I-WEST

Phase One Final Report | Detailed Chapter

Workforce Impacts

VERSION 1.0

ARIZONA STATE UNIVERSITY

DECEMBER 2022

About this report

The Intermountain West Energy Sustainability & Transitions (I-WEST) initiative is funded by the U.S. Department of Energy to develop a regional technology roadmap to transition six U.S. states to a carbon-neutral energy economy. I-WEST encompasses Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming. Each state is represented in this initiative by a local college, university, or national laboratory. Additional partners from beyond the region were selected for their expertise in applicable fields. In the first phase of I-WEST, the team built the foundation for a regional roadmap that models various energy transition scenarios, including the intersections between technologies, climate, energy policy, economics, and energy, environmental, and social justice. This chapter presents work led by an I-WEST partner on one or more of these focus areas. A summary of the entire I-WEST phase one effort is published online at www.iwest.org.

Authors

Robert Page, Arizona State University
Stephanie Arcusa, Arizona State University
Klaus Lackner, Arizona State University

Contributors

Vishrudh Sriramprasad, Arizona State University
Sourabh Patil, Arizona State University
Raghu Santanam, Arizona State University
Selena Gerace, University of Wyoming
Kipp Coddington, University of Wyoming
Charles Nye, University of Wyoming
Brooke Tucker, University of Utah

Table of Contents

INTRODUCTION 5
ASSUMPTIONS AND OUTLOOK 6
ENERGY WORKFORCE LANDSCAPE 10
DISRUPTIONS WITH REASONS FOR OPTIMISM 11
Historical trends 12
Case study: Utah 14
Relocation and training 14
Projected job changes for the next 5 to 15 years 16
Repurposing creates opportunities 18
FUTURE ENERGY WORKFORCE NEEDS 19
Overview 19
Funding 21
Education and training 23
The role of universities 26
Training workers 26
Training trainers 27
Training programs 28
ROADMAP FOR A REGIONAL ENERGY WORKFORCE DEVELOPMENT 28
Urgency 28
What is needed 29
Workforce roadmap 30
Five years: The Great Stall 30
Ten years: A Period of Chaos 30
Fifteen years: Demand 30
WORK BY CATEGORY 31
Solar 31
Hydro 32
Wind 32
Battery backup 32
Alternate back-up 33
Nuclear 33
Membrane capture of CO_2 33
Point source capture and storage (CCS) 33
CO_2 stimulated vertical agriculture 34
Mechanical direct air capture of CO_2 34
Sequestration and long-term storage of CO_2 34
New fuels and transportation 35
Energy efficiency 36
CONCLUSION 37
REFERENCES USED IN THIS CHAPTER 38

APPENDIX 1 .... **52**
APPENDIX 2 .... **65**
APPENDIX 3 .... **70**
APPENDIX 4 .... **71**

Introduction

"DOE plan(s) on the deployment and demonstration of carbon management and clean energy technologies to support the administration's goals of decarbonizing the electricity sector by 2035 and the economy by 2050." - Department of Energy Office of Fossil Energy and Carbon Management[1]

We are in for a lot of change. As the quote above notes, the U.S. intends to rapidly decarbonize electricity generation, to be followed by the decarbonization of transportation. Decarbonizing the electric sector by 2035 would result in the displacement of fossil fuel generation in a timeframe that is less than the expected operating life of many of the current fleet of generating plants.

This chapter postulates on what the changes in our energy mix will mean for labor over the next 15 years. Let's be clear, this is speculation with some data to support it. The energy transition we are going to experience will be too radical to project with clear foresight. One might think of this chapter as a guide to the possible and one might surmise from this guide that education, training, and research are going to be the hallmarks for labor in the coming decade. The more we focus on those three supports, the more successful the energy transition will be.

Worker evolution in the transitioning away from fossil extraction/generation and the accompanying jobs[2] will need a concentrated effort to find new opportunities for those and new workers. This chapter considers how the energy transition might introduce new jobs or growth in areas that already exist as well as entirely new sectors. As most excess CO_2 is emitted by the ubiquitous use of fossil fuels, the scale of the required changes provides perspective on the coming challenges.

There is reason for optimism. Consider the two quotes below; change can happen very rapidly. Humans are an adaptive species, we know how to change, and in this case, we will be adept at changing to save our environment.

"There is no reason anyone would want a computer in their home." Ken Olsen, President and founder of Digital Equipment Corp., 1977

"I think there is a world market for maybe five computers." Thomas Watson, President of IBM, 1943

---

[1] U.S. Department of Energy Office of Fossil Energy and Carbon Management; Request for Information: DE-FOA-0002660

[2] The US Labor Market in 2050; Holzer and LaFarge; Georgetown University. 2018

Our nation is about to embark on a journey to carbon neutrality including a reduction of CO_2 in the atmosphere to pre-2000 levels. As our nation, and others, take these steps we will focus on three approaches. First, we will reduce the production of CO_2 (and other greenhouse gases) and slowly at first, we will capture and "put away" the excess CO_2 that is in the atmosphere and oceans. Second, we will re-create the physical structure of our country. We will make changes to adapt to climate-induced changes such as droughts, fires, flooding, rising seas, and storms. Our transportation will change, our housing will be modified, we will have many new industries replacing ones that will disappear. Third, every nation-state is going to seek to fulfill its role to protect its citizens and enhance their well-being. That will be a tough obligation to meet.

Unequal impacts from extreme events will increase pressure on other regions to provide food and economic growth for their population. Food will be one of many elements that after many thousands of years of sameness will no longer be. Energy may face the biggest changes and the most difficult. We have slowly advanced our physical well-being and longevity through increasing amounts of energy consumption. Sustaining the growth of energy without the burning of fossil carbon is going to be a challenging task to fulfil. Our current world and its culture are going to change, and the coming decades will tell the tale of how successful we were.

Assumptions and outlook

This chapter focuses on the future workforce changes in the Intermountain West region. Efforts at decarbonizing the region are already underway, with all states and communities and companies displaying a certain level of planning and implementation. Many of the states already show decreasing emissions. Efforts at the federal level are ramping up under the Biden-Harris administration, providing funding and direction. International momentum is gaining and pressure from civil society is increasing. At the same time, renewables only provide 3% of the regional electricity generation, while the fossil industry employs over a million workers nationally in various tasks related to fuel extraction, electricity generation, and fossil related transportation (**Table 1**). While our decarbonization efforts lag decades behind what they should be (considering the scientific evidence), as the race to carbon neutrality ramps up there will be new jobs and careers. Achieving decarbonization plans will require a growth in energy production.

The Intermountain West is highly diverse and rapidly developing. It is already experiencing the impacts from the phasing out of coal and the growing pains of a rapid introduction of renewable energy. The region will need to address economic and environmental inequities which are much sharper in this region than in many parts of the US.

The outlook for the region is that fossil carbon will become a less acceptable member of the energy mix. This will not be an overnight change and sectors will experience different impacts. Coal mines and plants are closing in the Intermountain West and will continue to do so with most closures expected to be completed by the early 2030s. Oil extraction is also going to decline (notwithstanding some spikes in production) due to the increase of EVs and public transit. The oil decline will be more gradual and may not be universal until the late 2030s. Natural gas will likely be the slowest sector to close-up wells. While renewables are going to rapidly grow, the need for seasonal and daily backup will keep some fossil in the generation mix. Batteries will provide some backup and natural gas is likely in the next decade to provide the bulk of the remainder. In brief, the outlook for the region is an expansion of renewables, hardening[3] of the energy infrastructure, expanding electric transmission, building out of electric transportation, the introduction of capture technologies including fabrication and operation, and many new technological innovations that will need to be designed and built.

From this outlook, it is clear the transition to carbon neutrality will have a dramatic impact on the energy workforce in the region. The bad news is significant disruption of the workforce from the rapid decrease in fossil fuel extraction jobs. The good news is that energy related jobs will likely increase, and many of these jobs will be at a high skill level[4]. The new work will require retraining or added training and there will be relocation or workers. Jobs will not only need to be plentiful, but they will also need to be "good" jobs that pay a fair wage, offer a secure contract and the right to organize and defend employment and human rights, provide social protection, and offer training[5]. The planning will need to identify the conditions to make that happen.

Overall, it is a story of change but with benefits of new well-paying jobs as a big part of that change[6]. The changes will not just be in terms of the types of jobs; the way we work is also likely to change and evolve over the next fifteen years, not only because of continued automation and the rise of artificial intelligence. Industry will need to embrace training as a part of doing business. Existing community college training programs that are tied to industry as partners are examples of how this might be done[7]. There also will be other models created and used as the transition from a fossil-based energy evolves to one that incorporates more and more renewables.

---

[3] Hardening refers to physically changing the infrastructure to make it less susceptible to damage from extreme wind, flooding, or flying debris.

4 Net-Zero America: Potential pathways, infrastructure, and impacts. Larson et al. (2020). Interim report. Available at https://environmenthalfcentury.princeton.edu/sites/g/files/toruqf331/files/2020-12/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf

[5] "Why equipping workers is the key to energy transition"; Energy Monitor. Phipppa Jones. Sept. 2020

[6] Free market Approaches to Controlling Carbon Dioxide Emissions. Lackner, Wilson, and Ziock. 2000

[7] PVNGS Arizona Training programs

The coming changes have social justice implications. Rural lands, particularly those in tribal lands in each of the Intermountain West states are losing revenue and jobs from the closure of fossil fuel extraction activities and the closure of fossil carbon electricity generating stations. Areas facing economic distress should receive dedicated interventions and the advance of new technologies such as Direct Air Capture (DAC) or hydrogen production will create new possibilities. For example, could closed coal power stations be replaced by DAC facilities? A guide on what this energy transition could look like in terms of workforce will be developed in the following sections and appendices.

Table 1. US energy employment from the 2020 US Energy and Employment Report by the National Association of State Energy Officials and the Energy Futures Initiatives[8]		
Sector	**Employment**	**% Change**
All (4.6% of US population)	6,800,000	1.8%
Fuels	1,148,900	1.9%
Oil	615,500	
Natural Gas	276,000	
Biofuels	775	
Mining	7,000	
Coal Fuels	75,500	
Electricity Generation	896,800	2%
Natural Gas	122,000	8%
Solar	248,000	2.3%
Wind	114,800	3.2%
Coal	79,711	-8%
Transmission and Distribution (T&D)	2.400,000	1.3%
Construction	499,000	4%
T&D	417,600	0%
Energy Efficiency	2,380,000	3%
Motor Vehicles	2,550,000	1%
Alternative Fuels	266,300	-2%
Fuel Economy	494,000	0%

[8] 2020 US Energy & Employment Report. NASEO & Energy Futures Initiative. Available at https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5ee78423c6fcc20e01b83896/1592230956175/USEER+2020+0615.pdf

Energy workforce landscape

The states of the Intermountain West region are distinctive compared to the other U.S. states in several ways. They are mountainous, less urban, and do not have access to water transportation. The region has the highest percentage of government-controlled land and the highest percentage of Native American population of any combination of six states in the continental U.S. Economically, the region has relied heavily on agriculture and extraction of resources. Because land is less densely populated, transportation is heavily focused on roadways and individual vehicles.

The Intermountain West states differ in education, diversity of employment, and the reliance on energy as an economic driver. However, energy has played a significant economic role for all six. Four of the states are in the top ten for energy export and all six are in the top 20. The states have extracted and exported coal, copper, oil, uranium, and natural gas. They have also exported electricity to their more urban neighbors. The states have taken different approaches to carbon neutrality and continued reliance on fossil generation. Some anticipate continued reliance on fossil generation and transportation while others have policies that move away.

Direct employment by the energy sector across the Intermountain West is estimated to total over 500,000 workers (**Table 2**) representing a significant share of the national energy workforce. A typical profile of the workforce can be exemplified by the state of Utah. According to the Kem C. Gardner Policy Institute's Economic Impacts of Utah's Energy Industry Report, in 2017, Utah's energy industry directly and indirectly supported 3.8% of the state's employment, 4.2% of its earnings, and 5.7% of its gross domestic product[9]. According to the 2020 U.S. Energy and Employment Report (USEER)[10] Utah has 31,468 energy workers. The other states resemble this picture. Energy and its related industries are a major employer and pay relatively well.

[9] Kem C. Gardner Policy Institute, Economic Impacts of Utah's Energy Industry, 2017

[10] 2020 U.S. Energy and Employment Report - Utah

Table 2. Direct employment in the energy sector by category Data from the Employment by State 2020 report produced by the National Association of State Energy Officials and the Energy Futures Initiatives.[11]							
Employment Category	**AZ**	**UT**	**NM**	**CO**	**MT**	**WY**	**Total**
Fuels	2,095	11,885	25,123	38,708	5,506	22,191	105,508
Electricity Generation	24,080	11,853	5,321	25,397	1,376	1,526	69,553
T&D	20,776	7,730	13,668	28,480	8,648	9,556	88,858
Energy Efficiency	44,782	32,483	6,099	36,092	8,838	7,568	135,862
Motor Vehicles	31,949	23,266	7,882	32,321	6,226	3,215	104,859

At-risk workforce in the coming energy transition may include those employed in coal mining, coal plant operation and maintenance, fossil energy plant construction, and internal combustion engine maintenance. The workforce relying on natural gas will eventually become at-risk. These at-risk workers are mostly located in rural areas and in tribal communities, adding to challenges arising from historical injustices. For example, in many of the states, tribal nations are faced with the burden of fossil reduction more than the rest of the population. Tribal lands are mineral and resource rich and many fossil power plants were located there. This has meant that tribal communities hold the bulk of the on-site jobs for both coal extraction and coal plant operation and consequently will be at the front line in terms of job loss.

Disruptions with reasons for optimism

The transition will disrupt fossil fuel related jobs and will dislocate workers and communities. Communities in rural areas and on tribal lands will be at the forefront of that change. Yet, the transition is also an opportunity. As a region with recent historical experience in transitioning to become a net-energy exporter with highly trained workers to do so, the Intermountain West states are well positioned to lead the charge in this new transition. Growth in employment in clean energy will likely balance the losses, and most likely will exceed them. Targeted approaches must intentionally focus training and employment generation in distressed communities that have disproportionately lost (or

[11] Energy Employment by State – 2020. NASEO and Energy Futures Initiative. Available at https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5e78198f28dc473dd3225f04/1584929183186/USEER-Energy-Employment-by-State-2020.pdf

will lose) jobs. The synergies of fossil fuel operation repurposing with new technologies like DAC will create new opportunities for employment.

Historical trends

The disruption of the fossil energy related workforce has already begun. For example, in Arizona, the fossil generation plants are closing, and all coal mines are now closed. The Navajo Generating Station has closed, terminating employment for 433 people, the Kayenta mine closed and with it went 265 positions, and the Four Corners and Cholla plants have been assigned closure dates. Other Intermountain West states are experiencing similar closures and terminations.

Since the early 1980s, coal mining employment has decreased to a third of its former level (**Figure 1**). In the period from 2000-2012, employment levelled before reducing to 40,000 workers nationwide. These trends have local impacts that are masked by regional statistics[12]. In Wyoming for example, the number of people employed in coal mining has risen over the last 20 years, from 4,285 in 2001 to 4,781 in 2020. However, it declined significantly since reaching its peak of 7,054 employees in 2009 (**Figure 2**). This decline has not had an adverse impact on overall employment in Wyoming. The unemployment rate in Wyoming has been steeply declining since reaching a peak of 8.1% in May of 2020. As of October 2021, it was down to 4.1% which is lower than the pre-pandemic level of 4.8% in February 2020.

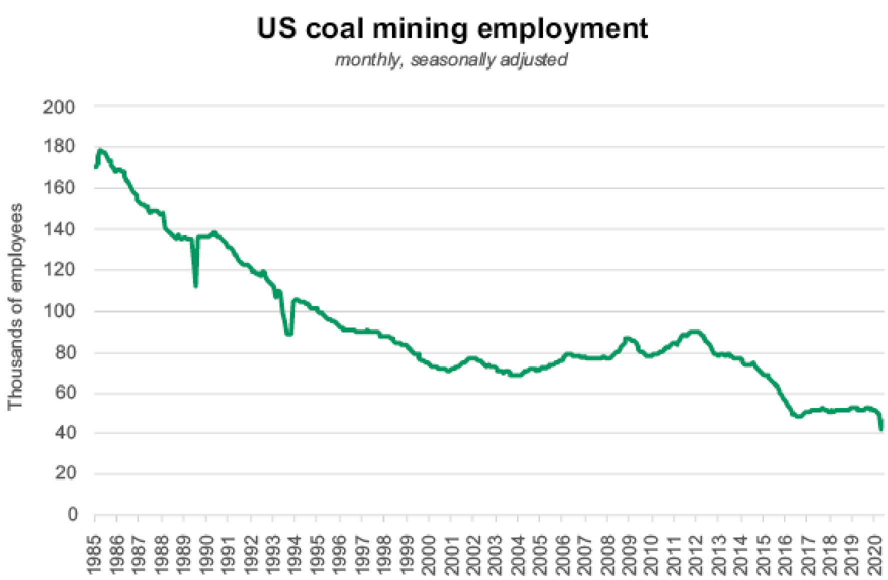

Figure 1. Workers employed in coal mining throughout the United States[13].

[12] Workforce Template for Response. *University of Wyoming School of Energy Resources. Dec. 17, 2021*

[13] EIA Coal Mining Jobs Since 1985; Bureau of Labor Statistics.

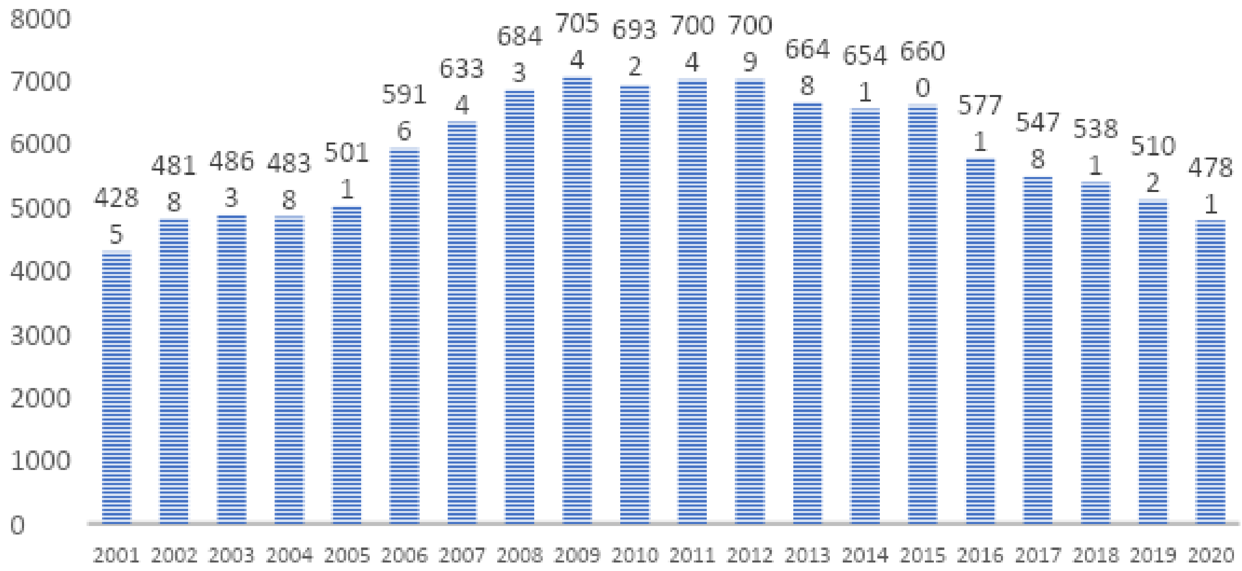

Figure 2. Wyoming residents employed in coal mining 2001-2020.

Table 3. Unemployment rates for October 2021 compared to the U.S. national average of 4.6% Data from U.S. Bureau of Labor Statistics		
State	**Rank**	**Rate %**
Utah	2	2.2
Montana	8	3.1
Wyoming	21	4.1
Arizona	31	5.2
Colorado	34	5.4
New Mexico	47	6.5

Table 4. Wages by state for clean energy jobs Data from Energy Monitor[14]		
State	**State clean energy job wage**	**% Above or below state median wage**
Arizona	$21.27	10.3
Colorado	$23.12	8.5
Montana	$18.08	3.9
New Mexico	$18.95	11.7
Utah	$19.30	5.5
Wyoming	$19.14	4.4

Case study: Utah

In Utah, employment trends are positive. Utah's unemployment rate was 2.2%, while the national unemployment rate was 4.6%. Utah's job growth rate was 3.7% while the U.S. 's was -2.2%. However, like other Intermountain West states, fossil generation is being phased out. Utah is part of PacificCoprs's six-state territory, and PacifiCorp's systemwide Integrated Resource Plan in Utah indicated the planned portfolio may include accelerated coal retirements, no new fossil-fueled resources, continued growth in energy efficiency programs, new transmission investments, and incremental renewable energy and storage resources. The USEER report estimates traditional fossil fuel power generation jobs in Utah at 3,304 in 2020, which was down 3%. Utah's 2021 Employment Summary for October 2021 indicated the mining and natural resources sector lost 1,200 jobs in the last two years. However, COVID-19 may have impacted job numbers during that time.

Relocation and training

Energy transitions are not new but this one will need to be rapid and large scale. As with previous transitions, workers, companies, and industries that navigate the present elegantly can endure while others may struggle. The loss of energy jobs at companies which do not decarbonize will force many people to change careers, and potentially relocate. Wyoming and other Intermountain West states have some transition programs in place, but most workers self-train or move to other positions that require similar skills. Examples might include natural gas pipeline workers shifting to hydrogen and CO_2

[14] Clean Jobs, Better Jobs. Oct 2020. E2, ACORE, CELI, and BW Research

pipelines, or oil and gas drillers switching to water, geothermal, and sequestration wells. These examples are in areas which will have future work nearby.

There will also be growth in the number of jobs in sectors such as transmission, engineering, and dispatching. Coal mines train general skills which can be transferred to any heavy equipment operation, but lack an adjacent industry to shift to, much less one located near existing coal mines. Some oil and gas workers will be able to move into new renewable capture and decarbonized energy jobs, but most coal and other workers do not have a clear path through the transition. These workers may be willing to find their own way, but state training matching market trends could be a significant help. There will also be entirely new occupations such as DAC operations, fabrication and installation of EV chargers, and manufacturing of carbon products from captured carbon.

One example of forward thinking is the "Wyoming Innovation Network," a partnership among the University of Wyoming and Wyoming's community colleges to address new forms of employment and related issues. At the local level, there are initiatives working to preserve jobs in the fossil industries while preparing for the day when those workers could perhaps be employed in new industries such as carbon-to-products. An example of success is the recently announced Natrium nuclear power plant, which will be built in Kemmerer, Wyoming. This new plant reflects success by Wyoming in attracting new energy industries that hold promise for both preserving existing jobs while creating new ones.

The changes and adaptation also impact workers indirectly employed in the energy sector. The commonly used equation that every power plant job translates into ten jobs off-site provides a conceptual guide to the impact of job loss[15]. Closure of extraction operations and generation plants means many other folks within the community are disadvantaged and all lose revenue including commercial, retail, local government, and service professionals. The local doctor and hospital lose revenue and patients, retail stores close, government and schools lay-off, local contractors and service providers lose work, and the entire community shrinks in both funds and population. These changes are felt even more when the communities are remote or isolated – which is the case with most mines and power plants.

Community losses are less direct and harder to both quantify and reverse. Additionally, the logistics of dealing with community loss is more complex. While not ideal, there is an assumption in industrial transitions that some portion of the harmed workforce will relocate. In contrast, communities seldom resettle. They may fail, but there are really only two alternatives which are to 1) bring in another source of employment and revenue or 2) abandon/denigrate the location. States will need to focus funding and plans for new development of employment centers in these locations. Training is going to need to

[15] The 10 to 1 rule, may or may not be accurate, but it is commonly used in power plant siting hearings.

be open to a wide swath of the community and not segregate between ex-energy employees and the local retail worker – they will all need a path forward.

States and communities are starting to consider what the new jobs are going to be and how the current and emerging workforce can be trained/educated to fulfil these new roles. The future jobs and revenue rests on how accurately states and local governments predict what new work might be developed in their locale and how quickly they can train their workforce to serve in these new roles. This is very much a winner and loser situation. Which states will develop the educational and research centers that attract the winners in the battery, DAC, alternative fuels, electric charging, and certification of sequestration industries? These fields and others are going to produce winners. The race to embrace one or more of these has begun.

