Plains CO_2 Reduction (PCOR) Partnership
Energy & Environmental Research Center (EERC)

REGIONAL BUSINESS MODEL ASSESSMENT: PART II

Plains CO_2 Reduction (PCOR) Partnership
Deliverable (D) 13

Prepared for:

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EERC DISCLAIMER

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EXECUTIVE SUMMARY

Comprising ten states and four Canadian provinces, the Plains CO_2 Reduction (PCOR) Partnership Initiative region is home to abundant and diverse sources of anthropogenic CO_2 (e.g., coal- and gas-fired power plants, gas-processing plants, ethanol plants), fitting geology for CO_2 storage and utilization, a history of CO_2 transport and expanding pipeline infrastructure, and an established industrial/energy commercial base.

Whether from a capture-ready, nearly pure CO_2 source associated with an ethanol plant or from the retrofit of a 1000-MW coal-fired power plant, implementing carbon capture and storage (CCS) is an expensive endeavor. This report is a follow-up to the Peck and others (2022) report entitled *CCUS Business Models in the PCOR Partnership Region*. That previous report discussed several business model frameworks that address the varied contractual relationships between the capture, transport, and storage components of the carbon capture, utilization, and storage (CCUS) value chain. The existing and developing projects in the PCOR Partnership region fit within one or more of these described business models.

For an industry to move forward with a CCUS project, a business model catalyzed with one or more viable drivers (e.g., CO_2 EOR, tax credits) must be adopted that does not negatively impact a company's bottom line. A diverse and robust commercial CCUS industry has evolved in the PCOR Partnership region over the past 30 years. Pathways, business models, and drivers that have facilitated existing and emerging CCUS development in the PCOR Partnership region have recently shifted from resource recovery (CO_2 EOR and associated CO_2 storage) to green growth dominated by dedicated storage. This fundamental shift can be shown based on the list of newly announced CCUS projects in the PCOR Partnership region. Although these projects include CO_2 EOR, most are being driven by tax credit or product value enhancement.

To incentivize dedicated CCUS where a market does not exist, the U.S. government has established a tax credit program for storing CO_2. The value of these tax credits drives a business case forward to enable the realization of CCUS projects. Some CCUS projects, like those associated with ethanol plants, can bolster their business case for CCUS by capitalizing on increased commodity values (higher value per gallon of ethanol). Leveraging low-carbon fuel standards, like those established by the California Air Resources Board (CARB), can provide direct financial gain to an ethanol company implementing CCUS. In fact, the ethanol company can stack the financial benefits of increased commodity prices and the tax credits gained from the U.S. government. This combination is the driver for two recently announced projects for large-scale gathering and transport of CO_2 from ethanol plants in the United States. In Canada, the federal government has put a price on CO_2 emissions (currently Can$30/tonne). Under this situation, there may be financial benefit to capture and store the CO_2 rather than pay the tax. This potential financial benefit would be a business driver for CCUS. Specific examples include the updates to the U.S. Section 45Q federal tax credits, which have improved the economics of potential CCUS projects, and the planned Canadian investment tax credit program and carbon-pricing framework. In addition, the recent U.S. Environmental Protection Agency approval of primacy applications by North Dakota and Wyoming for underground injection control Class VI regulations (wells used for geologic storage of CO_2) have provided potential CCUS project developers with the additional regulatory certainty needed to invest in commercial-scale CCUS projects.

REGIONAL BUSINESS MODEL ASSESSMENT: PART II

INTRODUCTION

The Plains CO_2 Reduction (PCOR) Partnership Initiative is one of four projects operating under the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Regional Initiative to Accelerate CCUS (carbon capture, utilization, and storage). The PCOR Partnership region encompasses ten U.S. states and four Canadian provinces in the upper Great Plains and northwestern regions of North America. The PCOR Partnership Initiative is led by the Energy & Environmental Research Center (EERC), with support from the University of Wyoming and the University of Alaska Fairbanks, and includes stakeholders from the public and private sectors. The goal of this joint government–industry effort is to identify and address regional capture, transport, use, and storage challenges facing commercial deployment of CCUS throughout the PCOR Partnership region.

A diverse and robust commercial CCUS industry is evolving in the PCOR Partnership region. Whether from a capture-ready, nearly pure CO_2 source associated with an ethanol plant or from the retrofit of a 1000-MW coal-fired power plant, implementing carbon capture and storage (CCS) is an expensive endeavor. This report is a follow-up to the Peck and others (2022) report entitled *CCUS Business Models in the PCOR Partnership Region*. That previous report discussed several business model frameworks that address the varied contractual relationships between the capture, transport, and storage components of the CCUS value chain. The existing and developing projects in the PCOR Partnership region fit within one or more of these described business models. For an industry to move forward with a CCUS project, a *business model catalyzed with one or more viable drivers* (e.g., CO_2 enhanced oil recovery [EOR], tax credits) must be adopted to avoid negatively impacting a company's bottom line. To incentivize CCUS where a market does not exist, the U.S. government established a tax credit program for storing CO_2. The value of these tax credits drives a business case forward to enable the realization of CCUS projects.

