I-WEST

Phase One Final Report | Detailed Chapter

CO_2 Point Source Management

VERSION 1.0

LOS ALAMOS NATIONAL LABORATORY

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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.

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Introduction

A carbon dioxide (CO_2) point source is a facility with a significant and concentrated output of CO_2. The dominant source for point source CO_2 emissions is fossil fuel combustion for electricity or heat, but other significant sources include the industrial production of hydrogen and hydrogen products (e.g., ammonia, lime, and cement), and fossil fuel processing and refining.

The threshold for defining a process CO_2 emission as a point source can vary. Historically, industry facilities were tracked given their function. More recently, the definitions in the federal Sequestration Tax Credit (45Q) dominate, as they define the likely economics of point source treatment. The sequestration credit can apply to electricity generation point sources at a scale of 18,750 t/y (metric tons per year), and industrial facilities at a scale of 12,500t/y, of CO_2 emissions abatement. This report uses the Environmental Protection Agency (EPA) eGRID database for electricity generation, which is a complete inventory of grid-connected generation, and the EPA Greenhouse Gas Reporting Program (GHGRP) data for other point sources, which is an inventory of all emitters greater than 25kt/y and many with smaller emissions.

Point source management considers the overall picture of existing point source emissions and how they might change. This report details the current point sources in the Intermountain West and what changes and treatments could make an impact on their emissions.

There are two main strategies for point-source emission abatement. First, point source capture (PSC) technologies separate, purify, and compress the CO_2 from point sources into concentrated streams. The PSC strategy goes hand-in-hand with carbon utilization and sequestration. Second, retiring point sources and potentially replacing their function with other technologies eliminates the emissions. In the near term, this strategy is closely tied with the transition to non-fossil electricity generation, and in the longer term it is connected with maturation of efficiency improvements and new technologies for industrial processes. A third strategy involves changing the fossil fuel that is used, which is quite significant. Natural gas generates less (roughly half of) CO_2 emissions than coal for the same energy output; therefore, continuing to transition from coal to natural gas for electricity generation would result in a significant change to emissions.

In an overall outlook, treating point sources is an available and impactful pathway for near-term CO_2 emissions reductions, and a significant aspect of the long-term outlook for emissions. Commercial at-scale deployment is available today for flue-gas emissions from electricity generation and industrial heat sources, and natural gas processing is inherently a CO_2 separation. Experimental technologies are being deployed at pilot scale or developed at lower technology readiness levels (TRLs) for CO_2 separation in other industrial processes.

The goal of this report is to provide an estimate and explanation of the potential for CO_2 emissions reduction with point source management in a low-medium-high adoption scenario format. Outcomes depend strongly on qualitative conditions like public acceptance and investment, which are largely unpredictable. The primary focus is the electricity sector, which is responsible for most CO_2 point source emissions, based on established estimates of future energy mix and qualitative underlying adoption scenarios. Remaining sources, given the lack of demonstration and low TRL, have more uncertainty in their scenarios. The intent a coarse low-medium-high adoption analysis is to provide insight into possible outcomes, rather than to make predictions.

Point sources in the Intermountain West

Point sources in the Intermountain West are shown in Figure 1. As the legend shows, the dominant emissions are electricity production from coal, as well as natural gas (NG) electricity generation plants. The emissions by major category are shown in Figure 2.

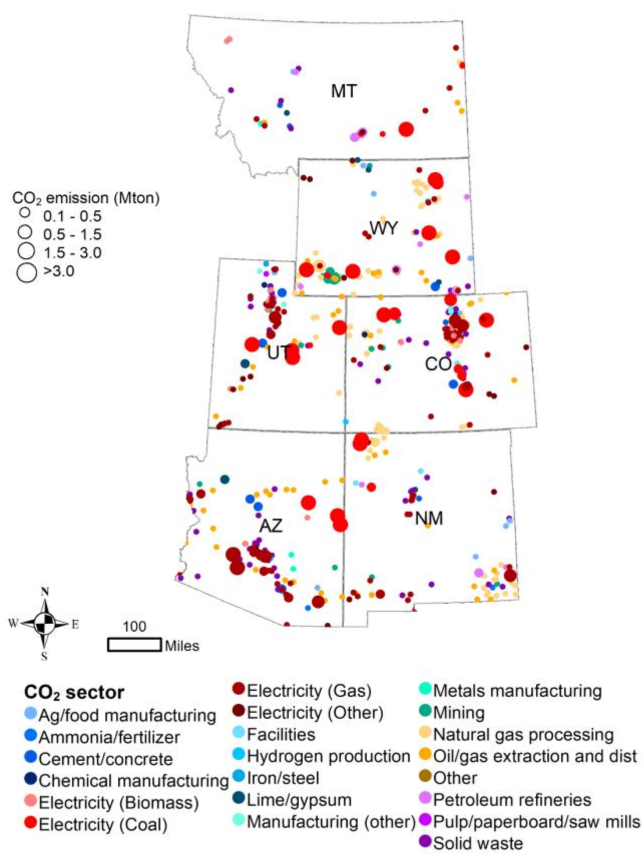

Figure 1. Map of emissions in the Intermountain West by category.

