SUMMARY REPORT

ALASKA'S RENEWABLE ENERGY FUTURE:

New Jobs, Affordable Energy

Developed for Regenerative Economies Working Group – Alaska Climate Alliance

ALASKA'S RENEWABLE ENERGY FUTURE:

New Jobs, Affordable Energy

KEY TAKEAWAYS:

- Alaska has a vast endowment of renewable energy resources
- Renewable energy technology costs continue to decline, while local and global fossil fuel costs continue to escalate
- Renewable energy technologies are on track to affordably replace legacy fossil fuel energy systems in the 2030-to-2050 time horizon
- The development of Alaska's vast renewable energy potential has the potential to generate more than 103,554 jobs across Alaska – more than replacing the jobs lost as fossil fuels become obsolete
- With continued federal support, renewable hydrogen-based fuels have the potential to replace fossil fuels in the marine and aviation sectors and form the basis of a new export economy

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Developed for: Alaska Climate Alliance – Regenerative Economies Working Group

The Regenerative Economies Working Group of the Alaska Climate Alliance is working with a broad coalition of entities and individuals with the goal of articulating and advancing an economic vision for a prosperous, clean energy future for Alaska. The Alaska Climate Alliance is a group of 50+ organizations and more than 120 participants united by our desire to align Alaska's climate action community with Just Transition principles, addressing the climate crisis head-on at all levels of society and shifting our state towards a joyful, interdependent and Indigenous-led future.

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Land Acknowledgement:

The authors and contributors (and readers, we hope!) of this report humbly and respectfully acknowledge that the land and resources we are describing and analyzing are the ancestral and unceded territory of the Indigenous Peoples of Alaska. We write this with deep gratitude to the Indigenous Peoples of Alaska for their continued care and stewardship of the land on which we live, work and play. We acknowledge this not only in thanks to the Indigenous communities who have held relationship with this land for generations but also in recognition of the historical and ongoing legacy of colonialism. Additionally, we acknowledge this as a point of reflection for us all as we work towards dismantling colonial practices.

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Executive Summary

Alaska has a vast endowment of renewable energy resources that can be tapped in its transition to a renewable energy future. Benefits of accelerating the energy transition in Alaska include more jobs, lower energy prices, higher energy security and the potential for renewable resources to support zero carbon hydrogen-based fuels for the aviation and maritime industries.

The state has already begun to develop its renewable energy resources and continues to support renewable technology development for Alaska's challenging environment. The scale of Alaska's vast undeveloped renewable energy resource endowment *remains more than 14 times the total U.S. energy consumption*.[1]

Alaska's historically high and volatile fossil fuel-based energy costs have been moderated by the successful development of renewable energy resources across the state, including:

- Bradley Lake & Battle Creek Diversion, Solomon Gulch, Terror Lake, Swan Lake, Tyee Lake, and other recent hydro projects in both the Southeast and Southwest
- Fire Island, Eva Creek, Kotzebue, Kodiak & AVEC Wind
- GVEA & HEA Battery Energy Storage Systems
- GVEA Solar PV, MEA Solar PV by Independent Power Producers; with discussions underway for a 20MW solar PV project in HEA territory
- Village scale solar PV projects in remote rural communities, e.g., Eagle, Hughes, Kaltag
- Juneau, Tok, Coffman Cove, Craig, Gulkana, Elim, Thorne Bay, Haines, and Tanana Biomass
- Chena Hot Springs Geothermal Heat and Electricity

Renewable energy technologies, including wind, solar, geothermal, and ocean and river hydrokinetic, along with complementary energy storage technologies, are continuing to exhibit declining costs which make them increasingly attractive as a primary energy source to substitute for fossil fuels in the electric sector and to support the electrification of buildings and the transformation of the transportation sector to electrification and renewable hydrogen-based fuels.

As local fossil fuel costs escalate across Alaska, from 2.5X higher in the Railbelt to as much as 4X higher in Rural Alaska (as compared to the U.S. average), renewable energy technologies are increasingly attractive investments and are poised to affordably replace legacy fossil fuel energy systems in the 2030-to-2050 time horizon while providing greater energy security, increased energy resiliency especially in rural Alaska, and broad environmental, economic and health benefits.[2]

Independent studies have confirmed that the development of Alaska's renewable energy potential will generate thousands of jobs – at least comparable in magnitude to the fossil fuel jobs that may be displaced by the transition to a clean renewable energy sector.[3]

Based on adjusting a sample of independent studies for Alaska cost differentials for renewable resource, energy storage and zero carbon hydrogen/clean fuels infrastructure, **we estimate that by 2050, the transition to a 100% clean renewable energy future for Alaska would generate a net increase of 67,216 jobs** (103,554 additional renewable jobs minus 36,338 fossil fuel energy related jobs lost).[4]

In addition to developing renewable energy resources on the supply side, the electric sector has opportunities to rebuild flagging electricity sales through building electrification and transformation of the transportation sector to electric and green hydrogen-based fuels. The acceleration of the transformation of the building heating and transportation sectors to clean renewable energy will require a sustained federal, public, and private investment in science, technology, including systems integrations.

Renewable hydrogen-based fuels have the potential to replace fossil fuels in the marine and aviation sectors as renewable energy, renewable hydrogen production, storage, and hydrogen fuel cell technologies continue to develop.

Collaborative consultations with key stakeholders, including local communities, Tribes, residential energy consumers, public and private sector energy consumers and producers (including Alaska Native Corporations), and local utilities will be essential to ensuring long term support for successful development of local renewable energy resources.

Introduction

This report examines the potential for 100% clean renewable energy to replace fossil fuel energy in Alaska by 2050 and attendant benefits including more jobs, lower energy prices, higher energy security and the potential for renewable resources to support the equitable transition to hydrogen-based fuels for the aviation and maritime industries.

Benefits of Accelerating the Transition to a Renewable Energy Future in Alaska by 2050

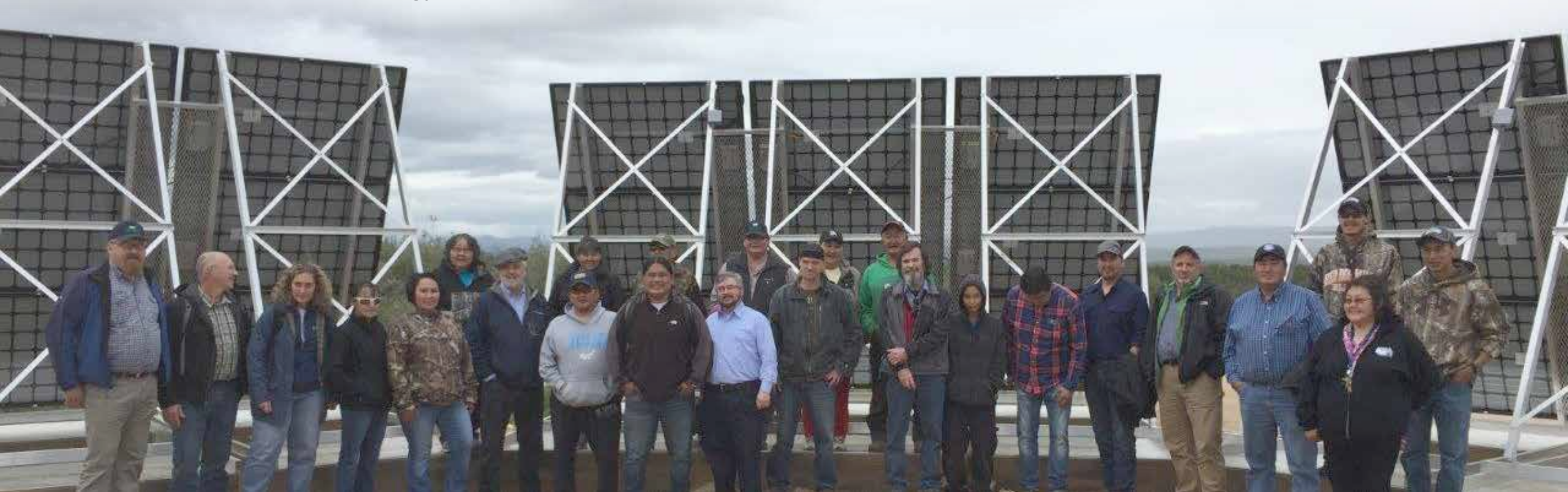
The benefits of transitioning to 100% clean renewables for all energy purposes (including electric, building heating and transportation fuels) by 2050 include:[5]

1. Creates 67,500 more long-term, full time jobs in Alaska than lost
2. Eliminates 43 million tonnes CO_{2equiv} per year in 2050 in Alaska
3. Reduces 2050 all-purpose, end-use energy requirements by roughly half
4. Reduces total annual energy, health and climate costs by 25%; from $23.2 billion to $17.3 billion per year

Costs – The substantial up-front investment costs, on the order of $128 billion over 30 years, can be mitigated by federal and state co-investment.

- Aggregate public co-investment on the order of 25% should be sufficient to more than buy down the net price of energy to be less than the superficial cash price of the business-as-usual fossil fuel projection.
- The 25% public co-investment, which could be split between state and federal consistent with the historic approach to federal highway funds, 1:9, would amount to $3.2 billion for the State of Alaska.

The final section of this report highlights key strategies to accelerate the transition to clean renewable energy.



Alaska's Energy Context

Alaska's unique geography of widely dispersed remote communities and variable local energy resources have contributed to a long history of high energy costs across the state, exemplified by rural electricity residential rates as high as 7X the U.S. average in remote rural locations.[6]

Over the decades, a wide variety of efforts to help mitigate the high cost of energy have been undertaken across the state.