This report focuses on select emerging (and reemerging) business strategies to make CCS more approachable/affordable for industries facing pressure to reduce their CO_2 emissions. The leftmost column in Figure 1 calls out two of the three business models discussed in this report. The third model is CO_2 EOR.

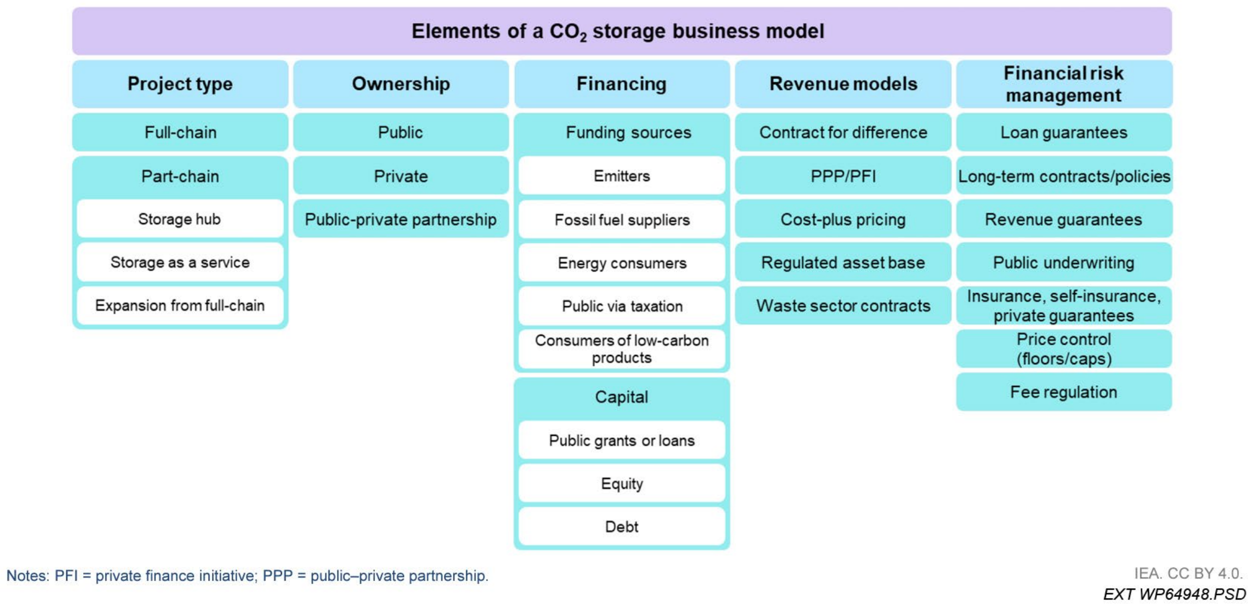

Figure 1. Elements to consider when defining a CO_2 storage business model (International Energy Agency, 2022b).

HUBS AND CLUSTERS

Throughout most of the past few decades, large-scale industrial CCS focused on single sources (such as individual electric generation stations or ethanol plants) and single, targeted storage (point-to-point, sink-source matching). This paradigm was appropriate for large sources with a critical mass of CO_2 to capture, transport, and geologically store (>~2 million tonnes per year). The point-to-point model is also attractive to smaller sources that sit directly over favorable geologic storage options (e.g., the Red Trail Energy ethanol facility in North Dakota).

CCS hubs can be a central collection point where it would service the collection of CO_2 from a capture cluster or distribution points for captured CO_2 to a storage cluster (such as a group of EOR fields). Centralized storage centers (hubs) make use of shared CO_2 transport and storage infrastructure and improve project economics by reducing costs through economies of scale. The improved economics that can be potentially realized through a storage hub concept can bolster the feasibility of capturing CO_2 at smaller industrial facilities through a reduced cost per ton of captured CO_2 (Pechman and others, 2022). Business models that decouple the capture, transport, and storage components of the CCS value chain and leverage the storage hub concept can reduce technical and commercial risks as well as costs (International Energy Agency, 2020).