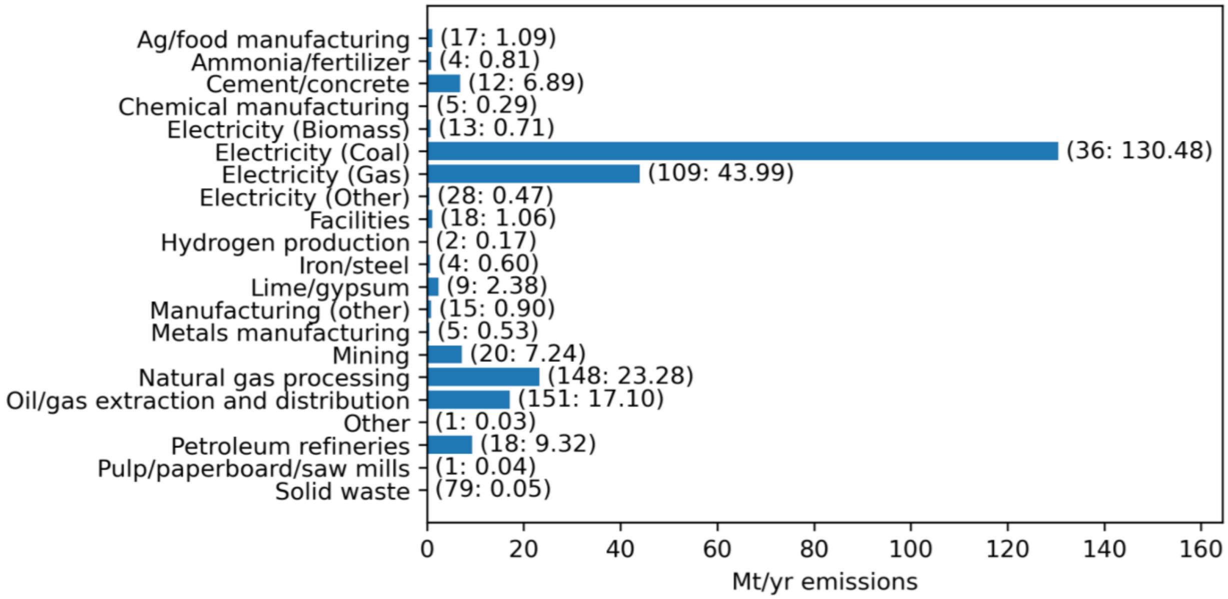

Figure 2. Emissions by facility types of point sources. Bar labels are number of facilities : total emissions of sector in kt/y.

Like all regions, the Intermountain West has a unique fingerprint of emissions types. It is a producer and net exporter of fossil energy, in particular coal and NG electricity generation, NG production and processing, and oil and gas refining. Industrial sources not related to fossil production are a relatively small part of total point source emissions, including mining, cement and lime production, and ammonia (fertilizer) production and agriculture. This analysis emphasizes the potential emissions reduction pathways associated with electricity production, given its dominance in regional point sources.

Emissions are driven by relatively large sources. Figure 3a shows the individual facility emissions sorted by emissions, and the corresponding cumulative emission amount for point sources in the region. The 90% and 95% of total point-source emissions levels are plotted. We can see from this that there is a long tail of very small sources.

The small sources shown in Figure 3a are difficult to treat with PSC for a number of reasons. First, the CO_2 capture becomes a less efficient and economical process as the scale reduces, where absolute costs vary with source purity but generally start to grow exponentially as the capture capacity goes below approximately 300kt/yr with currently mature technologies [1]. Second, the disposition of the CO_2 is such that, for any source in the tens of kt/yr range and up, transport via pipeline to CO_2 sequestration sites is required. Transportation for smaller capture would be even more expensive. Grouping industry into pipeline-accessible sites would be advantageous, but transitioning industrial locations is a long-term prospect requiring further analysis. Finally, smaller sources represent smaller industries, likely much more sensitive to capital investment costs.

For these reasons, it is worth considering the 22% of facilities that constitute 90% of point source emissions, which emit over 250kt/yr. Figure 3b shows these facilities broken down by sectors. The small sectors may be considered negligible for some purposes, either because they are single facilities or their total emissions are relatively small.

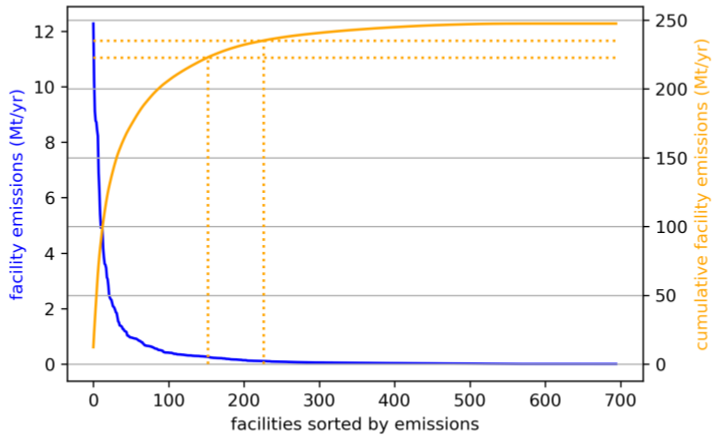

Figure 3a: Individual and cumulative emissions for regional point sources, sorted by emissions magnitude. The dotted lines are at the 90% and 95% of cumulative, corresponding to 153 and 227 facilities, respectively.