Beginning in the 1950s, the federal Alaska Power Administration built and operated hydroelectric projects in Alaska in part to mitigate the high cost of energy in Alaska. These assets were divested to local utilities over 1989-1991.[7]

In the 1980s, the State of Alaska began to invest in hydro resource development, including Bradley Lake (Railbelt) and the Four Dam Pool (Tyee Lake, Swam Lake, Solomon Gulch, Terror Lake).

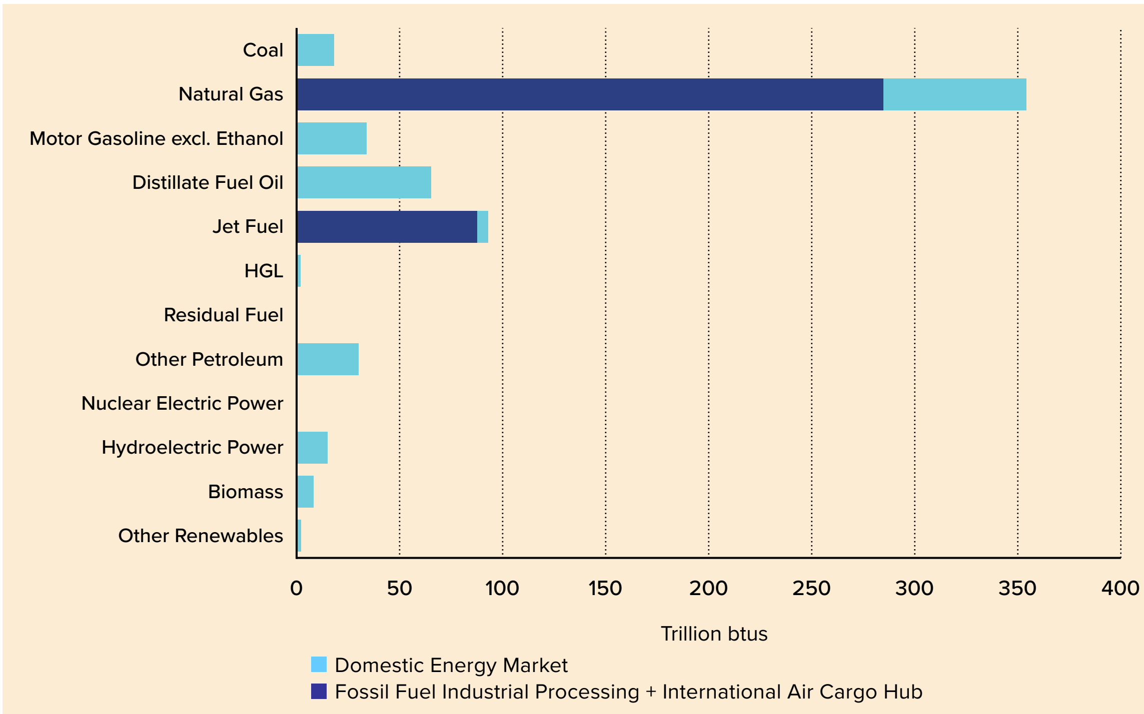
In the 2008 oil price spike era, the State of Alaska enacted and funded a renewable energy fund administered by the Alaska Energy Authority to help mitigate the high cost of fossil fuels.[8] More than 95 operating projects have been built, collectively saving more than 30 million gallons of diesel each year.

The net results of those investments have helped reduce residential electric rates across Alaska over the past 20 years – especially across rural and Southeast communities.

However, residential electric rates across most of Alaska remain extremely expensive compared to the U.S. and the upward trend in residential electric rates in the Railbelt continues to present a challenge to household budgets.

Alaska's Energy Consumption

FIGURE 1 Alaska Energy Consumption Estimates by Energy Source (EIA, 2019)



Source: EIA State Energy Data System, Alaska Energy Consumption, 2019

In 2019, Alaska consumed an estimated 616 trillion btus of energy. Roughly 57% of that total consumption was supplied by natural gas. Renewable energy resources generated an estimated 24 trillion btus or 4% of the total state energy supply.

Alaska North Slope and Cook Inlet Oil & Gas exploration, development and processing use almost 80% of the natural gas consumed in Alaska for those industrial processes.

In a 100% clean, renewable energy future, oil & gas exploration and development is expected to essentially fade away, leaving behind a very modest residual for non-energy end-use, e.g., asphalt, and be replaced by a robust mix of renewable energy resources with a markedly diminished energy footprint for their exploration, development, processing and production of end-use energy for electricity, heating/cooling and green hydrogen-based fuels.[9]

Thus, before taking into consideration population growth and other changes in the energy mix and production processes between now and 2050, we expect Alaska Energy Consumption to be roughly 280 trillion btus lower in a 100% clean renewable energy future.

The next largest energy resource consumed in Alaska after natural gas is jet fuel.

The Anchorage International Airport moved from the sixth to the fourth largest air cargo hub in the world in 2021. In 2019 (most recent EIA State Data), jet fuel consumption at the Anchorage International Airport was on the order of 17.5 million barrels of jet fuel in 2019. Jet fuel at the Anchorage International Airport is a substantial fossil fuel energy demand center in Alaska that merits special attention given its prominence in the Alaska energy picture; 90 trillion btus are associated with the international passenger and air cargo flights.[10]

Distillate fuel oil, the third largest energy resource consumed in Alaska, is widely used in truck, rail, and marine transport, and rural Alaska electric generation.

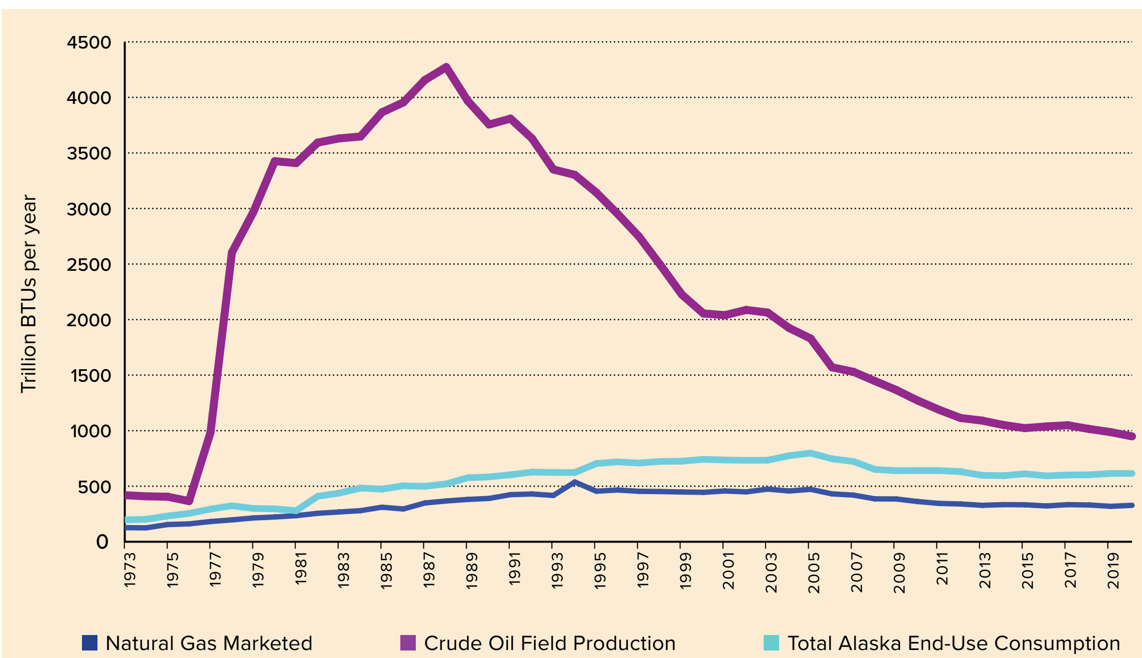
Renewables in Electricity Supply

Alaska's historically high and volatile fossil fuel-based energy costs have been moderated by utility and independent power producer investments in renewable energy resources across the state. Renewables have grown to supply 30% of the total electrical demand in Alaska. Renewable energy projects include:

- Bradley Lake & Brattle Creek, Four Dam Pool & other Southeast Hydro
- Fire Island, Eva Creek, Kotzebue, Kodiak & Alaska Village Electric Cooperative (AVEC) Wind
- GVEA Battery Energy Storage System (BESS)
- MEA Solar PV
- Juneau, Tok, Coffman Cove, Craig, Gulkana, Elim, Thorne Bay, Haines & Tanana Biomass
- Chena Hot Springs Geothermal
- Hydrokinetic power in Igiugig

DECLINING OIL INDUSTRY

FIGURE 2 Alaska Energy Production & Alaska's End-Use Energy Consumption Comparisons, 1973-2020



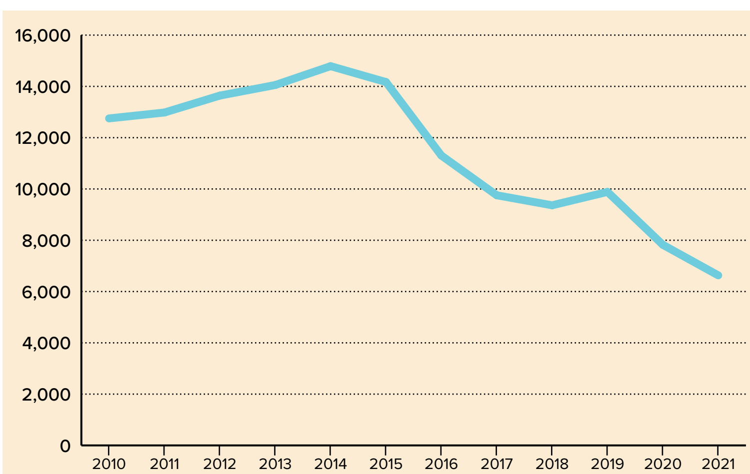
Source: EIA Crude Oil Production, Natural Gas Marketed Production, Alaska, 1973-2020

Alaska's energy production history took a quantum leap in 1977 with the completion and operation of the Trans-Alaska Pipeline Systems (TAPS) which enabled Alaska North Slope crude oil production.