A great example of a capture cluster in the PCOR Partnership region is being proposed in and around Iowa. Summit Carbon Solutions is looking to develop the world’s largest CCS project and support a cluster of 31 separate bioethanol plants with CO_2 transport and storage capacity of 11 Mt CO_2 year to a storage area in central North Dakota (Figure 2) (Summit Carbon Solutions,

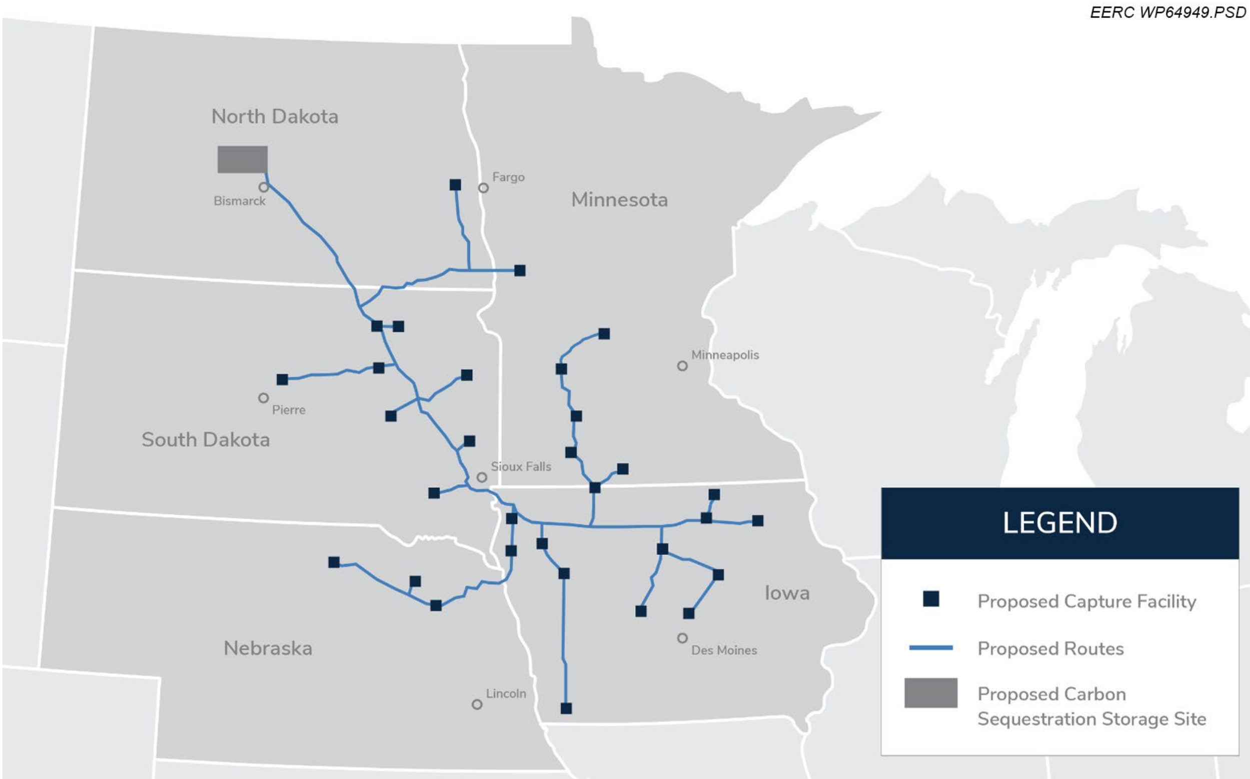

Figure 2. The Summit Carbon Solutions project area map showing CO_2 collection from a cluster of bioethanol plants and the basic routing to a centralized storage site.

2023). Alone, each of the bioethanol plants could not afford to capture and transport their CO_2 emissions to a qualified geologic storage facility. However, through a planned shared infrastructure, the economies of scale work in their favor.

Through the DOE Carbon Storage Assurance Facility Enterprise (CarbonSAFE) program, multiple CO_2 storage hubs have been proposed and are under investigation for either feasibility or at the level of pursuing underground injection control (UIC) Class VI permitting for CO_2 storage. One of the newest CarbonSAFE feasibility studies (the Roughrider Carbon Storage Hub) is focused on aggregating CO_2 from a cluster of gas processing facilities in western North Dakota and transporting the CO_2 to a single location for deep geologic storage. DOE also recently approved an investigation centered in Wyoming to determine the feasibility of capturing, transporting, and storing 10–25 million tonnes of CO_2/year from a diverse range of 30 facilities across the southern half of Wyoming (U.S. Department of Energy, 2023a). Wyoming is also the start of an expanding hub and cluster scenario. CO_2 being captured from two gas processing plants is aggregated via a multi-owner pipeline system and delivered to EOR fields in Wyoming, Montana, and North Dakota as well as a large proposed saline storage complex in southeastern Montana (Figure 3).