Projected job changes for the next 5 to 15 years

On the one hand, jobs in fossil-based industries are projected to continue to decline. The Arizona coal mines have closed, and the last coal power plant will soon close. The situation is similar in Wyoming, with the largest electric utility, Rocky Mountain Power, intending to retire its coal plants in the state in the years ahead. The stated goal in their 2021 Integrated Resource Plan (IRP) is a 74% reduction in greenhouse gas emission below 2005 levels by 2030. To meet this goal, they are scheduled to retire 14 of their coal-fired power plants across several states by 2030, and a total of 19 by 2040. Though they converted one unit at a coal-fired power plant to natural gas and are considering a similar conversion of two more units at a separate plant in Wyoming, they are not otherwise choosing to invest in future natural gas construction. Rocky Mountain Power is planning to continue to invest heavily in renewable energy technologies in the state (i.e., wind, solar, grid-scale storage) that should lead to new jobs in these new energy industries[16]. For states like Wyoming with very high shares of the population employed in fossil fuel industries, it is conceivable that energy-related employment may decrease as a share of the total employment[17].

In Utah, the situation is similar. The majority of Utah coal, 64% in 2018, was used in-state. In the past, Utah was a significant net exporter of coal, but out-of-state domestic demand has decreased from a high of 16 million tons in 2001 down to only 1.9 million tons in 2018 as coal has dropped out of favor as a fuel for electric and industrial needs. Utah's foreign exports peaked in the mid-1990s at about 5 million tons, then dropped to near zero in the mid-2000s. However, the foreign export market has seen a resurgence in the past few years, increasing to 3.1 million tons in 2018[18].

---

[16] PacifiCorp; Energy integrated-resource-plan.

[17] Net-Zero America: Potential pathways, infrastructure, and impacts. Larson et al. 2020

[18] Utah's Energy Landscape 5th Edition, Utah Geological Survey

The long-term decline in demand for coal, and anticipated decline in other fossil fuels, if not arrested through carbon capture and storage, will produce knock-on effects in energy generation, transmission, and distribution. The many associated industries such as heavy machinery servicing, environmental reclamation, and all commercial activities which multiply the value of each fossil energy job, will be impacted.

On the other hand, the Intermountain West states are working toward deploying renewables and have targeted other potential growth areas related to the energy transition. Wyoming has seen limited growth in solar PV generation. The only commercial operation in the state is Sweetwater Solar, installed by 174 Power Global. However, Wyoming has seen significant investment in wind generation. This is not only due to the strictly greater average wind speeds in the state, but also the tendency of these winds to blow at dusk and early night, allowing electricity from them to serve peak demand in the Rocky Mountains and west coast. The federal production tax credit for wind has also played a role. Formal electric vehicle infrastructure is limited to larger cities supportive of EV such as Jackson, Cheyenne, and Riverton, but private charging at home and incidental locations means electric vehicles can be found almost anywhere in Wyoming. The trend towards EVs in towns is increasing, but almost all rural areas such as ranches or utilities are dominated by gasoline vehicles. Public transportation follows EV trends, being overall rare, but present in Wyoming towns[19].

In 2018, Utah ranked 26th in the nation in percent of total net electric generation from renewable resources (11.2%) although Utah is one of only seven states where electricity is generated from geothermal resources. Utah's renewable electric generation is dominated by 914 MW of newly installed utility-scale solar farms (50%), followed by hydroelectric (21%), wind (18%), and geothermal (10%) power. Renewable energy sources now account for 11% of Utah's total electricity generation. The total capacity of net-metered PV solar installations (i.e., roof-top solar) in Utah has increased exponentially in the past few years, from a total of 3.4 MW in 2010 to 273 MW in 2018, 78% of which was in the residential sector[20].

Significant potential new transmission investments are underway in Utah, including PacifiCorp's Gateway South project, which filed for a Certificate of Public Convenience and Necessity at the Utah Public Service Commission in September 2021[21], and the TransWest Express project, which recently concluded its open solicitation process[22]. Utah's wind generation produced about 15% of Utah's renewable electricity in 2020. Utah has five wind farms operating with about 390 megawatts of generating capacity. The state's two largest wind farms send power to southern California. Commercial

[19] Workforce summary by Wyoming.

[20] Utah's Energy Landscape 5th Edition, Utah Geological Survey

[21] Utah Public Service Commission Docket No. 21-035-55

[22] TWE Project Open Solicitation

wind power potential is found in the Wasatch and Uinta Mountain ranges in Utah's north-central region and on the mesas in western Utah[23].

During the 2020 session, the Utah Legislature passed H.B.396 [24] which directed the Utah Public Service Commission to authorize Rocky Mountain Power to recover a $50 million investment in an electric vehicle charging infrastructure program. Rocky Mountain Power filed its proposed program with the Utah Public Service Commission in August 2021[25]. Furthermore, the Utah Legislature also passed H.B.259[26], directing the Utah Department of Transportation to lead the creation of a state-wide electric vehicle charging network plan, which was released later that year.[27] The state of Utah is well positioned to serve as a hub for emerging clean industries. The University of Utah Energy and Geoscience Institute has provided extensive characterization of geological formations and carbon sequestration opportunities across the state of Utah.

This balance between destruction and creation of employment will be at play in all Intermountain West states, each starting from a different share of employment in fossil fuel industries. Overall, despite significant job losses in the fossil fuel sector, the increase in activity in other energy sectors may result in either no overall change in employment numbers or see an increase in the 5 to 15 years[28], although locally the impact will be felt differently.

Repurposing creates opportunities

Repurposing abandoned fossil fuel operations for new technologies will bring opportunities to create new and keep existing employment. For example, abandoned strip mines, coal plants, oil fields might be repurposed for DAC, solar farms or wind. Electrical and pipeline infrastructure can be repurposed for renewable energy. This will vary with location. For example, in the Four Corners Region most of these sites would naturally lend themselves to redevelopment with solar energy and in some cases wind energy as well. Combining solar with DAC could develop synthetic liquid fuel. Abandoned oil fields are prime for carbon sequestration. With DAC, old coal mines, retrofitted with renewable energy facilities would lend themselves to the production of synthetic fuel and the production of synthetic chemicals that can be used to displace petrochemicals. Many synergies have yet to be imagined but it is clear

[23] U.S. Energy Information Administration – Utah State Profile and Energy Estimates

[24] H.B. 396 Electric Vehicle Charging Infrastructure Amendments

[25] Utah Public Service Commission Docket No. 20-035-34

[26] H.B. 259 Electric Vehicle Charging Network

[27] State of Utah Electric Vehicle Master Plan, Second Edition 2020

[28] Net-Zero America: Potential pathways, infrastructure, and impacts. Larson et al. 2020

that new technologies are creating opportunities. Repurposing and transformation will bring new workforce avenues.

Future energy workforce needs

Based on the postulated changes and an in-depth analysis of the various energy related activities (**Appendix 1**), we may start to define future workforce needs recognizing that the disruption of workforce by the energy transition will operate alongside other forces including automation and artificial intelligence (AI). To smoothen the disruption, funding, training, education, and policy are primordial needs. New fields of studies, interdisciplinary work, and transformed education centers will be required to support the new workforce. Planning at various levels will be crucial (**Appendix 2**). Communities at the frontlines of the energy transition should be prioritized for training that leads to high-wage, high-demand jobs in clean energy. All communities will need to add new academic subjects and craft training will need to prepare workers for entirely new roles with new skill sets.

Overview

The Intermountain West region ought to continue to have plentiful energy related work, assuming forward looking planning. The work will change, the skill sets to do the work will change, and the states that prepare for the change will benefit. The loss of extraction and closure of power plants will remove well paid jobs. The challenge for the region is to replace that work with new or expanded high skill jobs in the new low-carbon energy industries. Part of the challenge will be adapting to a change in energy production and use, analogous to the invention of the steam engine. Some of the energy mix changes do not demand the same high-level skillset, and thus they pay less. Other new energy jobs will demand a high skill set and as such pay well. The work to maintain a solar plant does not require the same level of worker skills as a coal plant nor does a solar farm employ as many workers per megawatt[29]. Fortunately, solar is not the only new technology that will be employing workers as we transition to the new low carbon future.

The Intermountain West states will need to be aggressive to achieve high employment in the new jobs coming out of the transition. Some areas of work such as manufacturing are less common in the region than other areas of the country. Other work such as the construction of pipelines and transmission lines are large employers in the region, due to the vast expanse of territory that pipe and wire need to cross, yet they do not offer the same large-scale in-place employment as manufacturing. As many of the new technologies are going to require manufacturing facilities that are new and different from any prior factories, the regionmay want to compete for those fabrication facilities and jobs. Tesla assembly in

[29] Parson Brinkerhoff jobs analysis

Nevada and the Kore Power battery plant in Arizona are examples of large new factories developed in non-traditional manufacturing locations[30]. Other examples in the region are the new EV manufacturing facilities for Lucid, Nikola, and ElectraMeccanica[31].

As technologies emerge and move from demonstration to commercial level production, the region will need to choose which opportunities to pursue. The region has done well with some of the new technologies, such as the growing amount of PV solar, EV manufacturing, and advanced battery technologies. By attracting more facilities in these industries and enticing other industries to locate in the region, job losses are less likely to result in extended raises in unemployment. The Intermountain West states will need to develop ways to maximize employment in the areas they are strong, grow the areas that are less robust, and continue to grow and exploit the employment opportunities in the new technologies.

The region will need to form one or more forums to evaluate technologies and estimate which might be pursued for future manufacturing. The I-WEST Initiative, led by Los Alamos National Laboratory, might be applied as a basis for such analysis and evaluation. Structured to include a national lab and research universities, the initiative might serve as a good start and study which of these technologies would benefit from fabrication, research, and development in the region.

In **Appendix 1**, a list of potential fields of employment is discussed in detail. The Appendix reviews areas of existing work that could be expanded and new technologies that are just being realized. While the list is not exhaustive, it is extensive. What the Intermountain West states need to consider is how they can become involved in the new fields such as battery chemistry, EV software, new poly manufacturing and DAC. Also, the states need to build on existing jobs such as pipeline and wire infrastructure.

Future energy worker needs ought to be viewed broadly. As an example, the installation of electric wiring and rails for mass transit should be viewed as a likely place to expand skilled workforce, based on skills that exist and would need only modest additional training. Building more efficient structures will employ workers dependent on skills that are already in place. Fabrication, assembly, and operation of carbon capture devices will need new skills and training, as will the associated chemistry for DAC sorbents.

The states and organizations that view what is coming most broadly and with a positive outlook will be in the best position to deliver high skill jobs to their workforce. Automation and AI are going to be more and more relied on to gain energy efficiency and to avoid harmful emissions. States will need to educate the disciplines that will work in these fields. From primary through graduate school, states will

[30] Kore Power Selects Arizona Site. AZ Governor's Office. July 2021

[31] Arizona could become an EV manufacturing hub. Associated Press. May 2021

need to focus on this and other fields anticipating the growth in the marketplace for skills and educating to fill the coming need.

A new field of study just for CO_2 management will also need to emerge. This new discipline will employ engineers, chemists, designers, mechanics, operators, and managers who understand this field. Just as we created a field of study called aerospace, we need to create a new area of study focused on the removal, sequestration, and use of CO_2.

Now we are heavily focused on fossil energy, and even when we look at the needs for energy work in the future we tend to train and educate for energy generation related jobs such as wind and solar. We need to look at a much broader landscape that will include a larger, more complex mix of work to meet the needs of the energy transition. This appears to be a new industry that will demand high skill levels for the coming work. As of this writing, not a single program of study has been found that encompasses the new work. Arizona State University, the University of Wyoming and a few others are beginning to form schools and research centers that will lead to educating these new disciplines.

Funding

In response to the deterioration of infrastructure across the nation, the Infrastructure Investment and Jobs Act (IIJA or the Infrastructure Bill) would provide for $1.2 trillion in spending, $550 billion of which would be new federal spending to be allocated over the next five years (**Table 5**). The investments would significantly reshape the future of work in the U.S., significantly increasing employment in clean energy, capture and other related areas (**Figure 3**).

Table 5. Funds break down in the Infrastructure Investment and Jobs Act[32]

Sector	**Allocated funds ($B)**
Transit	
Public	39
Railways	66
Electric vehicles	7.5
Electric buses	7.5

[32] At a glance: what's in the Infrastructure Bill? Ernest and Young. Available at: https://www.ey.com/en_us/infrastructure-investment-and-jobs-act

Electric Power	
Power grids	73
Resilience and climate change	
DAC	3.5
Other	50

The new legislation provides many opportunities for work, and we need to educate our workforce to secure them. There will be a lot of work for those who have the skills, if we keep both field and manufacturing work in the U.S. As this funding is on-going, when actual application will unfold is still unknown. There is some prognosis as to how the future work will be allocated. Anticipating what is coming, states that wish to secure fabrication and other employment will need to quickly roll out education and training programs. States and regions will need to analyze what type of education and training should be pursued and begin putting those programs in place. It is abundantly obvious that states must work on education and training so that they can avail themselves of this work.

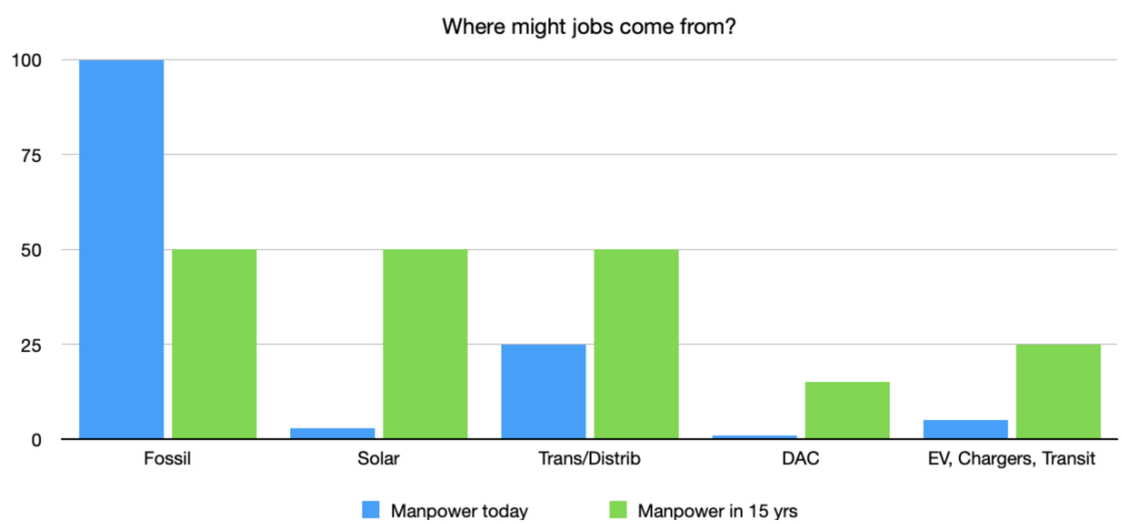

Figure 3. Projection of energy related jobs that could result from the Infrastructure Bill[33]

[33] CNCE analysis.

Education and training

Education may be the most critical factor in the transition of the workforce to new employment opportunities. The better the primary and secondary education the more likely the individual will learn a new skill set[34]. Some of the Intermountain West states have a strong or acceptable educational base. In others, such as Arizona and New Mexico, the education landscape is not encouraging (**Table 6**). Following a good foundational education training programs, colleges and universities can build the specific education/training curriculums that will build the future workforce. Training and education to fill the new jobs that will be appearing to enable the energy transition will depend on a workforce educated to succeed in these new occupations.

Educating new workers that will be entering the job market requires educational opportunities that lean toward new opportunities. Workers need training to pivot to new opportunities. Training will involve many skill sets and educational disciplines. A few areas to consider include design, engineering, construction, assembly and installation, social impact roles, quality and safety, operations and maintenance, electric line work (transmission and distribution), concentration and purification of CO_2, DAC sorbent design/fabrication/application, management, legal, supply chain and transportation, grid dispatching, land management, water reclamation, teaching, and training. States need to commit to build different yet compatible programs to prepare the different age levels and experience levels for new and existing work. There will be a significant range of new work with an equally significant range of educational needs. Programs with specificity should be created now with the expectation that these jobs are coming online quickly.

Potential workers in the education system now and the future need to be advised of the coming opportunities. Additionally, educational programs must be developed to suit those new careers. Consider a new educational discipline – carbonetics – a new applied field of study and training for carbon management. The goal of carbonetics is to advance carbon removal from the environment and provide a sustainable foundation for fighting climate change with a transition to renewable energy that cycles carbon taken from the air through long-term energy storage and transportation fuels. Carbonetics would provide research into carbon avoidance and removal forming a new discipline dedicated to fighting the growth of greenhouse gases.

Existing displaced workers have different challenges from the incoming workers. Not only does applicable training need to be developed, but training/education needs to be located where it is

[34] Union Station Job Training and Hiring Analysis (TECO); 2001

available to those workers. Also, provision needs to be made for education to be off hours for those still working and funding must be provided for those who have or will lose employment during the energy transition. Without life support funding, workers will not be able to sustain themselves while they are trained. Workers that are not adequately trained for jobs with similar skill levels as to what they now have will be disadvantaged.

Table 6. Arizona public school rating by WalletHub [35]	
	Ranking
Overall	49
Highest dropout rate	49
Highest student teacher ratio	50
US Department of Education	
Student reading proficiency	Bottom 10
Student proficiency in maths	Bottom 10
High school graduates to college	Bottom 10
Bachelor’s degree in six years	Bottom 10
US News and World Report Education Rankings by state	
Higher education	33
K12	47

High skill jobs whether “craft” or “professional” are based on education/training from an early age, i.e., on K-12 education. In the Intermountain West, educational ranking by states varies significantly. If we consider Arizona, the state with the lowest ranking in the region[36], it is worth noting that Arizona will have a tougher time with training beyond secondary schooling (**Table 6**).

States and communities need to keep in mind and continue to be mindful of new ideas and possibilities. Transitions such as we are just beginning are both disruptive and creative. Many of the solutions and jobs are not known today, they have not been invented yet. But these new ideas are going to be coming. By paying attention to the new ideas, we are better able to prepare the workforce

[35] Arizona Ranking. US News and World Report

[36] “Less educated; less trained”. Arizona Republic. Rachel Leingang. September 2019

for the changes and opportunities. For example, consider some of the following emerging “out of the box” ideas:

- DAC can be located anywhere; do it where you need it. One of the advantages of some DAC designs as they are agnostic to location allowing for DAC to be built close to a sequestration site or where employment is needed or where product delivery is required.
- Mineralization using volcanic material. Sequestration need not be underground; it can be mineralization that allows the sequestered carbon to be stored above ground or even applied within structures.
- Solar is more opportunistic about space. The photovoltaic industry is just becoming aware of the competition for land that solar will be confronting. Placing solar in space that does not compete with agriculture and recreation will lead to creative applications, and thus jobs that may not be obvious. Consider solar being placed in unique ways such as covering aqueducts and canals, while also reducing evaporation.
- Carbon based fabrication where captured carbon will be the base for new fabrication and fuel development. These industries have not begun and are only just being delineated. The Intermountain West states ought to be in as good a position as anywhere else to recruit these new factories. It is probable that the US will insist on some of these factories being placed within North America, which will be supported by the added cost that will be applied to ocean transport due to the excessive CO_2 released by ships.
- “Sequestration as a Service” (SaaS) initiative (Wyoming) that would build commercial sequestration sites with wells for injecting CO_2 deep beneath the earth’s surface. These sites would be operated by entities with knowledge in the practice of injecting CO_2, which would then offer this as a service to any CO_2 emitter. Wyoming has extensive CO_2 infrastructure. Successful establishment of a SaaS industry would benefit all CO_2 emitters in the state and facilitate establishment of other forward-looking “all of the above” energy prospects such as hydrogen and DAC industries. Near-term initiatives include mitigating liability of Class VI wells used for CCS, utilizing CO_2 for cement, and mitigating CO_2 emissions from the combustion of fossil fuels. The workforce requirements to support this service sector encompass every skill set – from trades to legal and financial, and from executives to scientists, engineers, and laborers.[37]
- Heavy batteries – Batteries have been viewed as an energy source that needs to be mobile. With the advent of large-scale battery backup for solar, batteries are being re-thought and the weight/portability is not a major consideration for stationary back-up. Iron and other materials are being investigated for fabrication.

[37] I-WEST Workforce Landscape. University of Wyoming School of Energy Resources. S. Gerace, K. Coddington, C. Nye. Dec. 2021

The role of universities

As major institutions whose mission it is to educate, universities will have a crucial role to play in the energy workforce transition alongside community colleges and technical schools. These institutions are prepared to upskill and train workers for many of the future energy jobs, especially those that have a direct transfer from existing sectors. However, as discussed previously, the energy transition will also require entirely new fields of study and research with entirely new skills, as well as workers able to bridge between disciplines in ways that have not been achieved to date. Interdisciplinary and transdisciplinary educators and researchers will have to be created to in turn educate and train the new workforce. This will take time to establish, and some efforts are already underway.

Training workers

Differences exist between retraining, reskilling, and upskilling[38]. Retraining refers to teaching new skills on a completely new subject. Reskilling is training the skills needed for a slightly different job at the same company. Whereas upskilling is teaching employees new skills to improve their performance in their current role without necessarily changing their position or career path[38]. The recommended approach is to focus on training, rather than re-training or reskilling. To view the needs of the workforce as anything other than education and training would be an unnecessary distraction. For instance, energy skills have not been particularly prone to re-training. Internal studies by Arizona Public Service, Palo Verde Nuclear generating Station, TECO Union plant, Calpine, and PetroSA GTL have shown that crediting experience and retraining is less effective than offering group training by starting the entire team at the same level assuming a need to bring the team up to the same level together.

Employers and training organizations do look for experience as a part of qualifying for training or education. However, here the energy industry is well accustomed with apprenticeship style training models where workers learn “on the job.” After a base training, employees can then advance individually into more complex and complicated skill sets[39]. This will be necessary as one considers the data analytic skills that would be needed for almost all workers if they have to prepare for the infusion of digital technologies in this industry (e.g., IoT, sensors, etc.). This will have to be from the technician level to the analyst/engineer/manager levels. The specific analytics skills would be at different levels too.

Workforce training will be critical to maintain the expansion of new and revised technologies during the coming energy transition. Some portion of the displaced workforce will be able to move to jobs

---

[38] What is retraining and why is it important? Sara Meij. Go Skills

[39] Project Management Training for Engineers. R. Page, SCM. 2015

related to what they have been trained to do. Others will need to acquire an entire new skill set. One might consider the transition from working a water powered mill to operating a steam engine to appreciate, graphically, the changes facing the workforce. Lateral skills mapping can help identify reskilling/upskilling program needs in this area.

Training trainers

We are about to embark on the greatest engineering challenge ever undertaken. If we are successful, we will not only develop an entirely new discipline of study and work but also have completed the most integrated engineering feat ever. A bold statement until one begins working through the challenges and changes we are facing.

The first question is who will provide "training for the trainer." Currently there are many universities offering courses on climate and the environment while very few have courses on the technologies that are emerging. During the rise of the computer age, many U.S. universities had courses in the basic technologies required to staff this emerging field. Today there are few courses that even touch on carbon management methods and techniques that are emerging.

The major engineering disciplines and some scientific disciplines such as chemistry will cover some of the needed expertise, although this still leaves a large gap in who is being trained for point source capture, carbon to fuel, mineralization, direct air capture, sorbent structure, etc. Not only do we need individuals trained to work in these fields, but we also need to be educating the trainers, the teachers, the researchers, and the professors that will educate the coming workforce.

What does this mean for the regional universities in terms of the energy transition to carbon neutrality? How are they preparing? Are the universities raising funds and finding new teachers, labs, and classrooms? Are new degrees being defined and lesson plans organized? How are new labs being structured, what instruments are being purchased, and who is writing the new test procedures? Many universities are not preparing and will be left behind.

Universities, colleges, and community colleges will need to acknowledge and accept roles in education for professional workers and technical training for craft and operators. Training will need to be broad based and may even blur the traditional lines of universities and community colleges. This will need to be an effort that is universally acknowledged and will drive all educational institutions to play multiple roles.

Training programs

Training will play a significant role in the transition. Some training examples are included in **Appendix 3**. Briefly, some model training programs have been created in the region. The Palo Verde Northern Arizona University training programs, the WYO-GTL program draft in 2014, and the Gila River Station rotational qualification program provide some examples. However, few documented studies exist that would apply to a shift in skills at the level mandated by the energy transition.