After peaking at slightly over 4200 trillion btus per year (2 million barrels of oil per day), crude oil production has declined rapidly through 2010 (5.4% per year), with the decline rate moderating to 2.6% per year since 2010.

Natural gas marketed production (approx. 80% of which supplies energy for the oil & gas industry exploration, development and production activities), has been declining at 2.4% per year.

FIGURE 3 Alaska Oil & Gas Sector Average Monthly Employment (2014-2021)



Source: Alaska Department of Labor Workforce Development, Research Analysis Section, Alaska Employment & Wages, 2010-2021

More recently, while the rate of decline of oil & gas production has moderated, oil & gas sector employment has been falling rapidly – the average annual employment decline has been 11% per year since 2014. This includes all those who receive compensation as employees, which typically include oil & gas companies as well as the oil & gas industry contractors who employee people. It does not include sole-proprietors.[11]

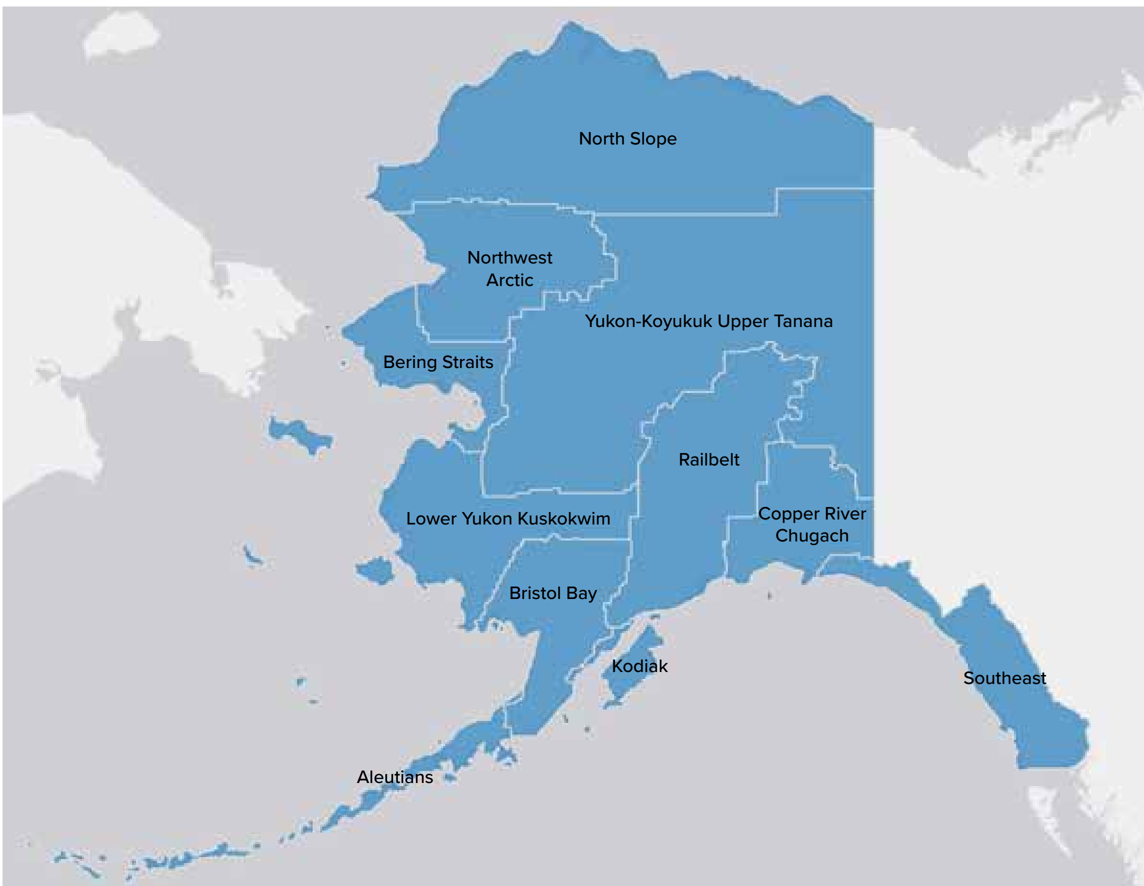
As noted above, transitioning to a 100% clean renewable energy future for Alaska is estimated to generate a net increase of 67,216 Alaska jobs by 2050 (103,554 additional renewable jobs minus 36,338 fossil fuel energy related jobs lost).

ALASKA'S UNIQUE ENERGY INFRASTRUCTURE

Alaska's unique energy supply infrastructure evolved around the state's vast and diverse geography. The Railbelt, which is interconnected by transmission facilities, stretches from the Interior down to the Kenai Peninsula and represents roughly 79% of the state's electric utility generation.

Alaska also has over 150 individual microgrids,[12] an estimated 12% of the planet's microgrid infrastructure. Found primarily in remote, rural Alaskan communities, microgrids can be more cost-effective and often more efficient in integrating multiple power sources compared to traditional large-scale energy grids.[13]

FIGURE 4 Alaska Energy Regions Map



Source: Alaska Energy Authority

Interestingly, key regional hub communities, including Kotzebue in the Northwest Arctic, Kodiak, as well as several communities across Southeast Alaska have been leaders in developing their local renewable resources. Many smaller rural community microgrids are powered by diesel generators, which often create challenges in transporting diesel and contribute to high electricity costs for remote communities.[14] Alaska's microgrid infrastructure poses both an opportunity and a challenge for the transition to renewable energy and remains a key consideration in the development and implementation of the strategies and approaches detailed in this report.

Vast Alaska Renewable Energy Resource Opportunity

SEVERAL STUDIES OVER THE PAST DECADE HAVE DOCUMENTED ALASKA’S VAST RENEWABLE ENERGY RESOURCE POTENTIAL.

Renewable Energy in Alaska, WH Pacific, Inc, National Renewable Energy Lab (NREL), March 2013, found:

- Alaska is uniquely endowed with a full range of renewable energy opportunities, including extensive and diverse biomass, hydropower that ranges from run-of-river and low-impact high-head to traditional massive dams; wind energy that ranges from micro, wind-hybrid turbines in small coastal villages to large wind farms [coastal + mountain range funnels]; world class tides; and huge geothermal potential on the northern edge of the Pacific Rim of Fire.
- The Levelized Cost of Electricity (LCOE)[15] from many renewable energy projects in Alaska, including energy efficiency initiatives, were competitive with local diesel fuel alternatives in the short term (2010-2020) and looked increasingly competitive with other fossil fuel alternatives (coal and natural gas) in the longer term (2020-2030) as natural gas prices were forecast to increase from below the U.S. market average to well above and increased regulation of coal was expected to add both capital and operating costs.



More recent studies have continued to document a large renewable energy resource base in Alaska:

- Onshore Wind = 37,753 TWh/yr (2.48 times Texas) and 6726 GW potential nameplate capacity, 2.4 times Texas, the next largest onshore wind potential state[16]
- Offshore Wind = 12,087 TWh/year, more than 2000 times the statewide energy consumption in Alaska and more than 3 times ***the total U.S. energy consumption***, a net offshore wind energy potential that is 68% higher than all other states combined[17]
- Onshore + Offshore Wind Potential = 49,840TWh/yr; more than 14 X the total U.S. energy consumption (EIA US Energy Consumption, 2020)
- Hydroelectric = 46.36 GW undeveloped potential of which 4.723 GW is feasible potential[18]
- Geothermal = 2.4 GW potential[19]
- Solar PV = the solar PV resource is comparable to Germany, which has a cumulative installed solar PV capacity of >55 GW[20]
- Tidal Power = Technical Power Potential of U.S. Marine Resources in Alaska = 1,100 TWh/year, 27% of the total U.S. electricity generation[21], of which Cook Inlet East-West Foreland Transect = 46MW, 400 GWh/year[22]

Renewable Energy Technology Trends

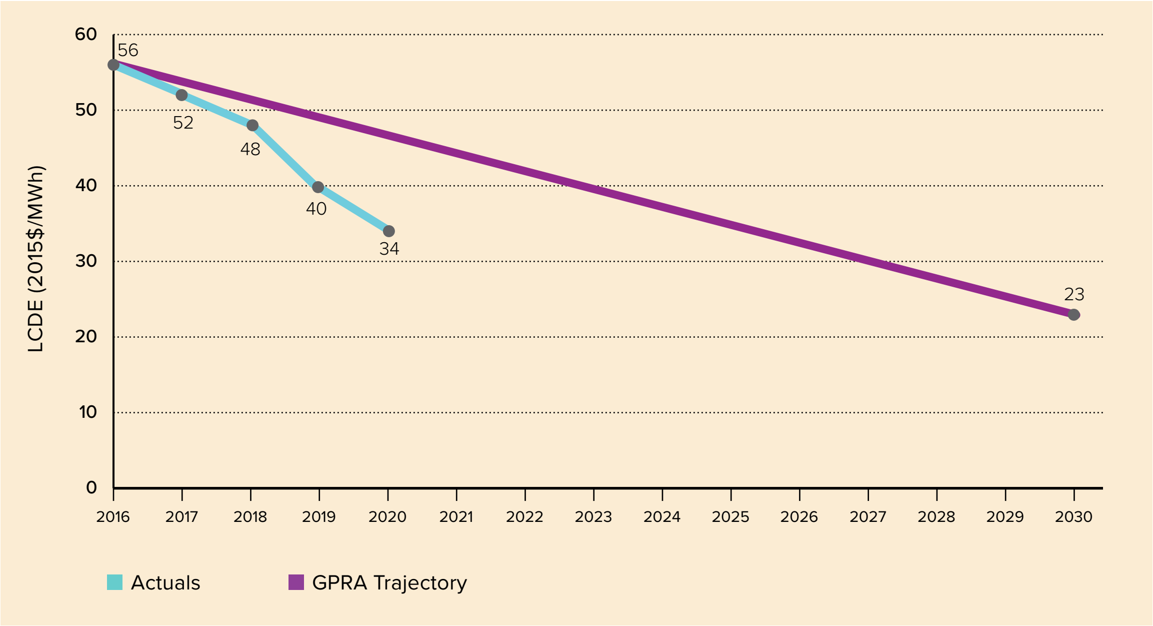
History – Rapid Reduction in Costs

Renewable energy costs, including battery storage and the integration of intermittent renewables into an electric grid, continue to decline.

