Innovation and Technology in the Era of Climate Change

Periodically, major new forces dramatically reshape the business world—as globalization and the information technology revolution have been doing for the past several decades. Climate change, in its complexity and potential impact, may rival them both. While many companies may still think of global warming as a corporate social responsibility issue, business leaders need to approach it in the same hard-headed manner as any other strategic threat or opportunity.

- Harvard Business Review, **Climate Business | Business Climate**

In the wake of the 1973 Arab oil embargo, a young research scientist at Mobil Exxon began work on fossil-free energy alternatives, particularly for use in cars. His research into superconductors led him to an energy-rich material which, when paired with metallic lithium, created a lightweight battery with 10 times as much energy potential as the conventional lead-acid battery\(^1\). In October 2019, the scientist, M. Stanley Whittingham, was one of three winners of the Nobel Prize in Chemistry for pioneering work on lithium ion batteries which today power our world, from cardiac defibrillators to electric cars.\(^2\)

While “clean” technology has boomed since 1973, linking the requisite scale of climate-mitigating technological solutions with a compressed timeline is imperative to constrain warming to the 2°C target while sustaining economic growth. At present, the atmosphere has the capacity to absorb only \(\times 800\) GT more carbon; with a current global emission rate of 40GT carbon per year, we have fewer than 20 years before we reach a 2°C temperature rise.\(^3,4\) Much like the U.S.’s efforts in the 1960s to land a man on the moon in less than one decade, the commitment to rein in global warming will require both a committed effort to develop technologies that are yet to be conceived, and the prioritization of funding to facilitate them.

According to Dr. Arun Majumdar of Stanford University’s Precourt Institute for Energy, “there has never been a more exciting time than now” to capitalize on the investment in a carbon neutral world, with a growing need for “start-ups, scale ups, visions, execution, talent and capital, for first adopters, new solutions, new markets, new technologies to take calculated risks, learn from others’ mistakes, forge partnerships, have flexibility, and agility”. This 21st century quest, he says, is “brimming with research and business opportunities to find new sources of zero- and low-carbon energy, including wind, solar, and nuclear; electric vehicles, heating systems, as well as technology to make buildings, appliances, and manufacturing more energy efficient.”

\(^3\) https://cedmcenter.org/tools-for-cedm/informing-the-public-about-low-carbon-technologies/
\(^4\) Majumdar, Arun. Precourt Institute for Energy, Stanford University; Founding Director of the Advanced Research Projects Agency, 2009-12
There are three general areas of action that can help to minimize the risks U.S. businesses currently face from climate change: business adaptation, investor adaptation, and private sector response.

**Clean Energy**

Energy use and consumption produces 72% of all GHG emissions.\(^5\) Replacing carbon-based power generation with electricity, including in the generation of electricity itself is a significant step toward carbon neutrality.

Since 2008, U.S. solar capacity has grown from 1.8 gigawatts to an estimated 62.5 gigawatts (GW) in 2019 — enough to power 12 million American homes.\(^6\) Costs for wind and solar power generation have dropped dramatically over recent years and are expected to continue to drop due to technical innovation and scaling.\(^7\)

At present, unsubsidized levelized cost of energy (LCOE) for utility-scale onshore wind and solar generation has dropped to be comparable to or below most other generation technologies in much of the world. Offshore wind generation has become the world’s lowest-cost energy source ($30-$60/MWh), well below the cheapest fossil fuel, natural gas ($42-$78/MWh). However, conventional source electricity production accommodates demand cycles where wind and solar require storage to even out distribution incompatibilities. Adding the costs of storage makes renewable generation-plus-distribution more expensive as a sole source of power, but this too has changed dramatically over recent years as storage device costs have dropped and capacities have increased. Battery-pack costs have dropped to less than $230 per kilowatt-hour in 2016, down from $1,000 per kWh in 2010.\(^8\) However, to meet the goal of providing 100% of US energy needs at today’s rates, the energy-capacity costs for renewables plus storage systems have to fall to about $20 per kilowatt hour.\(^9\)

It is important to note that the simple introduction of wind and solar generation has lowered overall energy consumption costs where a significant portion of generation relies on renewables. At present, three quarters of the top 20 solar and wind generation states in the US have electricity prices below the national average.\(^10\)

For tech giants Apple, Facebook and Google, making the switch to renewables makes good business sense: relying on renewable energy averts billions of dollars in potential product, service and

\(^5\) https://www.e-education.psu.edu/geog438w/node/531


productivity losses in the event of climate-induced weather disasters. Apple has converted 100% of its operations to renewable electricity, while Google similarly reports that it has matched 100% of its operations electricity with renewable energy, citing its optimal location to access renewables as a major factor. All three companies have built high-capacity data centers in Oregon: Apple powers up with a 56 megawatt solar plant developed by Portland-based Avangrid Renewables, while Facebook’s Prineville data center relies on three enormous solar farms, and Google’s data center in The Dalles purchases 100% renewable energy. Google cited wind power, at 2 cents/kwh, as the lowest cost option and an important budgeting bulwark against fuel price swings.