Roadmap for a regional energy workforce development

The complexity and uncertainty we face would tend to cause hesitation in developing a structural plan for worker development. Unfortunately, the impacts of climate change are demanding urgency. We attempt in this section to briefly indicate the urgency and then describe the work opportunities that we see coming. There will be work, but in many cases, it is going to be different from current roles. States are going to need to make projections and act on those projections[40].

Urgency

Fixing the climate requires more than climate science and engineering. It means nudging a complex dynamic system of physical and social forces toward a more sustainable state. This is not just about understanding climate, nor is it about promulgating one or more new engineering disciplines. It is about redoing the world's energy system, without missing a beat during the transformation. On the way, to resolution, we will need to learn how to scale up new technologies using massive parallel implementations; measuring the carbon footprint; monitoring and certifying carbon sequestration; and designing economic frameworks that will allow us to pay for carbon removal, even if carbon utilization opportunities remain limited[41].

Two insights into the climate-energy nexus are necessary to note. First, energy is a critical and limiting resource for all modern societies. Without continued growth of energy supply, living standards will drop, causing instability and eliminating any chance of stopping the world's population explosion. Second, to stop climate change, the world needs to become carbon negative, even though fossil carbon is not running out. Only a negative carbon budget can stop the inexorable rise in CO_2 concentrations. Sometime in the twenty-first century the world must become carbon negative, since it

[40] The Fuse has Blown. Jeff Goodell. Rolling Stone. Dec 2021

[41] Lackner, L. Arizona I-WEST Workshop

overshot its target, and find a way of recovering excess carbon from the environment. So far, all attempts to stop greenhouse gas emissions from fossil fuels have failed. The world has entered a dramatic overshoot scenario. Returning to a safe level of CO_2 requires removal and storage of over 100 ppm of CO_2 from the air, or about 1500 Gigaton of CO_2; more than the world emitted during the 20th century[42].

Developing a "workforce roadmap" for the Intermountain West involves planning (**Appendix 2**), education, research, training, recruitment, vision, and policy changes. Federal policy will also play a large role. For example, if the federal government were to adapt a standard for CO_2, as they have for many pollutants, requiring extraction companies to reduce CO_2 releases, with annual increases in the percentage[43] the approach described within this Chapter might be modified. Or, if federal policy required an increasing percentage of carbon extraction/import to be sequestered, such as with the carbon takeback obligation[44], against the assumptions underlying this Chapter would need to be modified. Whichever way this plays out, the states have enormous opportunities to offer their population many new well-paying jobs. The states will need to be active in education, policy, and other factors to allow this to happen. The good news is that it can be done, the bad news is that we are late.

What is needed

We need to start with the clarity of not knowing. What is coming cannot be known. In many instances we have made assumptions leading up to 2022 that have been incorrect, and in some instances, we have relied on false assumptions for years. We thought the changes might not be that severe, we thought it would come more slowly, we thought technology would solve the challenges, and we hoped it would not be up to us to decide what needed to be done.

States might want to consider developing their own knowledge base as to what is happening and where we might consider focusing workforce efforts. One might want to consider beginning with expertise advising the state including economics, physics, law, statistics, and social services. We often think of workers as those who build or service things. For what is coming we need to consider the impacts on the overall populace and how we best serve them. Work in the areas of physics, social services, and policy will all offer work opportunities (**Appendix 1**). In the following we describe a scenario to create a basic roadmap for the future and detail the possibilities for many clean energy

[42] Lackner, L. Intro to DAC. ASU/CNCE 2020

[43] We should harness oil companies to reduce greenhouse gas emissions. Hugh Helferty. The Hill. Dec. 22, 2021

[44] Jenkins, S., Mitchell-Larson, E., Ives, M. C., Haszeldine, S., & Allen, M. (2021). Upstream decarbonization through a carbon takeback obligation: An affordable backstop climate policy. Joule, 5(11), 2777-2796.

sectors. Quickly gathering information, analyzing approaches and needs, and committing to a plan to best serve each state and the region seems to be necessary and ought to begin.

Workforce roadmap

For the workforce roadmap, we consider a range of timescales of 5, 10, and 15 years into the future.

Five years: The Great Stall

The next five years will see a progression of new technologies struggling to find their place as a part of the solution. Oil and gas companies will continue to hold sway over policy. For the workforce this should be a time to position for the future. Education, training, and funding should be aligned to smooth the transition. Other than coal, old jobs in energy will remain or decline slowly. There will be added work, particularly in infrastructure upgrades, renewables, and research. While not a perfect scenario in terms of climate mitigation, this will allow communities to educate, develop policies, recruit employers that have long term growth, and reposition for the transition.

Ten years: A Period of Chaos

In the next ten years, the impacts of climate change will increase and demand attention. Focus will shift toward solving and mitigating. Work is going to ramp up in the energy transition fields. For those trained for the new zero carbon energy future this will be a rich field. New technologies will still be fighting for investment and modest commercial application, but the winners will have begun manufacturing at some scale. Solar and wind farms will blossom, transmission will expand, EVs will displace combustion vehicles, and public transit will dominate transportation funding.

Fifteen years: Demand

Climate will have convinced us that the situation is real and dramatic. Thoughts of halting warming to 1.5 °C will be long gone, and the focus will be on avoiding exceeding 3 °C by the end of the century. Mitigation and even significant migration will have begun. Demand for renewables and capture equipment will outpace production. Work will be abundant for those with experience and training in the technologies that have survived and the new ones that have begun commercial production. Manufacturing, installation, and operation of the various applications of the new energy future will have a high demand for workers. Stability of the local environment will be important for manufacturers and operators, which may be an opportunity for the Intermountain West.

We also consider some form of virtuous cycle that allows some carbon combustion for electric generation. Some fossil power jobs, and carbon extraction jobs would remain. The workers in those jobs would get a reprieve. We should acknowledge that it is a reprieve, not an end solution. Carbon extraction is going to end, probably by 2050. This scenario creates new jobs in capture and sequestration. The capture and storage process become a career path that is likely to remain until the twenty third century. Also, there will be new jobs in the use of CO_2 for products including agriculture and food. There would be additional jobs in products based on carbon extracted from DAC including liquid fuel production for airplanes, ships, other transport, and specialty fuels such as race cars[45]; gas fuel production for power plants, blast furnace, and heating; production of base material for plastics and other carbon-based structural materials.

The attraction of the scenario described above is that it provides a path to end fossil extraction. The discussion of ending fossil extraction tends to be made in absolutes, as if we can end airflight and blast furnaces and continue to have a vibrant economy. Even if the U.S. or some other nation states were to take such a step, it would have no impact other than moving those functions to other countries. When viewing future work, to adequately prepare our workforce for the future, we must be realistic to provide training for work that will exist. In general, the discussion related to workforce on DAC can be applied to point source capture[46]. In the following we detail a possible workforce in each clean energy sector within the context of this scenario.

Work by category

Solar

Solar related employment is expected to grow rapidly over the next 15 years. Solar jobs pay above the U.S. average, with a median base pay of $58,523 per year, 12.4 % above the overall U.S. median base. Recent tariffs on imported solar components should help drive more fabrication in the U.S.[47]

Workforce growth in solar looks good for the Intermountain West. High percentage of "sun days," open space, and available workforce should play well for the workers. Better paying jobs adds to the attraction. Tariffs may allow the states to bid for manufacturing facilities providing good jobs that are community based. Although operating jobs at solar farms use less workers per megawatt than fossil operations, there is a broad range of skills associated with operation and maintenance which is likely to keep the pay scales competitive[48].

---

[45] Synthetic gas as cheap as fossil. Sarah Wells. Inverse. February 2020

[46] Habib paper

[47] Glassdoor, Economic Research. Dr. A. Chamberlin. The Future of Solar Energy Jobs. Sept. 2018

[48] PB Project bid research 2016Wind power expansion. Gero Rueter. Dec 23, 2021. DW

The I-WEST roadmap for employment in this field is straightforward: develop policies that make siting of solar facilities as smooth and rapid as possible, incentivize utilities to transfer to renewables, educate the potential workforce in mechanical and electrical disciplines, software, expand support for engineering degrees, and seek opportunities to bring solar component manufacturing into the region.

Hydro

Hydro work is likely to decline along with the decline in megawatts generated. Drought, storm surges, and fish protection will all combine to create a decline in hydro. Intermountain West hydro facilities are closing, and new ones are not being added.[49] Natural resource protection and water conservation is forcing a reconsideration of hydro[50].

Wind

Wind represents a potential growth industry for the Intermountain West. While wind is limited to areas of high and relatively steady wind, such locations exist in the region. Manufacturing of components is preferred in North America due to shipping costs. The path to greater growth in this field is dependent on a mix of challenges. The cost needs to come down, environmental issues with wildlife need to be resolved, open space needs to be opened to wind farms, transmission lines need to be extended to areas that are compatible with wind production, and the technology needs to improve.

Workforce needs are broad from manufacturing of a variety of components, to installation, to maintenance of devices. Turbine design and manufacturing has long been an American strength that could be leveraged into world leadership in engineering and fabrication of wind turbines. Blade component fabrication also fits historic U.S. skill sets. While the field application will be applied locally, we should focus attention also on design and manufacture[51].

Battery backup

Large scale battery backup is an emerging field. Grid battery back-up is newer and is now entering a new phase of application for renewable power for utility grids. Battery backup will be a rapidly growing field with serious technical and safety challenges in front of it. Of course, challenges mean

---

[49] Dam it, don't dam it, undam it: America's hydropower future. Peter Gleick. Dec 17, 2017. Huff Post (Blog); Deal revives plan for largest US dam demolition. Gillian Flaccus. Nov 17, 2020. Assoc. Press; California hydroelectric plant expected to shut down for first time in 50 years. Joseph Choi, June 17, 2021. The Hill; Lake Powell could stop producing energy in 2023 as water levels plunge. Emma Newburger. Sep 23, 2021. CNBC

[50] How New England Bungled Its Plan to Transition to Renewable Energy. US News. A. Uteuova. Dec. 29, 2021

[51] Wind Power Expansion. Gero Rueter. Dec. 23, 2021. Deutsche Welle (DW)

opportunity. Battery back-up is going to need to be a big part of the future, solving the challenges will mean good work. Current design and chemical components are all subject to change opening up opportunities.

Workforce needs in this area are research and manufacturing. Intermountain West states should look to ways to gain from increased research in this field and consider encouraging manufacturing in the region. Manufacturing does have downsides as environmental issues are among the challenges holding back batteries. The environmental challenges of battery disposal will also create research and employment opportunities.

Alternate back-up

There will be other forms of back-up power. States might find this field attractive for research. Research may not create large numbers of jobs but if it leads to a solution there is opportunity for job growth based on the research.

Nuclear

Nuclear will be an area of research with the potential for growth. If an entity, consider Wyoming's experimental facility, can get in on the front end of new technologies and those technologies succeed there is opportunity for workers. Nuclear design and construction employees across many disciplines, as does operation.

Membrane capture of CO_2

Simple continuous transfer of CO_2 across the membrane as harvest into the "tube" as capture. While the chemistry and physics can be shown to work the application as a functional physical model has not yet been achieved[52].

Point source capture and storage (CCS)

Point source capture may allow some existing coal plants and other CO_2 generators to continue operation, thus extending employment at the fossil facility. However, CCS may not be a politically feasible approach, and has been described as an "orphan technology." The pressure to close coal generation and the stranded capital aspects of CCS may hinder development[53]. A key problem for all carbon capture technology is identifying a political economy framework that will allow, adopt, and

[52] ASU DOE MAAF Project

[53] Post Combustion Capture. Habib Azarabadi and Klaus Lackner. Environmental Science and Technology. 2020

promote development[54]. Point source capture is a multiplier for employment. The design, installation, and operation of CCS adds work opportunities. The continuation of existing fossil plants also allows workers to continue work at the existing location with existing skill sets.

CO_2 stimulated vertical agriculture

Vertical agriculture is going to be a part of our food supply chain. The questions are, will processes be developed that advantage agricultural growth based on added CO_2 and can the capture cycle be certified. Today these are open questions. Although simply applying the vertical aspect may reduce agricultural CO_2 pollution. Vertical agriculture will introduce new jobs with higher mechanical skills than older agricultural methods. Vertical agricultural concentration is an advantage for the workforce.

Mechanical direct air capture of CO_2

DAC makes it possible to treat CO_2 as a waste stream to be cleaned up (see DAC Chapter). It will put a real price on carbon the moment waste management is mandated. A waste removal effort to return the world to 300 or even 350 ppm would support an industry with a multi-trillion-dollar revenue stream. DAC will deliver CO_2 for storage and co-locate with storage infrastructure. It will also be used to produce liquid fuels and other carbon products from carbon dioxide taken from the air, and green hydrogen from water and sunshine. The sunny parts of the region can deliver all the fuel that is necessary to run the rest of the nation. Solar energy would be converted into liquid fuels that feed into the transport sector, but also provide energy in rainy and cold parts of the country when and where renewables are not available. Moving solar energy from one season to another and across continents will require synthetic fuels produced with air captured CO_2. DAC implementation would be a worker multiplier. DAC opens up many new fields for labor. From design of the DAC systems to the design and operation of the off shoots such as captured carbon to fuel or other products, DAC will produce work in design, mass production, assembly, and operation.

Sequestration and long-term storage of CO_2

Many forms of carbon sequestration exist, including forests, grasslands, EOR, deep geological burial, mineralization, and more. Each of these have different timeframes and advantages. Some like forests are currently going in the wrong direction, and others like EOR will have a shortened life unless it can be accomplished without the extraction of additional gas/oil. We must assure that storage is effective

54

and long term, as an example if the biomass stored is going to rot away in a decade or two there must be at the start a functional and measurable means to understand how that is going to be retrieved or covered by other storage[55].

Sequestration means jobs. The question remains as to which of these will do how much of the storage? One may assume that they all will have a role, so for early training purposes the weight to give each is not relevant, but in time it will be. The other quandary is that they are geographically specific. State policy and training will need to be taken into account which may be available to workers in each particular state. Certification, verification, and monitoring of sequestration sites will also create jobs and will require technical training.

New fuels and transportation

The race to create and produce the "new fuels" is wide open. Some ideas will succeed, and others will fail. One would hope that capitalism will once again select, if not the best choice, at least viable choices[56]. For this review we recognize that we do not know enough of how things will roll out to indicate winners and losers. We have therefore assumed a different filter – if the fuel suggests that it will require fossil extraction for the next 15 years, we assume it will not survive.

Hydrogen will likely be an important part of the new fuel mix. Both grey and blue hydrogen require fossil fuel extraction. Green hydrogen relies on renewable energy making it a potential zero-emissions power source but currently only provides 1% of the world's hydrogen[57]. Green hydrogen would be a dynamic job creator as the steps to produce are numerous and complex. Jobs could also be created in certification and verification. If this is one of the future fuels, many new jobs with new skills will result. The competition for green hydrogen will be natural gas with certified CCS and/or synthetic fuels from DAC and other sources.

Biofuel require fossil fuel to make (blend) and produce CO_2 when consumed[58]. It might be argued that by using DAC fuels can be carbon free, however at this stage of development it is hard to understand the benefit of adding more steps to a process that is already complex[59]. Theoretically biofuels could be developed into agricultural and forest-based recycling. This would require the continued commitment of acreage to non-food based growing and certification.

---

[55] Three Ideas for Managing Carbon. Lackner. ASU. Nov 2000

[56] Americana, 400 Years of American Capitalism. Bhu Srinivasan. 2017

[57] The world is addicted to natural gas. Angela Dewan, CNN. Dec. 23, 2021

[58] Biofuel. Science Direct. Series of collected articles. 2014 to 2021

[59] Biofuel Basics. Office of Energy Efficiency and Renewable Energy. US DOE. undated

Sustainable Aviation Fuel SAF is difficult to distinguish from other biofuels and we have reached the same conclusions as for biofuels as to it viability by the mid 2030s[60]. There has been some consideration recently to broaden SAF to include DAC to fuel.

CO_2 capture to carbon fuel pre-supposes the success of DAC. The conversion process is explained in a number of research papers including "The Role of Direct Air Capture of CO_2 in the Developing Energy Transition"[61] and "Closing the Carbon Cycle"[62]. One might view the continuation of carbon as a step in the wrong direction while others assume strict adherence to release and capture rules offers an easier path out of fossil extraction. The workforce implications are quite broad. If this process were to succeed and become mainstream it would offer jobs in capture, concentration, and conversion to fuel. This fuel might in some instances be similar to natural gas extending the life (and jobs) of natural gas pipelines. The continuation of a carbon-based liquid and gas fuel would extend the use of many aspects of the transportation and energy generation sectors.

Electric vehicles are coming in large numbers, although it is unlikely that EVs will reach yearly production at the levels of internal combustion engine vehicles in the near future. EVs are currently more limited in application. Still vehicles mean jobs and a wide variety of them.

Mass transit is the most energy efficient means of transportation, and electrified trains are the most effective mode of transportation to combat climate change. Once again, we are placing an additional burden on renewable generation and the grid. It does not take an advanced study to recognize the amount of renewable electricity that is going to need to be produced by 2050 to meet all of the disparate commitments that various carbon neutral plans have. Mass transit offers jobs from fabrication, installation through operation.

Energy efficiency

Appliances will need to be more efficient although from a workforce perspective manufacturing is likely to continue at the current facilities unless new supply chain and shipping constraints arise. Thus, this would mean less opportunity for the Intermountain West to bring in new manufacturing. Some mitigation options like modifying agricultural processes, increasing home energy efficiency, and increasing building efficiency, will produce a wide variety of jobs.

[60] What is SAF? British Petroleum. July 2021

[61] The Role of DAC in Developing Energy Transition. K Lackner. July 2019

[62] Closing the Carbon Cycle. CNCE/ASU. June 2019

Conclusion

This workforce analysis assumed that we are vigorous in our approach to a “net zero 2050” and the technologies this roadmap relies on must develop rapidly[63]. This provides good news for jobs as speedy change will be good for job growth, but also creates concerns for states in which technological changes are not rapid enough to confront climate change. There will be many challenges and for most of these challenges several things are clear: we need to adapt quickly, magnified opportunities will come for those who are trained/educated for the new roles, and some states/regions will work to get ready and take advantage of the change and others will not. With clear focus on the goal of doing the best for our workforce, there are abundant possibilities for success. Vision and policy will need to be clear and forward looking. Leveraging the assets of the state and locale will require clear-eyed analysis of what one has and how those things might be best leveraged.

**“The secret of change is to focus all of your energy,
not on fighting the old, but on building the new.”**

Socrates

[63] Climate Clubs Overcoming Free-Riding. William Nordhaus. American Economic Review. April 2015

References used in this chapter

1. Alden, E. and C. Hepburn (2019). 10 carbon capture methods compared: costs, stability, permanence, cleanness. EnergyPost.eu, Nov 11 2019. Available at https://energypost.eu/10-carbon-capture-methods-compared-costs-scalability-permanence-cleanness/
2. Morgan, B. (2019). 101 companies committed to reducing their carbon footprint, Forbes, Apr 26, 2019. Available at https://www.forbes.com/sites/blakemorgan/2019/08/26/101-companies-committed-to-reducing-their-carbon-footprint/?sh=69bfbe13260b
3. NASEO and EFI (2020). 2020 US Energy & Employment Report. Available at https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5ee78423c6fcc20e01b83896/1592230956175/USEER+2020+0615.pdf
4. Schleifstein, M. (2021). 2050 Carbon reduction goal could increase US jobs, but losses possible in Louisiana. NOLA.com, Feb 24, 2021. Available at https://www.nola.com/news/environment/article_b685c43e-76f3-11eb-99c9-53fec5e2d6a0.html
5. McCandless, J. (2021). 8 predictions about the future of the auto industry. Newsweek, Dec 23, 2021. Available at https://www.newsweek.com/8-predictions-about-future-auto-industry-1647470
6. St John, A. (2021). 9 hot startups that could make or break the electric car industry by rethinking how drivers plug in. Business Insider, Dec 30, 2021. Available at https://www.businessinsider.com/9-startups-leading-electric-car-vehicle-charging-industry-2021-12
7. Blaufelder, C., Levy, C., Mannion, P., and D. Pinner (2021). A blueprint for scaling voluntary carbon markets to meet the climate challenge. McKinsey & Co , Jan. 2021. Available at https://www.mckinsey.com/business-functions/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenge
8. Kelly, E. (2021). A clean energy transition for workers and communities. Kleinman Center, Univ. of Pennsylvania, January 15, 2021. Available at https://kleinmanenergy.upenn.edu/news-insights/a-clean-energy-transition-for-workers-and-communities/
9. Ibid 8
10. Attenborough, D. (2020). A life on our planet: my witness statement and a vision for the future. Grand Central Publishing, pp 272. ISBN13: 9781538719985.
11. Holness, C. (2022). A pathway to community centered DAC. Carbon180, Jan 5, 2022. Available at https://carbon180.medium.com/a-pathway-to-community-centered-dac-c5be55bf8feb
12. Meckling, J., and E. Biber (2021). A policy roadmap for negative emissions using direct air capture. Nature Communications, 12 (2051). https://doi.org/10.1038/s41467-021-22347-1

13. Smaje, C. (2020). A Small Farm Future: Making the Case for a Society Built Around Local Economies, Self-Provisioning, Agricultural Diversity and a Shared Earth. Chelsea Green Publishing, pp 320. ISBN: 9781603589024
14. Azarabadi, H. and K. Lackner (2019). A sorbent-focused techno-economic analysis of direct air capture. Applied Energy, 250, 959-975. https://doi.org/10.1016/j.apenergy.2019.04.012
15. Plasma Kinetics (n.d.). A zero-carbon hydrogen energy solution; capture, storage and delivery in one container. Available at https://plasmakinetics.com/#:~:text=capturing%20hydrogen&text=Plasma%20Kinetics%20Hydrogen%20Energy%20System,daily%20with%20zero%2Dcarbon%20production.&text=Our%20products%20are%20recyclable%2C%20and,is%20100%25%20zero%2Dcarbon.
16. Parsons Brinckerhoff and Global CCS Institute (2011). Accelerating the uptake of CCS: Industrial Use of Captured Carbon Dioxide. March, 2011. Available at https://www.globalccsinstitute.com/archive/hub/publications/14026/accelerating-uptake-ccs-industrial-use-captured-carbon-dioxide.pdf
17. Vanderpool, T. (2020). After the local coal mine shuts down, these Navajo and Hopi communities seek a just transition. NRDC, October 20, 2020. Available at https://www.nrdc.org/stories/after-local-coal-mine-shuts-down-these-navajo-and-hopi-communities-seek-just-transition
18. Arizona Public Service (2007). Algae oil refinery.
19. All American Marine (n.d.). All American Marine to complete construction of the first hydrogen fuel cell vessel in the US. Available at https://www.allamericanmarine.com/hydrogen-fuel-cell-project/
20. Arizona Public Service, (n.d.). Alternative Fuel Pilot Plant & Hydrogen Internal Combustion Engine Vehicle Testing. Available at https://avt.inl.gov/sites/default/files/pdf/hydrogen/h2factsheet.pdf
21. Newsweek Staff (2021). America's Greatest Disruptors: Hall of Famers. Dec 15, 2021. Newsweek, Special Issue. Available at https://www.newsweek.com/2021/12/24/americas-greatest-disruptors-hall-famers-1659077.html#:~:text=Klaus%20Lackner%20first%20floated%20the,seem%20like%20tilting%20at%20windmills.
22. Srinivasan, B. (2017). Americana: A 400 Year History of American Capitalism, Penguin Press, pp 576. ISBN13: 9780399563799.
23. Mider, Z. and R. Adams-Heard (2021). An empire of dying wells. Bloomberg Green, Oct 12, 2021. Available at https://www.bloomberg.com/features/diversified-energy-natural-gas-wells-methane-leaks-2021/?srnd=green&sref=fyhEsXfZ