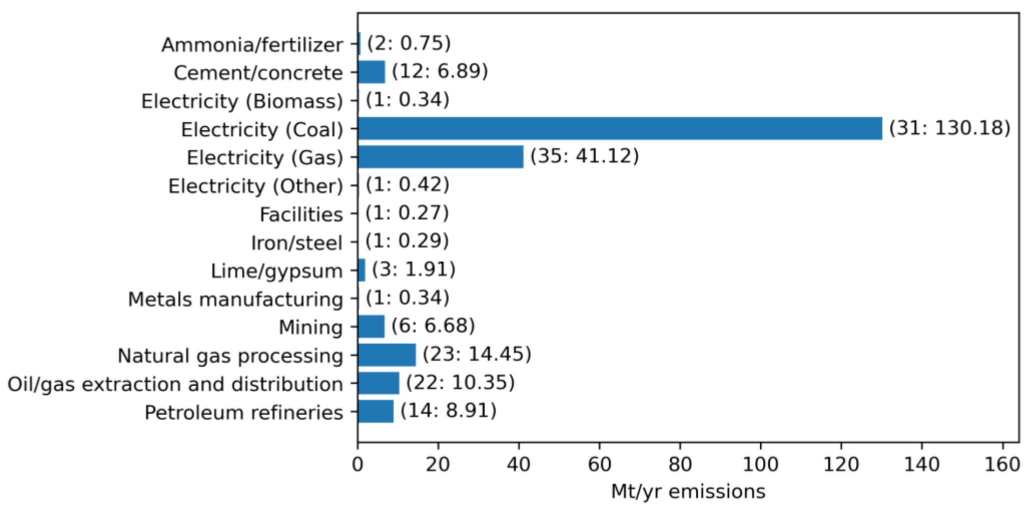

Figure 3b: Emissions constituting the largest emitters constituting 90% of all point source emissions by sector. This represents 22% of facilities, which are all above approximately 250kt/yr. Bar labels are (number of facilities : total emissions of sector) of the selected facilities.

A few key observations can be made by comparing the threshold emissions by sector to the complete emissions by sector. Sector distributions have differing characteristics. In electricity, most coal facilities are large emitters and are virtually 100% of sector emissions; with NG, two-thirds of facilities fall below the 250kt/yr, while the remainder still account for 93.5% of emissions. In NG processing, 85% are below the threshold while the remaining 15% of facilities are 65% of emissions. On the other hand, in cement/concrete there are no emitters below the threshold (emphasizing the economy of scale for this sector). However, the general character of smaller emitters in the Intermountain West is such that electricity production remains the dominating source of CO_2 emissions, whether looking at all facilities or just those with the largest emissions.

There is a gray area about the economics and pragmatics of capturing and disposing of the CO_2 from smaller sources, but it is clear that initiating capture in fossil electricity generation will optimize the potential reductions, both in near-term potential and in the magnitude of CO_2 stream separations. This issue of the pragmatic options for capture and disposal will be implicitly captured in the projection scenarios described below.

Point source capture technology and economics

Summary of point source capture technical considerations

There are three main avenues for treating point sources. The first is to retrofit a facility with point PSC technology to flue gas streams. Detailed in detail later in this report, PSC is a mature technical solution that can be fielded in the short term for fossil electricity generation, as well as the significant proportion of industrial emissions from flue streams coming from combustion of NG for heat. Using existing CO_2 separation techniques, NG processing is generally an easily captured, pure CO_2 stream, as are some of the streams from fossil refineries. The second avenue is replacement with new technology. New technologies for replacing existing sources can vary in technology readiness. In electricity production, this can be a new fossil facility that includes PSC, new technology that uses combustion in oxygen resulting in pure CO_2 output, or as simple as transitioning from coal to NG fuel, which will result in ca. 60% reduction in CO_2 emissions. Capture of non-heat CO_2 streams from industry is relatively low TRL and specialized in application. The third avenue is to retire a facility, which happens as fossil electricity generation is supplanted by non-fossil electricity generation. However, future economic growth in the Intermountain West will likely have more CO_2 emissions from industrial production in comparison to that from power generation.

Point source capture technical overview

There is a large body of literature on PSC technologies, from basic science on materials to systems techno-economic analyses. The technology to separate CO_2 has three main approaches: (1) a dry sorbent to chemically bind and release CO_2, (2) a liquid solvent (e.g., Monoethanol amine [MEATM]) process) to selectively dissolve and release CO_2, and (3) membranes (e.g. MTR Inc. Polaris membranes) that selectively allow gasses to penetrate at different rates. All three solutions have deployment in commercial separations; for example, in NG processing, separating methane from CO_2. All of these are being tested at pilot scale for deployment in flue-gas capture. Currently, liquid solvents in the amine family are the dominant choice when considering commercial deployment because of economics and a track record of at-scale deployment. It might be expected that the technology will transition over time with maturation, or that different solutions might be best in different settings. For example, coal flue gas has 14 volume percent CO_2 and perhaps substantial sulfur, while natural gas flue has 5 vol.% with very low impurities - a substantial difference in operating requirements.

Liquid solvent CO_2 separation is a well-understood industrial process. Flue gas is passed through an absorber exchange column that maximizes contact between the solvent liquid and the gas. The "rich" (high in CO_2 content) solvent is then heated in the stripper to release the CO_2. The flue gas and the lean solvent are contacting in the absorber exchange column, cooled to a temperature range amenable for the solvent to take up CO_2 removing both heat from flue gas and the exothermic reaction. Substantial energy is used in this heating and cooling cycle. In fossil electricity generation treating the capture process can require 20-30% of the system energy as a 'parasitic load', i.e., reduction in generation capacity. In an industrial heat setting, an equivalent amount of energy must be supplied.

To achieve PSC targets in the short to medium term, deploying PSC (and sequestration) will be a necessary and major industrial sector. Each instance is a substantial facility representing a major construction project, and substantial management, maintenance, and material operating support.