Energy Storage Options
Energy storage facilitates the integration of renewable energy resources into energy. Electric companies are using more energy storage: Investment in advanced energy storage is growing rapidly, with an estimated 280 megawatts (MW) installed in 2017 alone, up 400 percent from 2014, and another 338 MW of battery storage capacity was installed in 2018. New and more creative storage solutions must also be added to even out distribution fluctuations.

- **Tesla’s** rechargeable lithium-ion battery stationary energy storage systems were launched in 2015. The Powerwall works with or without solar for home energy storage, time of use load shifting, backup power, and off-the-grid use. During outages, the battery automatically powers on like a generator. The cost of the battery is roughly $7,800. The commercial version, the Powerpack, has a wider range of features that can assist local utility companies manage peak shaving, load shifting, backup power, demand response, microgrids, renewable power integration, frequency regulation, and voltage control. In May 2019, Vermont’s Green Mountain Power launched a pilot program for home consumers, leasing the Powerwall to customers for $30/month. The utility designed an innovative protocol to use the battery for a power meter tracking home energy use.

- **Thermal Storage:** Thermal-powered storage technologies may offer another flexible and reliable power alternative to back up the grid. Excess energy produced during peak sunlight is stored in the form of molten salt or other materials – and can be used to produce steam that produces turbine-driven electricity. Thermal storage facilities can use ‘off-peak’ electricity rates which are lower at night to generate ice, which can be used by a building’s cooling system to reduce energy demand during the day. Malta, Inc. is one such company whose molten salt thermal technology operates like a heat pump, enabling energy to be stored from any power generation source in any location – be it wind, solar, or fossil fuels – to help smooth out grid volatility.

---

11 [https://www.opb.org/news/article/google-says-it-will-consume-only-renewable-energy/](https://www.opb.org/news/article/google-says-it-will-consume-only-renewable-energy/)
14 [https://www.tesla.com/powerwall](https://www.tesla.com/powerwall)
15 [https://www.tesla.com/powerpack](https://www.tesla.com/powerpack)
17 [https://www.maltainc.com/](https://www.maltainc.com/)
Healthy Forests, Healthy Fuels
Aviation’s environmental impact is significant because aircraft engines emit carbon dioxide, water vapor, hydrocarbons, carbon monoxide, nitrogen oxides, sulfur oxides, and nonvolatile black carbon which interact among themselves and with the atmosphere.\(^{20}\) Colorado-based **Red Rock Biofuels** is building a jet and diesel fuel refinement facility in Lakeview, OR, that converts woody biomass and agricultural waste into 15 million gallons of usable fuel per year.\(^{21}\) Red Rock has secured contracts with FedEx, Southwest Airlines and the military.\(^{22}\) The company chose Lakeview because of its railroad access and regional abundance of forest fuels and wood biomass waste products. The first refinement facility of its kind in the world because of its use of biomass, the Red Rock plant is intended as a blueprint for keeping forests healthy and resilient while advancing the use of clean fuels.

At the **Malheur Lumber Company** in John Day, a new $15 million “torrefaction” (using high heat and low oxygen) facility named **Restoration Fuels**, will roast, then compress, biomass into briquettes that will be used in lieu of coal in electric power plants.\(^{23}\) Partnering with U.S. Endowment for Forest Communities and the Malheur National Forest, Malheur Lumber will process a sustainable supply of biomass from forest restoration work in the Forest into 80,000 to 90,000 tons of briquettes per year.\(^{24}\)

Torrefaction is also used to create biochar, a carbon-rich soil additive that can boost agricultural production up to 6.5% percent due to enhanced nitrogen stores, improved soil structure, better water retention, reduced nutrient leaching and a lower levels of nitrous oxide, which help improve air quality.\(^{25,26}\) Oregon State University is currently studying the benefits of biochar to reduce wildfire hazards while sequestering carbon and increasing dryland farming productivity.\(^{27}\)


\(^{27}\) https://www.forestry.oregonstate.edu/research/biochar
In 2015, the Oregon USDA Natural Resources Conservation Service (NRCS) awarded a Conservation Innovation Grant to the South Umpqua Rural Community Partnership for a pilot program called “On Farm Production and Use of Biochar for Composting with Manure” with the participation of a dozen farmers in Douglas, Josephine and Jackson counties. The project’s objective is to help transform manure and woody debris, into a high-quality compost for agricultural use; farm soils high in organic matter benefit from improved pastures and increased crop production.