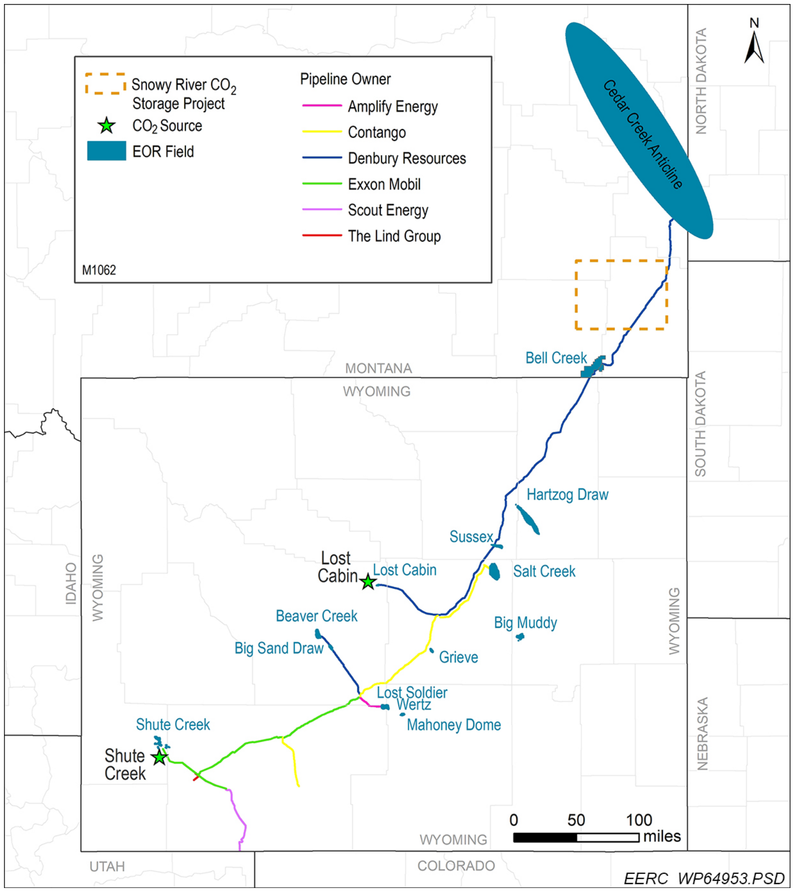

Figure 3. CO_2 storage hub and cluster configuration across Wyoming, Montana, and into North Dakota.

Alberta, Canada

In 2022, as a response to “a large number of inquiries and significant interest from entities looking to obtain carbon sequestration tenure, or pore space,” the Province of Alberta developed a competitive process to allocate carbon storage rights and work toward the most efficient use of the pore space. This competitive process is aimed at creating viable carbon storage hubs defined as “an area of pore space, such as rock formations, managed by a company that can effectively plan and enable carbon sequestration of captured carbon dioxide from various emissions sources” (Government of Alberta, 2023a).

Two rounds of competition have been held. Six proposals were selected from the first round, and nineteen were selected from the second round (Figure 4, Table 1) (Government of Alberta, 2023b). Each of the selected projects/proposals has entered into an evaluation agreement with the province. If the evaluation demonstrates that the proposed projects can provide safe, long-term permanent storage, companies will be able to apply for the right to inject captured CO_2. The evaluation agreement will also ensure that among other criteria, the lead company (hub operator) will 1) identify and address potential subsurface interactions and conflicts and 2) provide open access to all emitters and fair service rates.