ONSHORE WIND COST TRENDS

As illustrated in NREL's 2019 Cost of Wind Energy Review (December 2020), the actual onshore wind levelized cost of energy (LCOE) from 2016 to 2020 has declined from $56/MWh to $34/MWh in real $ terms (-39%), which is considerably faster than the previously projected cost decline trajectory.

FIGURE 5 Land Based Wind Cost Trajectories (NREL, 2020)



Source: NREL 2019 Cost of Wind Energy Review (December 2020)

Note: The drop in LCOE between 2019 and 2020 is largely because of updates made to the financing assumptions. Prior to the "2018 Cost of Wind Energy Review," WETO reported land-based financing using a constant and conservative FCR. The land-based FCR is updated in 2020 to maintain reporting consistency between land-based wind and offshore wind technologies. Land-based-wind cost of capital data collected by Lawrence Berkeley National Laboratory (Wiser and Bolinger 2020) gives a basis for WACC assumptions for the representative wind project in 2019 and results in a nominal WACC of 6.32%. A sensitivity analysis using the finance assumptions in last year's cost report is captured in Appendix A.

OFFSHORE WIND COST TRENDS

As illustrated in NREL's 2019 Cost of Wind Energy Review (December 2020), the actual offshore wind levelized cost of energy (LCOE) declined from $191/MWh to $83/MWh (2016-2020) in real $ terms (-56%). And the cost is projected to continue to decline toward $51/MWh (2018$).

BATTERY STORAGE COST TRENDS

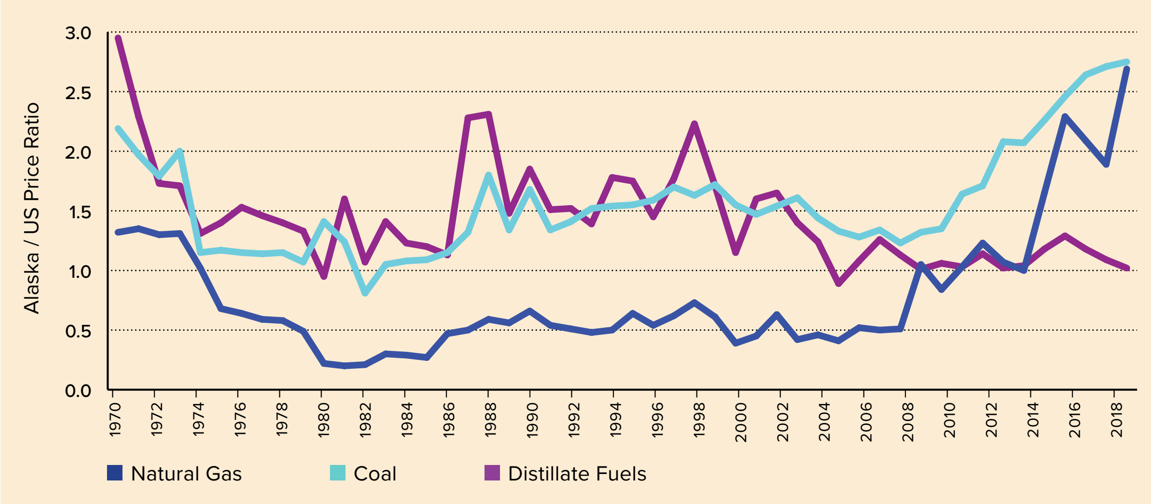
Electric power markets in the United States are undergoing significant structural change that are projected to result in the installation of the ability of large-scale battery storage to contribute 10,000 megawatts to the grid between 2021 and 2023 – 10 times the capacity in 2019.[23]

Average battery energy storage costs declined from $2012/kWh to $589/kWh from 2015-2019, an average rate of decline of 27% per year.[24] NREL's most recent comprehensive cost projections for utility-scale battery storage (2020) anticipate 4-hour battery costs will continue to fall, reaching $208/kWh by 2030 and $156/kWh by 2050.[25]

Rising Cost of Fossil Fuels

Against the backdrop of the rapid decline in the cost of renewables and projected future cost reductions, the electric power sector in Alaska has been experiencing an unusually rapid increase in the cost of fossil fuels since 2008.

FIGURE 6 Electric Power Sector Fossil Fuel Prices, Alaska to U.S. Price Ratio, 1970-2019

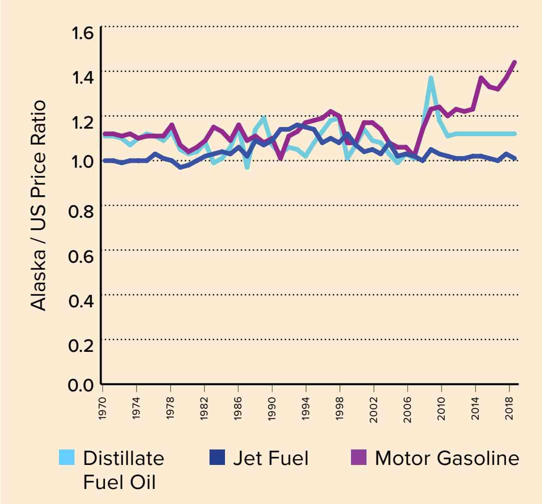


Source: EIA State Energy Data

Alaska electric sector price premium for coal and natural gas has been escalating at an unusually high rate since 2008. A State of Alaska Division of Oil and Gas Cook Inlet Natural Gas Availability study in 2018 projected the costs for Cook Inlet natural gas supply are poised to continue escalating rapidly.

Transportation Sector

FIGURE 7 Transportation Sector Fossil Fuels: Alaska to U.S. Price Ratio, 1970-2019



Source: EIA State Energy Data

From 1970-2008, the price premium for Alaska "retail" transportation fuels (diesel, motor gasoline) hovered around 5 to 15%.

From 2008-2019, the price premium for Alaska motor gasoline rose to over 40% above the U.S., the price premium for diesel fuel rose to 12% above the U.S.

Compared to the continental U.S. (aka Lower 48), Alaska motor gasoline prices have taken off since 2008 and appear poised to continue to escalate due to increasingly limited competitive alternatives.

Potential Paths for Renewables to Replace Fossil Fuels

Emerging Opportunities for Decarbonization of Building and Transportation Sectors

BUILDING ELECTRIFICATION

Building electrification has been incentivized by Alaska utilities with substantial hydroelectric resources, including AEL&P in Juneau, Kodiak Island Electric Association, AP&T on Prince of Wales Island, and Sitka.

The Northwest Arctic Borough engaged Analysis North to develop an Alaskan Heat Pump Calculator to help assess whether a heat pump may be an economic choice for a homeowner and to compile the results of the application of that model to a wide range of communities and home energy configurations around the state.[26]

The Mini-Split Heat Pumps in Alaska Report concluded:

- Heat pumps appear competitive in many cases in communities served by home heating oil or propane.
- At the then current residential prices for natural gas in the Cook Inlet and Railbelt electric rates, heat pumps did not appear economically competitive.

When utility prevailing natural gas prices rise into the $15/Mcf range (and residential retail rates rise toward $1.90/ccf) and electric utilities have migrated to a mix of renewables with residential electric rates around 20c/kWh, which appears to be a plausible scenario in the 2030-time frame, building heat pump technology will be competitive with natural gas and poised to quickly capture market share and grow electric demand.[27]

TRANSPORTATION ELECTRIFICATION

Electrifying transportation provides an opportunity to power vehicles and other modes of transportation with clean energy rather than fossil fuels, thereby reducing carbon emissions. Electric vehicles (EVs) are a key component of a renewable energy transition. In addition to emissions reductions, EVs offer health benefits and the future potential to support resilience via power to the grid.[28]

With the growing interest for EVs in Alaska, the Alaska Center for Energy and Power conducted a literature review to understand how these vehicles perform in colder weather. The results showed that EVs generally perform similar to or better than an internal combustion engine in the cold.[29] As of June 2021, Alaska had nearly 1,000 EVs on the road.[30] Currently, there are 62 public level 2 charging plugs and five public direct current fast charging (DCFC) plugs throughout the state.[31] To grow this number, recent funding efforts have been announced. In 2021, the AEA, with support from the Volkswagen Mitigation Trust Fund and the U.S. Department of Energy's State Energy

Program, awarded nearly $1 million in grants to add EV charging stations at nine sites along the state's backbone highway system.[32]

Alaska's ferry system also presents another opportunity to advance electrification of the transportation sector. The Infrastructure Investment and Jobs Act will fund at least one program in Alaska to pilot electric ferries.[33]

Electric vehicle purchases and charging have been incentivized and supported by Alaska utilities with substantial hydroelectric resources including AEL&P and AP&T.