Results and outcomes from low, medium, and high scenarios

The estimates of low, medium, and high scenarios have some different implications depending on the sector and technology. The main consideration will be PSC technology adoption (and associated transport and sequestration) for electricity generation, which in principle is commercially available. There are projects already online or in process, so a low adoption scenario isn't necessarily zero, although there is no trend yet to demonstrate that widespread commercial adoption is inevitable. We will only note here that adoption is a combination of permitting and legal status, economics and incentives, transport and storage availability, and sentiment. High adoption in the electricity sector is in principle achievable. On the other hand, industrial sector applications include lower-TRL methods, so the scenarios are a combination of development outcomes and adoption. Although high achievement of industrial PSC is possible, it is less likely even in a high scenario.

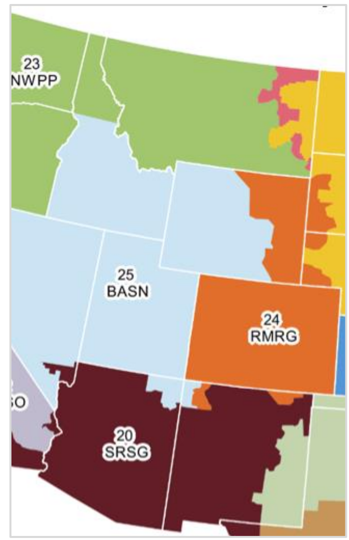

Figure 4. WECC regions relevant to I-WEST, with designations 20: Southwest, 23: Northwest, 24: Rockies, 25: Basin.

Electricity generation point sources

With the large proportion of electricity generated from fossil fuel, the focus of this analysis is on electricity generation. Currently, there are 145 listed electricity generation facilities–36 coal and 109 NG—together they comprise 175 Mt/yr CO_2 emitted. Although there is some small capacity from petroleum, these are largely backup and emergency generators, and not a focus.

To estimate the future of electricity generation, the Energy Information Agency's (EIA) Annual Energy Outlook (AEO) analysis was adopted. The region's facilities are in four of the Western Electricity Coordinating Council (WECC) sub-regions, as shown in the map in Figure 4.

The AEO makes projections at a sub-region level, as well as under different scenarios, including a reference scenario for nominal assumptions, and particularly relevant to this analysis, high and low renewable cost and high and low economic growth. The variation of the scenarios from the reference case is a few percent at most. The projections of the WECC sub-regions are shown in Figure 5.

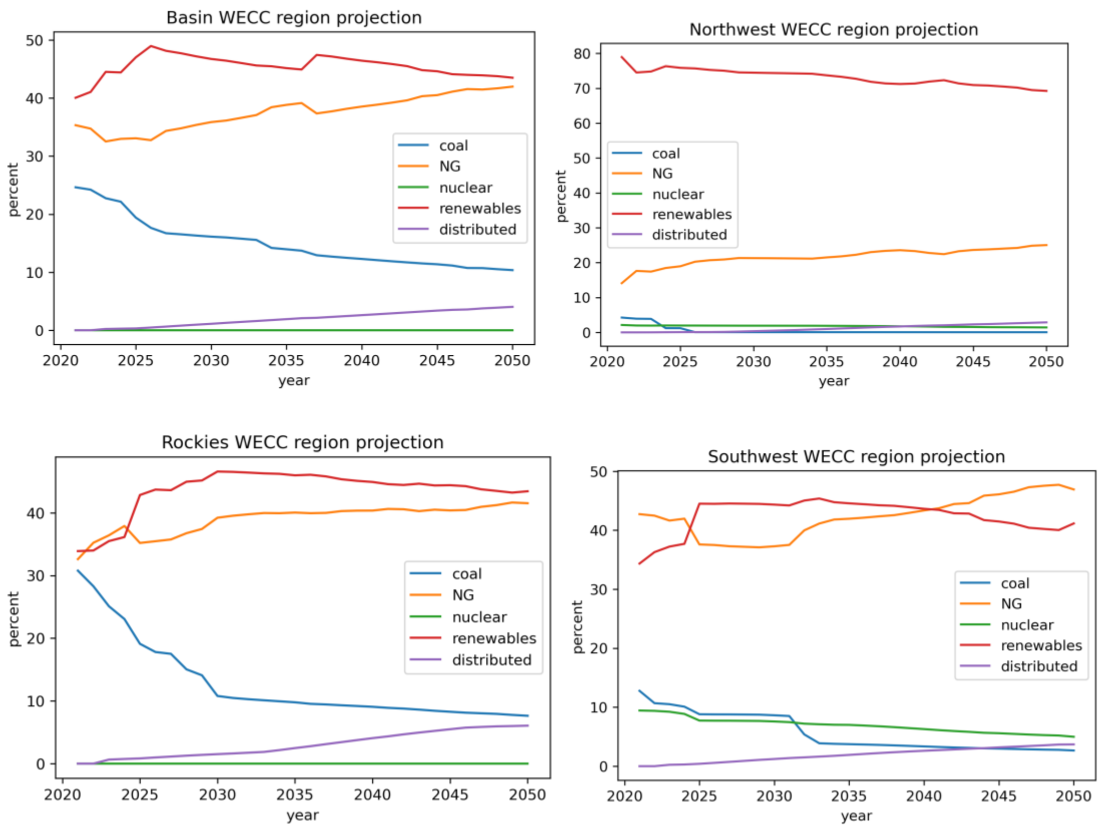

Figure 5. WECC sub-region AEO forecasts relevant to the Intermountain West.

