performance.

Blue Ridge Aquaculture in Martinsville, VA is an indoor fish farm that uses a technology called Recirculating Aquaculture Systems (RAS) which operates by filtering water from the fish (or shellfish) tanks so it can be reused within the tank. This dramatically reduces the amount of water and space required to intensively produce seafood products. The company is currently selling its fish to a small segment of the market: people who want to buy their fish live and are thus willing to pay more for them. The company cannot compete directly with the imported fish of the same species in the stores due to high operational costs.

The Institute of Marine and Environmental Technology in Baltimore is working on a model for a self-contained fish farm on land that is both technologically and economically viable.

**Digital Agriculture**

Digital agriculture is the use of new and advanced technologies, integrated into one system, to enable farmers and other stakeholders within the agriculture value chain to improve food production. The aim in digital farming is to use all available information and expertise to enable the automation of sustainable processes in agriculture. Technologies used include: sensors, communication networks, Unmanned Aviation Systems (UAS), Artificial Intelligence (AI), robotics and other advanced machinery and often draws on the principles of the Internet of Things. Examples of businesses pioneering these technologies are:

- Hortau and CropX—control water irrigation and optimized plant growth technologies
- Beehive Technologies and Nileworks—drone technology
- Descartes Labs and Orbital Insight—satellite imagery technology
- Ceres Imaging and FarmLogs—insights for growers to improve crop yields.

**Biotechnology Applications**

The application of biological sciences in agriculture has become increasingly prominent in the past decade. Agricultural biotechnology is a field of agricultural science which uses cell and molecular biology tools to improve genetic makeup and agronomic management of crops and animals. It provides farmers with tools that can make production cheaper and more manageable.

**Plant Genomics**

The goals of agricultural plant science are to increase crop productivity and the quality of agricultural products while protecting the environment. A growing global population, changing climate and environmental pressure generate the need to accelerate breeding novel crops with higher production, stress-resistant traits and less pesticide usage.

CRISPR technologies have been applied for the first time in 2012 and are new plant breeding methods that produce identical results to conventional breeding methods but faster, with lower costs and higher predictability. Promising uses of CRISPR tools in agriculture have already been shown in

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14 CRISPR is an abbreviation of Clustered Regularly Interspaced Short Palindromic Repeats. CRISPR technology is a tool for editing genomes and allows researchers to alter DNA sequences and modify gene function.
crop plants such as wheat, corn and tomatoes. CRISPR tools are currently spurring innovative research in academia and in companies of all sizes. For example, Benson Hill Biosystems has developed a new tool based on the CRISPR technology that can increase the nutritional density of crops and improve yield against stressors such as drought.

**Sustainable Forestry**

Sustainable forest management seeks to maintain and enhance forest resources, promote the health and vitality of forest ecosystems, conserve biodiversity and ensure forest land retains its natural relation to soil and water systems. The ultimate goal is to retain the forest’s ability to support ecological, socio-economic and cultural functions beyond timber harvesting. Over the past three centuries, timber extraction has caused a net loss of 7 to 11 million square kilometers of forest land. An additional 2 million square km have been converted to highly managed timber and palm oil plantations. Clean technologies represent new opportunities to reduce humans’ impact on native forests and improve the sustainability of silviculture stands.

**Underwater Logging**

Triton Logging has developed a pair of devices which enable the collection of submerged forests from dam reservoirs. The company has operations in Canada, the U.S. and Ghana and a prospective project in Brazil. It is the only company to offer a mechanized means of collecting submerged timber at this scale. For this reason, it holds considerable competitive advantage and with 60,000 reservoirs globally it addresses a large market.

**Key Assets and Strengths in Washington State**

**Agriculture & Forestry Industry Overview in Washington State**

Agriculture is a key component of Washington state’s economy and adds around $51 billion a year—or 12 percent—to the state’s GDP. There are over 300 crops grown in Washington state and the state ranks 14th nationally in overall commodity production.

In 2016, Washington state was home to 35,700 farm operations and 14.7 million acres of agriculture land. Major crops by value in 2016 include apples ($2.4 billion), potatoes ($813.3 million), wheat ($656.8 million), sweet cherries ($491.1 million), hay ($479.0 million) and wine grapes ($313.2 million).  

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Leading Companies and Associations

The following presents a summary of leading companies and associations by leading areas of innovation in agriculture and forestry.

Vertical Farming

Farmbox Greens is a vertical farm located in Seattle, Washington, that cultivates microgreens for restaurants, farmers markets, grocery stores and online grocery services. The company states that it uses energy-efficient LEDs and 90 percent less water than traditional farming. By growing its products within the urban city of Seattle, Farmbox Greens creates zero agricultural runoff and minimal distance for food transportation.16

Plenty is an indoor vertical farm headquartered in South San Francisco, California. In November 2017, the company announced that it would open a second farm in Kent, Washington, as it expands globally. The new 100,000-square-foot facility, which will grow 4.5 million pounds of greens annually, will be Plenty’s first full-scale farm using the innovative technology of indoor farming.17

Aquaculture

Taylor Shellfish Farms is large producer of aquaculture shellfish based in Shelton, Washington. Relying on clean water and a healthy ecosystem, the company has had to address ocean acidification due to increased carbon dioxide in the atmosphere.18

Other Sustainable Agriculture

Beta Hatch produces animal feed and fertilizer from insects. Located in Seattle, Washington, the farm is an indoor, climate-controlled and zero-waste system. Insects are grown and harvested to create products that can be used in gardens, backyard chicken coops and commercial chicken farms.19

Cedar Grove is an environmental compost company with locations across Western Washington. Using innovative technologies like the monitoring program OdoWatch, Cedar Grove recycles more than 350,000 tons of food

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waste annually into renewable energy and soil for home garden and commercial agriculture use.\(^{20}\)

**Vander Haak Dairy** is a dairy farm in Lynden, Washington, with 500 cows producing 14 million pounds of milk annually. In 2004, Vander Haak became the first to fully install and use an anaerobic digestor, which converts manure and food waste from nearby food processors into energy and other saleable products. The digestor helps recover 600,000 pounds of ammonium sulfate fertilizer and 3 million pounds of phosphorus-rich solids to be used in crop production. It also generates an alternative to peat moss and adds to the grid enough sustainable electricity to power 400 homes annually. Reducing carbon emissions by 17,000 pounds per year, Vander Haak’s digestor demonstrates a way for dairy to help create a more sustainable future, rather than be part of the problem.\(^{21}\)

**Washington Forest Protection Association (WFPA)** is a trade group representing private forest landowners in Washington state. Its members are large and small companies with about 4 million acres of combined forestland. WFPA states a commitment to sustainable forest management and wood production. The group promotes the use of biofuels created from wood products, wildlife protection, responsible forest cycling and combating climate change.\(^{22}\)

**Innovation and Research**

**The Center for International Trade in Forest Products (CINTRAFOR)** is one of three applied research centers within the University of Washington’s School of Environmental & Forest Sciences. With private, federal and state funding, CINTRAFOR is the only international forest products trade Center of Excellence in the United States. Part of its mission is to collect information on and address environmental problems that impede forest product exports. The center also trains professionals by funding graduate-level research.\(^{23}\)

**The Center for Sustaining Agriculture and Natural Resources** at Washington State University leads research and initiatives in sustainable


agriculture, food systems and natural resources. Its projects include energy and nutrient recovery from organic wastes, technologies to reduce pesticide use and the development of sustainable farming systems. Through its Food Systems Program, the center works with communities across Washington state to foster viable, sustainable farm businesses.24

**WSU Extension** is comprised of 39 locations across the state where Washington State University offers courses to the public. Many of these courses are intended for farmers and ranchers, and they teach professionals about both more efficient, economical methods and sustainable practices.25 By spreading university curricula, WSU Extension offers new and innovative ideas to agriculturists across Washington state.

**Workforce and Educational Institutions**

**The SARE Professional Development Program** at Washington State University states that its purpose is to help agricultural professionals increase their ability to respond to the needs of farmers, ranchers and the public regarding sustainable agriculture concepts and systems. Since 1988, SARE has awarded over $27.4 million in grants to fund educational programs for farmers and other professionals. These programs involve teaching about natural resource conservation, water use reduction and other sustainable practices.26

**Tilth Alliance** is a nonprofit organization whose goal is to educate people to safeguard natural resources and build a sustainable food system. The group offers financial assistance to improve the sustainability and economic viability of farm businesses in Washington state, and it gives training to thousands of farmers and others annually on current research and conservation practices.27

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**Allied Industries and Technology Capabilities**

**Biotechnology**

Some of Washington state’s biotech companies find natural partners in the agricultural and forest industries. For example, Seattle-based Arzeda applies its protein design technology to enable new crop traits, improving crop yields and improving farming efficiency.\(^{28}\) By creating technologies that make farming less water-dependent or wasteful, firms like Arzeda are the innovators behind progress in agriculture.