GREEN HYDROGEN-BASED FUELS

Hydrogen gas is anticipated to play a vital role in decarbonization, potentially addressing 30% of GHG emissions.[34]

When the electricity used to electrolyze water and create hydrogen is generated from renewable energy sources, it is termed "green hydrogen."[35]

A recent comprehensive study from the Columbia Center on Global Energy Policy, *Green Hydrogen in a Circular Economy: Opportunities and Limits*, Fan et al., August 2021 has a particularly insightful set of findings and analysis:

- Green hydrogen and fuels derived from it, e.g., ammonia, methanol, aviation fuels, can replace higher carbon fuels in some areas of the transportation sector, industrial sector, and power sector. They can provide low-carbon heat, serve as low-carbon feedstock, reduce gas for chemical processes, and act as an anchor for recycling CO2 [executive summary findings].
- The cost of green hydrogen is high today, between $6-14/kg on average in most markets [executive summary findings].
    - Dramatic technical improvements in key technologies, e.g., fuel cells and hydrogen tanks, have stimulated many recent analyses (IEA World Energy Outlook 2021) to see hydrogen as an essential component of the energy transition, provided its upstream production and use emit very few greenhouse gases and pollutants [background, page 16].
    - Mean 2030 levelized cost of hydrogen forecasts in the U.S. cluster around $4/kg [Figure 10].
- Green hydrogen commercialization is limited by existing infrastructure [executive summary findings].
- The governments of Japan, Canada, Australia, Germany, and the EU have published formal road maps for hydrogen production, use and growth. These plans include subsidies for manufacturing electrolyzer and fuel cells, port infrastructure, and market aligning policies. [executive summary findings].
- Use of green hydrogen and green hydrogen fuels could provide substantial additional benefits to local economies and environments, including reduction of particulate and sulfur pollution, maintenance or growth of high-wage jobs, and new export opportunities (fuels, commodities, and technologies) [executive summary findings].

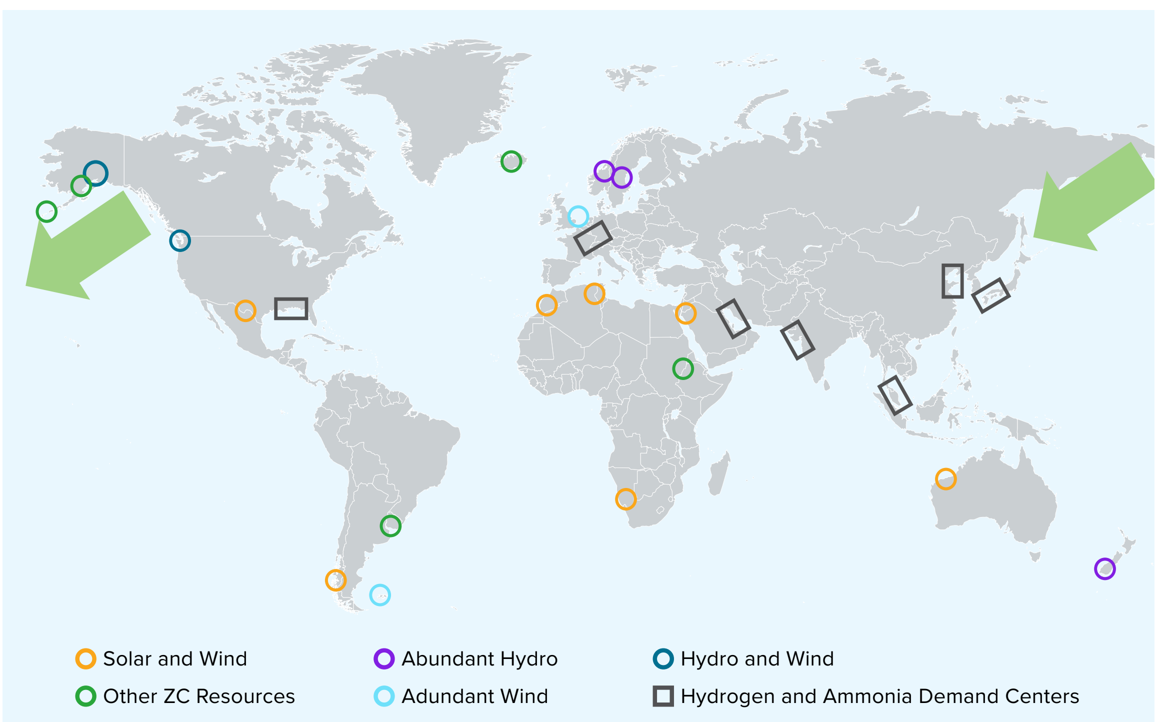
- Transportation Market Opportunities for Green Hydrogen
    - Medium- and Heavy-Duty Trucks (p. 38)
        - Both hydrogen fuel cells and lithium batteries are potential options for decarbonizing pathways for heavy-duty vehicles. However, batteries are not practical for many heavy applications.
        - A relatively small number of hydrogen fueling stations at key truck freight hubs could serve large hydrogen fuel cell powered truck fleets.
    - Ships (p. 38-39)
        - The global shipping industry currently exclusively uses heavy oil or marine diesel as fuel. Shipping fuel has a high concentration of sulfur that produces air polluting chemicals and particulates that are harmful to human health. These pollutants are concentrated near coastlines where densely populated communities reside. Changing to cleaner shipping fuels will not only reduce GHG emissions but also yield significant health benefits, especially to communities living near ports.
        - Similar to medium- and heavy-duty trucks, batteries are impractical for maritime applications due to their relatively heavy weight and limited range. Hydrogen can provide a range of different marine fuel options, including liquid hydrogen or gaseous compressed hydrogen, or methanol or ammonia, which are both made from hydrogen. Of these, ammonia is seen by many as most suitable for transition to a sustainable shipping industry, as liquid hydrogen cannot be blended into conventional marine fuels and must be kept at high pressures or extremely cold temperatures. Ammonia has a higher energy density than liquid hydrogen and lower overall fuel related costs because it can be easily stored as a liquid in inexpensive tanks at very low pressures. Additionally, ammonia can be used in internal combustion engines or fuel cells, and many ship engines can be retrofitted to adapt to use of ammonia fuel, making ammonia not just a low-carbon alternative but also available today and viable for rapid scaling. Methanol has also demonstrated many of these benefits; however, ammonia contains no carbon and releases no carbon dioxide in use, making it both a lower carbon and lower full-cost alternative.

Other countries have also been exploring the potential for green hydrogen. A recent feasibility study determined that Australia was ideal for green hydrogen development because of available infrastructure, land, and renewable resources.[36]

The Alaska Air Group is exploring green hydrogen to meet its goal of net-zero emissions by 2040. In partnership with ZeroAvia, a zero-emission aviation company, the two companies aim to develop a fleet of hydrogen fuel cell electric planes powered by green hydrogen.[37] If the technology is successful, it could serve as a model for future green hydrogen production and use at key airport hubs and beyond. In addition, with infrastructure improvements that could be sited in the Nikiski area, Alaska has the potential to manufacture green hydrogen to serve the international air cargo hub in Anchorage as well as export green hydrogen to Pacific Rim demand centers.

See Alaska opportunities in Figure below: *Geographies with combined zero-carbon resources of high capacity and low cost* [Fan, et al, p. 49, October 2021].

FIGURE 8 Geographies With Combined Zero-carbon Resources of High Capacity and Low Cost

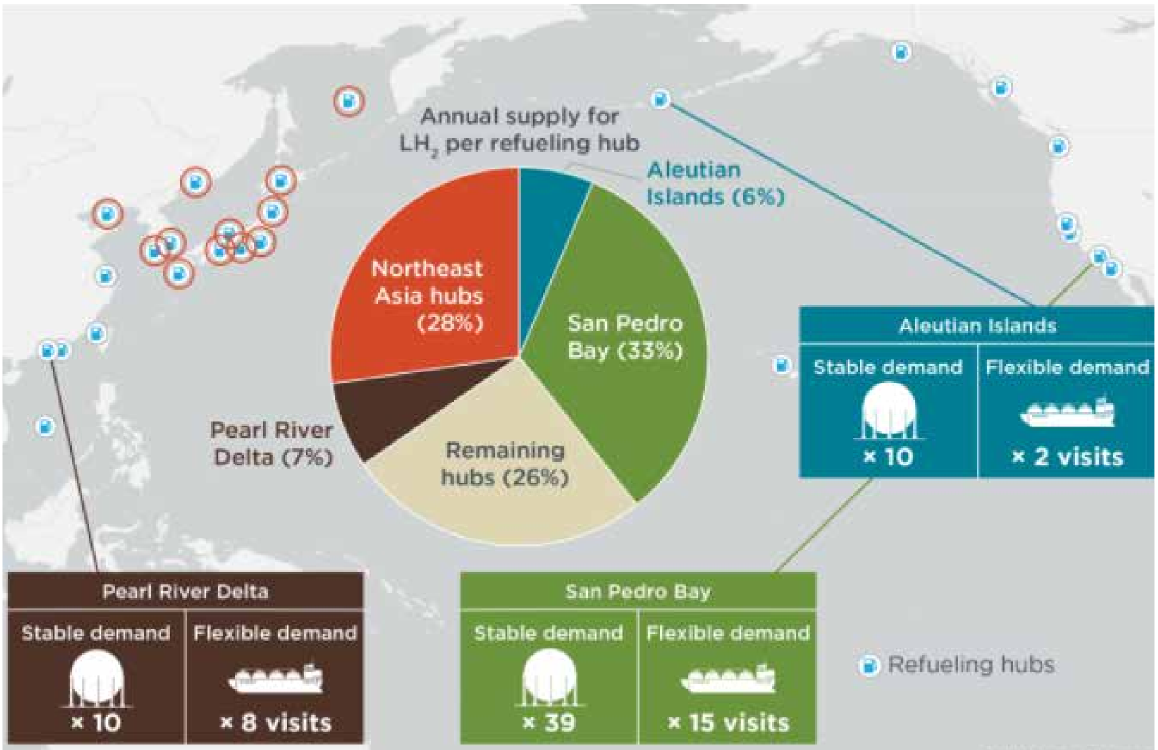


Source: Columbia Center on Global Energy Policy, *Green Hydrogen in a Circular Economy: Opportunities and Limits,* Fan et al., August 2021, page 49 (with additional annotations manually added for Alaska)

Note: Hydrogen demand centers represent regions of current and projected demand for hydrogen and ammonia based on existing infrastructure announced policies. (Authors' analysis)

The International Council on Clean Transportation has two recent working papers which highlight the potential for zero emission fuels in the Pacific and the potential for an Aleutians port to serve as a critical refueling hub.[38] See Figure below.