In this analysis, electricity from biomass, and electricity storage in pumped hydro and traditional batteries, are negligible (sub-percent) and not tracked. The projected regional characteristics vary considerably. To estimate the future energy mix for the region, a correspondence is made between emissions and power production: coal electricity production is approximately 1MWh/t (one megawatt-hour per ton of CO_2), and NG production 2.5 MWh/t. These conversion factors can vary depending on plant type, particularly for NG steam combustion vs. combined cycle generation, and should be refined as finer detail regarding power generation is collected about regional facilities. With these conversion factors from CO_2 emissions to generation, and knowing the location of the facilities, the relevant regions are assigned a weight according to production for their relevance to the Intermountain West, resulting in a synthesized AEO for the region. This is shown in Figure 6.

Following this mix projection, we can estimate the changes to emissions in the Intermountain West for coal and NG fossil generation, as shown in Figure 7.

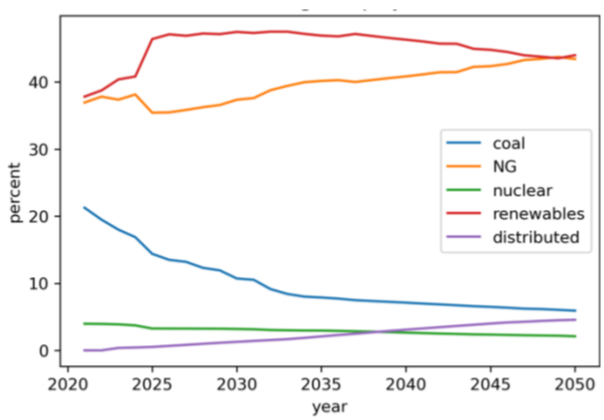

Figure 6. Weighted AEO for electricity generation reference projection for the Intermountain West region.

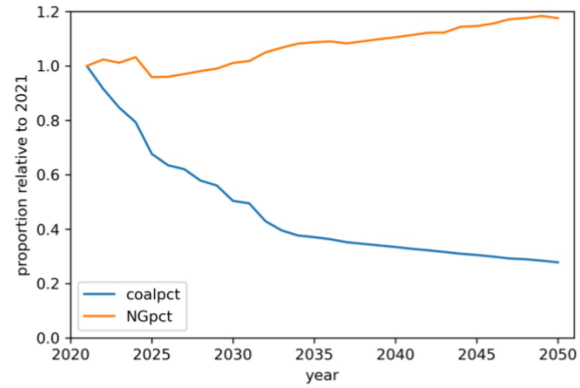

Figure 7. Change in fossil electricity generation, proportion relative to 2021.

Finally, by multiplying these profiles by their current levels, a projection of regional fossil electricity generation emissions is shown in Figure 8; this result includes the expected change in energy mix due to changing generation, including growth and replacement of fossil generation by renewables. The decrease is primarily driven by reduction in coal generation. It does not include the potential impact of point source capture technologies. The emissions can be further modified given assumptions about point-source capture adoption.

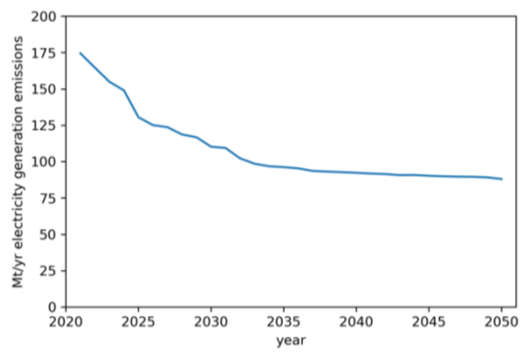

Figure 8. Total projected fossil emissions from electricity generation.

Adoption of PSC will be linear over time, as more complex alternatives have low impact to the outcome given other uncertainties. The low-adoption case will be greater than zero, as there are already capture and sequestration projects underway. PSC efficiency has historically had a goal of 90% capture, but is demonstrated to be possible at much higher rates, up to achieving net-zero emissions. There is a trade-off of diminishing returns in capture proportion to energy invested. Here, we will assume a nominal 98% capture at 30% parasitic power loss by the PSC process. If the electricity mix is to remain at projections through

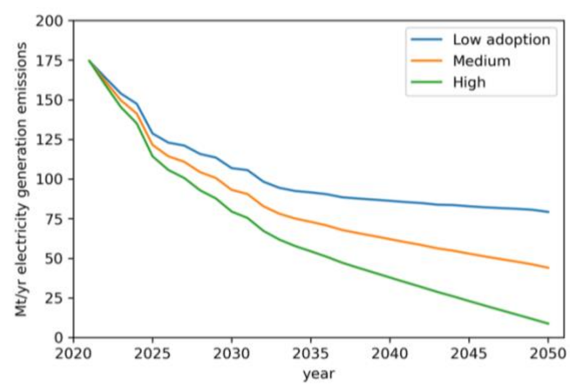

Figure 9. Projected emissions with linear adoption scenarios from present (zero) to 2050: low = 10% adoption, medium = 50% adoption, high = 90% adoption.

increasing system capacity, this implies a net capture of 97.5% of adoption. The low, medium, and high adoption cases are 10%, 50%, and 90% adoption by 2050. The modified curves are shown in Figure 9.

See the Appendix for regional project examples, featuring the San Juan Generating Station (SJGS), Dry Fork Station Complex, and Coyote Clean Power Project.

Industrial point sources

This section discusses point sources that are not related to coal and NG electricity generation. Industrial capture has many more facets than electricity production, due to the nature of the industrial sources and in terms of the technology readiness to address the emissions. Here, industrial processes are split into three main categories: fossil fuel production related, industrial heat streams, and other industrial CO_2.

Fossil fuel production is broken down in a more detailed discussion, due to the significance of the streams associated with region's fossil energy economy. Other industries of significance for regional point sources include cement/concrete/lime/gypsum (9.26 Mt.yr) (grouped here for similarity in production through calcination), and mining (7.25 Mt/yr).