**Plant and Livestock Genomics**

Genomics companies conduct research focusing on the structure, mapping and editing of genes. Changing the characteristics of organisms can make farming more economical and more environmentally-friendly. An example of this is the work of Phytelligence, a company founded in 2012 by Washington State University Horticulture Professor Amit Dhingra. Phytelligence has completed genome sequences for apples, pears, cherries, almonds and peaches that need less water than their counterparts producing the same volume. The company also offers citrus growers an engineered rootstock that is resistant to citrus greening disease, which in 2017 devastated growers in Florida, California and Texas and led to great waste of potential food.\(^{29}\)

**Policy and Government Support**

**Conservation Reserve Enhancement Program.** The Farm Service Agency and the Washington State Conservation Commission, which manages the states’ 45 conservation districts, compensates farmers for allowing salmon conservation projects in streamside areas of their property. The program offers rental income for 10 to 15 years, as well as a signing bonus, and all costs are covered or reimbursed through state and federal funds.\(^{30}\)

**Irrigation Efficiencies Grants Program.** The Washington State Conservation Commission offers to pay farming landowners up to 85 percent of total costs to implement efficient irrigation and conservation methods. This program is voluntary, and it intends to protect fish in critical basins

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while supporting irrigated agriculture. Each contract can bill up to $400,000.31

**Shellfish Initiative Phase II.** Led by former Governor Christine Gregoire, the 2011 Washington Shellfish Initiative was a partnership between state and federal government, tribes and the shellfish aquaculture industry. Current Governor Jay Inslee has made it one of his priorities to renew the Initiative’s commitments by preventing and fixing pollution problems, reopen shellfish beds, confront ocean acidification and improve the permitting process to increase sustainable aquaculture.32

**Funding for Ocean Acidification Research.** In 2013, the Washington State Legislature approved allocating $3.3 million to invest in scientific research on ocean acidification, which plagues the aquaculture industry.33

**Underwater Logging.** The Washington State Supreme Court decided in the 1990s that underwater logs at the bottom of Lake Washington were state property and could not be taken by logging companies. More recently, Washington’s Department of Natural Resources and the Grays Harbor County prosecutor have weighed charges of timber piracy against underwater loggers like Jimmy Smith, who was featured on the national TV show “Ax Men.”

**(Aquaculture) Atlantic Salmon Farming Ban.** In March 2018, the State Legislature passes a bill to ban Atlantic salmon and other non-native fish farming by 2025. Governor Jay Inslee signed it into law thereafter.

**Building Materials**

**Key Target Opportunities**

In this analysis, green economy building materials refers specifically to recycled products (such as recycled particle board), mass timber and its subset, cross-laminated timber (CLT), though there are other mass timber products with similar benefits to CLT, such as laminated strand lumber and laminated veneer lumber. Cross-laminated timber is a leading new

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technology within the mass timber group with significant growth prospects both in the U.S. and abroad. Mass timber refers to “a category of framing styles typically characterized by the use of large solid wood panels for wall, floor and roof construction.”

CLT involves a process whereby multiple (usually three to seven) layers of boards are stacked crosswise and glued together, typically with an orthogonal orientation. CLT has the potential to significantly alter the trajectory of the forestry and wood products industry in Washington, which after being the nation’s largest leader in the timber industry has gone through a multi-decade decline imperiling local economies in Grays Harbor, the Olympic Peninsula and other traditionally timber and wood products-reliant communities across the state. There are specific benefits associated with CLT.

Mass timber and CLT present multiple advantages over traditional building materials; these include:

- **Smaller carbon footprint**, owing to CLT’s use of a renewable and sustainable resource, compared to concrete, steel and other materials. A 2009 study by researchers at the University of Canterbury in New Zealand found that mid-rise steel or concrete buildings can produce up to 1,500 tons of carbon dioxide. This compares against an equivalent-timber building that can sequester 610 tons of net CO₂. According to the University of Washington, “using more CLT expends less energy than producing and transporting traditional building materials, such as concrete and steel.”


35 A report by the Canadian Wood Council in 2005 found steel and concrete designs “embody 26% and 57% more energy relative to wood design, emit 34% and 81% more greenhouse gases, release 24% and 47% more pollutants into the air, discharge 400% and 350% more water pollution, product 8% and 23% more solid waste, and use 11% and 81% more resources (from a weighted resource use perspective.” Canadian Wood Council, “Embodied Energy of WOOD Products,” *Quick Facts—Sustainable Building Series*, 2004: [http://www.cwc.ca/NR/rdonlyres/FD8693D4-C735-44CA-959C178D43FE092A/0/Quickfacts_Sustainable_Building_Series_05.pdf](http://www.cwc.ca/NR/rdonlyres/FD8693D4-C735-44CA-959C178D43FE092A/0/Quickfacts_Sustainable_Building_Series_05.pdf) (accessed April 27, 2018).


emits less carbon in its manufacture and helps sequester carbon during use. Tearing down and disposing of CLT structures results in an estimated 50-80% less global warming potential, as compared with traditional materials.  

- **Construction efficiencies.** Mass timber construction projects require fewer on-site workers than similarly sized projects using traditional materials, and they can be completed more quickly.
- **Fire safety.** Mass timber often provides better fire protection and seismic resistance. Under fire conditions, mass timber materials char and heat slowly, whereas steel heats up rapidly and fails.
- **Structural and weight.** As a significantly lighter material compared to steel, concrete and masonry, mass timber can be a solution for sites with poor soil.
- **Forestry management.** Mass timber provides an economic incentive and best use of forest thinning and associated waste byproduct.
- **Carbon sequestration.** As a wood product, mass timber can help address anthropogenic climate change through natural sequestration and storage of carbon.
- **Utilizing forest waste product.** Panel producers can use small trees cleared through forestry thinning operations, thus yielding healthier forests. CLT repurposes waste wood material (such as pest-damaged and/or less desirable lumber grades) while maintaining or exceeding tensile strength and not compromising panels overall integrity.
- **Exploiting economic value from waste.** CLT provides additional economic opportunity for landowners who would otherwise discard or burn waste forestry material from the thinning process.
- **Project savings.** CLT, as a lighter material, can lead to significant cost savings on foundation work.

### Leading Trends

Three important factors will support future demand for advanced, environmentally-friendly building materials:

- Continued population growth and urbanization, supporting overall demand for new residential and commercial building stock.

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• More recently, a reconfiguring of the global recycling system that will create new stresses and opportunities for repurposing solid waste for building materials; and
• Growing demands among businesses and consumers for technologies and materials that are less impactful on the environment compared with traditional building materials such as steel and concrete, based on a life-cycle assessment.

Population and Growth in the Built Environment

Between 1990 and 2015, the world urban population increased at a rate of more than 2% per year, reaching more than 4 billion people, or 54% of the global population. According to UN projections, this share is expected to increase to 66% by 2050, adding another 2.5 billion people to urban populations.

Continued urbanization will create significant demand for new housing stock across the world. Mass timber, and cross-laminated timber (CLT) specifically, offers opportunities to both address these construction needs and through a process and source material that is sustainable and yields a much lower carbon footprint compared with traditional building products.

Recycling Trends and Opportunities

In the nearer term, recent events in China will potentially upend the established recycling system, creating needed demand for new recycling capacity in the U.S. and opportunities for recycled building materials. China’s National Sword policy has drastically lowered the level of acceptable contamination in recycled products allowed for processing in China, effectively banning many types of solid waste. According to a recent report, China consumes 55 percent of the world’s scrap paper and is a major destination for other recyclables. If U.S. recycling centers are unable to find alternative destinations for further processing, many of these solid waste materials, such as plastics, glass and paper, many ultimately end up in landfills.

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Sources of Demand

Globally

Mass timber and CLT construction remain a relatively small global share of total new building stock, though there have been multiple showcase projects in recent years and interest is growing. These include an 18-story dormitory at the University of British Columbia, the 24-story HoHo Tower under construction in Vienna which will be 76% wood, the 35-story Baobab building in Paris (in works) and a proposal for the timber-framed 85-story Oakwood Tower in London.45

U.S.