FIGURE 9 **Hydrogen Demand and Refueling Infrastructure Needed for Transpacific Container Ships Under the Full Deployment Scenario**



Source: International Council on Clean Transportation: LIQUID HYDROGEN REFUELING INFRASTRUCTURE TO SUPPORT A ZERO-EMISSION U.S.–CHINA CONTAINER SHIPPING CORRIDOR, By: Elise Georgeff, Xiaoli Mao, Dan Rutherford, Ph.D., Liudmila Osipova, Ph.D., October 14, 2020

Strategies to Accelerate the Transition to Clean Renewable Energy

This section outlines some of the approaches in policy, planning, funding and financing, and workforce development that could help accelerate Alaska's transition to clean renewable energy.

Though few explicit barriers hinder renewable energy development in Alaska, the state currently lacks the regulatory framework and supporting legislation needed to attract additional investment in the industry at scale. Attracting private investment to facilitate further development in renewable energy remains a critical hurdle, as the market stability and predictability investors require is difficult to achieve if the state remains relatively silent in regulating the sector.

Additional federal and state investments are necessary if Alaska is to realize significant and achievable clean energy benefits (and get out from under the heavy burden of fossil fuels) by 2050.

ACTIONS THAT COULD HELP ACCELERATE ALASKA'S TRANSITION TO CLEAN RENEWABLE ENERGY ARE OUTLINED BELOW.

Transparent accounting – Encourage transparent accounting for the $1.2 trillion Infrastructure Investment and Jobs federal support. More transparent and accessible information will benefit private entrepreneurial, utility and community efforts to access and effectively deploy available funds. HB 177 would prevent a Governor, without legislative approval, from unilaterally spending large sums of federal money should it flow into the state when the legislature is not in session, thus ensuring an opportunity for public input. This bill is needed to correct a statutory blind spot as Alaska prepares to receive an influx of new federal infrastructure funds.

State Comprehensive Plan – Undertake a comprehensive statewide, strategic policy and planning effort, including an explicit goal of transitioning to 100% clean renewable energy by 2050, to help focus emerging integrated planning efforts, including the Railbelt Integrated Resource Plan required by recent 2020 legislation establishing an Electric Reliability Organization.

Legislation to set goal – Enact legislation requiring utilities to achieve 100% clean renewable energy by 2050, and to measure progress toward that goal. Legislation could encourage a supportive and transparent regulatory environment aimed at accelerating the transition to renewables by providing clear guidance and promoting creative solutions like power purchase agreements (PPAs) and community solar.

Investments – Provide funding and financing commensurate with the need to accelerate the transition to 100% clean renewable energy by 2050.[39]

FUNDING MECHANISMS COULD INCLUDE:

Alaska Renewable Energy Fund – Extend the Alaska Renewable Energy Fund (REF) beyond its current sunset of 2023 and fund it with a fresh round of seed capital in the range of $3.2 billion to help leverage federal and private co-investment.

In 2008, the Alaska State Legislature established the Renewable Energy Fund, a grant program administered by the Alaska Energy Authority (AEA). Between 2008 and 2015, this program was responsible for Alaska's largest public investment into renewable energy and efficiency projects, with wind and hydroelectric receiving majority of the funding. It is estimated that the program saved $74 million in diesel costs across the state. As of December 2020, the program has $6.5 million left and is scheduled to sunset in 2023.

The REF is managed by AEA in coordination with a nine-member Renewable Energy Fund Advisory Committee. The program provides grant funding for the development of qualifying and competitively selected renewable energy projects; as of February 2021, 287 REF grants have been awarded to projects totaling $268 million.[40] Over 90 operating projects have been built with REF contributions, collectively saving more than 30 million gallons of diesel each year. As of January 2018, operational REF projects have an overall benefit-cost ratio of 2.5 based on total known project cost, of which state funding is only a portion.[41]

Energy Efficiency Programs – Increase support for Building Energy Efficiency, including Building Envelope Improvements (AHFC/Cold Climate Housing), and Lighting and Energy Appliance upgrades (local electric utility programs).

Clean Energy Infrastructure – Invest in key renewable energy infrastructure including electric vehicle charging station infrastructure, upgrades and additions to electric transmission lines and energy storage capacity for renewable generated power.

> ***Energy Storage Capacity for Renewable Energy*** – Homer Electric Association's (HEA) investment in a new battery system for storing energy provides a great example for other utilities in Alaska. In 2021, HEA installed a large 46.5 MW (up to 93 MWh) Battery Energy Storage System (BESS) in preparation for developing alternatives to the high and escalating cost of natural gas, enabling the integration of non-firm energy sources, e.g., 20MW solar project. The battery project is expected to cost $40 million.[42]
>
> The new battery system will allow HEA to diversify its energy matrix and will meet reliability requirements without burning additional fuel. Incorporating the battery storage facility into HEA's grid structure will ultimately lower greenhouse gas production by allowing HEA to utilize non-dispatchable renewable energy instead of remaining over dependent on natural gas[43].
>
> ***Electric Vehicle Charging Station Expansion*** – As demand for Electric Vehicles (EVs) grows in Alaska, the need to expand EV charging infrastructure also grows. Recent investment in an EV fast-charging corridor from Healy to the Kenai Peninsula in the railbelt by Alaska Energy Authority (AEA)[44], via the Volkswagen Settlement funds, provides an example of the type of infrastructure needed in Alaska to support a transition to renewable energy.

Upgrade and Extend Railbelt/Rural Transmission Lines – The lowest potential cost energy resources, potentially including wind, geothermal, solar, and low-impact hydro may not be located adjacent to load centers and electric system substations. In CONUS markets, the cost of transmission system upgrades has become a significant hurdle for the integration of low-cost new renewable generation.[45] In the AEA's Railbelt Integrated Resource Plan (2009), the cost of transmission system upgrades to support renewable resource development was considered a system wide benefit and not charged to individual projects. Advocate for the upgrade and extension of transmission infrastructure (Railbelt, Rural, Southeast) where the total system wide benefits of access to low cost renewables (displacing the total cost of fossil fuels - direct, health and climate costs over the study time horizon) exceed the cost.

Alaska Permanent Fund (APF) investment policies – Seek Alaska Permanent Fund support for publication of environmental disclosures of its investments to ensure portfolio investments are accessing and addressing climate risks, analogous to the CALPERS initiative to require improved environmental disclosures among its investments of the nation's largest public pension fund.

Federal support of the transition to 100% clean renewable energy – Advocate for the revival of the national mandate to electrify America under the Rural Electrification Administration (now know as Rural Utility Service) under a new "clean energy for America" banner with funding support modeled on the federal highway funding program which grew out of the National Interstate and Defense Highways Act of 1956 with a state:federal funding ratio of 1:9.

IN ADDITION TO FUNDING RENEWABLE INVESTMENTS, OTHER ACTION ITEMS INCLUDE:

Disclosure – Encourage and support private and public sector entities that seek to develop and disclose their environmental impacts under the CDP (formerly known as "Climate Disclosure Project"), a leading global environmental disclosure system. See https://www.cdp.net/en

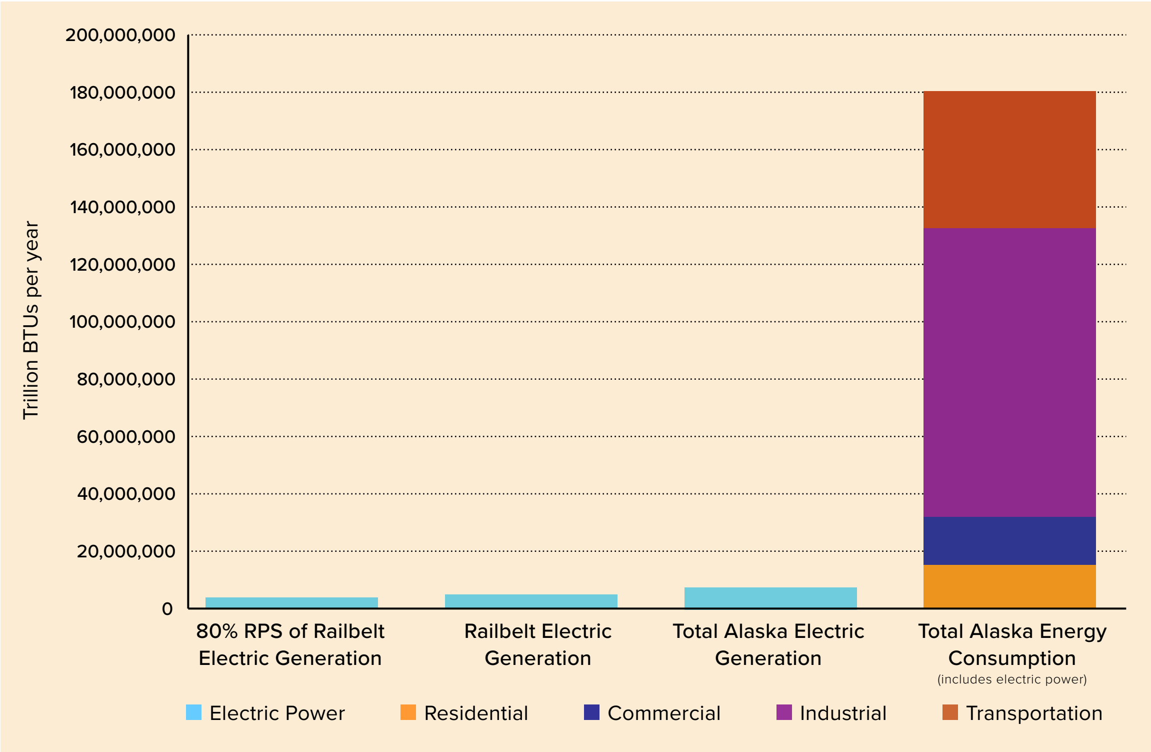
Regional Integrated Resource Plans – Advocate for Regional Integrated Resource Plans that include:

- Substantive opportunities for local collaboration/consultation;
- Consideration of future cost escalation associated with fossil fuel resources from both direct and indirect costs, e.g. $CO_{2\ equiv}$ emissions costs[46]; and
- Explicitly require regional plans to include the overarching policy goal of reaching 100% clean renewable energy for all energy needs by 2050 and include a pathway to achieve it within their options for consideration.