24. Pyper, J. (2019). APS plans to add nearly 1GW of new battery storage and solar resources by 2025. Feb 21, 2019. Available at https://www.greentechmedia.com/articles/read/aps-battery-storage-solar-2025
25. Arizona Board of Regents (2020). Arizona college-going and completion rates improve, but still lag nationally. Available at https://azregents.edu/news-releases/arizona-college-going-and-completion-rates-improve-still-lag-nationally
26. Arizona Corporation Commission (2022). Procedural workshop on the matter of impact of the closures of fossil-based generation plant on impacted communities. Jan 6, 2022. Available at https://azcc.granicus.com/DocumentViewer.php?file=azcc_35ca4c7847d2bcdc97da6f004c355f35.pdf&view=1
27. Associated Press (2021). Arizona could become an electric vehicle manufacturing hub. US News, May 9, 2021. Available at https://www.usnews.com/news/best-states/arizona/articles/2021-05-09/arizona-could-become-an-electric-vehicle-manufacturing-hub
28. Arizona employment - comparison western states. Arizona's economy. University of Arizona Economic and Business research Center. Available at https://www.azeconomy.org/arizona-employment-compare-western-states/
29. Gustafson, S. (2007). Arizona Energy Exports. Arizona Economics, June 2007. Available at http://azecon.blogspot.com/2007/06/?m=0
30. The Western Way (2021). Arizona is a Hotbed for Clean Energy. The WesternWay.org, June 28, 2021. Available at https://www.thewesternway.org/tww-blog/2021/6/30/arizona-is-a-hotbed-for-clean-energy-innovation#:~:text=Arizona%20is%20a%20hotbed%20for%20clean%20energy%20innovation.,innovative%20companies%20who%20need%20them.
31. US Bureau of Labor Statistics (2020). May 2020 Arizona occupational employment and wage statistics, 2020. Available at https://www.bls.gov/oes/current/oes_az.htm
32. Arizona Pilots CO2 Sequestration under APS Power Plant. Environmental Protection, Aug. 2009. Available at https://eponline.com/articles/2009/04/03/arizona-pilots-co2-sequestration-under-aps-power-plant.aspx
33. Randazzo, R. (2020). Arizona power must come from 100% carbon-free sources by 2050, regulators decide. Arizona Republic, Oct 29, 2020. Available at https://www.azcentral.com/story/money/business/energy/2020/10/29/arizona-regulators-require-utilities-have-100-carbon-free-power-2050/6071275002/
34. US EIA (2021). Arizona Profile Overview. US Energy Information Administration, March 18, 2021. Available at https://www.eia.gov/state/?sid=AZ
35. Office of the Governor Doug Ducey (2021). Arizona projected to add nearly 550,000 jobs by 2029. Office of the Governor, press release, May 6, 2021. Available at

https://azgovernor.gov/governor/news/2021/05/arizona-projected-add-nearly-550000-jobs-2029

36. Francfort, J.E. (2003). Arizona Public Service – Alternative Fuel (Hydrogen) Pilot Plant Design Report. United States. doi:10.2172/910735.
37. St John, J. (2020). Arizona public service lays out its options for reaching zero-carbon energy by 2050. Green Tech Media, June 30, 2020. Available at https://www.greentechmedia.com/articles/read/arizona-utility-aps-charts-path-to-zero-carbon-energy-by-2050#:~:text=Arizona%20Public%20Service%2C%20the%20state's,as%2Dyet%2Duntested%20technologies.
38. NS Energy Staff Writer (2019). Arizona Public Services to add 400 MW of renewable capacity. NS Energy, July 30, 2019. Available at https://www.nsenergybusiness.com/news/arizona-public-service-400mw-capacity/
39. AZ Big Media Staff Writer (2021). Arizona ranks among 15 best states for electric vehicles. AZ Big Media, Sep 30, 2021. Available at https://azbigmedia.com/business/arizona-ranks-among-15-best-states-for-electric-vehicles/
40. Energy and Environmental Economics (2021). Arizona Statewide Transportation Electrification Plan: Phase II. Available at https://illumeadvising.com/files/AZ_Statewide_Transportation_Electrification_Plan_2021-03-30.pdf
41. The Nature Conservancy (2019). Arizona Thrives; a path to a healthy and prosperous future. Dec 2019. Available at https://azthrives.org/wp-content/uploads/2021/03/Arizona-Thrives-Dec-2019.pdf
42. Armstrong, W. (2021). Arizona Thrives: Projections for Arizona Carbon Emissions. Jan 15, 2021. ASU.
43. Office of Economic Opportunity. Arizona 2020-2022 Projected Employment Report. Short term employment projections report. February 18, 2021. Available at https://www.azcommerce.com/media/1546810/2020-2022_projectionsnarrative.pdf
44. REAP (2022). Arizona vs. United States: Per Capita Personal Income Trends over 1958-2020. US Regional Economic Analysis Project. Available at https://united-states.reaproject.org/analysis/comparative-trends-analysis/per_capita_personal_income/tools/40000/0/
45. Vanek, C. (2021). Arizona's job growth to outpace the nation for next decade. Phoenix Business Journal, May 7, 2021. Available at https://www.bizjournals.com/phoenix/news/2021/05/07/arizona-job-growth-to-outpace-nation.html

46. Arizona Center for Investigative Reporting (2018). As coal plant shutdown looms, Arizona's Navajos and Hopis look for economic solutions. Huffpost, October 20, 2017. Available at https://www.huffpost.com/entry/arizona-navajo-hopi-coal-plant_n_59e61e0fe4b02a215b3379d7
47. Ulitskaya, J. (2021). Average age of U.S. vehicles hits record high, surpasses 12 years. Cars.com, June 15, 2021. Available at https://www.cars.com/articles/average-age-of-u-s-vehicles-hits-record-high-surpasses-12-years-437017/
48. Forbes (2019). Best states for business 2019. #18 Arizona. Available at https://www.forbes.com/places/az/?sh=61e3b00f62d4
49. Business and Sustainable Development Commission (2017). Better business, better world. Report, January 2017. Available at https://sdgs.un.org/sites/default/files/publications/2399BetterBusinessBetterWorld.pdf
50. Kaufman, L. (2022). Biden's $3.5 bet on carbon capture was the easy part. Bloomberg, January 11, 2022. Available at https://www.bloomberg.com/news/articles/2022-01-11/biden-s-3-5-billion-green-investment-on-carbon-capture-was-the-easy-part
51. Beck, C., D. Bellone, S. Hall, J. Kar, D. Olufon (2021). The big choices for oil and gas in navigating the energy transition. McKinsey and Company, March 10, 2021. Available at https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-big-choices-for-oil-and-gas-in-navigating-the-energy-transition
52. Mercado, A. (2021). Biofuels are having a government funding moment. Popular Science, December 24, 2021. Available at https://www.popsci.com/environment/us-government-biofuel/
53. Lackner, K. S., & Azarabadi, H. (2021). Buying down the Cost of Direct Air Capture. Industrial & Engineering Chemistry Research.
54. Choi, J. (2021). California hydroelectric plant expected to shut down for first time in 50 years. The Hill, June 17, 2021. Available at https://thehill.com/policy/energy-environment/559109-california-hydroelectric-plan-expected-to-shut-down-for-the-first
55. Cave, D. (2021). Can a carbon-emitting iron ore tycoon save the planet? The New York Times, October 16, 2021. Available at https://www.nytimes.com/2021/10/16/business/energy-environment/green-energy-fortescue-andrew-forrest.html
56. Carbon180 (n.d.). Mineralization. Available at https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/617fec7ce6f30a1e96cae5a2/1635773863390/Carbon180+FactSheet+Mineralization.pdf
57. Carbon180 (n.d.). Geologic carbon storage. Available at https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/6193e2536bb8037c44a7139a/1637696060921/Carbon180+ENG+FactSheet+GeologicStorage.pdf

58. Carbon180 (n.d.). Carbontech. Available at https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/5f6d056da955ac0f57e4a53d/1600980341861/C180+FactSheet+Carbontech+Sept+2020+Web.pdf
59. Miles, P. (2021). Carbon capture and storage from a point source. Peter Miles, May 20, 2021. Available at https://milespeter061.medium.com/carbon-capture-and-storage-from-a-point-source-1c1560611294
60. Congressional Research Service (2021). Carbon Capture and Sequestration (CCS) in the United States. CRS Report, R44902. Available at https://crsreports.congress.gov/product/pdf/R/R44902
61. Cirucci, J. (2018). Carbon dioxide direct air capture - a geographic gamechanger. ASU/CNCE report.
62. Skarn Associates (2020). Carbon emission curves for iron ore, copper, met coal and nickel. Mining.com, September 10, 2020. Available at https://www.mining.com/carbon-emission-curves-for-iron-ore-copper-met-coal-and-nickel/
63. Tilman, D., Hill, J., & Lehman, C. (2006). Carbon-negative biofuels from low-input high-diversity grassland biomass. Science, 314(5805), 1598-1600. DOI: 10.1126/science.1133306
64. Lackner, K. (2022). Carbon storage introduction. ASU Presentation, January 2022.
65. Wilkerson, I. (2020). Caste: the origins of our discontent. Random House, pp 496. ISBN13: 9780593230251
66. Center for Energy Workforce Development. Resource Sheets on Job Development. Available at https://cewd.org/
67. Friedman, T. (2021). Climate Summit has me energized, and very afraid. The Seattle Times, November 12, 2021. Available at https://www.seattletimes.com/opinion/the-climate-summit-has-me-energized-and-very-afraid/
68. Arcusa, S. (2021). Closing the carbon loop: designing and testing a practical solution for the chemical industry supply chain using certificates of sequestration. ASU Presentation, December 2021.
69. Kuckshinrichs, W., Zapp, P., & Poganietz, W. R. (2007). CO2 emissions of global metal-industries: The case of copper. Applied Energy, 84(7-8), 842-852.
70. Azarabadi, H. (2019). CO_2 capture from peaker plants. ASU presentation, January 23, 2019.
71. Bengaouer, A. and L. Bedel (2019). CO_2 hydrogenation to methane. Chapter 20, Volume 2 Transformations. https://doi.org/10.1515/9783110665147-020
72. Lackner, K. (2019). CO_2 to Zero; How? ASU/CNCE report, June 18, 2019.
73. Jones-Albertus, B. (2017). Confronting the duck curve. US Office of Energy Efficiency & Renewable Energy, October 12, 2017. Available at https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

74. Vetter, D. (2021). Could this revolutionary idea pay our climate change debt and supercharge CO_2 reductions? Forbes, July 9, 2021. Available at https://www.forbes.com/sites/davidrvetter/2021/07/09/could-this-revolutionary-idea-pay-our-climate-change-debt-and-supercharge-co2-reductions/?sh=1579594a640a
75. ASU/CNCE (2020). DAC acreage for capture. ASU/CNCE summary of mastery student work, Spring Semester, 2020.
76. Gleick, P. (2012). Dam it, don't dam it, undam it: America's hydropower future. Huffington Post, August 7, 2012. Available at https://www.huffpost.com/entry/americas-hydropower-future_b_1749182
77. Flaccus, G. (2020). Deal revives plan for largest US dam demolition. Associated Press, November 17, 2020. Available at https://indiancountrytoday.com/news/deal-revives-plan-for-largest-us-dam-demolition
78. ASU/CNCE (2020). Description of a passive carbon tree commercial facility. ASU/CNCE report, May 2020.
79. Buckley, C. (2022). Don't just watch: team behind "Don't Look Up" urges climate action. The New York Time, January 11, 2022. Available at https://www.nytimes.com/2022/01/11/climate/dont-look-up-climate.html
80. Biniek, K., K. Henderson, M. Rogers, G. Santoni (2020). Driving CO_2 emissions to zero (and beyond) with carbon capture, use, and storage. McKinsey Quarterly, June 30, 2020. Available at https://www.mckinsey.com/business-functions/sustainability/our-insights/driving-co2-emissions-to-zero-and-beyond-with-carbon-capture-use-and-storage
81. Schäppi R, Rutz D, Dähler F, Muroyama A, Haueter P, Lilliestam J, Patt A, Furler P, Steinfeld A. Drop-in fuels from sunlight and air. Nature. 2021 Nov 3:1-7.
82. The Nature Conservancy (2021). Economic brief: Advancing Arizona's economic base through high wage job creation in sustainable industries. April 2021. Rounds Consulting Group for The Nature Conservancy and Arizona Thrives.
83. Morris, E. (2019). Edison. Random House, pp 800. ISBN13: 9780812993110
84. Torpey, E. and A. Watson (2014). Education level and jobs: Opportunities by state. Career Outlook, U.S. Bureau of Labor Statistics, September 2014. Available at https://www.bls.gov/careeroutlook/2014/article/mobile/education-level-and-jobs.htm
85. Kamps, H.J. (2021). Energy Dome uses CO2 for long-term power storage for solar energy. TechCrunch, November 30, 2021. Available at https://techcrunch.com/2021/11/30/energy-dome/
86. NASEO and Energy Futures Initiative (2020). Energy Employment by State – 2020. Available at https://static1.squarespace.com/static/5a98cf80ec4eb7c5cd928c61/t/5e78198f28dc473dd3225f04/1584929183186/USEER-Energy-Employment-by-State-2020.pdf
87. Susteon Energy Solutions (2020). Energy Solutions for Net Zero. Available at https://susteon.com/

88. EVADOPTION (2022). EV market share by state. Available at https://evadoption.com/ev-market-share/ev-market-share-state/
89. Kiss, T., & Popovics, S. (2021). Evaluation on the effectiveness of energy policies–Evidence from the carbon reductions in 25 countries. Renewable and Sustainable Energy Reviews, 149, 111348.
90. Spray, A.J. (2021). Everything you need to know about Atlis motor vehicles' upcoming electric pickup truck. Hotcars, August 14, 2021. Available at https://www.hotcars.com/atlis-motor-vehicles-upcoming-electric-pickup-truck/
91. ASU Energy Policy Innovation Council (n.d.) Existing Arizona policies. Available at https://sustainability-innovation.asu.edu/energy-policy/category/existing-az-policies/
92. Reuter (2021). Fact box: Hydrogen's many colors. Reuters, November 18, 2021. Available at https://www.reuters.com/business/cop/hydrogens-many-colours-2021-11-18/
93. C40 Cities and McKinsey Sustainability (2021). Focused adaptation: A strategic approach to climate adaptation in cities. July, 2021. Report. Available at https://c40.my.salesforce.com/sfc/p/#36000001Enhz/a/1Q000000A9MA/ZOxO84.z876AUV3tsOFiauSxBcppcUFz0tqEr5xFz7g
94. Lackner, K.S., Wilson, R. and Ziock, H.J., 2001. Free-Market Approaches to Controlling Carbon Dioxide Emissions to the Atmosphere. In Global Warming and Energy Policy (pp. 31-46). Springer, Boston, MA.
95. McKinsey & Co (2021). Global energy landscape is going through major shifts: What does this mean for value pools in energy? November 30, 2021. Available at https://www.mckinsey.com/industries/oil-and-gas/our-insights/petroleum-blog/the-global-energy-landscape-is-going-through-major-shifts-what-does-this-mean-for-energy-value-pools
96. McKinsey & Co (2021). Global energy perspective 2021. January 2021. Available at https://www.mckinsey.com/~/media/McKinsey/Industries/Oil%20and%20Gas/Our%20Insights/Global%20Energy%20Perspective%202021/Global-Energy-Perspective-2021-final.pdf
97. McKinsey Sustainability (2021). Green corridors: A lane for zero carbon shipping. Report, December 21, 2021. Available at https://www.mckinsey.com/business-functions/sustainability/our-insights/green-corridors-a-lane-for-zero-carbon-shipping
98. USA Facts (2020). How many electric cars are on the road in the United States? USA Facts, October 22, 2021. Available at https://usafacts.org/articles/how-many-electric-cars-in-united-states/
99. Jacobo, J. (2021). Melting Arctic ice will have catastrophic effects on the world, experts say. Here's how. ABC news, December 24, 2021. Available at https://abcnews.go.com/International/melting-arctic-ice-catastrophic-effects-world-experts/story?id=81588333

100. EDF (2020). How the clean energy transition affects workers and communities. August 11, 2020. Available at https://www.edf.org/how-clean-energy-transition-affects-workers-and-communities
101. Murphy, J. (n.d.). How to retain employees: 20 practical takeaways from 8 case studies. Snacknation. Available at https://snacknation.com/blog/how-to-retain-employees/
102. Burrow, S. (2015). How will climate change affect jobs? World Economic Forum, December 1, 2015. Available at https://www.weforum.org/agenda/2015/12/how-will-climate-change-affect-jobs/
103. Morris, J. (2021). Hydrogen is not a fuel, it's a cult. Forbes, December 11, 2021. Available at https://www.forbes.com/sites/jamesmorris/2021/12/11/hydrogen-is-not-a-fuel-its-a-cult/?sh=29f36ad36d07
104. Ernest and Young (n.d,). At a glance: what's in the Infrastructure Bill? Available at: https://www.ey.com/en_us/infrastructure-investment-and-jobs-act
105. Hellstern, T., K. Henderson, S. Kane, and M.Rogers (2021). Innovating to net zero: An executive's guide to climate technology. McKinsey Sustainability, October 28, 2021. Available at https://www.mckinsey.com/business-functions/sustainability/our-insights/innovating-to-net-zero-an-executives-guide-to-climate-technology
106. Ferris, N. (2021). Investment in skills is key to realizing the clean energy transition. Energy Monitor, April 30, 2021. Available at https://www.energymonitor.ai/policy/just-transition/investment-in-skills-is-key-to-realising-the-clean-energy-transition
107. Thompson, C. (2021). Is sucking carbon out of the air the solution to the climate crisis. Mother Jones, December 2021. Available at https://www.motherjones.com/environment/2021/10/sucking-carbon-engineering-global-thermostat-co2-direct-air-capture-climeworks-solution-climate-crisis-big-oil-boondoggle-ipcc/
108. Hawkins, A. (2021). It's time for car companies to shup up about electric vehicles and just ship them. The Verge, December 21, 2021. Available at https://www.theverge.com/2021/12/21/22846960/electric-vehicles-car-companies-promises-ship-dates
109. McKinsey & Company (2017). Jobs lost, jobs gained: Workforce transition in a time of automation. McKinsey Global Institute, December 2017 report. Available at https://www.mckinsey.com/~/media/mckinsey/industries/public%20and%20social%20sector/our%20insights/what%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/mgi%20jobs%20lost-jobs%20gained_report_december%202017.pdf
110. Office of Governor Doug Ducey (2021). KORE Power Selects Arizona Site For One Million Square Foot "KOREPlex" Lithium-Ion Battery Manufacturing Facility. News Release, Governor's Office, July 19, 2021. Available at https://azgovernor.gov/governor/news/2021/07/kore-power-selects-arizona-site-one-million-square-foot-koreplex-lithium-ion

111. Newburger, E. (2021). Lake Powell could stop producing energy in 2023 as water levels plunge. CNBC, September 23, 2021. Available at https://www.cnbc.com/2021/09/23/lake-powell-hydropower-at-risk-as-water-levels-plunge-says-blm.html
112. Randazzo, R. (2019). Last coal train rolls to Arizona power plant as closure looms for major polluter. The Republic, August 26, 2019. Available at https://www.azcentral.com/story/money/business/energy/2019/08/26/navajo-generating-station-receives-last-trainload-coal-mine-kayenta/2089822001/
113. Leingang, R. (2019). Less educated. Less trained. If trends don't change, Arizonans' prosperity in peril. The Republic, September 19, 2019. Available at https://www.azcentral.com/in-depth/news/local/arizona-education/2019/09/18/life-after-high-school-education-level-by-state-arizona-trending-wrong-direction/1963893001/
114. Hammond, G.W. (2019). Let the good times roll: Arizona expansion stays strong. University of Arizona Eller College of Management, March 15, 2019. Available at https://eller.arizona.edu/news/2019/03/let-good-times-roll-arizona%E2%80%99s-expansion-stays-strong
115. Higginbotham, A. (2019). Midnight in Chernobyl: the untold story of the world's greatest nuclear disaster. Simon & Schuster, pp 538. ISBN13: 9781501134616
116. Green, M. (2021). Molecular mechanisms of moisture-driven DAC within polymeric sorbents. ASU internal report.
117. McKinsey & Co (2021). Net zero by 2035: A pathway to rapidly decarbonize the US power system. Article, October 14, 2021. Available at https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/net-zero-by-2035-a-pathway-to-rapidly-decarbonize-the-us-power-system
118. IEA (2021). Net zero by 2050: A roadmap for the global energy sector. Report, May 2021. Available at https://www.iea.org/reports/net-zero-by-2050
119. Deich, N. (2021). Net zero isn't enough. We need to get to net negative. Fortune, September 23, 2021. Available at https://fortune.com/2021/09/23/net-zero-emissions-carbon-removal-net-negative-cop26/
120. Wade, W. J. Tirone, S. Oda (2022). Nuclear Power gets a fresh look as nations chase climate goals. Bloomberg, January 10, 2022. Available at https://www.bloomberg.com/news/articles/2022-01-10/nuclear-power-reactors-could-be-way-for-nations-to-achieve-climate-goals
121. IEA (2019). Offshore wind outlook 2019. Report, November 2019. Available at https://www.iea.org/reports/offshore-wind-outlook-2019
122. Azarabadi, H. and Lackner, K.S., 2020. Postcombustion capture or direct air capture in decarbonizing US natural gas power?. Environmental science & technology, 54(8), pp.5102-5111.

123. McKinsey Sustainability (2021). Protecting people from a changing climate: the case for resilience. Article, November 8, 2021. Available at https://www.mckinsey.com/business-functions/sustainability/our-insights/protecting-people-from-a-changing-climate-the-case-for-resilience
124. Boudet, H.S., 2019. Public perceptions of and responses to new energy technologies. nature energy, 4(6), pp.446-455.
125. Henderson, R. (2020). Reimagining Capitalism: A World on Fire. Public Affairs, pp 336. ISBN13: 9781541730151
126. Marcacci, S. (2019). Renewable energy job boom creates economic opportunity as coal industry slumps. Forbes, April 22, 2019. Available at https://www.forbes.com/sites/energyinnovation/2019/04/22/renewable-energy-job-boom-creating-economic-opportunity-as-coal-industry-slumps/?sh=3ecf032f3665
127. REN21 (2018). Renewables global status report. Renewable Energy Policy Network for the 21st Century. Available at https://www.ren21.net/reports/global-status-report/
128. IEA (2019). Renewables – 2019. Report, October, 2019. Available at https://www.iea.org/reports/renewables-2019
129. De Vaus, R. (2001). Research design in social research. SAGE, pp 296. ISBN: 9781446226117
130. Illanes, P., S. Lund, M. Mourshed, S. Rutherford, M. Tyreman (2018). Retraining and reskilling workers in the age of automation. McKinsey Global Institute article, January 22, 2018. Available at https://www.mckinsey.com/featured-insights/future-of-work/retraining-and-reskilling-workers-in-the-age-of-automation
131. Kloeben, S. (2021). Rhode Osland's plan to combat climate change strategy leadership at an inflection point. Harvard Extension School, December 16, 2021.
132. Goldman, M.C. (2021). Rivian stock jolts higher, lifting market value past Ford and GM. The Street, November 11, 2021. Available at https://www.thestreet.com/markets/ipos/rivian-stock-jolts-higher-lifting-market-value-past-ford-and-gm
133. Lackner, K.S. (2019). Role of direct air capture of co2 in the developing energy transition. ASU/CNCE internal article, July 2019.
134. Honeywell (n.d.). Taking off soon: a new kind of sustainable aviation fuel (SAF). Article. Available at https://www.honeywell.com/us/en/news/2021/09/taking-off-soon-a-new-kind-of-sustainable-aviation-fuel-saf
135. Smith, J.E. (2021). San Diego overhauls flawed climate plan, aims for 'net zero' greenhouse gas by 2035. The San Diego Union Tribune, November 10, 2021. Available at https://www.sandiegouniontribune.com/news/environment/story/2021-11-10/san-diego-pledges-net-zero-greenhouse-gas-2035
136. Dahlgren, E., Göçmen, C., Lackner, K. and Van Ryzin, G., 2013. Small modular infrastructure. The Engineering Economist, 58(4), pp.231-264.