Within the U.S., mass timber and CLT similarly remain an early stage material. However, according to a 2016 report by Spiritos Properties, “CLT will be the dominant structural system in the U.S. for four- and 12-story buildings in the next five years to 10 years.”46

An industry assessment from 2015 projected a market potential in the U.S. of $4 billion, but according to the Softwood Lumber Board, an industry group, 77 percent of the square footage built each year in the U.S. is less than 12 stories high and could be made with mass timber. According to their research “[o]f nonresidential buildings under 12 stories, 90 percent today are made of steel and concrete.”47

However, there are at least two potential challenges to future adoption of CLT as a building material. Firstly, the costs of CLT remain high relative to traditional building costs. Across the U.S. and its Western states, single family construction remains the predominant type of construction project (Exhibits 12 and 13). In regions such as Seattle, where the real estate market is highly competitive, and demand is much higher than existing supply, resulting in a “seller’s market,” single family homebuilders have less incentive to invest in more environmentally friendly building materials such as CLT over existing materials. The homes that are built using CLT tend to be of custom design and more expensive.

CLT also presents risks for the developer, many of whom, according to interviews, tend to be more conservative with respect to building materials.

46 March, Mary Tyler, 2017.
So long as demand is high, builders will continue to work with the material with which they are most comfortable.


Source: U.S. Census Bureau, 2018; Community Attributes Inc., 2018.

*2018 monthly average based on first three months only.

Note: single-family statistics include fully detached, semidetached (semi attached, side-by-side), row houses and townhouses. In the case of attached units, each must be separated from the adjacent unit by a ground-to-roof wall in order to be classified as a single-family structure. Also, these units must not share heating/air-conditioning systems or utilities. Units built one on top of another and those built side-by-side that do not have a ground-to-roof wall and/or have common facilities (i.e., attic, basement, heating plant, plumbing, etc.) are not included in the single-family statistics.
Lastly, CLT-based construction requires a set of skills unique from standard construction processes. The major components of a construction project are fabricated at a mill and assembled at the project site. This process results in the need for less workers on-site, and of more specific, technical skills, such as crane operators.

Challenges

Mass Timber and CLT

- U.S. building codes currently allow for buildings up to only five stories to be built with CLT, though larger buildings can be (and have been) built through special exceptions in the code by jurisdiction.

- CLT materials, in order to represent a true reduction in environmental impacts based on a life-cycle assessment, need to use raw wood procured through sustainable building practices. There are concerns that, as CLT becomes a more popular building material, forest owners will opt to grow hemlock, poppy and other faster-growing species that are invasive and may adversely impact ecosystems in the Pacific Northwest.48

- Despite the environmental benefits of CLT and mass timber, current economic conditions inhibit widespread use of these materials. The majority of new residential construction remains predominately

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48 Interview with Patti Southard, GreenTools Program Manager, King County. May 8, 2018.
single-family, and according to stakeholder interviews, most homebuilders are hesitant to embrace CLT, especially in the current real estate market where demand exceeds supply.\textsuperscript{49}

**Recycle Building Materials**

- The Pacific Northwest does not yet have robust capacity to reclaim recycled wood products and will need to build out this capacity to allow for scalable recycled building materials.
- There is currently no standardized content formula for particle board, such as gypsum. Often times, particle board based on recycled materials vary widely in content composition, and often do not meet LEED and other green building certification standards.

**Key Assets and Strengths in Washington State**

**Building Materials Industry Overview in Washington State**

- Washington state has long been an important center for wood products, though in recent years the industry has experienced a decline in activity (Exhibit 14).
- The current model for wood building materials is for logs to be harvested in the Pacific Northwest and sent to China, Korea or Japan (or elsewhere) for processing. Due to environmental regulations, labor and production costs and other factors, many sawmills in the Pacific Northwest have closed, especially during the last recession. Rural communities have been hit hard by these closures.
- Forests need to be thinned periodically to improve wildlife habitat, enable faster tree growth and pre-emptively remove smaller brush and trees that could serve as kindling for forest fires, which make wildfires larger and more intense. Most of this excess waste is piled and burnt with no economic value extracted from it.

\textsuperscript{49} Interview with Leah Missik, Built Green Program Manager, Master Builders Association for King and Snohomish Counties, April 17, 2018.
Leading Companies and Associations

Mass Timber and CLT in Washington State

Two companies directly engaged in CLT and mass timber are Vaagen Timbers and the construction company Katerra. Their recent moves toward greater use of these materials signal growing optimism in the green building materials industry.

Vaagen Timbers was formed in 2017 when it announced its plans to construct a facility in Colville, Washington, that will produce exclusively CLT and glue-laminated beams. Lumber for the new company will be supplied by its partner Vaagen Brothers Lumber, which was founded in the early 1950s and has since grown to process logs from private, state, federal and tribal lands. Vaagen Bros. operates four sawmills in the Pacific Northwest, including a flagship facility in Colville. Vaagen Bros. promotes sustainable forestry by harvesting smaller logs and committing to optimal resource utilization, which uses as much of harvested logs as possible. Bark, chipped

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logs and other fiber from Vaagen logs are processed in the paper, landscaping and electricity industries.\(^{52}\)

**Katerra** is an innovative construction company that employs more than 1,500 employees across four countries.\(^{53}\) Investing heavily in research and development, Katerra has partnered with the Washington State University Composite Materials & Engineering Center to create and test a catalog of mass timber products for residential and commercial building projects.\(^{54}\) In September 2017, the company announced its plans to open a new factory in Spokane Valley, Washington, for the production of CLT and other mass timber materials. One of Katerra’s first local CLT projects will be the 2019 construction of the Spokane Hospitality Center for Ronald McDonald House and Kootenai Health.\(^{55}\)

**Forterra** is a nonprofit conservation group based in Seattle, Washington. It aims to provide sustainable building opportunities for rural Washington towns and it promotes maintaining urban green spaces through official partnerships with the cities of Everett, Kent, Kirkland, Redmond, Seattle and Tacoma.\(^{56}\) The group leads a coalition whose intent is to accelerate a market for the production and use of CLT and other mass timber products. The statewide coalition of private companies, government agencies, conservation groups and universities has received a $250,000 grant from the U.S. Forest Service.\(^{57}\)

**Weyerhaeuser** is one of the world’s largest private owners of timberlands and a major manufacturer of wood products. Based in Washington state since its founding in 1900, the company is now headquartered in Seattle and employs approximately 9,300 people.\(^{58}\) Weyerhaeuser promotes mass timber

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construction and sustainability through its divisions in product innovation and government relations.\textsuperscript{59}

**DCI Engineers** is a structural and civil engineering firm based in Seattle. Its engineers provide design and support services to construction projects primarily in Washington state.\textsuperscript{60} DCI is committed to sustainability and efficiency, and the firm promotes CLT as an advantageous material with great potential in the future of building.\textsuperscript{61}

**The Softwood Lumber Board** is an industry-funded initiative determined to increase demand for softwood lumber products in outdoor, residential and non-residential construction. The Board funds multiple groups that research, educate, and promote the lumber industry and innovative products like CLT. These include the American Wood Council, Think Wood, WoodWorks and the residential promotion campaign Wood Naturally.\textsuperscript{62}

**The American Wood Council** is a large and influential trade association for the wood products industry, which it estimates has approximately 400,000 employees. Its members comprise of 86 percent of the structural wood products industry, and its staff develop engineering data, technology and safety standards for wood products. The Council states that it is committed to innovation and sustainability.\textsuperscript{63}

**Recycled Materials**

KlipTech is the company behind the creation of durable countertops constructed from recycled paper. The surface material is called EcoTop, and it is comprised of a blend of post-consumer recycled fiber, renewable bamboo fiber and a water-based binding agent. Paper surfaces now constitute an entire product category in the countertop industry. In Washington state, KlipTech has a factory in Burlington, a manufacturing facility in Tacoma and corporate offices in Puyallup. The company is currently developing renewable resin systems and plans to keep expanding.\textsuperscript{64}

\textsuperscript{60} DCI Engineers, *About*, 2018: http://www.dci-engineers.com/about.
\textsuperscript{63} American Wood Council, *About Us*.
**Bedrock Industries** manufactures Blazestone Tile, a 100 percent recycled glass product handmade in Seattle, Washington. Stating that it specializes in trash beautification, the company has recycled hundreds of tons of material that would otherwise have gone to landfills. Its products include glass tiles, glass décor and tumbled glass. The company also operates several community programs, such as bottle drives, classes and tours in conjunction with elementary schoolchildren.\(^6\)