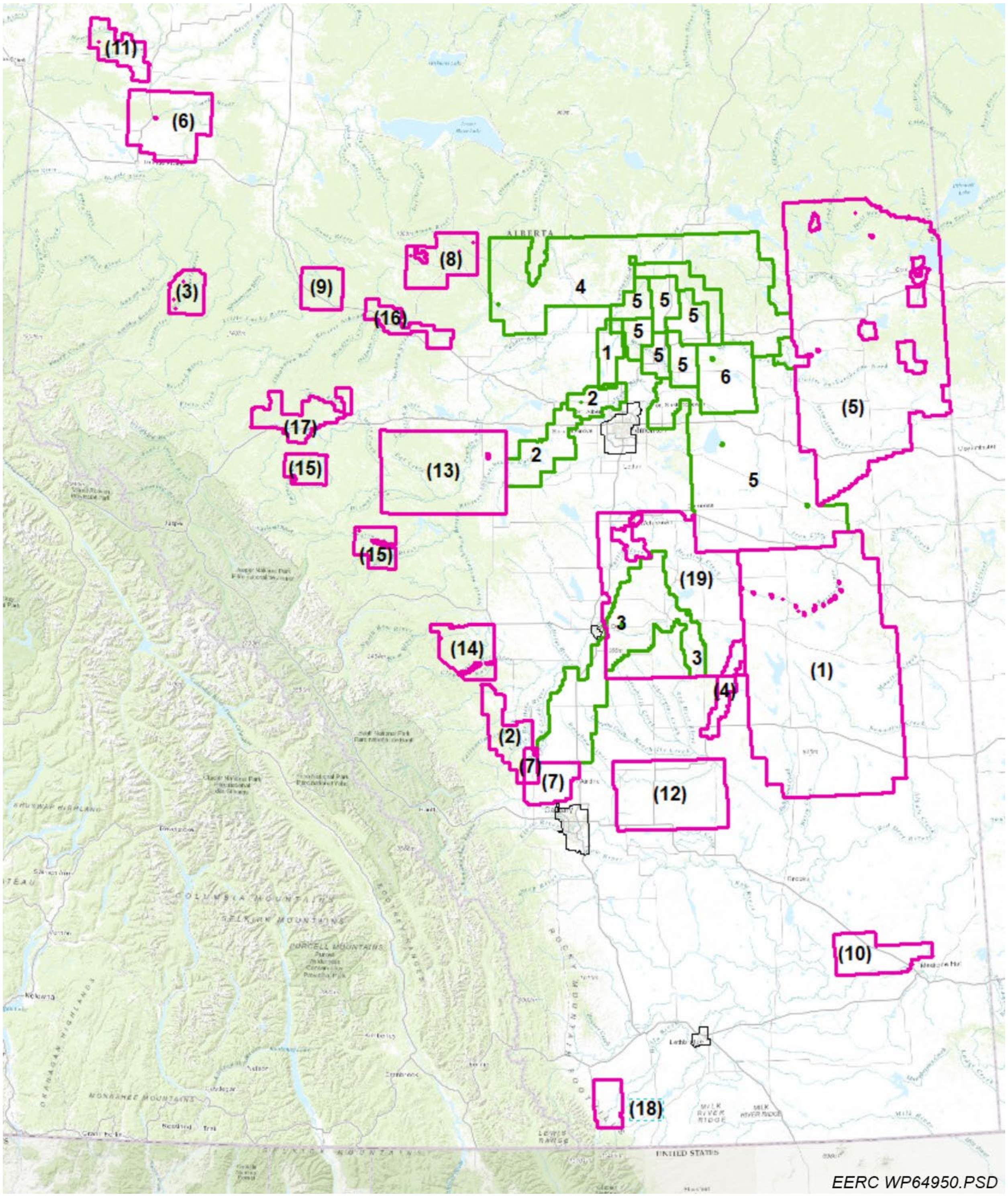

Figure 4. Map showing the distribution of proposed CO_2 storage hubs in Alberta, Canada. See Table 1 for a cross reference of hub locations, proposal rounds, and project names. Some of the hub locations fall in the same geographic area but are separated vertically in the subsurface.

Table 1. List of Proposed CO_2 Storage Hubs from the First and Second Rounds of Competition

Round One Projects		Round Two Projects	
1	Bison Low Carbon Ventures Inc.	1	Alberta Power (2000) Ltd.
2	Enbridge Wabamun Hub Ltd.	2	Altagas Ltd.
3	Enhance Energy Inc.	3	Arc Resources Ltd.
4	Pembina Pipeline Corporation	4	Bison Low Carbon Ventures Inc.
5	Shell Canada Limited	5	Canadian Natural Resources Limited
6	Wolf Carbon Hub GP Inc.	6	Enhance Energy Inc.
		7	Inter Pipeline Ltd.
		8	Kiwetinohk Energy Corp.
		9	Kiwetinohk Energy Corp.
		10	City of Medicine Hat
		11	Northriver Midstream GP Net Zero Inc.
		12	Reconciliation Energy Transition Inc.
		13	Tidewater Midstream and Infrastructure Ltd.
		14	Tidewater Midstream and Infrastructure Ltd.
		15	Tourmaline Oil Corp.
		16	Vault 44.01 Ltd.
		17	Vault 44.01 Ltd.
		18	West Lake Energy Corp.
		19	Wolf Central Alberta Carbon Hub Inc.

In addition to the development process for proposed storage hubs, Alberta is home to the Alberta Carbon Trunk Line (ACTL), which integrates CO_2 capture from a refinery and a fertilizer facility near Edmonton. The CO_2 is then sent via a 40-cm diameter, 240-km-long pipeline to be used and stored in mature oil fields through the EOR process (Figure 5). The ACTL can transport up to 14.6 Mt of CO_2 per year.