137. Krishnan, M., T. Naucler, D. Pacthod, D. Pinner, H. Samandari, S. Smit, H. Tai (2021). Solving the net-zero equation: Nine requirements for a more orderly transition. McKinsey Sustainability, article. Available at https://www.mckinsey.com/business-functions/sustainability/our-insights/solving-the-net-zero-equation-nine-requirements-for-a-more-orderly-transition
138. Doerr, J. (2021). Speed & scale: an action plan for solving our climate crisis now. Portfolio, pp 448. ISBN:0593420470.
139. Azadi, M., Northey, S.A., Ali, S.H. and Edraki, M., 2020. Transparency on greenhouse gas emissions from mining to enable climate change mitigation. Nature Geoscience, 13(2), pp.100-104.
140. Schwartz, N. (2022). Supply chain woes prompt a new push to revive US factories. The New York Times, January 5, 2022. Available at https://www.nytimes.com/2022/01/05/business/economy/supply-chain-reshoring-us-manufacturing.html
141. Anderson, C. (2020). Carbon capture. Prime Movers Lab, report. Available at https://www.primemoverslab.com/resources/ideas/carbon-capture.pdf
142. Center for the Future of Arizona (2021). The Arizona we want: The decade ahead. Available at https://www.arizonafuture.org/media/unfojhmh/cfa_arizona_we_want_the_decade_ahead_digital.pdf
143. Lewis, M. (2018). The Fifth Risk: Undoing Democracy. W.W. Norton Company, pp 256. ISBN13: 9780393357455
144. Selingo, J. (2018). The false promises of worker retraining. The Atlantic, January 8, 2018. Available at https://www.theatlantic.com/education/archive/2018/01/the-false-promises-of-worker-retraining/549398/
145. Chamberlain, A. (2018). The future of solar energy jobs: bright or mostly overcast? Glassdoor Economic Research, September 21, 2018. Available at https://www.glassdoor.com/research/solar-energy-jobs/
146. West, D.M. (2013). The paradox of worker shortages at a time of high national unemployment. Brookings, article, April 10, 2013. Available at https://www.brookings.edu/research/the-paradox-of-worker-shortages-at-a-time-of-high-national-unemployment/
147. Cohen, S. (2021). The practical path to America's electric vehicle transition. Columbia Climate School, August 9, 2021. Available at https://news.climate.columbia.edu/2021/08/09/the-practical-path-to-americas-electric-vehicle-transition/
148. The Brattle Group and Rhode Island Office of Energy Resources (2020). The road to 100% renewable electricity. Report. Available at http://www.energy.ri.gov/documents/renewable/The%20Road%20to%20100%20Percent%20Renewable%20Electricity%20-%20Brattle%2004Feb2021.pdf

149. Lackner, K.S., Brennan, S., Matter, J.M., Park, A.H.A., Wright, A. and Van Der Zwaan, B., 2012. The urgency of the development of CO2 capture from ambient air. Proceedings of the National Academy of Sciences, 109(33), pp.13156-13162.
150. Holzer, H.J. (2019). The US labor market in 2050: Supply, demand, and policies to improve outcomes. IZA Policy Paper No. 148. Available at https://www.iza.org/en/publications/pp/148/imprint
151. Dewan, A. (2021). The world is addicted to natural gas. Fossil fuel companies are lobbying hard to keep it that way. CNN, December 23, 2021. Available at https://www.cnn.com/2021/12/23/europe/natural-gas-green-hydrogen-fossil-fuel-lobbying-climate-cmd-intl/index.html
152. Meyer, R. (2022). The world is half-prepared for a different energy future. The Atlantic, January 5, 2022. Available at https://www.theatlantic.com/science/archive/2022/01/oil-prices-clean-energy-investments/621161/
153. Lackner, K.S. (2022). These machines scrub greenhouse gases from the air – an inventor of direct air capture technology shows how it works. The Conversation, January 18, 2022. Available at https://theconversation.com/these-machines-scrub-greenhouse-gases-from-the-air-an-inventor-of-direct-air-capture-technology-shows-how-it-works-172306
154. Hammond, G. (2021). Arizona's hot summer recovery. Third Quarter 2021 Forecast. Economic and Business Research Center, University of Arizona. Available at https://www.azeconomy.org/2021/09/outlook/arizonas-hot-summer-recovery/
155. Lackner, K.S. (2020). Three ideas for managing carbon waste. ASU/CNCE internal document, November 17, 2020.
156. Kloeben, S. (2021). US energy model for 2050. Harvard Extension School.
157. Helferty, H. (2021). We should harness oil companies to reduce greenhouse gas emissions. The Hill, December 22, 2021. Available at https://thehill.com/opinion/energy-environment/586991-we-should-harness-oil-companies-to-reduce-greenhouse-gas-emissions
158. Moyes, A. (2021). What is sustainable aviation fuel? BP Petroleum, July 2021. Available at https://www.bp.com/en/global/air-bp/news-and-views/views/what-is-sustainable-aviation-fuel-saf-and-why-is-it-important.html
159. Meij, S. (n.d.) What retraining is and why it is important? GoSkills, article. Available at https://www.goskills.com/Resources/Retraining.
160. Bradstock, F. (2021). What will happen to oil and gas workers after the energy transition? Oilprice.com, December 2, 2021. Available at https://oilprice.com/Energy/Energy-General/What-Will-Happen-To-Oil-And-Gas-Workers-After-The-Energy-Transition.html
161. US Government Agencies (2014). What works in job training: a synthesis of the evidence? US Department of Labor, US Department of Commerce, US Department of Education, US

Department of Health and Human Services, report, July 22, 2014. Available at https://www.dol.gov/sites/dolgov/files/OASP/legacy/files/jdt.pdf
162. Peach, S. (2021). Which climate change jobs will be in high demand in the future? Yale Climate Connections, May 5, 2021. Available at https://yaleclimateconnections.org/2021/05/which-climate-change-jobs-will-be-in-high-demand-in-the-future/
163. Friedemann, A. Why net zero carbon contraptions are absurd. Energyskeptic, October 14, 2021. Available at https://energyskeptic.com/2021/carbon-capture-and-storage/
164. DW (n.d.). Wind power expansion creates millions of new jobs. DW, article. Available at https://www.dw.com/en/wind-power-expansion-creates-millions-of-new-jobs/a-60172954
165. Lackner, K.S. and H. Azarabadi (2021). Why small modular direct air capture? ASU/CNCE internal paper.
166. Page, R. (2021). Worker fossil waste litany. ASU/CNCE internal paper.
167. Raghu, S., T. Sugar, K. Watanabe-Sailor, A. Mada Kannan (2021). Arizona Workforce Training Accelerator Partnership for Next Generation Jobs (AZNext). Available at https://asu.pure.elsevier.com/en/projects/arizona-workforce-training-accelerator-partnership-for-next-gener

Appendix 1

Future Energy Workforce Needs. How might we look at the work that is coming or could be coming if the Intermountain West is positioned to gather its share of the new energy economy.

Next 15 years energy work that might develop in the Intermountain Region

1. Technology development
    a. Engineering firms with a presence in the Intermountain West (IMW) such as Jacobs and Burns & McDonnell will have many opportunities to design and engineer the emerging technologies.
    b. The IMW Universities are positioned to be on the forefront of some of the emerging critical fields in the transition. The University of Wyoming is known to be a leader in climate research.
2. Manufacturing and Fabrication of Solar PV
    a. The design and fabrication of EV's is already occurring in the IMW and DAC devices and equipment will need to be manufactured.
    b. The US has lost the fabrication of solar to China and there are signs that the Chinese quality may reduce the lifespan of Chinese PV thus opening a potential opportunity for fabrication outside of the PRC. Also, First Solar is headquartered in the IMW and may for some reasons of quality and supply chain return a portion of PV fabrication to the US.
3. Manufacturing and Fabrication of Capture Devices
    a. Currently there are two approaches to capture devices, and a third coming. The two approaches:
        i. #1. **Source capture**: Source capture will require the fabrication of many parts and pieces including the final equipment that will align to the "Stack". Therefore, fabrication will create jobs requiring a variety of skills and one might assume that much of this fabrication will go to companies that already make the pumps, fans and other equipment that is similar to what is manufactured today for other purposes. The final factory assembly and some of the components will be new fabrication facilities. For passive capture there may be more that is new such as capture vessels out of poly.
        ii. #2. **Direct Air Capture**

1. Active – fabrication and supply chain may be similar to the description above.
2. Passive – fabrication for passive may be a hybrid, with some of the components coming from existing manufacturers, and other components may be entirely new such as the vessel and the sorbent holder out of poly material creating a new fabrication design and execution. For the IMW the interesting thing would be if this new fabrication might be done in the IMW. Currently there are supply discussions on-going that favor fabrication for passive equipment to be "close" to the capture farm. Thus, if the IMW attracts the farms the IMW has an opportunity. To attract the accompanying fabrication of passive systems.

iii. **Developing a membrane that uses water evaporation to passively concentrate CO_2 in a continuous fashion.**

4. Extraction
   a. The IMW is an exporter of energy largely through the extraction of fossil fuels. That is going to be reduced. However, oil and gas will continue to be pumped for the next 15 years (and beyond), and the extraction of uranium may actually increase toward the end of the 15-year period. While extraction will experience a decline, the probability that the decline will be gradual provides the opportunity for re-training and transition of the workforce.
   b. One part of extraction will create new jobs. The pressure to contain methane leakage from wells will require new projects at well heads and probably piping or storage. Once captured, this now excess methane will need to be turned into a product – more jobs.
5. Renewables
   a. Solar install and operation are going to need to proceed at a much faster pace to meet the committed objectives of the energy transition. Solar installation and operation are less labor intensive than most forms of fossil generation, but the need for massive amounts of growth should provide a large number of jobs. A great deal of solar generation improvement is in front of us that would create many design and engineering jobs. The IMW has several advantages including open space for solar, more sunshine than other regions, an existing skilled workforce that will be looking for energy jobs, and research institutions currently working on solar.

      In addition, to the quality concerns that are just beginning to impact solar, the use of land will need to be addressed. Locations still exist where expanding solar will not compete with other uses, and this is going to be a growing challenge. Solar may not be the highest and best use when compared to agriculture, housing, and other land use. We will need to design new approaches that accommodate dual uses.

Currently only a very small portion of grid power uses solar, so land use is not now an issue, but will need to be considered in the future. With the expansion of solar into a significant portion of the US energy, solar will compete with agriculture, housing, park lands, transportation and forests for land. Solar will have many trade-offs to surmount, not the least of which will be the removal of woods and forests that provide a natural CO_2 collection sink and water collection tank.

Renewables have some downsides including land use and geographic preferences (solar needs to be where the sun shines and wind power needs relatively constant wind), and intermittent supply. Solar will not be economical in all areas of the US or the IMW due to the amount of sun power per day and the cost of land. Yet, solar canopies are barely beginning to show up in this country's endless acreage of parking lots. The Washington, D.C., Metro transit system, for instance, has just contracted to build its first solar canopies at four of its rail station parking lots, with a projected capacity of 12.8 megawatts. New York's John F. Kennedy International Airport is now building its first, a 12.3-megawatt canopy costing $56 million. Evansville (Indiana) Regional Airport, however, already has two, covering 368 parking spaces, at a cost of $6.5 million. According to a spokesperson, the solar canopy earned a $310,000 profit in its first year of operation, based on premium pricing of those spaces and the sale of power at wholesale rates to the local utility.

b. Wind turbines are geographically more limited in the IMW than in some areas of the US (such as coastal states). However, there are a few excellent areas for wind generation and funding is already being directed to farms in these IMW regions. Wind turbines have the advantage of transitioning workers into a technology that many are already trained in – turbines. Due to the isolation of most of the farms there will be transmission jobs associated with wind generation advancement.

6. Battery Manufacturing

    a. Battery manufacturing employs a good number of high paying employees. The recently announced Kore battery plant will employ 3,000 permanent employees and support 10,000 indirect jobs to produce lithium batteries. There will additionally be 3,400 jobs to construct the 1 million square foot facility.

b. A transfer of some battery manufacturing back to the US would open up opportunities for the IMW. The Kore facility will be in Arizona, signalling the potential for the IMW region.

7. Generation

a. The IMW is an exporter of electricity, and this is likely to grow. Arizona, the largest regional exporter, is a good example to follow. Arizona exported 300 trillion Btu of electricity in 2020. As the US 4th largest producer of solar electricity a portion of the export was dedicated to solar generation based on customer contracts requiring (and paying a premium) for that generation source. Like other IMW states, AZ has many megawatts of stranded generation (generation plants that are not run at capacity). With the two new transmission lines being built (halted since the initial request from California in 2007) there will be more power flowing out of the state, and the underutilized natural gas plants and new solar farms in the Hassayampa Basin will operate closer to capacity.

Arizona has 14,000 MW of natural gas generation in total underutilized. Other IMW states also have stranded ng generation. The IMW is surrounded by states without adequate generation. The potential for the IMW to be a supplier to other states and benefit from the job growth resulting from running these plants is a large potential job creator. If a rough rule of thumb is used that every 100 MW of generation creates 100 well-paying jobs 14,000 MW means a good number of jobs.

This section seems to fly in the face of our need to reduce CO_2 as a part of our transition. What we are recognizing here is that this will be a transition, and some of the old CO_2 producing generation will survive for a while and possibly longer if we can capture and recycle CO_2 into fuels.

b. Other thoughts on generation: Coal will be gone before 2030 in the IMW. There will be many arguments resisting this projection, but in the end it is the most likely outcome. Oil will be depressed but not go away within the next 15 years. Hydro is in trouble and will decline as water becomes more important than power. Finally, the premium for solar and wind generation will grow rapidly helping to spur renewable generation & installation.

8. Direct Air Capture (refer also to the ASU report on DAC)

a. DAC is going to be a part of the transition to carbon neutrality and bringing the CO2 ppm back to under 350. While the amount of DAC is thoroughly debated elsewhere it is fair to project DAC as being a job creator in the IMW. DAC has job creation potential from design through product development. The IMW already is a leader in DAC design and testing. Based on the ability in the IMW to tie DAC to solar, one ought to assume that DAC farms will be built in the IMW. DAC farms will require skilled workers to build and operate. The plans, including the concentration of the CO_2, will employ a full-time workforce with a range of technical and skilled craft jobs.

    b. As DAC farms are built in the IMW there will be the accompanying need for renewables to be built as a part of the concentration process. Once concentrated the CO_2 has numerous product routes including fuel. Fuel development from DAC would create more jobs including the pipelines to move the fuel to areas of the country that are less geographically blessed to capture CO_2.
    c. The engineering and fabrication of DAC equipment will also create many new jobs. The manufacturing locations of DAC equipment have not been determined, and the IMW could be a potential location.
9. Pollution control and point source
    a. Point source or capture at the stack of CO_2 will create jobs to engineer, install, and to operate. Point source capture is plant specific which will mean the need for engineering at each site and the re-work to accommodate the addition of capture. Point source capture in most cases will result in a concentration facility at the location -more design and construction employment.
    b. Pollution control at the fossil plants that continue to operate will add jobs as pollution will continue to be restricted along with CO_2 reduction. Some laws, rules, and agreements are currently in place that obligate future operation to make modifications, and as plants continue to operate these obligations will be met with new engineering and construction at sites.
10. Source Capture of CO_2
    a. The capture of CO_2 at the "smoke-stack" is appealing as a concept but has not been successful as an application. Dr. Azarabadi's paper covers this thoroughly[64]. In essence, for source capture to be economically feasible the plant emitting the CO_2 needs to operate in

---

[64] Azarabadi, H., & Lackner, K. S. (2020). Post Combustion capture or direct air capture in decarbonizing US natural gas power?. Environmental science & technology, 54(8), 5102-5111.

the range of 70% of the time. Fossil power plants aren't operating at those load levels anymore. No plans currently exist for source capture in Arizona.

b. The advantage of source capture is the application of capture at the plant allowing for reduced operational cost, and potentially lower construction cost.

c. Source capture does present the challenge of what to do with the CO_2 as the site can not be chosen at a sequestration site. This ought not be an insurmountable problem as the CO_2 might be converted to a product or mineralized for sequestration and transported as a solid to a sequestration location.

11. EV s and EV Chargers

    a. The manufacturing of EVs is going to ramp up very fast. The IMW is fortunate that some of the EV startups are located in the IMW and some have already begun assembly plants in the IMW. This industry is just beginning to sort itself out, so it is premature to project how many jobs the IMW will be able to count on.

    b. Every local is going to have EV public and private chargers installed. The recent Infrastructure bill provides $7.5B for charging build out. Installing and maintaining public charging is labor intensive.

    c. The current fabrication of chargers is not being done in the IMW. Possibly something to focus on for the future.

12. Public transit.

    a. Electric public and school transportation will receive $7.5B in the infrastructure bill. The largest portion goes to school buses, creating new work adding charging and other infrastructure for buses.

    b. Inner city electric transit is also growing creating new construction jobs.

13. Transmission

    a. We are moving into a more electrified world and transmission grids will need a major makeover. Not only will we need more expansive and robust transmission lines, but we will also need to change the lines and equipment. The disasters that climate change is going to bring to us will require more underground lines, stronger and re-engineered transmission towers, and substations that can withstand much more violent storms. The IMW has large open areas that transmission needs to cross, increasing the difficulty of maintaining lines and reaching them when disaster strikes.

    b. Similar to the rest of the country the IMW grids need upgrading and expanding. The recent events in Texas and California were caused by an antiquated grid that was not adequately tied to other systems. While more severe in those two states, the IMW states have similar weaknesses that need to be dealt with. Designing and building transmission is a large undertaking requiring a large workforce with specialized skills.

c. In addition to the overall system weakness the IMW transmission system is particularly vulnerable to natural events. Fires, floods, and heat endanger many miles of IMW transmission. The lines that are vulnerable to fire, floods and heat sag will need to be upgraded or entirely rebuilt. This is going to become urgent and will create jobs.

d. Transmission needs go well beyond repair and upgrade. Renewables are going to often be installed and produced at locations not ideal for the existing grid. Coal plants were built away from urban areas, and hopefully some of those locations will be used for solar and wind, but there will be other locations chosen for land cost or wind or sun that may not have easy access to existing transmission.

e. The infrastructure bill sets aside $73B for upgrades, and the states will undoubtedly add to that.

14. Distribution

a. Distribution is equally problematic in its current state. During the initial rollout of EV chargers in Arizona it became clear that the distribution system was not adequate for level two and level three charger installations in many desired locations. The distribution system proved entirely inadequate in large portions of the rural system. Chargers will be only one of many challenges for distribution. Current distribution infrastructure is not prepared for distributed solar generation. Nor is the grid ready for the removal of natural gas heating and industrial use. Other challenges include the need for undergrounding to avoid increased storm and fire losses, substations that are adequate for the load and more severe storms, increased multi-family housing and an increase in electric supported mass transit.

b. Even the basic structure of electric lines is going to change. For example, lines that are typically strung from poles, to reduce outages (winds, flooding, fires), will need to be placed underground. The poles that remain will need to be stronger to withstand the new climate challenges. Reporting of outages will need to be better so that crews have an understanding as to what they are facing as they are required to work in conditions that they currently don’t experience.

c. Electric distribution is too often viewed as a simple matter of connection. Distribution systems in much of the IMW has recently become a greater focus of interest and concern as distribution systems that were thought to have been complete and adequate for their application have become strained. Distribution networks generally were not built to have level 2 chargers in every garage. In many cases were designed to operate in connection with gas heating; that is now being phased out. Consider the impact of removing gas heating and cooking from a high-rise residential building. The utility distribution to the building and the distribution within the building was not designed for the new electric load it is being asked to carry. This looks like a lot of new electrician jobs.

   d. Distribution is also beginning to feel the impact of storms. In many parts of the IMW for distribution to be reliable the lines will need to be underground, a very big change from where we are currently.

15. Mitigation and adaptation
   a. The IMW will need to deal with adapting energy systems to the impacts of climate change. Everything from electric lines to plant infrastructure will need to be “hardened”.
   b. Part of adaptation and mitigation will be working with customers. Large portion of the population will be made vulnerable for long- and short-term climate impacts. Energy companies are going to be expected to play a role in mitigating the impacts and recovering from events. While this is a very minor aspect of energy company employment today, the circumstances are going to force a much more active role.
16. Batteries
   a. Fabrication of batteries has not been a major employer in the IMW. This may change as some battery start-ups are located in IMW states.
   b. Battery testing and installation will occur in all of the IMW states. Large back up battery installations for utilities and business will grow over the next 15 years. At least one international battery experimentation and battery testing facility is located in the IMW.
17. New Fuels
   a. Hydrogen: Many new hydrogen programs are being introduced. Hydrogen has many potential applications as a fuel or as a vehicle for energy storage. While the IMW does not have any particular advantage over other parts of the country it seems likely that some of this work will develop in the west (the 1st commercial hydrogen filling station is in California).
   b. Recycled carbon: The future of recycling carbon captured as CO_2 is interesting. If this becomes a means of creating and distributing fuels the IMW has some advantages including space, sun, and initial engineering efforts. It would be gratifying if some or all of the fuel

extraction jobs could be replaced with recycling carbon from the air into fuel and shipped to states with less favorable environments for capture.

18. Bio
    a. Biology as capture may take many forms, and at its simplest is raising a forest to capture and hold CO_2.
    b. Biology as a source for fuel is a bit more problematic. So far, the biofuels concepts have not dealt with the CO2 discharge from burning the fuel. The level of interest indicates that this obvious flaw will be rectified. (ASU is pursuing such a course along with Northern Arizona University).
    c. Algae is a bio fuel that can (in the lab) be converted to fuel without releasing CO_2. The future application of algae as a CO_2 capture vehicle and then to a product is being worked on by several IMW universities and start-ups. Future success of one or more of these programs would open up another potential industry in the IMW.
19. Back-up Power
    a. Solar and wind require that there be a backup power source to supply power when the renewables aren't producing. Battery power can cover short term timeframes up to approximately 24 hours. Nuclear could be a good answer if plants can be built to cycle for short periods of time (currently not the case).
    b. The future of renewables is going to require new answers for back-up. Batteries are short lived providers, nuclear does not cycle well, and natural gas produces CO_2. It is possible that recycled CO_2 may provide an answer or ideas that have not yet been commercialized may energy
20. Certification
    a. The "proof" of permanent storage for the captured CO_2 will be an industry all on its own. Storage and permeance will need to be verified and parodically audited
    b. Certification itself will for the early years be a process that changes with circumstances and new means of storage. One might think of this as similar to a standards committee on an international scale.
    c. Sequestration will have design, policy, financial and implementation considerations.
21. A-I and Controls
    a. Control systems will play an ever-growing role in many of the systems that will need to be built and maintained. I&C professionals are already in high demand, the changes in energy that are described above are going to increase that need.

b. A-I is going to need to be a part of many of the new technologies. Just consider the ramifications of A-I for direct air capture – the cycle timing of capture & harvest, adjustments for day and night, the weight of the lift in different weather, sorbent longevity, measurement of CO_2 on the sorbent, …

22. Sorbent and Chemistry.

    a. For the CO_2 capture portion of the energy transition sorbents will play an outsized role in the potential for success. The chemical make-up will determine the propensity for capture and the ability to release the CO_2 for harvest. The chemistry will determine the volume of CO_2 capture in a given time scale.

    b. The chemical make-up will determine the ability of the sorbent to exist in different environments and probably sorbents will be designed for particular environments. The flexibility and brittleness will be important in application to the capture machinery.

    c. The ramifications related to sorbent chemistry are many and expand based on the interactions with the equipment, the environment, and the application to source capture, direct air capture, and mineralization.

23. Carbon-neutral fuels for jets and more)Manufacturing fuel)

    a. Technically, CO_2 could be used to create virtually any type of fuel. Through a chemical reaction, CO_2 captured from industry can be combined with hydrogen to create synthetic gasoline, jet fuel, and diesel. The key would be to produce ample amounts of hydrogen sustainably. One segment keen on seeing synthetics take off is the aviation industry, which consumes a lot of fuel and whose airborne emissions are otherwise hard to abate. By 2030 this technology could abate roughly 15 Mtpa of CO_2.[65]

24. Carbon fiber fabrication

    a. Carbon fiber (which can be both light and strong) is used to make products from airplane wings to wind-turbine blades, and its market is booming. The price of the component carbon is high ($20,000 a ton),and a CO_2-derived substitute would fit well in this market. Moreover, the volume of CO_2 used could become significant if cost-effective carbon fiber could be used widely to reinforce building materials. A number of pilot projects in the works focus on cracking the tough chemistry involved, but a commercially viable process appears to be perhaps a decade or more away. By 2030 the contribution to CO_2 abatement could be greater than 0.1 Mtpa of CO_2.