**PaperStone** is a solid building material comprised of 50- to 100-percent recycled paper and petroleum-free resins. Produced at the Paneltech Manufacturing Plant in Hoquiam, Washington, PaperStone countertops, partitions, paneling and furniture have been installed in homes, restaurants, laboratories, office buildings, universities and museums. The product allows builders to receive points in the LEED green building program.\(^6\)

**Daltile** is a leading manufacturer and distributor of ceramic tile and natural stone. The company states that its environmentally-friendly manufacturing process includes recycled scrap tile and minimizing waste. Its range of products is broad, and the company also offers nonmanufactured stone.\(^6\) Daltile operates 11 manufacturing facilities in North America and employs more than 8,500 people, including in Washington state. It is a subsidiary of Mohawk Industries.\(^6\)

**Richlite** is a company that manufactures a durable material made from approximately 65 percent recycled paper and 35 percent phenolic resin. The company is headquartered in Tacoma, Washington, and names its product lines after Washington mountains and other landmarks. Its products are used by the aerospace, marine, action sports and architecture industries.\(^6\) Richlite states that it has made and exceeded goals to reduce CO\(_2\) emissions.\(^6\)

**Recycled Granite Seattle** diverts stone from the construction industry and recycles it into split stone tiles, pavers, fire pits and other manufactured products. The company states that its materials keep millions of pounds of waste out of landfills and are not processed with any chemicals. Recycled

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Granite Seattle products earn LEED points for new projects and renovations.\(^71\)

**Innovation and Research**

**Washington State University** researchers received a $1.5 million National Science Foundation grant in 2017 to develop guidelines for sustainable building in earthquake-prone areas. In collaboration with scholars at other universities, the Forest Products Laboratory and American Wood Council, these researchers test CLT structures and assess their sustainable impact. The Brelsford WSU Visitor Center is one of only a few buildings in the Pacific Northwest that currently include CLT materials.\(^72\)

**The University of Washington**, under the leadership of scholars like Indroneil Ganguly, also fosters research on building with CLT materials. Ganguly is an assistant professor at the UW School of Environmental and Forest Sciences and associate director of the school’s Center for International Trade in Forest Products.\(^73\) One of his studies published in 2017 forecasts that overall demand for CLT panels in the Pacific Northwest will increase to 6 to 12 million cubic feet annually by 2035.\(^74\)

**Think Wood** is an industry group that promotes the economic, environmental and societal benefits of using softwood lumber in building construction. The group highlights economic and scientific research related to building with CLT materials, and it coordinates with WoodWorks to provide assistance to wood building construction projects. Think Wood is funded by the Softwood Lumber Board.\(^75\)

**The Forest Products Laboratory** is the national research laboratory of the United States Forest Service. Employing 60 scientists in Madison, Wisconsin, the Forest Products Laboratory has partnerships across the country, including in Washington state.\(^76\) It has published research highlighting the

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73 University of Washington College of the Environment, Faculty: Indroneil Ganguly, 2018: [https://environment.uw.edu/faculty/indroneil-ganguly/](https://environment.uw.edu/faculty/indroneil-ganguly/).
75 Think Wood, About, 2018: [https://www.thinkwood.com/about](https://www.thinkwood.com/about).
76 USDA Forest Products Laboratory, About Us: [https://www.fpl.fs.fed.us/about/index.shtml](https://www.fpl.fs.fed.us/about/index.shtml).
structural and environmental benefits of building with CLT materials, and it has encouraged coordination among timber engineering players.77

Workforce and Educational Institutions

WoodWorks provides free technical support, training and resources related to the code-compliant design of non-residential and multi-family wood buildings. Its funding partners are the Softwood Lumber Board, the U.S. Forest Service and the British Columbia agency Forestry Innovation Investment. WoodWorks is also partnered with many private companies, such as Weyerhaeuser, to assist with construction projects.78 The group offers training and guidance related to construction with CLT materials.79

Washington State University, through the Voiland College of Engineering and Architecture, offers an array of undergraduate and graduate degrees related to innovating building materials. These include degrees in the areas of architecture, construction, civil engineering, environmental engineering and materials engineering.80 The institution states that most students studying these subjects are sought by employers even before graduation.

The University of Washington offers relevant degrees in architecture, built environments, construction, civil engineering, environmental engineering and forest sciences.81 Its College of Engineering has researched mass timber construction, and it has collaborated with other universities, WoodWorks and the National Science Foundation to test CLT structures and educate students on their benefits.82

80 Washington State University Voiland College of Engineering and Architecture, Schools and Departments: https://vcea.wsu.edu/departments/.
81 University of Washington, Degree Programs: https://www.washington.edu/students/gencat/degree_programsTOC.html (accessed May 29, 2018).
Policy and Government Support

New Mass Timber Construction Law. In March 2018, the Washington State Legislature passed Senate Bill 5450, which requires the Washington State Building Code Council to update its codes to account for mass timber products, including CLT. The new law will make it easier for developers to use sustainable building materials by adding more certainty to the permitting process.83

Demonstration Projects. In 2017, the Washington State Legislature approved allocating $5.5 million to the Department of Enterprise Services for the construction of 20 kindergarten through third-grade classrooms using CLT materials. These demonstration projects will take place in five school districts across Washington state, specifically in Mount Vernon, Seattle, Sequim, Wapato, and Toppenish school districts.84

Production Technical Assistance. In the 2016 Supplemental Capital Budget, the Washington State Legislature approved allocating $50,000 to the Department of Commerce to assist prospective CLT manufacturers in evaluating the potential market and determine necessary investments to manufacture CLT.85

Federal Support. According to Forterra, The Timber Innovation Act of 2016 was introduced in the 114th Congress to “accelerate the use of wood in buildings, especially tall wood buildings” over 85 feet in height by providing additional resources for research, technical assistance and a tall wood building competition.86 The bill was reintroduced in 2017, and as of May 29, 2018, it had been read twice and referred to the Committee on Agriculture, Nutrition, and Forestry.87

86 CLT Summit Brochure, 2016.
Key Target Opportunities

Water access, supply and management are and will continue to be critical issues across the globe. Population growth combined with continued industrialization, environmental degradation and the effects of climate change will spur demand for new methods, technologies and solutions for water resource management.

In this analysis, the water industry covers businesses in water engineering, operations, water and wastewater plant construction, equipment supplies and specialist water treatment chemicals to residential, commercial and industrial sectors of the economy. According to the water technology industry incubator PureBlue: 88

The Global Water Crisis can be turned into an economic development opportunity by creating a water innovation ecosystem that increases the efficiency, resilience and adaptive capacity of Washington’s water infrastructure. This can be realized by connecting and aligning players toward shared strategies, goals and outcomes.

In this report, four key themes are identified:

- **Potable water.** Growing stress on available water for human consumption due to population growth, competing uses and climate change.
- **Water treatment.** Improved methods for treating and reusing water, helping to address competing uses for water among residents, businesses and ecosystems.
- **Irrigation.** New methods and technologies for more efficiently using water, such as precision-based sprinkler systems and drip irrigation.
- **Surface water.** Including the growing need to manage stormwater runoff.

Macro Trends—Population Growth, Urbanization, and Global Food Supply

Several key global trends transcend all or near all focus areas with respect to water. These include population growth, concomitant urbanization, climate change-based disruptions to water sources and over use and depletion of aquifers.

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Population Growth and Urbanization

According to the United Nations Food and Agriculture Organization (FAO), the current food system is on track, in aggregate, to sufficiently supply the food required of the global population by 2050. However, the FAO predicts that “many regions will face substantial water scarcity [resulting in] increasing competition, which will constrain agricultural production and affect the incomes and livelihood opportunities of many residents in rural and urban areas.” The same report finds that despite important gains in the global food production system, agriculture will continue to be the largest user of water globally, “accounting for more than half of withdrawals from rivers, lakes and aquifers, and will need to become increasingly efficient.”

World population growth will be a significant stress on the global water supplies without concomitant improvements in water resource management. The global population increased at an annual rate of 1.3% between 1990 to 2017 (Exhibit 15). According to the United Nations Department of Economic and Social Affairs, between 2011 and 2050, the world population is expected to increase 33% from 7.0 billion to 9.3 billion. Meanwhile, food demand—a major source of water demand—will increase by 60%.