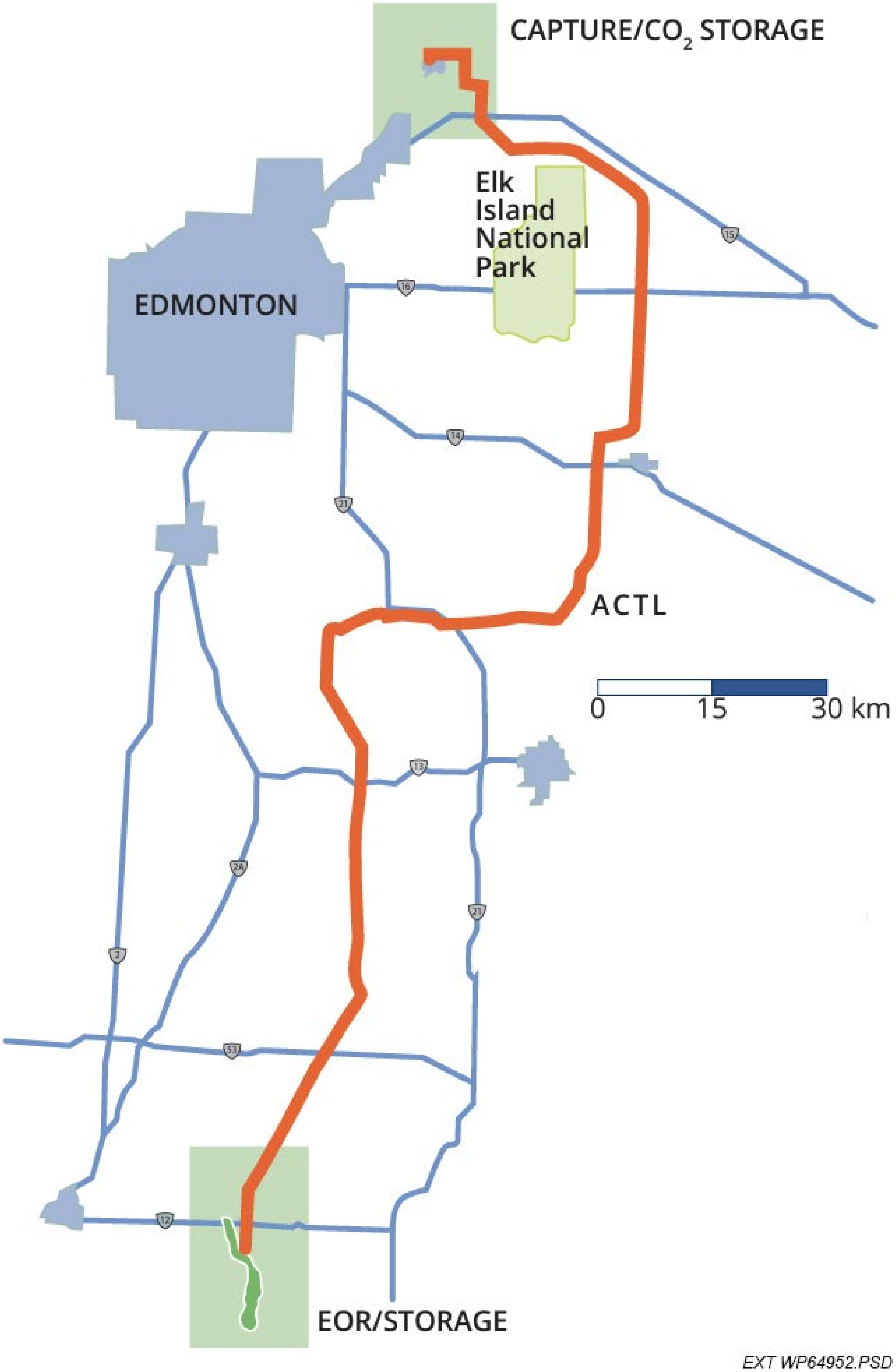

Figure 5. Map of the ACTL in the vicinity of Edmonton, Alberta, Canada.

STORAGE AS A SERVICE

Adjacent to the Hubs and Cluster scenario is the emerging "as-a-service" business model, sometimes presented as CCaaS. Data storage has emerged as a classic as-a-service model. Customers large and small pay for access to data storage so that they don't need to make large capital investments in complicated and unfamiliar technology. In the CCaaS model, it is recognized that many companies are not suited to manage the development and deployment of a new specific service or operations such as carbon capture, transport, and storage. Thus, the CCaaS model supports the development of specialized companies to address components of the CCUS value chain. These new companies can reduce the CO_2 source and the company's exposure to storage-specific financial risks and allow it to focus on its core activities (e.g., making electricity in the case of a power plant) (International Energy Agency, 2022a, 2022b, 2023).