In industrial processes, a significant portion of emissions is associated with industrial heat production, effectively all associated with combustion of NG (as opposed to other fossil fuels, light industry can also use electricity). Separating this in processes will be industry and facility dependent, but this is a significant portion of cement/concrete/lime production (calcination), petroleum refining, metals production, ammonia production, and potentially future blue hydrogen production. In these cases, the heat component generates a flue stream that is a straightforward candidate for PSC. Other components of the industrial processes may also release significant CO_2 and be amenable to capture, although this is at a lower TRL, notably the calcination in cement/concrete/lime production or the process output from ammonia production and future blue hydrogen production. Finally, there are industrial processes where the emissions are not pure CO_2 and PSC treatment is experimental; for example, in refining process waste flares, agriculture/food, and oil and gas extraction. Many of these sources are also smaller, and may be better candidates for migrating the point source to replacement technology rather than a simple retrofit-style application of point source capture.

The estimates in this section are more speculative than in the electricity sector, and are open to future refinement as cataloging and analysis of the regional point sources become available in more detail.

Fossil fuel production

As shown in the chart in Figure 2, fossil fuel production sources include: NG processing (23.28 Mt/yr), oil and gas extraction (17.1 Mt/yr), and petroleum refineries (9.32 Mt.yr).

The low, medium, and high scenarios in this area are a combination of change in fossil fuels, and PSC adoption. At this time, we do not have an estimate of the change to oil and gas production, although we may expect this to decline significantly and further contribute to CO_2 point source reductions in this sector.

Natural gas processing

Natural gas processing is an existing separation process, which involves separating hydrocarbons as in petroleum refining, in addition to separating varying but significant CO_2 streams (with CO_2 concentration depending on the well). This is a high-TRL application, with existing operational facilities and application projects in progress within the region. In a scenario, the potential for adoption can be taken as relatively high, as the application requires low technology development and low adoption costs. A low-adoption scenario may still be low for a number of pragmatic reasons, at 10% by 2050, medium will be relatively higher at 70%, and high adoption is 95%.

See the Appendix for a regional example featuring the Piñon Midstream NG Processing project.

Petroleum refining

Petroleum refining has a total of 9.32 Mt/yr emissions and represents varied sources associated with the refining process, from large to small, and various considerations of associated capture. Emissions include sources such as gas flaring (combustion of waste gasses), and process heat (see industrial heat, below). These sources also have a range of sizes, with the small scale sources making capture and storage challenging. Petroleum refining is difficult to address technically, so the estimates of adoption are relatively conservative. We adopted a low scenario of 10% capture by 2050, medium of 40%, and high of 75%.

Oil and gas extraction

For oil and gas extraction, the range of TRLs lead to a relatively low adoption pathway for the various components. We adopted a low scenario of 10% adoption by 2050, medium 35% adoption, and high 60% adoption.

Other major industrial sources

As discussed above, other significant sources in sectors cement/concrete and lime/gypsum currently exist in the Intermountain West. A significant portion of emissions are from heat generation in combustion of NG for heat, while the calcination process of producing CaO from $CaCO_3$ also releases significant CO_2. In these cases, capturing CO_2 from the NG combustion flue is an available technology, but capturing the process CO_2 stream is a lower-TRL that is understood in principle but is at the technology evaluation level. There is a similar situation for ammonia where NG combustion supplies heat and an associated CO_2 flue stream, and the process of producing NH_3 (ammonia) from CH_4 (methane) releases CO_2. As with other NG combustion, the flue stream is available, and with ammonia the ability to easily generate a nearly pure CO_2 process output stream is also well understood and high-TRL; capture from ammonia generation is an available technology. All of these industry sectors have a very high potential for adoption of PSC and management for CO_2 abatement, as high as 95% in the long term, but with some challenges in investment of significant process changes.

In mining, a variety of sources lead to difficult capture scenarios. The potential to address these with capture has challenges, but the potential to address these with process changes is moderate.

See the Appendix for a regional example featuring the Lafarge / Holcim Cement project.

Other sources

The remaining small sectors not discussed are shown in Figure 1, with labels: ag/food manufacturing, chemical manufacturing, electricity (biomass), electricity (other), facilities, hydrogen production, iron/steel, manufacturing (other), metals manufacturing, other, pulp/paperboard/saw mills, and solid waste. These sectors are either composed of small facilities or are not a single clear source to treat. However, collectively they make up 6 Mt/y of emissions. With a combination of technology updates and efficiency improvements, a conservative estimate of treatment is between 10% and 50%.

Industrial sources emissions summary

Table 1 shows the scenario assumptions by emissions type. These estimates are round numbers considered appropriate to the sectors with some reasoning given above. These are general estimates consistent with available literature and will be a topic for future revision and detailed analysis. Putting these together, the summary CO_2 reduction, with regional sector emissions weighting is shown in Table 2. The summary reduction is the amount below the current total for the selected industry sectors of 67 Mt/yr.

Table 1			
	low % by 2050	**medium % by 2050**	**high % by 2050**
Oil and gas extraction	10	35	60
NG processing	10	70	95
Petroleum refineries	10	40	75
Cement/concrete/lime	10	60	95
Ammonia production	10	80	95
Mining	10	50	70
Other	10	30	50

Table 2			
	low % by 2050	**medium % by 2050**	**high % by 2050**
Summary CO_2 emissions	10%	51.6%	78.1%
Summary Reduction	7.3	37.6	57

New sources

New point sources may include industrial growth in the region, new sources related to a hydrogen economy, including blue hydrogen (hydrogen from methane) and carriers like ammonia, and the sources coming from direct air capture. In a future targeting zero emissions, new sources would be born with appropriate technologies that integrate CO_2 capture as part of the process. Future development of significant sources of CO_2 will connect directly with CO_2 utilization and sequestration. Here, we will not consider these sources, although in the future, their development and deployment will be a key part of eliminating CO_2 emissions from what are currently typical point sources.