<table>
<thead>
<tr>
<th>Year</th>
<th>Population, Billions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>5.3</td>
</tr>
<tr>
<td>2000</td>
<td>6.1</td>
</tr>
<tr>
<td>2010</td>
<td>7.0</td>
</tr>
<tr>
<td>2020</td>
<td>7.8</td>
</tr>
<tr>
<td>2030</td>
<td>8.6</td>
</tr>
<tr>
<td>2040</td>
<td>9.2</td>
</tr>
<tr>
<td>2050</td>
<td>9.8</td>
</tr>
</tbody>
</table>


A significant share of this growth will be in urban areas. Between 1990 and 2016, the world’s urban population increased 78% from 2.26 billion to 4.03 billion.


91 Population after 2015 is forecasted based on medium fertility variant.
billion (Exhibit 16). According to the United Nations, the continuous robust growth of urbanization will result in 6.3 billion urban residents by 2050. This growth in urban populations will require larger and more robust systems for managing solid waste, potable water distribution and stormwater management systems.

The World Bank projects that the urban population in Africa will quadruple by 2037, resulting in a large-scale increase in wastewater production. However, half of the urban infrastructure needed by African cities by 2035 has yet to be built. This scenario may offer opportunities for innovative water management solutions, such as integrated urban water management.

![Exhibit 16. Urban Population, World, 1990-2016](image)


### Diminishing Water Supplies

As regions of the world become more populous and industrialized, water supplies are becoming increasingly stressed. An estimated one in three people lives in a country that faces a nationwide water crisis (which leaves out many people struggling with water supply in countries like the USA and Australia, who do not face nationwide crisis). Less than 5% of people in the world live in countries with more water today than 20 years ago (all in countries in Eastern Europe plus Germany).  

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• **Water use efficiencies.** According to the United Nations, water-use efficiency improvements are expected to address a projected 40% gap between water demand and supply by 2030.

• **Agriculture water demand.** Globally, roughly 70% of freshwater withdrawals came from agricultural water consumption and drainage. According to the Food and Agriculture Organization of the United Nations, 90% of total agricultural water consumption came from the majority of least developed countries. By 2050, the global agricultural water consumption is anticipated an 20% growth without efficiency improvements.

• **Municipal water systems**, providing driving water, sanitation, hygiene and other water-related household needs, account for roughly 11% total freshwater withdrawals (Exhibit 17).

Exhibit 17. Global Freshwater Withdrawals, Consumption and Wastewater Production by Major Water Use, circa 2010

![Exhibit 17](image)


• **Industrialization and water demand.** Industrialization creates a strong need for more robust and scalable water treatment technologies to treat industrial waste water. According to the Organization for Economic Co-operation and Development, water consumption by the manufacturing sector is projected to increase 400% by 2050.  

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Potable Water

Providing access to clean drinking water is one of the world’s leading challenges, with strong connections to economic development, political rights and public health. According to the United Nations Millennium Development Goals, 2.6 billion people gained access to improved drinking water between 1990 and 2015. However, hundreds of millions of people remain without a clean water source close to their homes. In the United States, 1.6 million people reported in 2014 that they lacked access to either a toilet, a tub, a shower or running water.

Several global organizations and charities are devoted to bringing these numbers down, particularly in sub-Saharan Africa, Southeast Asia and Southern Asia. PotaVida, based in Seattle, Washington, collects field data from water-unstable regions and creates technical solutions in the form of solar purifiers. Splash, a nonprofit also located in Seattle, serves children living in urban poverty across Asia and Africa with water filtration systems and durable drinking stations. To date, Splash serves 403,365 children every day through international safe drinking water projects.

Private technology companies in Washington state are also involved in the global effort to improve drinking water access. In 2015, billionaire philanthropist and Washington resident Bill Gates famously profiled a machine capable of treating human waste and producing from it clean drinking water. Janicki Bioenergy, part of the Skagit County engineering firm Janicki Industries, is the company responsible for creating this technology. With funding from the Bill & Melinda Gates Foundation, Janicki brought a treatment machine to Dakar, Senegal, in 2015 to pilot its potential in bringing drinking water to those who need it most.

Whether it be fostered by venture philanthropy, like that of the Bill & Melinda Gates Foundation, or economic prospects, innovation in potable water technology is strong in Washington state yet has room for growth.

Water Treatment

Wastewater treatment refers to the process of removing contaminants and undesirable particulates from domestic, industrial, and polluted waters in order to safely return to the environment or for drinking, irrigation, industrial, and other uses.

Today, wastewater is considered a raw product rather than a waste product. Examples of clean technologies and/or sustainable practices in waste water treatment include the following:

- **Bioreactors.** A device containing bacteria and microorganisms is placed within a water body. It is usually equipped with separators linked to sequential tanks and a mechanical separator aimed at accelerating the splitting of liquid water from biosolids.

- **Biofiltration.** In biofiltration, some selected species of bacteria and microorganisms are grown on a biofilter to form a biofilm. It is commonly used in the application for removal of heavy metals from industrial wastewaters.

- **Bioremediation.** A process that employs living microorganisms to remove and neutralize pollutants and hazardous species from contaminated wastewater sites to yield less toxic or nontoxic materials.

- **Electrowinning.** In electrowinning, a current is passed between two electrodes immersed in an electrolyte solution, from which heavy metals including copper, nickel, silver, gold, cadmium, bismuth, cobalt and others can be recovered from wastewaters.

- **Electrocoagulation.** Similar to electrowinning, the electrocoagulation also uses an electric current to remove contaminants from wastewaters.

Global Market for Waste Water Treatment

According to an industry report by Hexa research,\(^{101}\) the global water and wastewater treatment market size was valued at $478.2 billion in 2016 and is expected to maintain strong growth over the next few years. This is due to population growth, the effects of climate change and increasing industrial activities. Specifically, the municipal water & wastewater treatment market is expected an 3.9% annual growth rate through 2025.

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There are three types of markets generally considered in water and wastewater treatment market: 1) Chemicals; 2) Treatment Technologies; and 3) Equipment & Services. According to Hexa:\footnote{\textit{Water and Wastewater Treatment Market Size and Forecast, By Type (Chemicals, Treatment Technologies, Equipment & Services), By End Use (Municipal, Industrial) And Trend Analysis, 2014 – 2025, Hexa Research, 2017.}}

- Chemical-based water & wastewater treatment was valued at $14.9 billion in 2016. Due to the stress on recycling and reuse of water, the use of corrosion & scale inhibitors chemicals is anticipated to grow substantially.
- The market for related technologies is projected to grow 4.2% per year through 2025.
- Equipment & services constitutes 85.8% of the overall market.
- Industrial wastewater is projected to double by 2025, support a 50% increase in industrial wastewater treatment.\footnote{\textit{The United Nations World Water Development Report 2017, The United Nations, 2017.}}
- According to the 2017 United Nations World Water Development Report, roughly only one tenth of all irrigated land across the globe is irrigated with treated wastewater, the remainder using unsafe untreated irrigated water.

\textbf{Key Foreign Markets}

- Middle East region has been investing heavily in water treatment technology, such as Multi-Stage Flash (MSF), Reverse Osmosis and Multi Effect Distillation (MED) used in desalination process. The market in the region is expected to grow 4.5% annually, driven by increased disposable income and infrastructure investments. In 2016, Saudi Arabia’s municipal wastewater treatment market reached $4.69 billion.\footnote{\textit{Water and Wastewater Treatment Market Size and Forecast, By Type (Chemicals, Treatment Technologies, Equipment & Services), By End Use (Municipal, Industrial) And Trend Analysis, 2014 – 2025, Hexa Research, 2017.}}
- The Asia-Pacific market accounted for 43.9% of the wastewater treatment market in 2016.\footnote{\textit{Water and Wastewater Treatment Market Size And Forecast, By Type (Chemicals, Treatment Technologies, Equipment & Services), By End Use (Municipal, Industrial) And Trend Analysis, 2014 – 2025, Hexa Research, 2017.}}
- According to the Organization for Economic Co-operation and Development, in Europe and North America, there are significant challenges to meet infrastructure needs as the water supply and
sanitation tariffs are too low when compared the costs of operation and maintenance of the services.\textsuperscript{106}

- According to the United Nations 2017 World Water Development Report, the increase in investment needed for wastewater treatment in Latin America is 64%, AND $33 billion in the Caribbean by 2030.

**Domestic Market**

In 2010, investment in wastewater treatment in the U.S. reached $88.5 billion.\textsuperscript{107} According to the American Society of Civil Engineers, by 2040 only $25.2 billion out of a projected $138.1 billion in needed wastewater treatment investments will be made, based on current spending levels (Exhibit 18).