**Dual Use Farming**

Oregon State University’s Rabbit Hill solar array farm is the research site for a study in agrivoltaics, also known as dual use farming. The findings from a recent study funded by the National Renewable Energy Laboratory (NREL) determined that farmland like Oregon’s semi-arid pastures coupled with wet winters are ideal locations for dual use farming, as evidenced by a documented 90% gain in crop productivity during Summer 2015. The solar panel array provides shade for biomass which increases soil water retention and water efficiency; the potential exists for the panels to also provide shade for livestock as well. More dramatic is OSU researchers’ finding that only dedicating only 1% of farmland to agrivoltaics could meet global energy demand. Another side benefit of dual use farming is that it may be a solution to the inherent tug-of-war between agriculture and renewable energy over land use.

**A Win-Win-Win for Farmers, Truckers and the Environment**

Threemile Canyon Farms in Boardman, Oregon is the largest dairy farm in the state, home to over 68,000 head of cattle, including 33,000 dairy cows. In 2009, Threemile installed a biodigester that captures and transforms the methane from its herd’s manure into gas which it then sells to PacifiCorp for electricity generation. Digesters also eliminate close to 99% of the pathogens in both manure and wastewater and digested fiber by-product can be used as animal bedding and fertilizer. This year the farm joined forces with investment firm Equilibrium Capital, an Oregon benefit company, to expand and retrofit the digester to produce a natural gas product that will be piped to California to make cleaner burning fuel for trucks.

---

**Hydropower**

Oregon communities are also benefiting from several micro-hydropower projects around the state that improve water quality and maximize water conservation all while generating clean, renewable energy.\(^{35}\) With low impact micro-hydropower systems, water spins turbines attached to generators to produce about 100 kilowatts of energy, substantially offsetting electricity costs. Not only is irrigation water free of fish, channeling it through hydroelectric generators doubles its value to farmers.\(^{36}\) The Farmers Irrigation District in Hood River supplies the agricultural powerhouses that provide apples, pears and wine grapes nationwide and generated upwards of $260 million in annual revenue.

Climate change has wreaked havoc on Hood River in the last several decades, from intense flooding resulting in intense sedimentation and severely impaired water quality, to record low flows as a result of drought conditions in 2015.\(^{37}\) The FID capitalized on a loan from the Clean Water State Revolving Fund to convert its irrigation canals to a piped, pressurized irrigation system that better regulated water conservation and water delivery to crops; by linking the new system with two existing hydroelectric stations, the District benefits a $200,000 revenue windfall and 26 million kilowatts of electricity annually. The environment has been the biggest beneficiary, with over 6 billion gallons of water conserved annually, nearly 8,000 trees planted in riparian areas, and 2,000 supplemental water rights acres relinquished and left instream for endangered fish.\(^{38}\)

In Wallowa County, the implementation of gravity-fed hydro turbine situated in Wallowa Lake State Park, will provide 134 megawatts of electricity valued at $15,000 which will significantly offset the $20,000 price tag to operate the water pump and sewer lift station/pump at the head of Wallowa Lake. Wallowa Resources Community Solutions spearheaded the feasibility study, and worked with a consortium of local stakeholders including the Farmer’s Conservation Alliance, the Natural Resource Conservation Service, Nez Perce Tribes, Anderson Perry & Associates and Black Rock Consulting.\(^{39}\) The project was funded by a $60,000 grant from PacificPower’s BlueSky program and an $80,000 incentive package from Energy Trust of Oregon.


\(^{38}\) EPA, 2016.