Summary and outlook

Summarizing the projections above for point sources from electricity generation and industry, the three scenarios are shown in Figure 10.

There are a variety of point sources in the Intermountain West, and understanding their outlook and potential treatment outcomes is a critical part of reducing emissions, while providing economic energy and growth. PSC is an available technology with significant potential in the region.

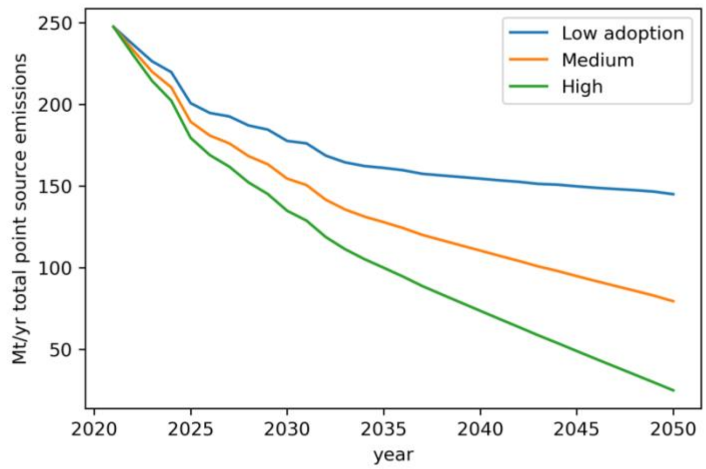

Figure 10. Emissions reduction potential including electricity generation projected mix change and low, medium, high adoption of PSC; plus, a low, medium, high estimate of industrial emissions potential change including PSC, technology changes, and efficiency changes.

PSC adoption in fossil electricity generation is a path to near-term emissions reductions, with commercially available technology. A likely future technical pathway through at least the medium term (10-20 years) is the requirement to match adoption of wind and solar renewables with NG baseload to provide electricity when renewables are not active—the key to addressing the corresponding emissions in that timeframe is point source capture. This report used the EIA's Annual Energy Outlook study as a baseline for electricity generation projections and associated emissions estimates, which is consistent with that scenario. On top of that overall reduction in emissions due to reductions in coal as a fossil fuel, PSC adoption low, medium, and high scenarios reflect a range of outcomes for emissions.

Industry emissions in the Intermountain West are relatively small compared to current electricity generation, but are significant and potentially growing, although here the emissions are taken as not changing over the study period. The disposition of these sources in terms of technology change are difficult to project, and the potential for adoption of PSC is also unclear due to low TRL and small emissions sources that are expensive to treat (both in PSC economies of scale and in disposition of the CO_2 through pipelines and sequestration). Major industrial processes using NG combustion for heat are potentially addressable in the near term. This report gives low, medium, and high capture scenarios by industry sector, showing a potential range of outcomes.

It is important to recognize that possible energy transition scenarios may rely on the growth of calcination, ammonia production, and blue hydrogen. If the driver for the adoption of these technologies is CO_2 emissions reduction, we can expect that new sources will be equipped inherently with managed point source capture technologies and will not contribute significantly to emissions. However, in these scenarios there remains significant CO_2 streams for transport and sequestration.

In summary, of the approximately 250 Mt/yr of emissions from point sources, a low adoption scenario for PSC technology combined with expected electricity generation changes may reduce emissions by approximately 100 Mt/yr. The low adoption scenario would include a relatively modest change from the current trajectory of carbon capture projects, and incentivized technology and efficiency changes. A medium adoption scenario represents a significant increase in adoption and technology alternatives from current trajectory, and may be more in the range of an overall decrease of emissions of approximately two-thirds, or 165 Mt/yr. The high scenario combines an aggressive adoption of PSC technology in electricity generation, and an aggressive combination of PSC, and maturation and adoption of process change in industry, which combine for emissions reductions of 90%.

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Appendix: Regional Projects

This appendix summarizes some of the projects in the Intermountain West, both planned and in process, demonstrating potential paths for PSC in electricity, energy, and industrial processes.

San Juan Generating Station

The San Juan Generating Station (SJGS) is a coal-fired facility that began operating in the 1970s with four coal-burning stacks generating a capacity of 1,684 megawatts. As of the writing of this report, there are two coal-burning stacks still in operation, generating 847 megawatts. There are plans to sell the facility to Enchant Energy Corp. in 2022. Under Enchant, the SJGS would be retrofitted with carbon capture and storage (CCS) to a projected 95% capture rate using Mitsubishi's demonstrated amine-based carbon capture system. The amine solvent which was jointly developed by MHI and Kansai Electric Power Co. is used for CO_2 absorption and desorption.

This project could lead to the capture and potential sequestration of 6 million metric tons of CO_2 annually. To store the captured carbon, Enchant plans to drill 10 carbon injection wells near the power plant, which would have dedicated storage in saline formations. Enchant could also sell the CO_2 for enhanced-oil recovery through the Cortez Pipeline, located 20 miles away, which is a connecting link to EPA-certified storage. The capture facility would utilize approximately 29% of electricity generated from SJGS. The planned project could potentially go online by 2025.