<table>
<thead>
<tr>
<th>Year</th>
<th>Funded</th>
<th>Unfunded</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>$18.3</td>
<td>$47.9</td>
</tr>
<tr>
<td>2020</td>
<td>$20.4</td>
<td>$48.1</td>
</tr>
<tr>
<td>2040</td>
<td>$25.2</td>
<td>$112.9</td>
</tr>
</tbody>
</table>

Sources: American Society of Civil Engineers, 2011; Community Attributes Inc., 2018.

- According to the U.S. Environmental Protection Agency, the estimated investment needed to meet the country’s wastewater infrastructure needs is now $271 billion, 52% of which is for combined sewer overflows correction, the rehabilitation and replacement of existing conveyance systems and the installation of new sewer collection systems.

**Irrigation**

Irrigation is old technology with new, innovative improvements emerging today. Conventional irrigation and sprinklers consume a great deal of freshwater, dwarfing other water uses and it can result in water logging of


\textsuperscript{107} The Failure to Act: The Economic Impact of Current Investment Trends in Water and Waste Treatment Infrastructure, American Society of Civil Engineers, 2011.
crops and an unsustainable buildup of salts in irrigated land. In 2010, 64 percent of all water withdrawn in Washington State was used for agriculture irrigation.\textsuperscript{108} Making significant improvements in water conservation, then, requires a focus on agricultural uses.

Fortunately, there exists a close relationship in irrigation between the economic goals of farmers and environmental conservation. Farmers benefit from making their water use more efficient and less costly, and the environment benefits from sustainable practices that recognize water as a limited resource. Companies and research centers worldwide, including in Washington state, show optimism in innovating irrigation techniques. A few major trends are emerging.

Drip irrigation is the practice of applying small amounts of water uniformly across an agricultural area, close to the roots of crops. By delivering water directly to their crops’ roots, farmers can reduce runoff and evaporation. This saves them money and requires less water in total. Drip irrigation systems involve many pieces of equipment with potential for advancing technology, including valves, filters, emitters, pipes and drip tubes.\textsuperscript{109}

Solar-powered irrigation is another modern watering technique, in which pumps used for the transport of water are equipped with solar cells. The energy generated by these solar cells powers the pump, driving the water’s passage from its source through tubing and across the irrigated land. With only a direct orientation toward the sun, this technology can irrigate land without draining the power grid or requiring other electrical lines around irrigated crops.\textsuperscript{110}

Techniques like drip and solar-powered irrigation are being used in areas ranging from Walla Walla, Washington,\textsuperscript{111} to rural parts of India.\textsuperscript{112} More research and innovation will make them more cost- and resource-efficient.


\textsuperscript{111} USDA, \textit{Micro-irrigation System Conserves Water and Expenses for Vegetable Farm}, \url{https://www.nrcs.usda.gov/wps/portal/nrcs/detail/or/home/?cid=nrcs142p2_046086}.

Surface Water

Stormwater management is a significant challenge, both domestically and internationally, particularly among cities with older conveyance systems.

Global Market

In China’s large cities, urban flooding due to groundwater over-extraction and waterway degradation has proven to be a major problem. In response, the government has unveiled a new ‘sponge city initiative’ to develop and install permeable surfaces to absorb rainwater. Its goals are lofty: for 80 percent of urban areas to absorb and reuse 70 percent of rainwater. According to CNN, the initiative faces two challenges.\(^{113}\)

First, local governments in China lack expertise in effectively coordinating and integrating the complex activities required for the ‘sponge cities.’ Second, they are constrained financially. Should China loosen its restrictions and incentivize more private investment from overseas, companies and researchers in states like Washington could become key players in this market, like Herrera Environmental Consultants, Inc. who led a planning effort in the city of Zhenjiang.\(^{114}\)

‘Sponge cities’ and green infrastructure projects are taking root in countries other than China as well. For example, Berlin, Germany, is also making its paved streets more absorbent,\(^{115}\) and Philadelphia is now in the seventh year of a 25-year project designed to reduce its sewer outflows by 85 percent. Projects like these involve outfitting streets and sidewalks with runoff-capturing materials, planting urban gardens and modernizing sewer systems.\(^{116}\)

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Domestic and Local Markets

- In Washington state, pollution from stormwater sources accounts for one-third of all polluted water.\textsuperscript{117}
- During rainstorms, twenty-three types of pesticides are found in Puget Sound streams, five of which have concentrations higher than acceptable levels for aquatic life.
- Since 1980, more than 45,000 of Puget Sound’s 140,000 acres of commercial, certified shellfish growing areas closed or partially closed for harvesting due to the water pollution. Meanwhile, more than half of all salmon and steelhead stocks in Puget Sound are considered unhealthy to eat.
- Sixty-five percent of estuary miles in Washington state have temperatures exceeding state water quality standards; 57 percent of stream miles in the Puget Sound lowlands exceed state water quality standards for fecal coliform bacteria.
- Every one-inch of rain or snow melt will cause 748 gallons of stormwater runoff from a 1,200 square-foot roof and 27,000 gallons of stormwater runoff from a one-acre parking lot (Exhibit 19).\textsuperscript{118}

Exhibit 19. Annual Stormwater Runoff Volume, Washington State

<table>
<thead>
<tr>
<th>Potential Runoff</th>
<th>1,200-square ft. roof</th>
<th>1-acre of pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch of rain or snow melt</td>
<td>748 gallons</td>
<td>27,150 gallons</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Annual Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seattle (37 in./yr)</td>
</tr>
<tr>
<td>Spokane (17 in./yr)</td>
</tr>
<tr>
<td>Olympia (51 in./yr)</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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</tbody>
</table>


Green Infrastructure Solutions and Leading Technologies

Clean technology in stormwater management has primarily focused on filtration, capture and reuse of stormwater to maintain or restore natural hydrologies. Examples include:

- Rain gardens (i.e., bio-retention).
- Stormwater filtration systems that remove pollutants.
- Stormwater detention and retention basins—the collection of stormwater and slowly releasing it at a controlled rate so that downstream areas are not flooded or eroded. Though this method is

\textsuperscript{117} \url{https://www.kingcounty.gov/services/environment/water-and-land/stormwater/introduction/stormwater-runoff.aspx}
effective for flood control, it has significant limitations for water quality treatment and for preventing impacts to stream systems.

- Street sweeping—though only 16 percent of Seattle’s surface area is streets, these surfaces contribute more than 40 percent of the pollution load in stormwater runoff. Street sweeping helps remove pollutants from streets and keep them out of storm drains.\textsuperscript{119}

- Permeable pavement—a specific type of pavement with a high porosity that allows rainwater to pass through it into the ground below. It helps reduce runoff and returns water to underground aquifers. It also traps suspended solids and pollutants, keeping them from polluting the water stream.

**Water Conservation and Infrastructure**

The existing U.S. water infrastructure system is old, inefficient and prone to breakage and leakages. According to the National Infrastructure Advisory Council (NIAC), the current aging water infrastructure accounts for roughly 240,000 water main breaks and between 23,000 and 75,000 sanitary sewage overflows per year.\textsuperscript{120} The NIAC has emphasized the gap between existing funding and the investment needed to restore water infrastructure to maintain current service levels ranges from between $400 billion to nearly $1 trillion in U.S.\textsuperscript{121}

The Congressional Budget Office estimated that between 2008 and 2014, the cost to maintain, operate and build water and wastewater infrastructure was more than $100 billion per year.\textsuperscript{122} Integrated water systems (interplay between drinking water for consumption and wastewater to water bodies) has been widely accepted as an efficient, more affordable, resilient and sustainable water use strategies. Utilities investing in water reuse and recycling must integrate their water and wastewater infrastructure operations.

According to the Washington State Office of Financial Management, over a 20-year period beginning in 2017, the total cost to expand and replace existing water infrastructure will sum to nearly $33 billion (\textit{Exhibit 20}).\textsuperscript{123}


\textsuperscript{121} A Northwest Vision for 2040 Water Infrastructure, Center for Sustainable Infrastructure at The Evergreen State College, 2017.

\textsuperscript{122}Public Spending on Transportation and Water Infrastructure, 1956 to 2014, Congressional Budget Office, 2015.