[65] McKinsey Quarterly June 30, 2020

25. Industrial Electrification
    a. industrial companies could lower costs and emissions by electrifying their operations. The opportunity appears large. Industrial sectors such as cement, chemicals, and steel together consume more energy than other sectors (such as electric power and transportation), and only 20 percent of that energy is electricity. What's more, electrical equipment is less costly and more reliable for many industrial applications, though not all. Electric furnaces, for example, can make heat up to 350°C, but not the high heat of up to 1,000°C that many industrial processes need. Innovation will be needed to address these gaps.
26. Advanced controls. [66]
    a. Grid utilization tends to average below 50 percent because the grid is built for times of peak demand and its performance worsens in extreme heat or cold. As more renewables and storage systems are deployed at the grid edge, in homes and commercial sites, this will make power grids more complicated to operate.
    b. Resilience, flexibility, safety, and efficiency can be improved with technologies such as solid-state transformers, advanced flexible AC controllers that allow more controlled grid flow, and high-voltage DC technologies for data centers.
    c. The broad stretches of low use land in the I West has created long transmission runs. These will need to be adjusted to renewable applications to the grid and the modifications on where power will be needed.
27. Software and communications.
    a. Traditional electrical grids use idling power plants to maintain grid balance. Spinning reserves are expensive to run but can respond quickly when demand fluctuates. Modern electric grids should rely on ultrafast communications to maintain grid balance by managing every device on the network.
    b. Software-defined inertial substitution (to maintain grid balance when there are fewer spinning reserves), advanced "volt-var" management (to maintain proper voltage over long transmission lines or in highly congested urban markets), and network-wide instrumentation for condition monitoring and fault isolation would help utilities spot issues

[66] Innovating to net zero: An executive's guide to climate technology; Tom Hellstern, Kimberly Henderson, Sean Kane, and Matt Rogers; October 28, 2021 (Items 26 through 30)

and prevent interruptions. Distributed energy-management software can coordinate all these elements. Digitized grids will require better cybersecurity protection.

28. Vehicle-to-grid integration.
    a. As more drivers switch to EVs, the big batteries in their driveways and garages could be hooked up to the grid to provide energy-storage capacity. One million typical EVs would offer about 75 gigawatts of storage, hundreds of times more than today's single biggest utility-scale storage facility provides. Residential backup batteries add more. Accomplishing this integration requires technologies such as inverters that connect rooftop solar, wall batteries, EV batteries, and the grid, as well as fast chargers that buffer the grid from demand spikes while keeping EV batteries full.
29. Building-to-grid integration.
    a. As buildings' energy controls improve, the buildings can be dispatched to the grid—that is, used to supply power—in ways that improve system performance. Buildings with energy storage or cogeneration could feed power onto the grid when called for, producing income for their owners. If a utility could reduce power demand slightly in a central business district by signaling buildings to turn down lights, it could cope with demand spikes less expensively than by turning on a gas peaker plant.
    b. Buildings are going to be a frontier for many changes if we are to make the efficiency improvements called for by 2050. Many of these improvements will relate to jobs for those in the energy sector.
30. Next-generation nuclear.
    a. Nuclear energy has an uneven history: from the 1950s' promise of "too cheap to meter" energy to construction-cost overruns in the 1970s to post-Fukushima fears. Now, the push to decarbonize power has lent new appeal to nuclear generation, which is emissions-free.
    b. Emerging technologies include the sodium-cooled, molten salt, and helium-cooled reactors known as "GenIV"; small, sealed, modular, factory-built reactors; and fusion energy, an area where new start-ups are pushing costs down and timelines forward to prototype devices in the mid-2020s, ahead of government-backed research programs.

A quick list of jobs roughly based on the information above:

- Engineers in all disciplines (and probably some new disciplines)
- Chemists

- Designers
- PhD candidates,
- University faculty and research teams.
- Social and field services to deal with storms, fires, and heat waves.
- Battery engineers, chemists, designers, testers, technicians, and fabricators
- Construction (all crafts)
- Manufacturing line workers
- Plant operation, maintenance, outage support, start-up, and commissioning
- All craft - pipefitters, machinists, electricians, welders, etc.
- Forestry
- Biology
- Machinists,
- Lawyers
- Scientists
- I&C technicians
- Trucker drivers, equipment operators, and loaders
- Auto workers and mechanics
- Well workers, engineers, pipe fitters, equipment operators,
- Land use planning
- Longshoreman
- Management, sales, logistics, chemists, QA, safety, …
- Dispatchers, power plant workers, outage workers, plant operators
- Communications technicians,
- Rail workers,
- Heavy equipment operators, line crews, hot stick crews.

"We are caught in an inescapable network of mutuality, tied in a single garment of destiny. Whatever affects one directly, affects all indirectly."

Martin Luther King Jr.

Appendix 2

Conceptual outlines

Once accepted that the coming changes are going to be very disruptive for our workforce, and likely the changes are coming soon, it is time to consider how to plan to best serve our workforce. These plans ought to be place based and adjusted to fit local circumstances, focused on local objectives and outcomes. Now is the time to start. The infrastructure legislation will provide at least some funding to prepare the state's workforce for the opportunities that will be coming.

1. Start with a plan. Review Appendix One and prioritize those types of work that are anticipated or possible for the state. Then add more work ideas based on the state's experience and expectations. Ask local industries, NGOs, and communities what they see coming. Prioritize work opportunities based on the list developed by the state using Appendix One as a guide. Consider in prioritization what is likely or relatively available and what work the state would like to bring in. Also be careful to include work areas that are necessary, such as hardening of energy infrastructure and building grid capacity. Next, reorient the prioritized list based on timing, what is here now, what is coming during the next five years. Work the plan around the likelihood of the work and the timing of the work. Do not hold back from including potential work that may seem hard to get but would be beneficial for the state workforce. Build-in a change process within the plan, what is thought to be the best path at the start will be modified as time introduces new realities.

2. Structure communication. Build a briefing paper on the work that is coming (or may come) and include rough ideas on timing – "Work is Coming". For each type of work, clearly spell out the type of skill sets that will be in demand for the work, and rough ideas on numbers to be employed. Indicate, if known, what locales the work might take place in. Communicate "Work is Coming" (WIC) briefing to school districts, post-secondary schools, unions, town councils, utilities, major employers, recruiters, etc. Take extra steps with unions and post-secondary schools to discuss what the needs for various skill sets might be and how they are being addressed in preparing the workforce. Set up a team to build and distribute lesson plans and curriculum for secondary schools to help them prepare for the changes that are coming to the job market. The curriculum might focus on opportunities, but also provide "hope" that steps are being taken to mitigate the changes and disruption from the changing climate. The plan needs to be sold and it needs to have buy-in. Focus on the key elements of the plan and why the future is hopeful.

The Arizona Thrives Study[67] offers some ideas on how states might benefit from the future and how "hope" might be positioned within communications. The study found that absolute carbon emissions in Arizona as of 2019 have already declined by 26.6% since 2005. Carbon intensity of the same period declined by 28.3%. These numbers demonstrate that at least for Arizona, changes are in motion.

[67] Arizona Thrives: Projections for Arizona Carbon Emissions. Jan. 15, 2021. Arizona State University

3. Draft a fill-in the holes diagram. If we need or want a particular type of work, do we have the ability to train the workers? If not, what is needed? Do we need to train trainers or educators? Build a structured plan to develop the type of workers and the skill sets that the WIC indicates will be needed. Training takes time, particularly if the trainers or educators are not already in place. As new fields of work develop the skill sets of those who would do the training won't necessarily exist. Even starting with an experienced electrical or mechanical journeyman, a power plant operator takes at least two years of training, and a water chemistry tech an additional year. An engineer generally needs four to five years of university training and at least an additional year in the field before taking on meaningful assignments. Physicists and scientists generally need a decade after secondary schooling before they can take on research. The state must address needs based on realistic lead times. Based on the timeframes just mentioned for many of the jobs that are coming, states are already behind. In particular, workers in new fields need to be educated and trained. Are the educators in place to do this, and if not how long might the educating of the educators take? When will it begin? The states ought to develop a comprehensive gap analysis based on skill sets they can list that are likely to be called on over the next decade and begin the process of building that workforce that has those skill sets. Some of this may be solved by recruiting, and of course some training will be carried out by private industry. It will be important to allow time to recruit and be aware of another fifty states and many countries will soon be after the same skill sets. Private companies need encouragement and direction if they are to build this workforce. Private employers won't act unless they have some assurance that the jobs are coming. States need to signal what the long-term carbon neutrality plan is to help industry comprehend what will be needed.

4. Recruit work. In parallel with step two consider those areas of work/production that won't of their own volition come to the state but may be influenced to locate in the state. Which of these might the state want, and if desired does the state have a realistic chance of bringing some portion of that work to the state? If brought in would the effort be worth the value in employment and state revenues. Prioritize which industries or companies to recruit to the state. Build a plan to provide the state the opportunity to have the work brought in, including how to recruit and how to demonstrate the viability of the workforce that will be required. For example, EVs and chargers are going to be built in the US. Might the state pursue startups or even established manufactures? Manufacturing of existing and new EV/charging technologies is not necessarily established. This is one of the more dramatic workforce changes that is going to occur. Not only EVs but batteries, capture devices, electric trains, electric buses, electric outboard motors, carbon conversion, wind turbines and blades, and many more things that will need to be made do not have established manufacturing sites. The state will be competing with other states and with overseas opportunities. States understand and should exploit the advantages they may have over other states. States will have new advantages over foreign manufacturing for new fabrication. Transportation by sea and air is going to be much more expensive as ships and planes need to pay for the CO_2 they put in the air. States will have opportunities that may not have existed previously. Some states have by design or luck already begun the process; a new type of battery fabrication has just announced a new factory in Arizona. Several western states have EV start-ups that have opened new manufacturing facilities rather than refurbish existing ones in the east and midwest.

5. Education and training. States might group education and training into tiers based on when the work might be needed and what skill sets are likely. For example, transmission work is likely to begin very soon, while fabrication of new batteries will await the construction of the battery factory. For transmission work a focus on utilities and electrical unions to provide training for linemen, engineers, and heavy equipment operators would be wise. To attract a battery fabricator a focus on chemists, research scientists, line workers, supply-chain/procurement, and safety that will require courses at universities and other post-secondary schools.

Timeframe	High School & Tech Training	Post Secondary & University
Next 2 yrs.	Transmission, Distribution, building efficiency, installing EV chargers, conversion from natural gas to electric, source capture construction, civil construction to harden the energy infrastructure, pipeline conversion, methane site mitigation, hot stick crew, mine mitigation, trubine mechanic	Engineering and siting new transmission, grid management, distribution underground design & engineering, capture research scientists, scientists studying mitigation, capture device engineering, hydrogen vehicle engineering, Chemistry for sorbent design, geologist,
Next 5 yrs.	Battery manufacturing line work, EV manufacturing, electric train rail lines, electric train & bus manufacturing, Direct Air Capture farm installation & operation, gas & oil field conversion, agricultural changes, "restoration of "brown field" sites	Electrolysis design, CO2 concentration, carbon to plastics, captured carbon to fuel, bio capture engineers, agricultural mitigation and crop conversion scientists, chemists and chemical engineers for batteries and the application of captured CO2 to product, project manager

Figure 13. The above chart is a sample. Each state will have their own set of prioritized work and timing.

The plan would need to be crafted to build on early education and training toward future need. For example, reading and maths skills would need to be emphasized as these skills are a building block toward future training. Early training might be a requirement to secure later projects. As an example, DAC devices are now being manufactured and will soon be deployed in capture farms. Early training of operators and maintenance workers would provide the state with a small group that might train and lead the larger workforce that will soon be needed. The state that has this early cohort trained will stand at the front of the line for the coming larger farms.

6. Build the energy mix. There is an energy crunch coming. It would be naïve to believe that restrictions on CO_2 pollution will be perfectly matched with the need for energy. Sometimes the restrictions on CO_2 growth in the atmosphere will be too little and other times restrictions on CO_2 will be harsh enough to limit energy production and access. States as a part of their planning need to build a workforce, including the engineers and planners, that allows the state to anticipate and mitigate energy shortages and energy over pricing. As these disruptions are inevitable the state should prepare to have in place the workers to best navigate the challenges that are ahead. The electrical and other engineers, dispatchers, load planners, renewable integration engineers, outage managers and schedulers, and others to ease the burden of shortages and to maximize the capacity factor of electrical producers.

7. Risk and mitigation: Consider the risks within the plan and the risk of not including various aspects in the plan. Develop a mitigation strategy for each risk. When the mitigation requires more resources than avoiding the risk, avoid the risk. Communities and states probably ought to recruit physicists, climate scientists, and others to advise on what is occurring and what solutions might be considered. Other risks that need to go into planning are using models. Might some forms of electric draw be avoided or minimized? What is the risk/reward balance of EV daytime charging, should a state encourage cyber coin mining, are data centers an advantage or too big a draw, should budget dollars be spent on roads or electric trains? Risk and mitigation is a powerful evaluation tool. It should be tied to a value assignment equation to assist leaders in decision making. Consider what to require and what to encourage. It may be necessary to modify building codes to require greater insulation and passive energy saving measures for all new and remodeled buildings. On the other hand it may be more effective and palatable to encourage rooftop solar. Thousands of these types of decisions will impact the workforce and what skill sets will be needed. Decisions of this type must consider workforce availability and how to build the workforce skill sets to fulfill the decisions.

8. Consensus. Visit with constituencies and develop consensus. Sell the plan and bring in stakeholders. Outreach is critical in building support and starting a process of training a workforce for the future. Great change has historically created winners and losers, there is no reason to believe that the coming change will be different from the past. This is a big change, and it is hard for most to comprehend what is occurring and what the impacts are going to be. By discussing the coming changes and the worker needs that will be created we develop a positive look at the future while engaging support from our constituencies. Success will come to communities that learn to work together toward common goals.

9. Execution. Plans need effort. They need to be able to change and they need a commitment to a timeframe. Follow the following steps: 1) create a schedule that is both ambitious and possible; 2) build a budget considering what the infrastructure legislation might be able to help fund; 3) draft a

comprehensive inclusive plan for workforce growth and success; 4) prioritize what work is likely and what is desired and develop workforce training that considers priorities; 5) create within the plan a change consensus and approval process to deal with the adjustments that will come; and 6) sell the plan and the vision.

10. Workforce use cases: It may be helpful for communities to consider use case studies to align work with the skilled workforce that will be necessary to meet demand. A couple of sample use cases below are described at the simplest level:
    a. Large distances of the distribution line will need to be buried as there are now areas newly subject to high winds. Before planning such a step a community would need to consider start date, digging equipment and operators, delivery of material tied to procurement and supply chain specialists, community outreach officers, surveyors and right of way engineers, “blue stake” technicians, electrical and civil engineers, shoring material and the crews to put up shoring, U/G safety officers, procedure writers, management and accounting staff, line trucks, shading material and crew, joint use engineers, substation engineers and electricians, landscape crews, … One would need to map out the staffing needs, the qualifications, the timing and the education and training. The use case would consider these factors to create a schedule, a plan, and a budget.
    b. States will seek to have some of the CO_2 capture farms within their state as this form of industrial activity will help replace lost mining and coal plant jobs. Seeking to entice a developer to locate in a particular area requires an effort on the part of the state and local community. The factors to consider might be staffing. The community leaders might draft a position paper on why the community has the manpower and training that would staff the capture farm. How might this be presented as a part of the “sale”? Staff potentially would need engineers and construction workers to build the farm, a permanent operations, maintenance, and support crew. The Ops crew would need to include equipment operators, plant operators, engineers, chemists, pipe fitters and welders, machinists, warehouseman, procurement, quality control officers, safety staff, and a range of maintenance specialists. Big farms will need large and skilled staffing. While some training and experience may be applied to workers in this new field all the staff will need some new training, and many will require extensive education. The use case would pull together the target capture developers, what features need to be covered, how to deliver the workers and the training, and what it takes to bring all the elements together.

Appendix 3

Here are a few examples of worker training programs, but none were found that apply to a shift in skills in the scope this chapter foresees.

Arizona Public Service and Northern Arizona University provide a Bachelor degree in electrical engineering technology for workers at the Palo Verde Generating Station. More information at: https://nau.edu/legacy/educational-partnerships/aps/

AZNext initiative is a workforce training accelerator partnership developing paid internships, apprenticeships, train-to-hire programs, boot camps, and simulated work experiences intended to create talent solutions to meet industry needs. The initative focuses on IT and cybersecurity and advanced manufacturing. More information at: https://wpcarey.asu.edu/aznext

Native Renewables, Inc. provides short-term workforce training on solar PV installation on Navajo and Hopi Nations. More information at: https://www.nativerenewables.org/

Institute for Tribal Environmental Professionals (ITEP) provides 1-2 days training for tribal environmental professionals nationally on a range of topics including air quality, climate change, energy and more. The energy training focuses on hand-on training for PV installation. More information at: http://www7.nau.edu/itep/main/Training/training_energy

Gila River Indian Community Utility Authority provides a 12-month Technical Training Program for Native members to prepare for GRICUA Line Worker, Solar Technician or Meter Technician Apprentice Programs. More information at: https://gricua.net/careers/training-programs/technical-training-program/

Appendix 4

This chapter drew information from current events and trends, from peer-review material, news articles, and internal documents and reports. To supplement and inform the analysis, the Intermountain West states were requested to provide information on specific aspects of the workforce in their states. The full information from the two states that responded is included here.

Workforce Template for Response

1.5	*Evaluate Workforce landscape*

This subtask will assess the current energy-related workforce demographics and scope for workforce retraining.

1.5.1 Catalogue existing regional workforce

1.5.2 Evaluate at-risk workforce in context of energy transition

1.5.3 Write summary of workforce landscape (Chapter 9.2)

D1.5.3	Product: Written summary of the workforce landscape for the region, to be incorporated into Chapter 9 of final report (date 31 Jan 2022) (**ASU:** R. Page with inputs from team)

<u>Workforce Summary by UTAH</u>

Prepared by: Brooke Tucker

Energy & Geoscience Institute

University of Utah

Workforce today:

- Size of current workforce
    - *Census: Utah Total employment, 2019: 1,373,876*[68]
    - *Census: Utah Civilian labor force, total, percent of population age 16+, 2015-2019: 68.3%*[69]
    - *Bureau of Labor Statistics: All occupations employment, Utah, May 2020: 1,489,020*[70]
- Make up
    - Education levels as related to employment

---

[68] U.S. Census Bureau Quick Facts – Utah

[69] U.S. Census Bureau Quick Facts – Utah

[70] Bureau of Labor Statistics – Utah

        - *Census Bureau: Bachelor's degree or higher, percent of persons 25 years+, 2015-2019: 34%*[71]
        - *State of Utah Public Health Indicator Based Information System Table*[72]

	Utah	***U.S.***
Less than High School	*6.9%*	*11.4%*
High School	*23.1%*	*26.9%*
Some college	*25.5%*	*U.S. 20%*
Associates	*9.7%*	*8.6%*
Bachelor's	*23.4%*	*20.3%*

    - Leading employment categories and projected growth
        - *Utah's 2021 Employment Summary for October 2021*[73] *indicated:*
            - *Utah's unemployment rate was 2.2%, while the U.S.'s unemployment rate was 4.6%*
            - *Utah's job growth rate was 3.7% while the U.S.'s was -2.2%*
            - *Utah's largest private sector gains in the past two years:*
                - *Trade, Transportation and Utilities: 20,900 jobs*
                - *Professional and Business Services: 15,500 jobs*
                - *Construction: 10,800 jobs*
                - *Manufacturing: 7,900 jobs*
            - *Largest private sector losses during the past two years:*
                - *Leisure and Hospitality Services: -1,200 jobs*
                - *Natural Resources and Mining: -1,200 jobs*
    - Labor force employment vs. US average
        - *Census: Civilian labor force, total, percent of population age 16+, 2015-2019: Utah 68.3%, U.S. 63%*[74]

- Trends expected by 2030
        - *In October 2021, Governor Cox released version 2.0 of the One Utah Roadmap.*[75] *The Roadmap calls for updating the statewide energy plan to ensure Utah's energy future is secure, innovative, and reliable. The Roadmap also highlights ways Utah can lead out on public-private partnerships focusing on clean energy (such as microgrids, battery storage, solar, hydrogen, etc.) in a fiscally prudent way.*

---

[71] U.S. Census Bureau Quick Facts – Utah

[72] State of Utah Public Health Indicator Based Information System

[73] Utah Department of Workforce Services Utah Employment Summary: October 2021

[74] U.S. Census Bureau QuickFacts: Utah; United States

[75] One Utah Roadmap 2.0

- *PacifiCorp's 2021 Integrated Resource Plan[76] indicated its preferred portfolio may entail accelerated coal retirements, no new fossil-fueled resources, continued growth in energy efficiency programs, new transmission investments, and incremental renewable energy and storage resources.*
- *A number of western states have passed Renewable Portfolio Standards.[77] As certain mandates go into effect over the coming years, it will likely affect generation portfolios and how the transmission system is utilized in the region.*

Energy transition is creating loss of jobs: (closure of mines, power plants, drilling, etc.)

- Numbers
    - Number of workers in the energy industry (mines, plants, utilities)
        - *According to the Kem C. Gardner Policy Institute's Economic Impacts of Utah's Energy Industry Report, in 2017, Utah's Energy industry directly and indirectly supported 3.8% of the state's employment, 4.2% of its earnings, and 5.7% of its gross domestic product.[78]*
        - *According to the 2020 U.S. Energy and Employment Report (USEER),[79] Utah has:*
            - *31,468 Energy Workers*
                - *11,853 Electric Power Generation*
                - *11,885 Fuels*
                - *7,730 Transmission, Distribution, Storage*
    - Estimate of lost jobs to date
        - *The USEER report estimates traditional fossil fuel power generation jobs in Utah at 3,304 in 2020, which was down 3%.*
        - *Utah's 2021 Employment Summary for October 2021 indicated the mining and natural resources sector lost 1,200 jobs in the last two years.[80] However, COVID-19 may have impacted jobs numbers during the time period recorded.*
    - Project for job loss due to closing and reduction of operation for the next 5 years
        - *PacifiCorp's 2021 Integrated Resource Plan does not assume the closure of its Utah coal-fired power plants within the next 5 years.[81]*
        - *The Intermountain Power Agency intends to convert the Intermountain Power Project (IPP) coal-fired plant to 30% hydrogen and 70% natural gas by 2025 and expand to 100% hydrogen by 2045. Construction for the conversion is expected to support about 450 construction jobs, though, the rebuilt plant is expected to employ 120 workers, less than the number that work at IPP now (~400[82]).[83]*

- Types/sectors of workers
    - Workers by type or craft
    - Sectors where jobs are declining (Utility, mines, extraction, etc.)