In 2022, Gulf Energy Information surveyed the hydrocarbon processing industry and found that 84% of the 145 respondents plan on installing CCUS technology over the next decade. Nearly one-third of the respondents indicated that CCUS provided as a service would make carbon capture more attractive to their business (www.carbonclean.com/news/hydrocarbon-survey).

CO_2 EOR

One of the original business drivers for the use and ultimately incidental storage of CO_2 is EOR, which involves injecting substances into a reservoir to recover additional oil through thermal, chemical, and/or miscible gas processes. CO_2 EOR is a miscible process that involves the injection of CO_2 into an oil reservoir whereupon it mixes with the oil. The presence of CO_2 causes the oil to swell and also reduces its viscosity, the combined effect of which increases reservoir pressure and allows the oil to flow more freely. Water and additional CO_2 can then displace this mixture toward the producing wells to recover potentially over 20% of the original oil in place after previous stages of production. The era of CO_2 EOR began with two large-scale projects in West Texas in the 1970s. The industry has now expanded to 11 states and produces over 90 million barrels of oil per year to support the U.S. economy.

Some injected CO_2 returns to the surface with the recovered oil, where the CO_2 is separated from the oil, recovered, and reinjected into the reservoir to recover additional oil and maximize economic and environmental benefits. Typically, this recycled volume amounts to between 40% to 50% of the total CO_2 injection over the lifetime of an EOR project. CO_2 EOR operators refer to the ratio of CO_2 stored in the reservoir divided by the total amount of CO_2 injected as "CO_2 retention." This has been occasionally misinterpreted to mean that 40%–50% of the emitted CO_2 that is captured and transported to the EOR site does not remain in the reservoir but instead is emitted to the atmosphere. Ultimately, all CO_2 used for EOR is stored in the oil reservoir. Figure 6, a plot of cumulative injection of new and reinjected (recycled) CO_2 over time, illustrates this concept.

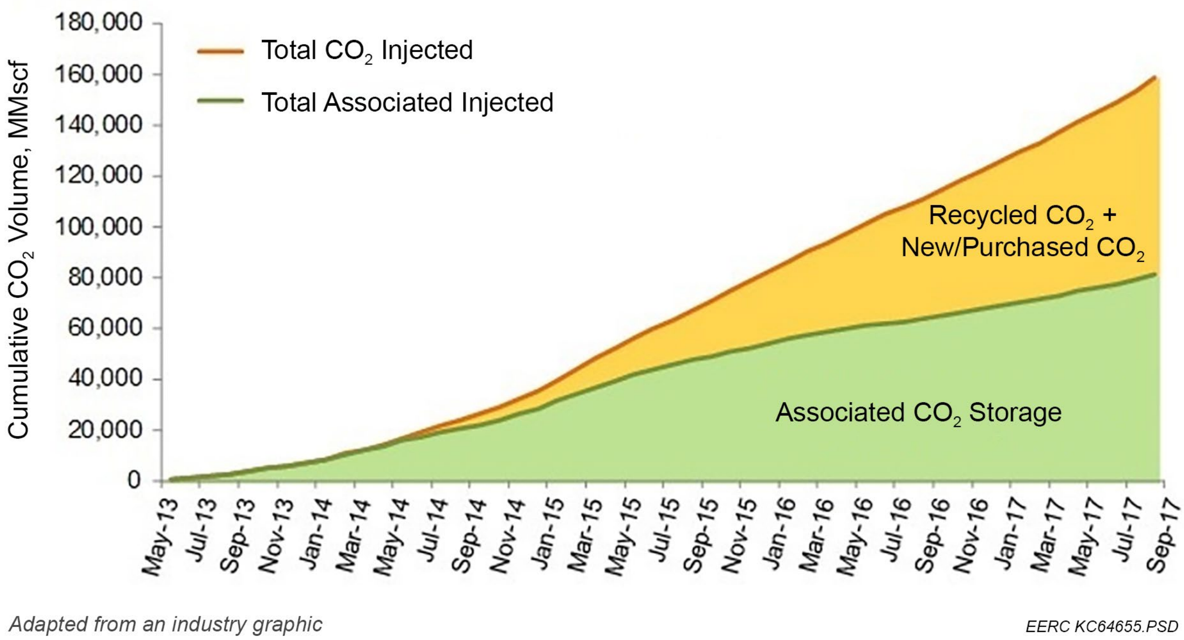

Figure 6. Graphical depiction of how total CO_2 injection comprises captured CO_2 from industrial sources and CO_2 that is recycled after being coproduced with recovered oil. *The contribution of CO_2 to associated storage during EOR requires additional CO_2 to be added; often it is referred to as new or "purchased" CO_2 and is brought to the field from an outside source.