\textsuperscript{123} Washington State Office of Financial Management, Economic Analysis of Water Infrastructure and Fisheries Habitat Restoration Needs, 2017, Olympia, WA:
Trends in Water Technology and Water Economics

- **Costs of water efficiency improvements.** According to a United Nations report, the cost of water-use efficiency improvements is projected to cost $50-60 billion per year over the next 20 years,\(^ {124}\) half of which is expected to be comprised by private sector investments.

- **Gains from water productivity.** According to the same report, improvements in water productivity in irrigation will generate $115 billion (in $2011) in savings per year by 2030. Meanwhile, efficient water technologies, which may benefit over 100 million farmers in poverty, could generate a total net direct benefit of between $100 billion and $200 billion.

Economic Development Opportunities from Water Industries and Sustainable Practices

- **Multiplier impacts.** Each job created in local water and wastewater industries supports 3.68 secondary (indirect and induced) jobs nationally.\(^ {125}\) The 2016 United Nations World Water Development Report found that every $1 million investments in sustainable water

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\(^{125}\) U.S. Bureau of Economic Analysis, United States Conference of Mayors, 2018.
practices are estimated to generate 10 to 15 direct, indirect and induced jobs.

- **Losses from inadequate water.** According to the World Health Organization, the challenges of inadequate water, sanitation and hygiene (WASH) is associated with global economic losses of $260 billion every year. Though these challenges are costly to address, the estimated rates of return on water supply and sanitation investments could reach $3-34 for every $1 of investment.

- **Investment and job creation.** According to the Environmental Protection Agency, the level of investment required for stormwater management and water quality prevention in the U.S. is up to $188.4 billion. Such investment could generate $265.6 billion in economic activity, and 2.5 million jobs through direct, indirect and induced effect.126

- **Water industry employment.** An analysis from UNESCO-UNEVOC found that 80% of water industry employment comes from water supply and wastewater facility operations.127

- **Skilled labor shortages.** According to the World Health Organization, more than 80% of 67 countries that reported on systems operation and maintenance has a shortage of skilled labor and technicians in needs in rural sanitation.

Key Assets and Strengths in Washington State

**Leading Companies and Associations**

- **Nelsen Irrigation** designs, manufactures and sells irrigation products for agricultural and industrial applications. Based in Walla Walla, Washington, Nelson has more than 70 active patents on innovative sprinklers, nozzles and irrigation control devices.128 The company’s stated purpose is to satisfy the increasing demand for food and fiber while simultaneously protecting the world’s natural resources.129

- **Herrera Environmental Consultants, Inc.** is an employee-owned consulting firm focused in water, restoration, and sustainable development.130 The firm’s 100 staff members design projects in many areas of water resource development, including stormwater

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engineering, water quality analysis, flood management and hydrologic modeling.\textsuperscript{131} Herrera collaborates with both the public sector and private business.

- **HDR** is an architectural, engineering and consulting firm with nearly 10,000 employees and more than 225 offices around the world, 8 of which are in Washington state.\textsuperscript{132} In 2015, the company was awarded a work order with King County, Washington, for the research of sustainable products and materials used for wastewater facilities. Another example of HDR’s local work was sustainably upgrading primary sedimentation basins of the Budd Inlet water treatment plant in Olympia, Washington.\textsuperscript{133}

- **Parametrix** is an employee-owned engineering firm based in Washington state that provides multidisciplinary services in transportation, environmental compliance and water resources.\textsuperscript{134} The firm completes projects for private companies, public agencies and tribal governments. With water, Parametrix designs systems for power stations, flood control, stormwater, wastewater and drinking water management.\textsuperscript{135} For example, the company restored Donkey Creek and its estuarine habitat for Gig Harbor, Washington, in 2014.\textsuperscript{136}

- **Janicki Industries** is an engineering and manufacturing firm that produces parts and tooling for a broad set of industries. Located in Sedro-Woolley, Washington, the company has multiple facilities in Skagit County.\textsuperscript{137} One of its products, the Janicki Omni Processor, is a waste-to-energy system that converts wet waste to electric power and reusable water. Technologies like this showcase Janicki’s focus on creating cost-efficient and sustainable products.\textsuperscript{138}

- **The Washington State Ground Water Association** is a technical and professional group leading many companies with activities related to groundwater. The group’s stated goals are to protect access to

\textsuperscript{131} Herrera, Services: https://www.herrerainc.com/services/.
\textsuperscript{132} HDR, History, 2018: https://www.hdrinc.com/about-us/history.
\textsuperscript{133} HDR, Sustainability + Corporate Responsibility, 2016 (pp. 5 and 90): https://www.hdrinc.com/sites/default/files/2017-05/2016-hdr-sustainability-corp-responsibility.pdf.
\textsuperscript{134} Parametrix, Who We Are: About Parametrix: https://www.parametrix.com/who-we-are/about-parametrix.
\textsuperscript{135} Parametrix, What We Do: Water Resources: https://www.parametrix.com/what-we-do/water-resources.
\textsuperscript{137} Janicki Industries, About Us: https://www.janicki.com/about-us/.
groundwater, educated its members on the latest technology in the industry, and provide information on groundwater to legislators and the public. It is a state affiliate of the National Ground Water Association.139

Innovation and Research

- **Washington Stormwater Center** is a technical resource and research center in partnership with the City of Puyallup, Washington State University and the University of Washington. It was created by state legislative action to provide numerous services, such as developing innovative and cost-effective solutions to runoff pollution, coordinating with the Department of Ecology to administer stormwater treatment and consulting with both public and private interests.

- **PureBlue** is a Seattle-based incubator for startup technology and research companies in the water industry. It provides these companies with business resources, data and other support, and it receives solution requests from public and private entities. PureBlue leverages its team of 7 employees and its network of technology experts to recommend strategies in areas of municipal drinking water, wastewater and stormwater, as well as desalination and other water challenges.140

- **The Center for Urban Waters** is a research center focused on developing sustainable ways to restore and protect urban waterways. Its environmental scientists, analysts and engineers bring diverse backgrounds together to maintain a stormwater technology certification program and connect innovators to potential users.141 The Center also states that it is home to Washington state’s Clean Water Technology Innovative Partnership Zone, a collaboration among businesses, the Tacoma/Pierce County Economic Development Board, the City of Tacoma, the Port of Tacoma, the University of Washington and others aiming to catalyze water technology businesses in Tacoma.142

Workforce and Educational Institutions

- **The Pacific Northwest Section of the American Water Works Association** was founded in 1927 and provides leadership to the

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141 Center for Urban Waters, *About the Center*, 2018: [https://www.urbanwaters.org/about-the-center/](https://www.urbanwaters.org/about-the-center/).
drinking water profession in areas of water quality, water resource policy and water-related planning issues. The group provides its 3,000 members with trainings, professional certifications and conferences on infrastructure, regulations, water conservation and other topics.\textsuperscript{143}

- **The Evergreen Rural Water of Washington Association** is a nonprofit organization based in Shelton, Washington, with field staff across the state. The group is an affiliate of the National Rural Water Association and its stated mission is to provide free training and technical assistance to water and wastewater systems personnel. It works independently of state agencies, but it does collaborate with the Department of Health, Department of Ecology, USDA Rural Development, the Environmental Protection Agency, local health districts and other agencies. The group is funded by grants to combat regulatory and financial challenges faced by water systems in Washington state.