---

76 PacifiCorp 2021 Integrated Resource Plan

77 Lawrence Berkeley Lab Renewable Portfolio Standards Resources

78 Kem C. Gardner Policy Institute, Economic Impacts of Utah's Energy Industry, 2017 (published February 2020)

79 2020 U.S. Energy and Employment Report - Utah

80 Utah Department of Workforce Services Utah Employment Summary: October 2021

81 PacifiCorp 2021 Integrated Resource Plan

82 ABC Utah: Utah's largest coal plant converting to hydrogen power

83 Salt Lake Tribune: Intermountain Power Project's switch from coal to hydrogen could power rural Utah job growth

    - *Prior to the COVID-19 pandemic, the energy sector had been one of the fastest growing job markets. From 2015 to 2019, the annual growth rate for energy employment in the United States was 3%—double compared to 1.5% in the general economy. The USEER report found that energy job totals reached 7.5 million by the end of 2020, a decrease of 840,000 jobs or 10% decline year-over-year. While there was a clear decline, there were also positive signs that the sector was on the rebound—at the pandemic's peak in mid-2020 energy jobs had decreased by 1.4 million. By the end of 2020, 520,000 energy jobs had already returned. Additionally, employers that responded to the survey also signalled confidence in the upward employment trend continuing through 2021.*[84]
- Geographic area
    - *For information and maps on resource potential areas and development activities across the state of Utah, please see Utah's Energy Landscape 5th Edition.*[85]

Looking at the future

- Energy transition will cause these changes in my state:
    - Impact of gas and oil based on current trends and regulation
        - *Crude oil and natural gas liquids reserves mostly correlate with oil prices but with a several year lag after major price spikes. After peaking in 2013 at 896 million barrels, reserves retreated with falling prices, but bounced back to 528 million barrels in 2018.*[86]
        - *Although Utah holds less than 1% of the nation's proved natural gas reserves, the state has 3 of the 100 largest U.S. natural gas fields. Utah's marketed natural gas production, most of which is in Uintah County in the northeastern corner of the state, accounted for about 1% of U.S. natural gas output in 2020. The state's natural gas production rose steadily for three decades starting in the mid-1980s, and it peaked in 2012. Annual production has decreased every year since in response to low market prices and reduced crude oil drilling.*[87]
        - *Among the 50 states, Utah has the fourth-highest number of producing oil and natural gas leases on federal lands,*[88] *meaning federal policies/regulations/executive orders have the potential to impact development activities in Utah.*
    - Impact of mining
        - *The majority of Utah coal, 64% in 2018, was used in-state. In the past, Utah was a significant net exporter of coal, but out-of-state domestic demand has decreased from a high of 16 million tons in 2001 down to only 1.9 million tons in 2018 as coal has dropped out of favor as a fuel for electric and industrial needs. Utah's foreign exports peaked in the mid-1990s at about 5 million tons, then dropped to near zero in the mid-2000s. However, the foreign export market has seen a resurgence in the past few years, increasing to 3.1 million tons in 2018.*[89]
    - Impact on utilities and other energy providers

---

[84] U.S. Department of Energy, US Energy & Employment Jobs Report Fact Sheet

[85] Utah's Energy Landscape 5th Edition, Utah Geological Survey

[86] Utah's Energy Landscape 5th Edition, Utah Geological Survey

[87] U.S. Energy Information Administration – Utah State Profile and Energy Estimates

[88] U.S. Energy Information Administration – Utah State Profile and Energy Estimates

[89] Utah's Energy Landscape 5th Edition, Utah Geological Survey

        - Generation
        - Transmission
        - Distribution
        - "Green" research
    - Growth or decline in pipeline installation
        - *Utah is crossed by several interstate pipelines that transport natural gas from the Opal Hub in Wyoming, from the Piceance Basin in western Colorado, and from Utah's in-state production to markets in Nevada, Idaho, and Colorado.*[90]
        - *Utah's five oil refineries, all located in the Salt Lake City area, process nearly 200,000 barrels of crude oil per calendar day. Much of the oil processed by the refineries is brought in by pipeline from Utah, Colorado, Wyoming, and Canada. Utah's refineries have about three-tenths of the refining capacity in the Rocky Mountain region. Pipelines carry refined products from Salt Lake City's refineries to markets in Utah, Idaho, Nevada, Wyoming, eastern Washington, and Oregon. Petroleum products also enter Utah by pipeline from refineries in Wyoming and Montana.*[91]
    - Solar generation growth. (also, consider transmission)
        - *In 2018, Utah ranked 26th in the nation in percent of total net electric generation from renewable resources (11.2%). Of particular note, Utah is one of only seven states where electricity is generated from geothermal resources Utah's renewable electric generation is dominated by 914 MW of newly installed utility-scale solar farms (50%), followed by hydroelectric (21%), wind (18%), and geothermal (10%) power. The biomass portion is mainly electricity generated from burning landfill gases. Renewable energy sources now account for 11% of Utah's total electricity generation.*
        - *The total capacity of net-metered PV solar installations (i.e., roof-top solar) in Utah has increased exponentially in the past few years, from a total of 3.4 MW in 2010 to 273 MW in 2018, 78% of which was in the residential sector.*[92]
        - *Additionally, significant potential new transmission investments are underway in Utah, including PacifiCorp's Gateway South project, which filed for a Certificate of Public Convenience and Necessity at the Utah Public Service Commission in September 2021,*[93] *and the TransWest Express project, which recently concluded its open solicitation process.*[94]
    - Wind generation growth
        - *Wind energy produced about 15% of Utah's renewable electricity in 2020. Utah has five wind farms operating with about 390 megawatts of generating capacity. The state's two largest wind farms send power to southern California. There is commercial wind power potential in the Wasatch and Uinta mountain ranges in Utah's north-central region and on the mesas in western Utah.*[95]
    - EV infrastructure

---

[90] U.S. Energy Information Administration – Utah State Profile and Energy Estimates

[91] U.S. Energy Information Administration – Utah State Profile and Energy Estimates

[92] Utah's Energy Landscape 5th Edition, Utah Geological Survey

[93] Utah Public Service Commission Docket No. 21-035-55

[94] TWE Project Open Solicitation

[95] U.S. Energy Information Administration – Utah State Profile and Energy Estimates

        - *During the 2020 session, the Utah Legislature passed H.B. 396,[96] which directed the Utah Public Service Commission to authorize Rocky Mountain Power to recover a $50 million investment in an electric vehicle charging infrastructure program. Rocky Mountain Power filed its proposed program with the Utah Public Service Commission in August 2021.[97]*
        - *During the 2020 session, the Utah Legislature also passed H.B. 259,[98] directing the Utah Department of Transportation to lead the creation of a state-wide electric vehicle charging network plan, which was released later that year.[99]*
    - Public transportation
        - *As Utah's population grows, public transportation is an important tool to help improve air quality along the Wasatch Front.*
    - New green industries (capture, mitigation, batteries, EV's, etc.)
        - *The state of Utah is well positioned to serve as a hub for emerging clean industries. The University of Utah Energy and Geoscience Institute has provided extensive characterization of geological formations and carbon sequestration opportunities across the state of Utah.*
- Transition to a carbon neutral energy economy would offer these potential work opportunities:
    - Building insulation and other upgrades
    - Public transit
    - Renewables
    - Carbon capture
    - Methane to liquid fuels
    - Forestry
    - Infrastructure upgrades (EV charging, electric transmission & distribution, bike paths, etc.)
- The workforce will need to adjust in these ways
    - To deal with the loss of energy jobs:
        - Are there transition programs in place?
        - Are workers geographically located in areas that will have future work?
        - Can skills be transferred?
    - To prepare for the new renewable, capture and energy jobs:
        - Is training adequate?
            - *In the USEER Report,[100] employers in Utah gave the following as the top three reasons for reported difficulty in hiring:*
                - *Lack of experience, training, or technical skills*
                - *Competition/small applicant pool*
                - *Difficulty finding industry-specific knowledge, skills, and interest*
        - Who will design and build these new projects? Based in the state?
            - *Investor-owned utilities*
            - *Electric cooperatives*
            - *Independent power producers*
            - *Independent transmission developers*
            - *Research universities*

---

[96] H.B. 396 Electric Vehicle Charging Infrastructure Amendments

[97] Utah Public Service Commission Docket No. 20-035-34

[98] H.B. 259 Electric Vehicle Charging Network

[99] State of Utah Electric Vehicle Master Plan, Second Edition 2020

[100] 2020 U.S. Energy and Employment Report - Utah

- Positive policies in the state (both government and private
    - Transition programs that appear to be working
        - *In 2008, Utah enacted S.B. 202,[101] which established a goal for renewables to account for 20% of 2025 adjusted retail electric sales, if it is cost effective to do so.*
        - *In 2019, the Utah Legislature pass H.B. 411,[102] which created a voluntary pathway for local governments to procure 100% net renewable energy from Rocky Mountain Power by 2030 (though, individuals living within the communities will have the opportunity to opt-out of the program if they wish). As of July 2021, 14 communities signed the Governance Agreement. The communities are currently working through the program design phase, and it is anticipated a program application will be filed at the Utah Public Service Commission in early 2022.[103]*
    - Adaption that is underway or planned
    - Recommendations for policies that ought to be implemented or steps taken by industry
        - *It is recommended that Utah adopt a coherent and consistent regulatory framework for carbon capture/storage/utilization in the state.*
    - These policies in our state will impact workers
    - These policies should be implemented to improve things for workers
- Comments on what we ought to do that would be supportive of our workforce during the transition:

Open comments:

Please add a sheet to indicate references and sources for data. Footnotes would be helpful.

- 2020 U.S. Energy and Employment Report - Utah
- Economic Impacts of Utah's Energy Industry, 2017, Kem C. Gardner Policy Institute
- Utah's Energy Landscape 5th Edition, Utah Geological Survey
- U.S. Energy Information Administration – Utah
- One Utah Roadmap
- Foundations for a Better Energy Future
- Utah Department of Workforce Services – Economic Data
- PacifiCorp 2021 Integrated Resource Plan
- Bureau of Labor Statistics – Utah
- Utah Department of Workforce Services Utah Annual Report, 2019 Labor Market Information (Published January 2021)
- 2021 Utah Economic Report to the Governor

[101] S.B. 202 Energy Resource and Carbon Emission Reduction Initiative

[102] H.B. 411 Community Renewable Energy Act

[103] Utah 100 Communities

Workforce Summary by Wyoming

Prepared by: *University of Wyoming School of Energy Resources*

Selena Gerace

Kipp Coddington

Charles Nye

Date: *December 17, 2021*

1. Workforce Today:

Size of current workforce in Wyoming

Civilian Labor Force: 293,000

Employed: 281,000

Unemployed: 12,000

Unemployment rate: 4.1%

The unemployment rate in Wyoming has been steeply declining since reaching a peak of 8.1% in May of 2020. As of October 2021, it was down to 4.1% which is lower than the pre-pandemic level of 4.8% in February 2020 (*Figure 1*).

Figure 1: Wyoming Unemployment Rate, January 2001-October 2021

Data Source: Bureau of Labor Statistics

Education levels as related to employment

Nationally, employment rates increase with education level. The Bureau of Labor Statistics (BLS) reports that labor force participation rates are 58.1% for men and 33.3% for women without a high school diploma. With a Bachelor's degree, these rates increase to 79.3% for men and 68.5% for women.[104]

High percentages of Wyoming's workforce have at least a high school diploma (*Figure 2*). For members of the workforce ages 25 and up, over 90% have a high school diploma or higher. Much lower proportions of the workforce have a higher degree. For workforce participants ages 35-44, just over 30% have a bachelor's degree or higher. For ages 25-34 and 45 and over, under 30% have a bachelor's degree or higher.

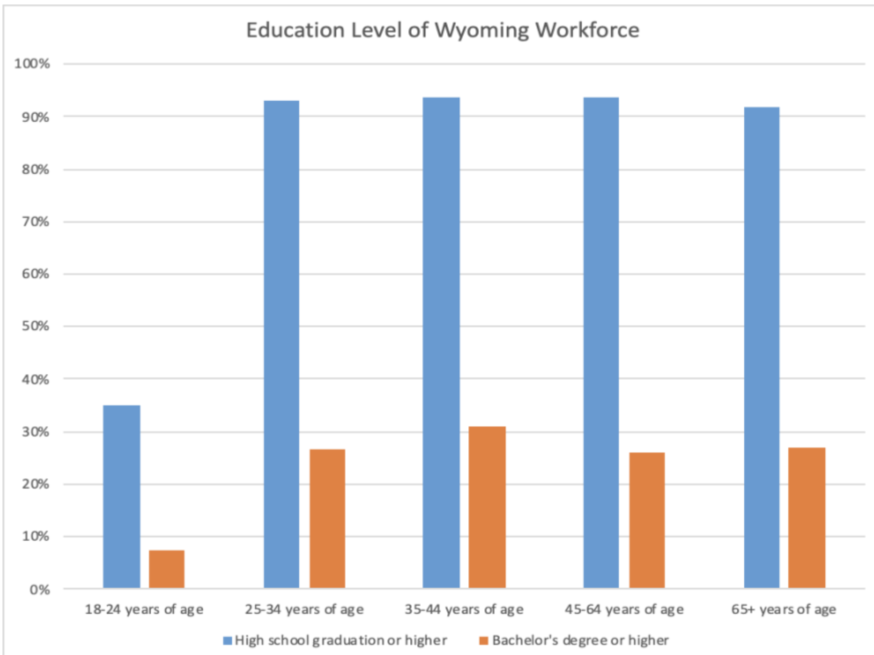

Figure 2: Estimated Percentages of Education Levels of Wyoming's Workforce

Data Source: American Community Survey, conducted by the U.S. Census Bureau

In Wyoming, the percentage of jobs that require at least some postsecondary education is lower than for most other states in the nation--only 39.3% of all jobs in the state. Louisiana is the only state that had a slightly lower percentage of jobs requiring post-secondary education, at 39.2%.[105]

The largest proportion of jobs in Wyoming requires just a high school diploma (44.6% of total jobs in the state). 20.7% of jobs require a bachelor's degree and 16.1% of jobs do not require any formal education. Only 2.3% of jobs in Wyoming require a master's degree, but this is higher than the proportion of jobs in the US requiring a master's degree (1.7%).

[104] https://www.bls.gov/spotlight/2017/educational-attainment-of-the-labor-force/home.htm

[105] https://doe.state.wy.us/lmi/trends/0621/0621.pdf

Nationally, higher levels of education are correlated with higher wages. In 2018, jobs that required some postsecondary education paid a median rate of $17.81 per hour, while jobs that only required a high school education paid $16.48 per hour. Likewise in Wyoming, wages increased with increased education level. The average annual wage for jobs that don't require any formal education in Wyoming is $31,916, while the average annual wage for jobs that require a doctorate or professional education is $114,593.

Interestingly, Wyoming has a higher than average annual wage than the US average in 17 of the 508 occupations in the state. Fourteen of those 17 jobs require a high school diploma or less and were positions often found in mining such as derrick operators ($58,890) and continuous mining machine operators ($80, 890).[106]

Leading employment categories and projected growth

Industries that employ the most people in Wyoming in the first quarter of 2021 include local government, leisure and hospitality, retail trade, health care and social assistance, and educational services (*Figure 3*).

Industry	Number of People Employed
Local Government	44,784
Leisure & Hospitality	31,807
Retail Trade	28,638
Health Care & Social Assist.	25,374
Educational Services	22,983

Figure 3: Industries with Highest Average Monthly Employment in Wyoming

Data Source: Wyoming Workforce Services, Trends Vol. 58 No. 10[107]

In Wyoming, there are nine industries that are currently experiencing growth, as of the second quarter of 2021 (*Figure 4*). Top growing industries were food manufacturing, data processing, and administration.

[106] https://doe.state.wy.us/lmi/trends/0621/0621.pdf

[107] https://doe.state.wy.us/lmi/trends/1021/1021.pdf

Growing Industries	Annual % Increase in Employment
Food Manufacturing	37.80%
ISPs, Search Portals, & Data Processing	15.20%
Administrative & Support Services	12.50%
Couriers & Messengers	11.50%
Warehousing & Storage	8.70%
Primary Metal Manufacturing	8.60%
Construction of Buildings	8%
Pipeline Transportation	6.70%
Wood Product Manufacturing	6.30%

Figure 4: Growing Industries in Wyoming

Data Source: Wyoming Workforce Services, Wyoming Growing and Declining Industries Report, Second Quarter 2021108

Nine industries are experiencing declines in Wyoming (*Figure 5*). Interestingly, the top most declining industry is oil and gas extraction (-20.2% change from last year). Three of the other eight declining jobs are also mining-related industries: support activities for mining (-14%), petroleum and coal products manufacturing (-12.7%), mining (except oil and gas) (-7.3%).

[108] https://doe.state.wy.us/lmi/G_DInd/Report_21Q2.pdf

Declining Industries	Annual % Decrease in Employment
Oil & Gas Extraction	-20.2
Heavy & Civil Engineering Construction	-15.8
Support Activities For Mining	-14
Petroleum & Coal Products Manufacturing	-12.7
Nursing & Residential Care Facilities	-8.3
Mining, Except Oil & Gas	-7.3
Merchant Wholesalers, Durable Goods	-7.3
Broadcasting, Except Internet	-5.7
Support Activities for Transportation	-5.4

Figure 5: Declining Industries in Wyoming

Data Source: Wyoming Workforce Services, Wyoming Growing and Declining Industries Report, Second Quarter 2021[109]

Labor force employment vs. US average

Wyoming's current unemployment rate (4.1%) is similar to the US unemployment rate, which was at 4.2% in November 2021 (*Figure 6*). The US unemployment rate reached a peak of 14.8% in April 2020 and has been declining since.

109 https://doe.state.wy.us/lmi/G_DInd/Report_21Q2.pdf

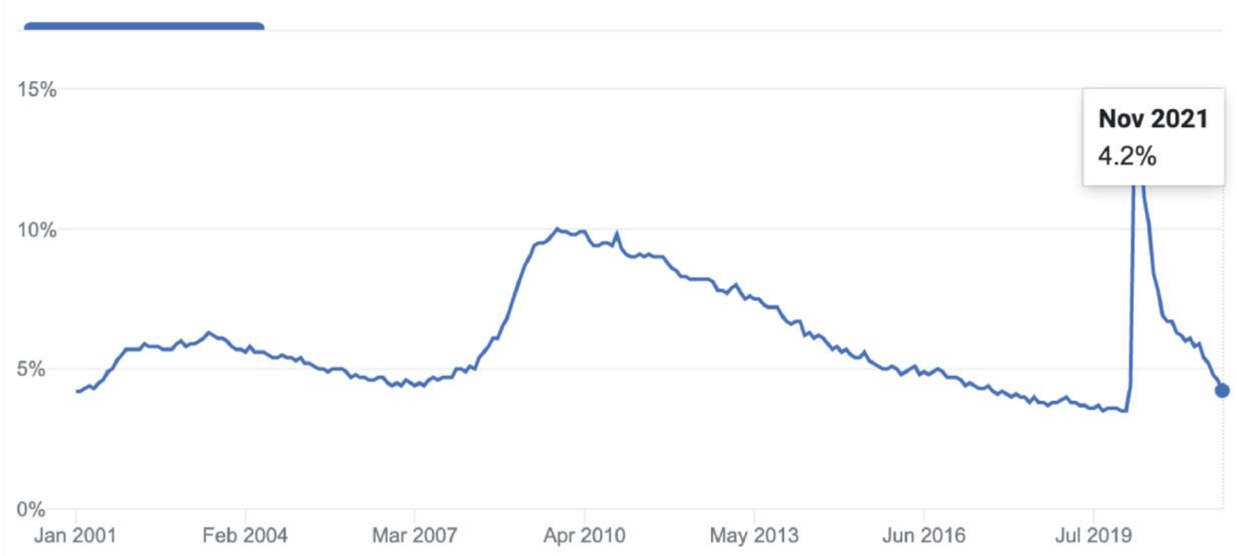

Figure 6: US Unemployment Rate, January 2001-November 2021
Data from the Bureau of Labor Statistics

Trends expected by 2030

The number of Wyoming jobs is expected to grow by 7% by 2028 (above 2018 levels), with an addition of more than 19,000 new jobs. However, not all sectors will see job growth. For example, mining jobs are expected to decline, which will be significant since mining has been an important industry in Wyoming historically. Oil and gas extraction is expected to decline by 1.4%, down from 3,039 in 2018 to 2,997 by 2028. Likewise, all other mining (including coal) is expected to decline from 8,101 to 6,671, a decrease of -17.7%. Jobs in the utility industries are expected to increase, however. In 2018 utilities employed 2,508 people in Wyoming; by 2028 they are expected to employ 2,615—a 4.3% increase.[110]

Other industries that are expected to decline include retail trade (-1.4%), information (-9%), and management of companies and enterprises (-1.4%). Industries that are expected to expand include leisure and hospitality (13.3%), professional, scientific, & technical services (16.8%), health care & social assistance (16.5%), administration & support & waste management & remediation services (15.4%), construction (11.4%), wholesale trade (10.5%), and real estate & rental & leasing (10.1%).[111]

2. Energy transition is creating loss of jobs:

The energy transition is not new. Consumer preference and prices have always played a role in energy markets. Historically this was seen in the benign consumer-preference to cook with natural gas, the dominance of electric lighting, and the volatile geopolitics of petrostates. What is new is the rising importance consumers place on low-pollutant (esp. low carbon) energy sources. An anticipation of this new pollution concern can be seen in the activism leading to the 1970 Clean Air Act amendments. Anthropogenic global climate change became a public concern in the late 20th century, and culminated with the US EPA's

[110] https://doe.state.wy.us/lmi/trends/0820/0820.pdf#page=5

[111] https://doe.state.wy.us/lmi/trends/0820/0820.pdf#page=5

2009 endangerment finding that greenhouse gases are "air pollutants" under the Clean Air Act. Like previous transitions, companies and industries which navigate the present elegantly can endure while others may struggle.

Numbers of workers in energy industries and job losses

Coal Mining

The number of people employed in coal mining in Wyoming has risen over the last 20 years, from 4,285 in 2001 to 4,781 in 2020. However, it has declined significantly since reaching its peak of 7054 employees in 2009 (*Figure 7*).

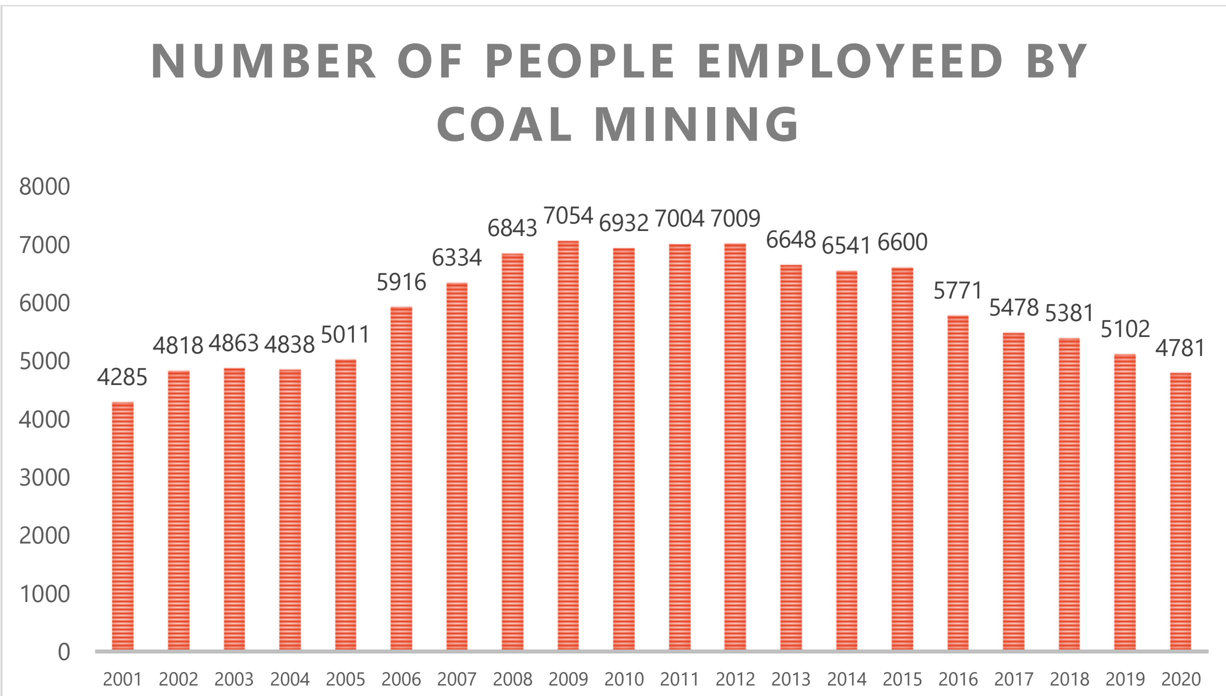

Figure 7: Wyoming residents employed in coal mining 2001-2020

Data Source: Bureau of Labor Statistics[112]

[112] https://www.bls.gov/data/

Oil and Gas

The number of people employed by the oil and gas industry in Wyoming has declined in the last 20 years. In 2001, there were 3323 jobs in oil and gas, while in 2020 there were 2,757. Similar to coal, oil and gas has seen a particularly steep drop in jobs in recent years. It reached a peak in 2008 with 4,673 jobs and has been steadily decreasing since 2014 (*Figure 8*).