The average CO_2 flood in a conventional reservoir permanently stores 8700 standard cubic feet (scf), or 0.45 tonnes, of CO_2 per barrel of incremental oil recovered. U.S. CO_2 floods have recovered 2.7 billion barrels of oil to date, which translates to over 23 trillion scf (1.2 billion tonnes) of permanently stored CO_2 in already-executed EOR projects (Azzolina and others, 2016). Despite this success, expansion to most other oil-producing areas outside of Texas and Wyoming has been restricted chiefly because of the lack of CO_2 sources. This CO_2 shortage can be resolved with anthropogenic CO_2 when CCS and EOR join hands to benefit American society and the environment.

Passage of the 2018 Bipartisan Budget Act increased the 45Q tax credit to $35 a tonne for EOR. A further increase in the tax credit to $60 a tonne for EOR was put into place by the passage of the Inflation Reduction Act of 2022 (Federation of American Scientists, 2023). Although there have been no new announcements of planned EOR development since 2018, a 2019 report by the National Petroleum Council (NPC) stated that U.S. CO_2 EOR development has the potential to store 274 billion tonnes of CO_2 (National Petroleum Council, 2019). Correspondingly, published expectations for U.S. emissions reduction due to CCS range from 50 to 150 billion tonnes by 2100. Expansion of CO_2 EOR to new fields offers a significant opportunity for emissions reduction relative to these stated emissions reduction goals.

CO_2 EOR will involve the redevelopment of existing mature oil fields where the surface footprint has already been disturbed. Therefore, additional extractive activities (and injection) will occur with minimal land and habitat disturbance while efficiently using existing infrastructure.

However, redevelopment of oil fields for CO_2 EOR operations will require reinvestment in and revitalization of existing infrastructure (e.g., wells and production facilities) to ensure continued environmental protection and permanence of CO_2 stored in association with EOR operations. It is important to note that the mature existing CO_2 EOR industry possesses the operational practices and expertise to manage large volumes of CO_2 safely and effectively. Partnerships between research organizations and oil producers, working in EOR fields, developed and evaluated the technology currently used to plan for or monitor saline storage projects. EOR projects, with their operational synergies and the considerable number of available wells, can continue to provide excellent settings for further development of monitoring projects and technology.

A full life cycle analysis shows that oil produced by injecting CO_2 captured from coal-fired power plants has a 20% lower carbon footprint than typical oil production (Azzolina and others, 2016). This makes CO_2 EOR an effective carbon mitigation strategy without further enhancement. However, EOR projects have traditionally operated in a manner designed to minimize CO_2 utilization and its associated cost. If maximizing storage becomes an expressed goal of an EOR project, the produced oil would be carbon neutral or negative. While a typical EOR project uses (stores) 0.45 tonnes of CO_2 to recover one barrel of incremental oil, the International Energy Agency (IEA) projects in its "Maximum Storage EOR+" scenario that EOR projects operated to maximize storage could store 0.9 tonnes of CO_2 per barrel of oil recovered (International Energy Agency, 2015). This means that potentially, EOR oil would be carbon neutral even under the assumption that the EOR production translates directly to additional oil consumption and does not merely displace oil production from other sources.

Because all the CO_2 used in the EOR process is stored, CO_2 EOR should be considered a critical component of a carbon mitigation strategy. Geopolitical realities underscore the value of new, stable domestic oil supplies, such as that provided by CO_2 EOR, in increasing energy security. Increased energy security and carbon mitigation can be realized using CO_2 EOR.

SUMMARY

The emerging commercial CCS industry in the PCOR Partnership region is leveraging multiple business models that are in most cases fueled by government-backed incentives such as the IRS 45Q tax credit program. Early CCS projects operated on the full-chain business model—one capture facility transporting the CO_2 a very short distance to one injection site and involving a single operator. The shift to break up the CCS value chain and integrate shared infrastructure is facilitating growth in CO_2 management. This growth is demonstrated in a recent IEA report that notes that over 140 CCS hubs are in development (International Energy Agency, 2023). As an example of how this shift in business approach is manifesting itself in the United States, in November of 2023, DOE released the project selections for the second round of the Carbon Storage Validation and Testing funding opportunity (U.S. Department of Energy, 2023b). The 16 selected projects across 12 states (two of which are in the PCOR Partnership region) will support the CarbonSAFE Initiative. Fourteen of the selected projects call out the CO_2 storage hub concept as a major component of their proposed efforts.

The next 5 years will be very dynamic in the CCS world. Business cases are being refined, case studies and pilot projects are fueling commercial investment, and regional carbon management knowledge centers like the PCOR Partnership are tackling technical and regulatory obstacles that are still impeding a more accelerated deployment of CCS technology.

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