- **The Water & Environmental Center** was founded in 2007 at Walla Walla Community College. Closely tied to regional employers, the Center provides the community college’s Water Technologies & Management programs. Degrees offered in these programs include Irrigation Technology, Natural Resources Technology & Management and Watershed Ecology. Students who earn these associate degrees are able to transfer to a four-year university or move directly into the workforce as technicians in water quality, conservation, irrigation or biology. The Center also provides community and K-12 education opportunities.\textsuperscript{144} Graduates from the Water & Environmental Center have gone to work for employers such as Nelson Irrigation, Rock Creek Cattle Company and Walla Walla County.\textsuperscript{145}

- **Washington State University** offers undergraduate and graduate degrees in a broad range of sciences related to water. Within agriculture, the university offers degrees in agricultural biotechnology, agricultural technology, field crop management and turfgrass management. Within environmental sciences, there are degrees in ecosystems sciences, conservation sciences and natural resource policy. There is also a wide array of engineering degrees attainable by Washington State University students, and


\textsuperscript{144} Water & Environmental Center, History: http://watereducationcenter.org/about-us/history/history/.

specializations include environmental engineering and water resource engineering.\textsuperscript{146}

- **The University of Washington** is Washington state’s largest educational institution, within it existing multiple sources of special water-related degrees: the College of the Environment, the School of Environmental and Forest Sciences, the School of Marine and Environmental Affairs and the College of Ocean and Fishery Sciences. Students can work toward degrees in aquatic and fishery sciences, civil engineering, environmental management, hydrology and hydrodynamics, marine affairs and oceanography.\textsuperscript{147} Employers who seek University of Washington graduates with water-related degrees include BiOWiSH Technologies, Loki Fish Company and the National Park Service.\textsuperscript{148}

- **Whitman College** is a small yet nationally-recognized college in Walla Walla, Washington that offers degrees in water-related studies from a liberal arts perspective. These cover areas such as oceanography and environmental studies.\textsuperscript{149} Whitman College does not offer engineering degrees, but, like many of Washington state’s diverse educational institutions, it has prepared many of its students for science and engineering occupations such as in the water industry.\textsuperscript{150}

**Policy and Government Support**

- **New Streamflow Restoration Law.** In January 2018, the Washington State Legislature passed Engrossed Substitute Senate Bill (ESSB) 6091 in response to the Whatcom County vs. Hirst, Futurewise, et al. decision. Part of the new law will invest $300 million over the next 15 years in projects designed to improve streamflows and provide water to rural areas in 15 watersheds (Exhibit 21).\textsuperscript{151}

\textsuperscript{146} Washington State University, *Fields of Study*: \url{https://admission.wsu.edu/academics/fos/Public/index.castle}.

\textsuperscript{147} University of Washington, *Degree Programs*, \url{https://www.washington.edu/students/gencat/degree_programsTOC.html}.


\textsuperscript{149} Whitman College, *Departments and Programs*: \url{https://www.whitman.edu/academics/departments-and-programs}.


Exhibit 21. Areas Affected by 2018 Stream Restoration Law


- **Columbia Basin.** The purpose of the Odessa Groundwater Replacement Project is to replace groundwater from declining irrigation wells in the Odessa Subarea, reducing the risk of economic loss. Farmers and owners of irrigated land are eligible for replacement water. The total cost of the systems yet to be built is roughly $175 million in state, federal and landowner funds. The project is estimated to protect 3,600 jobs, $211 million in regional income and $630 million annually in the potato industry.\(^\text{152}\)

- **Lake Roosevelt.** Readily available water stored behind the Grand Coulee Dam is supplying a portion of the replacement water for farmers drawing on the declining Odessa subarea aquifer. Also, new water is being made available for cities and industries which apply. The project is estimated to add 35,000 jobs and $3 billion in economic value.\(^\text{153}\)

- **Kachess Lake.** The Washington State Department of Ecology and the Bureau of Reclamation have proposed the Kachess Drought Relief Pumping Plant to meet future demand for water in Eastern Washington.


Washington. The project would build a pump facility in Kachess Lake that would pump additional 200,000 acre-feet, or enough water to cover 200,000 acres in one foot of water, to prevent potential drought in the Yakima River Basin.\textsuperscript{154}

- **Yakima River Basin.** Numerous other projects are designed to quickly improve stream flows, prevent drought and secure water for farms, cities and industry in the Yakima River Basin. Together they will support what the Washington State Department of Ecology estimates as a $4.5 billion agricultural and food production industry.\textsuperscript{155}


Opportunities for Washington

Identification of potential opportunities for Washington state businesses, organizations, and communities is based on a comparison of targeted opportunities and alignment of existing assets. Opportunities are presented in Exhibit 22 below. The opportunities in some instances represent two or more of the industries reviewed in this report, such as the nexus between food production, energy, and water.
### Exhibit 22. Summary of Opportunities for Washington State in the Green Economy

<table>
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<th>Opportunity</th>
<th>Description and Key Observations</th>
<th>Illustrative Key Assets</th>
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| **Develop alternative and renewable energy systems and be a leading hub for R&D.** | • Demand for renewables is driven by multiple factors including: growth in population; increasing focus on resilience, especially because of more severe weather events; corporations increasingly demanding cleaner energy; aging infrastructure; and decarbonization.  
• Clean energy technologies are increasingly cost competitive. The significant decline in the cost of electricity from renewable energy technologies, especially wind and solar, has made power generation from renewable sources increasingly competitive with and less costly than fossil-based or nuclear power.  
• Much of the clean energy revolution will entail the intersection of energy and information technology, making Washington uniquely positioned for this opportunity.  
• Global investment in clean energy increased from $62 billion in 2004 to $334 billion in 2017. China continues to be a major source for this new investment; Washington already has strong economic and trade ties with China which could be leveraged. | Washington state has leading companies in the development and installation of wind and solar energy systems. The state is also a leading hub for research on renewables, led by Washington State University, PNNL, and the McKinstry Innovation Center.  
Strong government support for clean energy technology and business development, such as Clean Energy Fund and tax incentives and other incentives. |
| **Develop and export grid management systems and power storage technology.** | Electricity distribution and transmission systems require complex software and management solutions, as well as advanced metering technology. In all of these areas, Washington has a unique advantage, as home to leading companies, research & development, and allied industries able to develop necessary solution platforms. As the global energy market continues to embrace renewable energy sources, the management and storage of these sources will require new storage solutions, such as advanced batteries and associated energy management tools. | Leading companies that are already developing energy storage and management solutions and hardware, such as UniEnergy Technologies, Itron, Schweitzer Engineering, EnerG2, Demand Energy, and Group14 Technologies.  
Washington is also a hub for R&D in energy storage and smart grid, including research Washington State University, the University of Washington Clean Energy Institute, and PNNL. |
| Development of water resource management solutions that efficiently manage allocations across multiple uses. | • Food production, energy, and water (FEW) are closely intertwined in the Pacific Northwest and thus require integrated solutions to resource management.  
• Due to the impacts of climate change (such as drought) in other parts of the U.S., Washington may become more critical as a source of food production for the U.S. in the coming years, further stressing water supplies.  
• Efficiencies in water use and distribution across multiple uses, such as drip irrigation technology and household water use metering | • Washington State University  
• PureBlue, a technology incubator focused on water  
• Washington Stormwater Center  
• Center for Urban Waters  
• Janicki Industries, which recently developed a wet waste-to-energy converter and reusable water. |
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<td>New water infrastructure solutions developed and applied in Washington and exportable to other parts of the U.S.</td>
<td>Many water systems suffer from older infrastructure in need of replacement, but this can be improved through application of big data and metering technology to track the performance of each segment of a water infrastructure system. Washington is well-poised to support innovation in this space through its existing, robust tech industry.</td>
<td>Washington’s tech industry, including software and metering technology firms, availability of angel and venture capital, and tech incubators such as PureBlue.</td>
</tr>
</tbody>
</table>
| Development of water irrigation technology and conservation systems that can be applied in Washington and exported to other parts of the country and world. | Development of technologies that improve water usage efficiencies, such as drip irrigation and household water use metering systems. | Companies such as Nelsen Irrigation.  
Washington’s large agriculture sector in Central and Eastern Washington is a potential customer base for new irrigation and water conservation solutions. |
| Stormwater management solutions | Stormwater management is a challenge both in the developed and developing world. Countries such as China have been significant investments in managing stormwater flow in recent years and look to outside firms for expertise in systems design Washington is already home to several leading companies and organizations with expertise in stormwater management. | HDR, Parametrix, Herrera Environmental Consultants, |
| Revising building codes to support manufacture and use of cross-laminated timber and mass timber in Washington state. | Mass timber and CLT provide an economic opportunity for tree farmers and forest land owners to generate income through using otherwise waste forest byproduct, such as forest thinnings and tree tops, into a source material for building materials. Washington’s shuttered or underutilized lumber mills could be repurposed to support this industry, though with modifications to account for the technologies associated with mass timber and CLT products. | • Washington’s existing lumber mill facilities and forestry industry. • Companies that have recently started CLT production projects in Washington: Vaagen Brothers and Katerra. • Weyerhaeuser • University of Washington |
| Developing capacity for recycled building materials in Washington state. | Recent policy shifts in China may force solid waste to other parts of the world for processing and/or significantly reduce the amount of material that can be collected and recycled. This scenario may present an opportunity for Washington state businesses to develop in-state processing facilities to recycle solid waste materials that can be repurposed for building materials, such as particle board and tiling. However, further efforts would be needed to standardize the recycled compositions of these materials to meet LEED building standards. | Several Washington companies are already engaged in recycled building materials. These include Kiptech, PaperStone, and Bedrock Industries, to name just a few. |