Renewable Portfolio Standard – Enact Renewable Portfolio Standard. Alaska Gov. Mike Dunleavy recently introduced SB 179 and HB 301 to establish a Renewable Portfolio Standard (RPS) for the Railbelt region of Alaska. The proposed bills would require the five electric utilities on the Railbelt to generate a specified percentage of their electricity from renewable resources according to the following timeline: 20% by 2025, 30% by 2030, 55% by 2035 and 80% by 2040.

Under current end-use energy consumption patterns, the 80% renewable portfolio standard applied to the Railbelt Electric Utilities amounts to roughly 3% of the total energy consumption in Alaska. See chart below.

FIGURE 10 80% Renewable Portfolio Standard (RPS) for Alaska Railbelt Electric Utilities Compared to Total Alaska Energy Consumption by Market Segment (2019 data)



Source: Energy Information Administration, State Energy Data System, 2019 data

An 80% renewable portfolio standard for the Railbelt electric utilities, expressly limited to clean renewable energy, would be a welcome first step toward 100% clean renewable energy by 2050.

However, recognizing that more than 90% of Alaska end-use energy is not electrified, an 80% renewable portfolio standard for the current railbelt electric utilities, would fall far short of the need to transform our collective energy use to clean renewable energy by 2050.

Regulatory Commission of Alaska – Enact regulatory reforms to encourage renewable energy development, improve transparency and support community involvement. The Regulatory Commission of Alaska (RCA) regulates public utilities by certifying qualified providers of public utility services and ensuring that they provide safe and adequate services and facilities at just and reasonable rates, terms, and conditions.

Raise the Net Metering Cap – Raise the net metering cap so utilities can enable electric customers who produce their own electricity to receive a credit for the excess energy they transfer back to the utility. Caps are set on most net metering policies to limit the utility's risk of lost revenue. The most common cap type is set at a percentage of the utility's or state's peak demand, capacity, or load in a given year. Most states have a peak demand cap between 0.2% and 9%. Credit amounts, eligible technologies, and caps vary by state and

locality.[47] Net metering policies not only incentivize customers to invest in renewable energy technologies, they also can help utilities meet their requirements to achieve 100% clean renewables by 2050.

Alaska's net metering policies apply to renewable energy systems that are 25 kW or less and set a cap of 1.5% of the utility's average load. Customers who export excess energy to the utility receive a credit equal to the utility's savings on fuel and operations necessary to generate that electricity. With an increase in solar projects,[48] there is a need for raising the net metering cap for all utilities in Alaska under the current regulatory framework. As of 2021, with the approval from the Regulatory Commission of Alaska, GVEA raised its net metering cap from 1.5% to 3%. Homer Electric Association, which had already previously raised its cap, did so again, from 3% to 7%. At the end of 2020, the installed net metered capacity across the Railbelt rose 52% from 2019 and involved 1,638 net metered customers. Solar PV was responsible for 97% of the total energy fed to the Railbelt grid.[49]

Good Governance Regulations – Enact regulations that improve transparency and support community involvement in the transition to lowest reasonable cost renewable energy. For example, ensuring that fuel and operation costs for utilities are transparent and accessible to the public and/or utility cooperative members would allow for better planning and understanding of a renewable energy transition and true energy costs, as would enforcing timelines for cost- and energy-saving programs like tight power pools. Eliminating any "pancaking" or stacking of rates through the Electric Reliability Organization's reliability standards would lower the cost of adding renewable energy to the grid and increase trust with ratepayers. Providing member lists to community members seeking to serve on utility boards and ensuring that utility board and member meetings and minutes are accessible via the internet, as well as scheduling public comment and public portions of meetings before executive sessions, would allow for more efficient engagement between electric co-ops and members. And, developing guidelines on on-bill financing programs as well as moving from promises to action on building community solar programs would allow for a better interface between community advocates and utilities.

Increase expertise – Increase funding to both the Regulatory Commission of Alaska and outside advocacy groups (ie, ratepayer groups) to increase staffing and expertise to better balance the energy industry, private and member-owned electric utilities, and ratepayer needs and help ensure the capacity needed to foster an accelerated transition to renewable energy.

Private Sector Initiatives – Encourage and support public and private sector entities to disclose their Scope 1, 2 and 3 climate emissions.[50]

WORKFORCE DEVELOPMENT

Incentivize industry-led training curriculum for the construction and operations of renewable energy technologies to provide current industry workers with renewable energy skills and alignment with existing jobs. Building the skills of workers in existing construction and operations fields, such as fossil fuels, HVAC, and electrical, will be essential to a renewable energy transition. Most of these occupations already require continuous learning and skill development.[51] The state can partner with these industries and fund development of training curriculums that can be incorporated into existing training, rather than develop training specifically for renewable energy technologies. In addition, industries can drive curriculum development according to the skills needed for available jobs.

Alaska has several training programs funded by the Alaska Workforce Investment Board (AWIB). These programs include the Alaska Construction Academies (ACA) trainings offered by the Alaska Works Partnership, Alaska Technical Vocational Education Program (TVEP), State Training and Employment Program (STEP), and youth training program. Through these programs, organizations, and state entities can receive support to train and prepare workers for jobs that align with AWIB's industry priorities.[52] According to the State Integrated Workforce Plan, there is still heavy emphasis on training for the oil and gas industry. However, the plan notes that Alaskans should grow their skillsets as demand for renewable energy workers grows.[53] As the industry expands in Alaska, AWIB could identify renewable energy as a priority and fund entities to develop training curriculum through the existing training programs.

Incorporate training curriculum into a state-certified apprenticeship program that offers a paid opportunity for individuals entering a workforce to gain skills, knowledge, and mentorship without obtaining an advanced degree. These programs also connect employers with qualified workers.[54] Incorporating renewable energy training curriculum into a state-registered apprenticeship program can help standardize the level of renewable energy knowledge and skills needed to enter the workforce. An example of a statewide training initiative is the California Advanced Lighting Controls Training, which was developed to teach employed electricians how to install and maintain advanced lighting systems and energy efficiency technologies. The curriculum was also integrated into the apprenticeship program to build a pipeline of qualified workers.[55]

Since 2015, there has been an emphasis placed on expanding apprenticeship programs in Alaska, with a primary focus on new industries and occupations.[56] With a majority of apprentices in construction, there is a significant opportunity to incorporate established renewable energy training programs into the existing construction apprenticeships as the demand for these jobs grows.

The Alaska IBEW/NECA apprenticeship program for electricians has adopted a standardized curriculum for the installation of electric vehicle charging equipment. It's called the Electric Vehicle Infrastructure Training Program (EVITP) and the curriculum has been adopted by several other apprenticeship programs around the country.

Encourage engagement of students in renewable energy technology education to give them early exposure to career possibilities and create a network of educated individuals who could later contribute to a renewable energy transition. With a focus on clean energy and job creation, the Colorado Energy Office, U.S. Department of Energy, and Tri-State Generation and Transmission funded the Colorado State University Extension to develop a clean energy curriculum for middle and high school students. The curriculum includes hands-on activities and locally relevant examples that can be tailored by teachers for any grade level.[57]

Currently, the Renewable Energy Alaska Project (REAP) is working to connect energy education to Alaskans. Through its initiative, Alaska Network for Energy Education and Employment, REAP compiles and categorizes energy curricula so they can be easily accessed by Alaskans.[58] This institutional knowledge presents an opportunity to understand gaps in existing curricula and inform development of a state-funded renewable energy technology education curriculum.

OTHER FUNDING MECHANISMS

Green Bank – A Green Bank is a capital management program that leverages limited public dollars to attract greater private investment in clean energy. Its goal is to accelerate growth in the clean energy market while making energy cheaper and cleaner for consumers, driving job creation, and preserving taxpayer dollars. A Green Bank is intended to deploy public capital efficiently through financing to help maximize private investment and lower the costs of clean energy to spark consumer demand. A Green Bank also facilitates market development by working with originators and lenders and offering the information consumers and businesses need to confidently purchase clean energy.[59]

Pending legislation, SB 123 in the Senate and HB 170 in the House of Representatives, known as the Alaska Energy Independence Fund, would support the creation of a Green Bank in Alaska.[60,61] The Alaska Energy Independence Fund would be under the jurisdiction of the Alaska Industrial Development and Export Authority (AIDEA) and would support public-private partnerships oriented toward renewable energy.[62] The proposed Green Bank would require starting capital; pending legislation recommends $10 million in unrestricted general funds, which could be augmented by $130 million in expected federal funds. After that initial capital, the Green Bank would use payments from its borrowers to pay for future loans.[63]

Commercial Property Assessed Clean Energy (C-PACE) Loans – Broader investment in marketing and implementing C-PACE programs in municipalities around Alaska could benefit the transition to renewable energy. C-PACE is a financing tool for improving commercial buildings with energy efficiency measures or renewable energy systems. Unlike conventional construction loans, C-PACE is designed to work specifically with the unique needs and barriers of financing building improvements, including longer loan terms, off-book debt, and repayment that transfers with the sale of property just as does the savings generated by the building improvements. Debt associated with doing the improvements is repaid via a line item on local tax assessments. Authorizing legislation was adopted into Alaska law in 2017 (AS 29.55.100) that allows local governments to create and manage C-PACE programs[64].