\(^{39}\) Chieftain, Jennifer Hobbs, 2018.
A Sea Change in Clean Energy

The wave energy potential of the coastal areas of the U.S. could supply energy to meet up to 15% of the country’s annual demand. For Oregon, the projected economic value of tapping wave energy could reach $2.4 billion a year and create as many as 13,000 new jobs.40

- **Pacific Marine Energy Center (PMEC):** PMEC is funded by the Department of Energy Funded Research in partnership with University of Washington, Oregon State University and the University of Alaska Fairbanks. It is focused on advancing marine renewable energy, “working closely with marine energy technology developers, academic and National Laboratory researchers, coastal community members, ocean users, federal and state regulators, and other government officials to address key challenges in the sector and accelerate its emergence.”41

- **Oregon State University’s PacWave South Project:** With help from the US Department of Energy, OSU is currently planning to develop a wave-energy testing facility off the coast of Oregon, enabling energy developers to test wave energy converters in an effort to access an as-yet-untapped source of clean energy.42

- **Vigor Industrial:** This Portland, Oregon-based industrial company completed production of a first-of-its kind renewable wave energy device known as “OE 35 buoy” with a potential rate capacity of up to 1.25 megawatts in electrical power production. Vigor partnered with Irish company Ocean Energy to construct the buoy which has the potential to reduce CO2 emissions by over 3,600 tons annually; deploying multiple buoys as a utility-scale wave farm of 100 MW could reduce up to 180,000 tons of CO2 in a full year while powering up to 18,750 homes.43

Hybrid Energy

**Vigor Industries** also recently contracted with Washington State Ferries to produce five 144-car Olympic-class, hybrid-electric ferries. The ferries feature an energy-efficient hull with less drag and a small wake that will minimize the potential for shoreline erosion and turbidity. The fleet will eventually be capable of 100% electric operation on most routes. With an anticipated 60 year life span, these innovative ferries will lower carbon emissions by 94% and significantly reduce operating costs for the ferry system.44

Carbon-Neutral, Hydrogen-Powered Vehicles

In Oregon, the Invent Oregon Collegiate Challenge seeks out next-gen inventors and entrepreneurs by providing student teams with creative problem solving to take an idea with the potential for positive impact through all the stages of invention prototyping and commercialization. In June 2019, a team from

---

41https://www.pmem.us/mission-organization
Portland State University, in collaboration with Turner Automotive, developed a conversion kit that can transform an existing gasoline-burning vehicle into a carbon-neutral, hydrogen-powered vehicle. The kit doesn’t modify any existing components in the car, allowing a 1996 Honda Accord to run entirely on zero-emission energy.\(^{45}\)

**Nuclear Power**

NuScale, a Portland-Oregon based company is reinventing the nuclear reactor. While working to remain a relevant and carbon-free power source, replacing fossil fuels, reducing greenhouse gas emissions, and taking up significantly less space than the average nuclear power plant, NuScale has designed a small modular reactor that would take up 1% of the space of a conventional reactor.\(^{46}\)

**Building Blocks for Sustainable Building**

**Mass Timber**

According to the Environmental and Energy Study Institute, the U.S. residential and commercial building sector is responsible for upwards of 39% of greenhouse gas emissions per year. Including lighting, heating, cooling, and appliances, residential and commercial buildings use 40% of the total electricity usage in the country, almost a third of which is generated by coal burning power plants.\(^{47}\) The Intergovernmental Panel on Climate Change (IPCC) states that “reducing the energy embodied in building materials provides further energy and GHG savings, in particular through increased use of bio-based materials and wood construction.”\(^{48}\)

Developed in Europe over twenty-years ago, cross laminated timber (CLT) — commonly referred to as “mass timber” — is considered by a growing body of environmental, architectural, construction and policy leaders to be an effective sustainable solution to reduce the building industry’s carbon footprint. Using logs smaller than 9" in diameter that are harvested from sustainably managed forests, CLT panels are made of five layers of wood glued at right angles to one another under high pressure to form solid panels.\(^{49}\)

According to the Urban Land Institute, among CLT’s benefits are that it:

- Has a lower carbon footprint than steel manufacturing, is renewable and, because it is incorporated within the building envelope, rates high in carbon sequestration.