Dry Fork Station Complex

Globally, coal plants generate around 2,000 gigawatts, which is over one-third of global electricity demand. In the electricity sector, coal produces more than one-fifth of global greenhouse gas emissions. On average, a coal-based power plant emits 915 grams of CO_2 power per kilowatt hour of electricity produced.

The Dry Fork Generating Station is a single unit 420 MW capacity generating facility using subbituminous coal. The $1.35 billion facility began operating commercially in 2011 and is currently one the most efficient and cost effective coal fired generating facilities in the United States. The facility's emissions levels are currently below both federal and state requirements, and the water consumption is minimal as it is a zero- liquid discharge facility. In 2014, Dry Fork Station became a test center for carbon capture, utilization and sequestration technologies. The Wyoming Integrated Test Center has used the site to test viable technologies using the site's flue gas. More than $336 million have been invested into advancing Dry Fork's environmental technologies. Dry Fork Station is part of the Basin Electric power cooperative.

These technologies include a reflux circulating fluid bed scrubber, air condenser, CCS, etc. The reflux circulating fluid bed scrubber uses lime to capture and remove more than 95% of sulfur dioxide emissions, and mercury emissions. The Dry Fork Station's scrubber is the largest of this design. An air-cooled condenser uses outside air to condense steam back to water, reducing the amount of water required for plant operations. It is the largest air-cooled condenser in North America and the first application of this kind of cooling technology in Basin Electric's generating fleet.

Coyote Clean Power Project

Gas-fired power generation supplies 20% of the global electricity production capacity. These facilities have low installation costs, high efficiency and are a reliable source of electricity for developing countries. Increasing the efficiency of existing fossil fuel-fired power plants is possible using advanced technologies, substituting less carbon-intensive fuels, and shifting generation from higher-emitting to lower-emitting power plants. Natural gas facilities emit an average of 549 grams of CO_2 per kilowatt hour.

The Coyote Clean Power Project will be a 280 MW gas-fired power plant, using NET Power technology for zero-emissions electricity generation. The company 8 Rivers is working with the Southern Ute Indian Reservation to build the carbon capture facility. The Southern Ute Indian Reservation implemented one of the first utility solar projects in Colorado and has promoted alternative energy projects. The NET Power system uses the Allam-Fetvedt Cycle, which combusts natural gas with oxygen and uses CO_2 as a working fluid to drive a turbine instead of steam. This eliminates all air emissions from combustion, including traditional pollutants and CO_2, and inherently produces pipeline-quality CO_2 that can be sequestered. This facility will also be water free by using air cooling, which does not consume or produce wastewater

With an investment decision for the Coyote Clean Power project in 2022, production could begin by 2025. The project is projected to cost $500 million prior to federal tax credits. This project is expected to add 1,000 jobs both on and off the Reservation during peak construction.

Piñon Midstream NG Processing

Sour gas refers to natural gas that contains a significant amount of hydrogen sulfide and CO_2. High levels of these contaminants are removed from natural gas before entering a pipeline due to the environmental harm and the possibility of it affecting down-stream technology. Piñon Midstream NG Processing was created in December 2020, to provide a solution for sour gas that is long-term, economic, and environmentally responsible. Sour gas has been a problem in the Northeastern Delaware Basin since it limits the ability to deliver gas to processing plants due to extreme concentrations of hydrogen sulfide (H_2S) in the gas stream. This has forced operators to flare sour gas, shut-in wells, or delay drilling activity, affecting the resource development opportunities and revenue streams.

Piñon uses the Dark Horse Facility to remove and sequester H_2S and CO_2, which allows companies to drill and produce high levels of sour gas. By removing these contaminants, Piñon is sweetening the gas to be able to transport by pipeline. Piñon Midstream's Dark Horse facility removes the CO_2 from the natural gas and permanently sequesters it more than 17,000 feet below the surface in geologic formations that are highly suitable for this purpose. The CO_2 never has to enter pipelines for further transport once it enters the Dark Horse facility for geologic sequestration. Piñon's total sour gas treating capacity is approximately 170 million cubic feet per day.

Lafarge/ Holcim Cement Project

The cement industry contributes 5-7% of global CO_2 emissions. Around half of those emissions occur from calcination, which occurs when calcium carbonate is heated and the calcium oxide and CO_2 separate. Research and pilot programs for carbon capture in the cement sector are increasing, and studies have shown that there is too much CO_2 for the facility to reuse; instead, it needs to be sent to a sequestration site. To drive the circular economy, Lafarge Canada is also working on various other methods to reuse the captured CO_2, including investment into other products such as concrete and aggregates.

The LafargeHolcim Cement Project is designed to improve carbon-efficiency in cement production through a full-cycle solution of capturing and reusing the CO_2 to limit emissions. The LafargeHolcim Cement plant in Colorado is a dry process cement plant that became operational in 1996. The facility has previously invested in environmental technologies including a flue gas desulfurization scrubber and a low nitrogen oxide calciner. LafargeHolcim received a $1.5 million grant from the U.S. Department of Energy for design and development of a carbon capture technology on a commercial scale. The project is currently in the feasibility phase to assess the Svante technology at LafargeHolcim cement plant. The Svante system captures a portion of the flue gas and scrubs it through an amine system. Svante's carbon capture technology consists of a patented architecture of structured adsorbent laminate (spaced sheets), proprietary process cycle design, and a rotary mechanical contactor to capture, release and regenerate the adsorbent in a single unit. Once the CO_2 is captured in a proprietary filter, steam is used to release it for storage or industrial use. The system has the potential to capture more than 700,000 tons per year, which can either be sold for enhanced oil recovery or sequestered. The LafargeHolcim Cement plant is near the Sheep Mountain CO_2 pipeline that runs south to Texas.

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