On-bill Financing and On-bill Repayment – Further investment in marketing and expanding the program could benefit utility ratepayers and the transition to clean energy. On-bill financing allows the utility to incur the cost of the clean energy upgrade, which is then repaid on the utility bill. On-bill repayment options require the customer to repay the investment through a charge on their monthly utility bill as well, but with this option, the upfront capital is provided by a third party, not the utility. Additionally, on-bill repayment allows for a streamlined process as utilities already have a billing relationship with their customers, as well as access to information about their energy usage patterns and payment history. In some on-bill repayment programs, the loan is transferable to the next owner of the home or building[65]. Authorizing legislation (HB374[66]) was passed in 2018.

Utility Incentive Programs – There are numerous examples of successful incentive programs in Alaska that could be expanded to support a transition to renewable energy and reduce costs for consumers. Alaska Power and Telephone Company (AP&T) in Southeast Alaska has an incentivized installation of ground or air-source heat pumps with a $500 rebate matched by Sealaska Corporation for shareholders.[67] AP&T also offers a $1000 cash incentive for customers in their service area who purchase Electric Vehicles (EVs), and offers a $1000 cash incentive to local or tribal governments that install EV charging stations.[68] Utilities may also offer lower rates for charging EVs during off-peak hours as Alaska Electric Light & Power does for its service area.[69]

Conclusion

Alaska has the potential to create many thousands of jobs and make the high cost of energy more affordable for Alaskans by accelerating its transition to a clean energy future. Worsening climate impacts throughout Alaska and globally make this transition urgent, and ultimately inevitable, as the world moves away from fossil fuels.

Global leaders agree that atmospheric temperature rise must be held to 1.5 degrees C or well below 2 degrees C above pre-industrial levels to avoid catastrophic impacts on people and the planet. The international movement away from climate-damaging fossil fuels is driving transformative energy changes that present new opportunities for Alaska's economy.

Alaska is well positioned to be part of the new energy economy with its vast endowment of renewable energy resources. Renewable energy technology costs continue to decline, while the local and global fossil fuel costs continue to escalate. The resulting confluence of factors makes it possible that renewable energy technologies will affordably replace Alaska's legacy fossil fuel energy systems in the 2030-to-2050 time horizon.

The development of Alaska's vast renewable energy potential will generate thousands of jobs across Alaska – with the potential to more than replace the jobs lost as fossil fuels become obsolete. Renewable hydrogen-based fuels have the potential to replace fossil fuels in the marine and aviation sectors and form the basis of a new export economy.

Substantial funding and effort on the part of many will be required to achieve the aspirational goal of achieving 100% renewable energy use and production across all sectors of Alaska's economy by 2050.

Clean and affordable energy is good for our economy, our pocketbooks, our health and the planet, and one of the best ways to achieve those benefits is to accelerate Alaska's transition to renewable energy. Alaska can benefit by increasing investment now in the clean energy revolution, creating thousands of jobs, reducing the cost of energy, improving health, slowing the Arctic melt, and building climate stability for future generations.

Endnotes

1 The combination of Onshore and Offshore Wind Energy potential alone, in and around Alaska, has been estimated to be on the order of 37,753 TWh/yr (onshore) + 10,043 TWh/yr (offshore) for a total of 47,796 TWh/year which is 14 times the total U.S. energy consumption of 3,397 TWh/yr (EIA, U.S. Energy Consumption, 2020, 11.59 Quads). Onshore wind energy potential estimate from *Onshore wind energy atlas for the United States accounting for land use restrictions and wind speed thresholds*, von Krauland, et al, Smart Energy, 3 (2021), 100046. Offshore wind energy potential estimate from *Offshore Wind Energy Resource Assessment for Alaska*, Doubrawa, et al, Golden, CO: NREL, December 2017.

2 The net zero emissions by 2050 target derives from The Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5°C which points to the need for carbon neutrality by mid-century (2050).

3 We asked local Alaska energy sector consultant Mark Foster (MAFA), to review multiple recent studies on the local Alaska employment potential of transitioning the Alaska energy sector to 100% clean renewables. He reviewed four studies (JH Williams et al, *Carbon Neutral Pathways for the United States*, AGU Advances, Research Article 10.1029/2020AV000284, 12 Nov 2020; Cadmus, Alaska's Renewable Energy Future: New Jobs, Affordable Energy, December 2021; MZ Jacobson et al, *Zero Air Pollution and Zero Carbon from All Energy Without Blackouts at Low Cost in Alaska*, December 7, 2021; McKinsey, *The Net-Zero Transition: What it would cost, what it could bring*, January 2022) for their investment, benefits, jobs and economic impact estimates and adjusted their estimated costs and benefits to reflect local Alaska capital, operating, fuel costs and energy systems performance and extended those results through the NREL Jobs and Economic Impact (JEDI) models to derive estimates of the jobs potential of a transition to 100% clean renewables.

4 For an illustrative example of the basis for the job estimates, MAFA adjusted the Jacobson job estimates Table 14. Changes in Employment, Zero Air Pollution and Zero Carbon From All Energy Without Blackouts at Low Cost in Alaska, Professor Mark Z. Jacobson, Stanford University, December 7, 2021. https://web.stanford.edu/group/efmh/jacobson/Articles/I/21-USStates-PDFs/21-WWS-Alaska.pdf

The MAFA job estimates were developed based on Alaska capital and operating costs [which ran from 25% to 225% above the continental United States (hereinafter CONUS) basis used by Jacobson] and rerun the resulting cost estimates through the JEDI models for each respective renewable energy technology. The result is an increase in local Alaska jobs from 82,843 to 103,554 which are offset by the Jacobson identified anticipated loss of 36,338, for a net gain on the order of 67,216 jobs. MAFA notes that this may be a conservative figure in light of the estimated magnitude of the capital investment associated with the construction of the infrastructure to support a transition to 100% clean renewable energy of roughly $128 billion (2020$) over 30 years. This is roughly comparable to building the equivalent of the TransAlaska Pipeline System ($32 billion in 2020$) every 8 years.

5 Synthesis of findings from the four reports reviewed by MAFA (see endote 3), benchmarked to Alaska construction, operating and fuel costs, project development scale and productivity, and extended through the NREL Jobs and Economic Impact (JEDI) models for each respective renewable technology. Independent estimates of storage, transmission and distribution system costs, including both renewable energy resource and demand side resource integrations into a more complex and robust grid were developed from local project cost estimates and local/outside spending patterns and comparable JEDI model multipliers.

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7 GAO Federal Electric Power: Views on the Sale of Alaska Power Administration Hydropower Assets (February 1990), GAO / RCED-90-93.

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11 The State of Alaska Department of Labor and Workforce Development "live labor stats" exclude self-employed workers, fishers, domestics and unpaid family workers.

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Photo Acknowledgements

Cover: *Top:* U.S. Department of Energy. (Jun 17, 2015). *NorthWind 100 turbine in Toksook Bay, Alaska. Photo from Northern Power Systems* [Photograph]. https://www.flickr.com/photos/departmentofenergy/18897521825/in/album-72157652097688443/

Bottom: Renewable Energy Systems Fairbanks, Lower Tanana Dene lands, Alaska

Pg 3: *Top:* U.S. Department of Energy (May 23, 2012). *Repairing the tracking motor on a PV array in the native village of Venetie, Alaska*. Photo courtesy of Brian Hirsch, NREL. https://www.flickr.com/photos/departmentofenergy/9076328721/in/album-72157652097688443/

Bottom: Fairbanks Solarizer Glenna Ganna, Lower Tanana Dene lands, Alaska

Pg 4: U.S. Department of Energy. (Aug 21, 2015). *At a ground-mounted solar installation in Buckland, Alaska* [Photograph]. https://www.flickr.com/photos/departmentofenergy/20740596856/in/album-72157652097688443/

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Pg 8: GPA Photo Archive. The Alaska Pipeline, more formally called the Trans-Alaska Pipeline System (TAPS). [Photograph] Source: en.wikipedia.org/wiki/Trans-Alaska_Pipeline_System. Photo by Carol M. Highsmith.

Pg 10: *Left:* Lamoix via Openverse. *Wind Turbine*. https://wordpress.org/openverse/image/b1fc10ba-880b-4231-849b-1320e23e302c/

Center: iStockphoto, Geothermal steam vent

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Pg 12: Flickr from Pexels via Canva. *Silhouette Photo of Wind Energys during Golden Hour*. https://www.canva.com/photos/MADGxnQbUKM-silhouette-photo-of-wind-energys-during-golden-hour/

Pg 17: Joseph Umnak via Openverse. *Moon Setting Anchorage Airport*. https://wordpress.org/openverse/image/1f672a84-cf20-453a-ae7e-08d4f2b194f1/

Pg 18: U.S. Department of Energy (May 14, 2018). *Kodiak, Alaska* [Photograph] A cargo ship unloads at a crane in the Port of Kodiak. (Photo by Dennis Schroeder / NREL). https://www.flickr.com/photos/departmentofenergy/42644973511/in/album-72157652097688443/

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