• Is comparable to steel and concrete in structural performance, but with less than 20 percent of their weight, thus able to be maneuvered with smaller cranes.
• Thermally outperforms concrete and steel.
• Is earthquake-resistant
• Is prefabricated off site and shipped for “just-in-time” scheduling for greater cost efficiency, shortening construction schedules by up to 40% and potentially reducing construction loan interest and land carrying costs.\(^{50}\)

Both Washington and Oregon have revised their building codes to allow the use of CLT, and the International Building Code (IBC) has amended its code effective 2020.\(^{51}\) Previously, in Oregon, Code required buildings six or more stories to be constructed using steel or reinforced concrete\(^{52}\) -- the manufacturing for which use 80 percent more energy.\(^{53}\)

Oregon has positioned itself as a national player in the CLT market, with public and private investments supporting research production, and design with the added benefit of tapping into the forest products industry that has long been key to rural economies. Both Oregon State University and the University of Oregon have been awarded grants from the U.S. Department of Agriculture to “expand and accelerate wood products and wood energy markets”, with the added benefit of promoting forest health, reducing wildfire risk and costs of forest management; the grants match funds from business, university, nonprofit, and tribal partners.\(^{54,55}\) The two Oregon state schools collaborated to form the TallWood Design Institute (TDI), 17,500-square-foot lab constructed with CLT, where researchers from top U.S. wood products, engineering and sustainable design programs will focus on mass timber and structural wood products used to construct high-rise and other multi-story buildings. TDI will also perform fire-resistance testing, seismic and structural performance tests, and analyses of carbon and environmental impacts; it is part of the Oregon Forest Science Complex on OSU’s Corvallis campus.\(^{56}\)

Sierra Pacific donated $6 million to OSU’s forest science program and Oregon’s leading CLT firms, D.R. Johnson and Freres Lumber, are among the Institute’s partners.\(^{57}\) Freres Lumber was named one of Fast Company’s “Most Innovative Companies in 2019”.\(^{58}\)
Concrete
Concrete is the most widely used synthetic material in the world. The manufacturing of cement, a component of concrete, is responsible for 5% of global carbon dioxide (CO2) emissions: for every kilogram of cement produced, around the same amount of CO2 is released into the atmosphere. Researchers at universities and in private industry have been developing products that yield a concrete that meets or exceeds the strength and durability characteristics of concrete made from Portland cement.

- California company Calera seeks to replace limestone in concrete by using CO2 emissions as source material. Modeled after how nature creates coral reefs, the process filters the collected CO2 emissions through seawater. The result is a chalky material that can be used as a concrete ingredient and that doesn’t require the extreme heat of limestone for processing.
- University of Arizona researchers developed Ferrock™, a replacement for Portland cement, by converting steel dust into a binder that replaces cement in concrete. The process for converting the steel dust requires high amounts of CO2, thereby absorbing CO2 instead of emitting it.
- Wagners, an Australian construction materials company created EFC (“Earth Friendly Concrete”) that is literally green on the inside by combining industrial waste from steel production with fly ash, a waste from coal power generation, in lieu of Portland cement. This substitution reduces carbon emissions by an estimated 90%, at a cost akin to that of Portland cement-based concrete.

Incentives to Invest in a Carbon Neutral Future
The impacts of climate change on local, national and global economies is writ large on the bar charts representing insurance payouts in the wake of the increasing instability of global climate patterns. Carriers’ confidence regarding the economic threats imposed by climate change is wavering in the face of science, data, litigation, and cost. According to a whitepaper co-authored by Traub Lieberman Straus & Shrewsberry LLP, a law firm representing the insurance industry, and Aspen Re, a global reinsurance carrier, the global economic cost of weather-related catastrophic events in 2017 was $330 billion, with insurance loss estimates reaching $140 billion. Swiss Re, the world’s largest reinsurance carrier, paid out $219 billion as the result of “natural catastrophes and man-made disasters occurring in 2017 and 2018, with the bulk of 2018 claims paid as a result of wildfires, thunderstorms and hurricanes in North America.”

In September 2019, Swiss Re announced that it will begin to divest from mining companies producing in excess of 20 million tons of coal per year and large coal powered generators with a 10-gigawatt capacity.

or greater. It further committed to making its investment portfolio and insurance bookings carbon neutral by 2050.63

Thinking Globally, Acting Locally
Portland-based VertueLab, formerly known as Oregon Best recently landed a $300,000 grant by the U.S. Economic Development Administration and an additional $70,000 from Wells Fargo to fund early-stage startups that create solutions to climate change.64 According to its founders, the VertueLab Climate Impact Fund, itself innovative, is “designed to fill the persistent investment gap between government grants and conventional investments that results in a choke point for innovative climate solutions,” blending the “impact orientation of a nonprofit with the financial strategies of venture capital.”65 VertueLab has underwritten the Cascade CleanTech Accelerator which recently awarded $220,000 to five clean-tech startups.66

---

65 https://vertuelab.org/