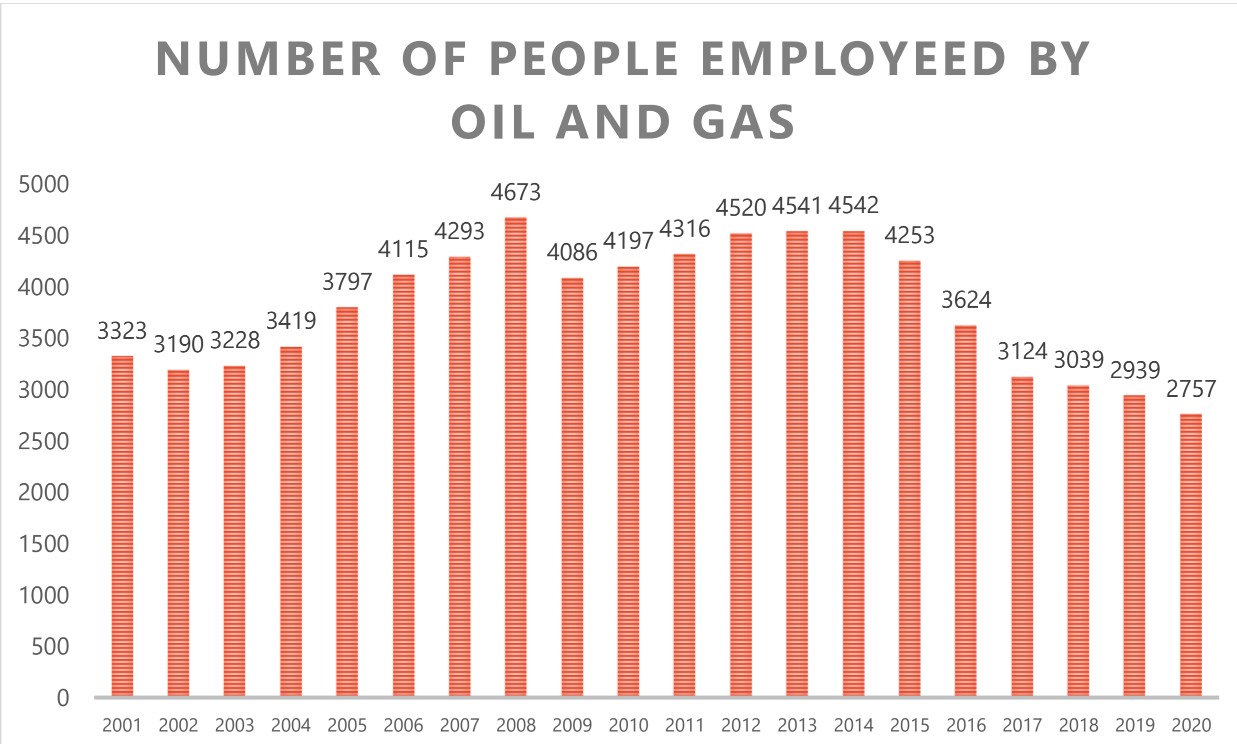

Figure 8: Wyoming residents employed in oil and gas 2001-2020

Data Source: Bureau of Labor Statistics[113]

Utilities

The number of jobs in utilities has been relatively consistent in Wyoming since 2007. There has been a slight increase since 2003 when utilities employed 2,314 people to 2020 when they employed 2,582. However, there haven't been any big increases or decreases in utility employment levels. They also are not predicted to decrease as other fossil-based energy industry jobs are in Wyoming (*Figure 9*).

[113] https://www.bls.gov/data/

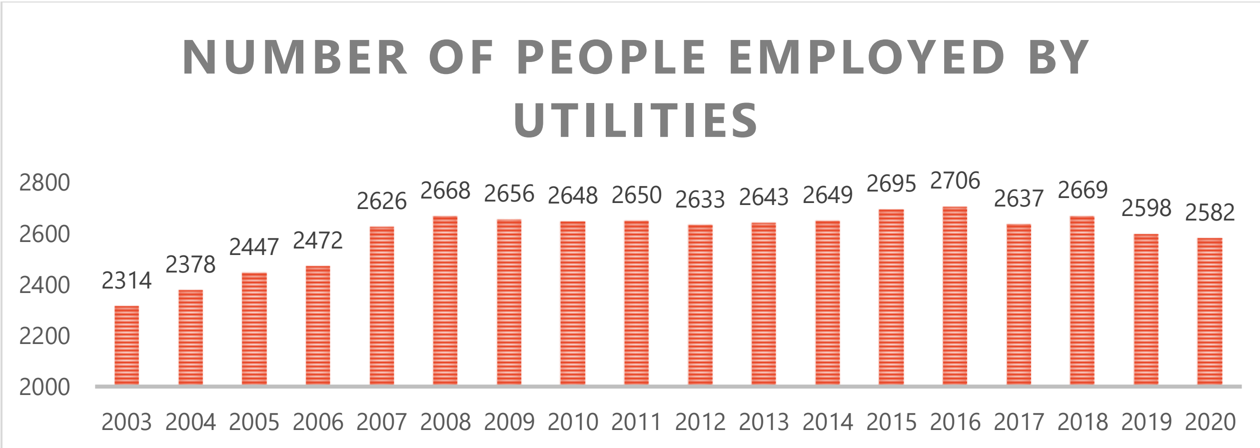

Figure 9: Wyoming residents employed by utilities 2001-2020

Data Source: Bureau of Labor Statistics[114]

Projected job losses due to closing and reduction of operation for the next 5 years

Jobs in fossil-based industries are projected to continue to decline in Wyoming especially in light of the fact that Wyoming's largest electric utility, Rocky Mountain Power, intends to retire its coal plants in the state in the years ahead. Their stated goal in their 2021 Integrated Resource Plan (IRP) is a 74% reduction in greenhouse gas emission below 2005 levels by 2030. To meet this goal, they are scheduled to retire 14 of their coal-fired power plants across several states by 2030, and a total of 19 by 2040. Though they converted one unit at a coal-fired power plant to natural gas and are considering a similar conversion of two more units at a separate plant in Wyoming, they are not otherwise choosing to invest in future natural gas construction. This will certainly have an impact on mining jobs in Wyoming, as well as jobs at fossil-based power-plants. However, Rocky Mountain Power is planning to continue to invest heavily in renewable energy technologies in the state (i.e., wind, solar, grid-scale storage) that should lead to new jobs in these new energy industries. How many jobs will be created and if they will be located in Wyoming, however, remains to be seen.[115]

3. Looking at the future

The energy transition affects Wyoming through a reduced emphasis on fossil energy. Wyoming can expect reduced demand for coal, oil, and natural gas as consumers and governments prefer other sources of electrical, mechanical, and thermal energy. This preference for alternatives is caused by a growing ability of consumers to distinguish low-carbon electricity from high-carbon electricity and to internalize the cost of carbon through fees, taxes, and refusal to buy. Wyoming stands to benefit from a well-informed consumer who understands that fossil fuels do not necessarily have high carbon intensity. Like all energy transitions before, the present transition stresses existing industries and may eventually relegate some industries to niche applications.

---

[114] https://www.bls.gov/data/

[115] https://www.pacificorp.com/energy/integrated-resource-plan.html

Coal, oil, and gas industries -- as traditionally operated – are responsible for significant carbon dioxide (CO_2) and methane emissions. These industries are central to Wyoming's economy and directly stressed by consumer emphasis on energy sources which do not significantly exacerbate global climate change. Accordingly, both regulation and trends in consumer choice are reducing demand for coal (*Figure 10*). Demand for Wyoming's oil and gas continues to operate in somewhat normal conditions. However, if consumers' preference for low-carbon energy strengthens, and these industries do not meaningfully and publicly decarbonize, then Wyoming stands to lose significant revenue.

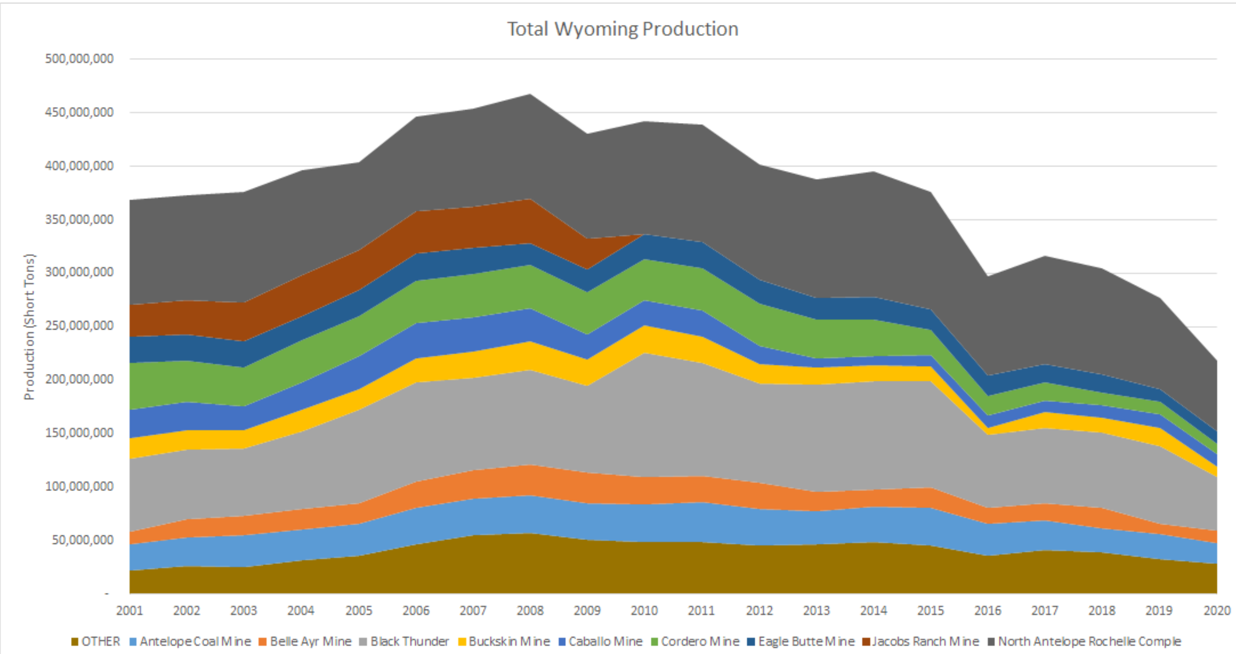

Figure 10: Stacked yearly output of Wyoming Coal mines, showing the long-term decline in production since 2008. Most of Wyoming's exports come from the Black Thunder mine (light gray) and North Antelope Rochelle mine (dark gray).

Data Source: EIA Coal Data Browser https://www.eia.gov/coal/data/browser/

The long-term decline in demand for coal, and anticipated decline in other fossil fuels, if not arrested through decarbonization, will produce knock-on effects in energy generation, transmission, and distribution. The many associated industries such as heavy machinery servicing, environmental reclamation, and all commercial activities which multiply the value of each fossil energy job.

Wyoming has seen limited growth in solar PV generation. The only commercial operation in the state is Sweetwater Solar, installed by 174 Power Global. However, Wyoming has seen significant investment in wind generation. This is not only due to the strictly greater average wind speeds in the state, but also the tendency of these winds to blow at dusk and early night, allowing electricity from them to serve peak demand in the Rocky Mountains and west coast. The federal production tax credit for wind has also played a role. Formal electric vehicle infrastructure is limited to larger cities supportive of EV such as Jackson, Cheyenne, and Riverton, but private charging at home and incidental locations means electric vehicles can be found almost anywhere in Wyoming. The trend towards EVs in towns is increasing, but almost all rural areas such as ranches or utilities are dominated by gasoline vehicles. Public transportation follows EV trends, being overall rare, but present in Wyoming towns.

If Wyoming's electric grid improved then Wyoming would be well-placed for most parts of the energy transition. The desert conditions and thin atmosphere found in much of the central and southwest of the state are conducive to solar PV generation. Wind generation could expand much more, and spread out across Wyoming to smooth out production spikes and gaps. Wyoming's cities could benefit from EVs and public transit, but remote areas with rugged geography and harsh weather will probably require gasoline vehicles well after EVs provide the majority of transport in the rest of the United States. Wyoming can adapt to the energy transition, but requires electric grid improvements to compensate for the large distances between population centers in the state.

For many years during the energy transition Wyoming will be a unique state using old technologies internally for daily life, but taking advantage of new technologies to deliver exports and novel work opportunities. For example, although no CO_2 has been stored in the state aside from that stored as part of enhanced oil recovery (CO_2-EOR), Wyoming has two well-characterized saline storage complexes. Given economic support and political support for carbon capture & storage (CCS) and carbon capture, utilization and storage (CCUS), Wyoming's geology enables carbon capture which could be the envy of North America.

Most of Wyoming's buildings are constructed to withstand harsh winter conditions, and are therefore generally well insulated against wind, water, and cold. The state may benefit from adding insulation against heat as extreme temperatures become more common. Some building owners may have to add HVAC to residences which historically were only heated, not cooled. While some jobs may be created in this area, Wyoming's low overall population means demand for building upgrades will be low.

Transition to a carbon neutral energy economy would offer these potential work opportunities

The loss of energy jobs at companies which do not decarbonize will force many people to change careers. Wyoming has some transition programs in place, but most workers self-train or move to other positions that require similar skills. Examples include natural gas pipeline workers shifting to hydrogen and CO_2 pipelines, or oil and gas drillers switching to water, geothermal, and sequestration wells. These examples are in areas which will have future work nearby. Coal mines, however, train general skills which can be transferred to any heavy equipment operation, but lack an adjacent industry to shift to, much less one located near existing coal mines. Some oil and gas workers will be able to move into new renewable capture and decarbonized energy jobs, but most coal and other workers do not have a clear path through the transition. These workers may be willing to find their own way, but more state training matching market trends could be a significant help.

Positive policies in the state (both government and private)

The State of Wyoming and local communities within the state have not adopted energy transition policies per se, but nonetheless have enacted policies to encourage research regarding and the deployment of technologies such as CCS and CCUS that are expected to be critically important as energy systems continue to decarbonize.

State Policies

Relevant state policies fall into the following categories: (1) government agencies; (2) infrastructure; (3) policies, laws and regulations; and (4) research.

Government Agencies. Several state agencies in Wyoming have missions that are dedicated, in whole or in part, to advancing policies and projects related to CCS/CCUS, CO_2-EOR, critical minerals (CM)/rare earth elements, and future fuels such as hydrogen. These agencies include, but are not limited to: (1) the Wyoming Energy Authority (WEA) (formerly the Wyoming Infrastructure Authority), whose mission is “to advance Wyoming’s energy strategy by driving data, technology and infrastructure investments” (https://www.wyoenergy.org/); and (2) the School of Energy Resources at the University of Wyoming (UW), whose mission is “dedicated to the energy-driven economic development for the state of Wyoming” (http://www.uwyo.edu/ser/). Other agencies playing a role include the Enhanced Oil Recovery Institute which leads in areas such as CO_2-EOR.

Infrastructure. Wyoming’s Integrated Test Center (ITC) in Gillette provides a facility for CCUS researchers to work on technologies while making use of flue gas from Basin Electric Power Cooperative’s (BEPC) Dry Fork Station (DFS). The ITC is one of only two such facilities like it in the United States, and the only one that operates at its scale. The ITC is a public-private partnership that brings together government, industry and cooperatives with the shared goal of developing commercially viable uses for CO_2 emissions from power plants. BEPC, along with co-owner Wyoming Municipal Power Company, is the site for the ITC at DFS and has provided significant in-kind contributions for the design, engineering and construction of the facility. Tri-State Generation and Transmission Association committed \$5M to match Wyoming’s \$15M commitment. The National Rural Electric Cooperative Association provided an additional \$1M in support as well.

Also in Gillette, in June 2021 ground was broken on the \$3.5M Wyoming Innovation Center, a facility that will focus on the development of high-value, non-fuel, coal-based processes and products. The project is the first major capital investment as part of the Carbon Valley™ initiative being advanced by Energy Capital Economic Development, Campbell County and the City of Gillette. The project is supported by funding from the Economic Development Administration (\$1.46M), the Wyoming Business Council (\$1.5M), the City of Gillette, Campbell County, and private businesses.

Policies, Laws and Regulations. Wyoming policymakers have long recognized the imperative to lower the carbon content of fossil fuels.

<u>Policies & Initiatives</u>

In his March 2, 2021, State of the State address, Governor Gordon called on the state to become “net negative” in CO_2 emissions. With the assistance of a leading energy consultancy, WEA is currently working to develop an energy strategy that implements that vision. The energy strategy:

> Focuses on empowering the nation with a net-zero energy mix. This includes harnessing the full value of our energy resources with an “all-of-the-above” energy mix: products from our legacy industries, along with the newer players of renewable energy and emerging opportunities in hydrogen, advanced modular nuclear, geothermal and rare earth elements.

A final version of the energy strategy is expected to be complete in the first half of 2022.

WEA is leading and/or otherwise supporting the following initiatives: (1) UW’s Wyoming CarbonSAFE project; (2) ITC; (3) Wyoming Pipeline Corridor Initiative (WPCI); (4) “Sequestration as a Service”; and (5) Wyoming Hydrogen Initiative. More details on each of these are provided next.

- *Wyoming CarbonSAFE*. The Wyoming CarbonSAFE Project, which stands for the “Carbon Storage Assurance Facility Enterprise,” is one of thirteen original CCUS project sites in the United States funded by DOE with the ultimate goal of ensuring carbon storage complexes will be ready for integrated CCUS deployment. Through a competitive down-select process, four of the original projects have advanced to Phase III (site characterization and CO_2 capture assessment), including Wyoming CarbonSAFE.
- *ITC*. The ITC is discussed above.

- *WPCI*. The WPCI aims to establish corridors on public lands dedicated for the future use of pipelines associated with CCS, CCUS, CO_2-EOR and the delivery of associated products. In coordination with the U.S. Department of Interior's Bureau of Land Management (BLM), researchers, industry representatives and state organizations, approximately 2,000 miles of pipeline corridors were identified throughout central and western regions of Wyoming with the goal of reducing the time and cost it takes for developers to permit these large infrastructure projects while also balancing the environmental concerns associated with these lands by reducing the disturbance footprint. The WPCI was initially proposed in 2012 as part of Governor Mead's energy strategy. The public comment period on BLM's draft environmental impact statement closed in July 2020, and the record of decision was granted by BLM in January 2021.
- *"Sequestration as a Service*." "Sequestration as a Service" (SaaS) is a WEA initiative that would involve building commercial sequestration sites with wells for injecting CO_2 deep beneath the earth's surface. These sites would be operated by entities with vast knowledge in the practice of injecting CO_2, which would then offer this as a service to any CO_2 emitter. Wyoming has a competitive advantage for this service. It already has extensive CO_2 infrastructure, it leads the nation in CO_2 centric policy, it has an experienced workforce in CO_2 operations, and it has a favorable business environment. Successful establishment of a SaaS industry would benefit all CO_2 emitters in the state and facilitate establishment of other forward-looking "all of the above" energy prospects such as hydrogen and direct air capture (DAC) industries. Near-term initiatives include mitigating liability of Class VI wells used for CCS, utilizing CO_2 for cement, and mitigating CO2 emissions from the combustion of fossil fuels. The workforce requirements to support this service sector encompass every skill set – from trades to legal and financial, and from executives to scientists, engineers, and laborers. SaaS supports Wyoming's heritage industries and also provides a bridge for Wyoming to become economically sustainable and a critical leader in the net-zero energy economy, making it an important initiative in our state's energy strategy.
- *Wyoming Hydrogen Initiative*. Through public and private partnerships in research, development, demonstration, and deployment activities, Wyoming is investigating the potential for upgrading its rich hydrocarbon resources to decarbonized hydrogen and leveraging our world-class renewable resources for production of zero-carbon hydrogen. Hydrogen manufacturing could be centralized or dispatched in modular form, making it suitable for a wide range of siting locations and thus encouraging statewide economic inclusion. The state's natural gas pipeline infrastructure could be repurposed to transport hydrogen while the existing power grid could support additional electric generation. Wyoming has a unique opportunity given its overlapping abundance of natural resources (both hydrocarbon and renewable) and existing infrastructure to support hydrogen production and become an export powerhouse in the future.

  In April 2021 WEA issued a call for proposals to scope out the viability for a pilot project to demonstrate the potential for hydrogen production, export, and use in the state. The robust response indicates an encouraging level of interest and potential for investment in these projects.

  On a related front, SER is in the midst of establishing a Hydrogen Energy Research Center at UW.

Laws

More than a decade ago the Wyoming Legislature enacted a statutory framework for CCS and CCUS projects, including permitting. That framework:

- Specifies who owns the pore space (*Wyo. Stat. § 34-1-152 (2020)*);
- Establishes permitting procedures and requirements for CCS sites, including permits for time-limited research (*id. § 35-11-313*);
- Provides a mechanism for post-closure “measurement, monitoring and verification” (“MRV”) via a trust fund approach (*id. § 35-11-318*);
- Provides a mechanism for unitization of storage interests (*id. §§ 35-11-314, 315, 316, 317*)
- Specifies that the injector, not the owner of pore space, is generally liable (*id. § 34-1-153*);
- Clarifies that vis-à-vis storage rights, production rights are dominant but cannot interfere with storage (*id. § 30-5-501*); and
- Provides a certification procedure for CO_2 incidentally stored during EOR (*id. § 30-5-502*).

On March 24, 2020, Wyoming Governor Gordon signed into law H.B. 200, a new CCUS-related law in Wyoming entitled “Reliable and Dispatchable Low-Carbon Energy Standards.” The law requires regulated utilities to closely evaluate whether they can retrofit CO_2 capture technology to their coal plants. The law is emblematic of Wyoming's efforts to encourage coal-fired power plants in the State to retrofit CCS/CCUS technology, and thus cements Wyoming’s role as being in the vanguard of CCS/CCUS standards for electricity generation in the United States.

In the summer of 2021, the Joint Minerals, Business & Economic Development Committee of the Wyoming Legislature considered draft legislation related to potential state roles in: (1) the long-term stewardship of CO_2 in geologic storage; and (2) voluntary carbon markets. Both bills remain pending and have not been formally introduced.

Regulations

Wyoming remains at the vanguard of states with progressive low-carbon regulations. For example, in the fall of 2020, the U.S. Environmental Protection Agency approved the Wyoming Department of Environmental Quality’s (DEQ) application for primacy over the Class VI program of the Safe Drinking Water Act’s Underground Injection Control Program. DEQ’s final Class VI regulations were released in the fall of 2021. Wyoming remains one of one two states (North Dakota being the other) with Class VI primacy.

In the fall of 2021, the Wyoming Public Service Commission published the final regulations governing implementation of H.B. 200, discussed above.

Local Policies

Communities around Wyoming are not sitting passively as the energy transition occurs.

A prime example is Campbell County’s Carbon Valley™ initiative. It is hoped that Carbon Valley™ will be a mix of commercial manufacturing facilities, test facilities and businesses with new technology proven at these testing sites. Since the PRB coal will be used as a raw material, the businesses would not be directly minerals related and would not experience the boom-bust cycle. This will help stabilize the economy while still creating a demand for coal as a raw material to help keep existing coal mines in operation.

Research. The School of Energy Resources at UW is dedicated to energy-driven economic development for the state of Wyoming. Created in 2006, SER enhances the university's energy-related education, research and outreach. SER directs and integrates cutting edge energy research and academic programs at UW and bridges academics and industry through targeted outreach programs. SER's mission spans academics, research and outreach, all of which bear on energy transition issues to a greater or lesser extent.

In terms of research, SER largely operates by providing seed-funding to topic-specific centers of excellence, several of which are working on issues to prepare Wyoming for ongoing changes to energy systems and markets. The Center for Economic Geology Research, for example, leads applied research on the geologic storage of CO_2, CM/REE identification and characterization, and related topics. The Center for Carbon Capture and Conversion leads applied research on topics such as non-Btu products from coal. The Center for Air Quality is advancing research related to detecting and reducing fugitive methane emissions from the production, processing, transportation and storage of natural gas and oil.

SER also leads the Wyoming CarbonSAFE project, discussed above.

- ***Comments on what we ought to do that would be supportive of our workforce during the transition***

Wyoming continues to explore ways to diversify its economy, and in so doing ensure job opportunities. Most recently, for example, Governor Gordon launched the "Wyoming Innovation Network," a partnership among UW and Wyoming's community colleges to address this and related issues. At the local level, initiatives such as Campbell County's Carbon Valley™ initiative are working hard to preserve jobs in the fossil industries while preparing for the day when those workers could perhaps be employed in new industries such as coal-to-products. The recently announced Natrium nuclear power plant, which will be built in Kemmerer, Wyoming, reflects success by the state in attracting new energy industries that hold promise for both preserving existing jobs while creating new ones.

It is likely, however, that direct financial support from the federal government will be required in some form or fashion. To that end, in 2021 WEA, UW, Campbell County, and the City of Cheyenne submitted individual applications to the federal Build Back Better Challenge program, which had solicited regional-scale plans to diversify local economies, with coal communities as a priority target. Unfortunately, none of those applications were selected for the award.

Wyoming policymakers and others are participating in the federal Interagency Working Group on Coal and Power Plant Communities (IWG) which is also looking at policy solutions to address, in part, worker transition issues. On December 17, 2021, the IWG held a virtual Wyoming-focused event.