A Phased Approach to Building a Hypothetical Pipeline Network for CO_2 Transport During CCUS

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Introduction

Carbon capture, utilization, and storage (CCUS) continue to receive considerable attention as an approach to reduce carbon dioxide (CO_2) emissions. Unfortunately, many of the large CO_2 sources are not located near appropriate geologic storage areas such as enhanced oil recovery (EOR) sites, enhanced coalbed methane (ECBM) recovery sites, or deep saline formations. It is likely that a pipeline network would be needed to transport the CO_2 from the sources to the storage sinks.

Various approaches could be taken to planning a CO_2 pipeline network that supports widespread CCUS [1]:

1. Nationwide network transporting CO_2 from larger, geographically diverse industrial sources to large-scale geologic storage sites.
2. A gradual build-out of regional networks in which large CO_2 sources are connected to existing pipeline infrastructure that serves EOR operations.
3. Shorter pipelines directly linking many large CO_2 sources with nearby storage locations such as large EOR injection sites.

A pipeline network might be built in stages or phases, with the first phase consisting of pipeline segments that connect sources with EOR opportunities, followed by the addition of other sources and sinks as dictated either by the marketplace (in the case of EOR) or national or regional carbon management policy.

Methodology

Approach

The Plains CO_2 Reduction (PCOR) Partnership developed a methodology to estimate how a CO_2 pipeline network might be built in the future. In the methodology, the development of regional pipeline hubs and limited networks will begin by building out the infrastructure needed for enhanced resource recovery (particularly EOR). As long as EOR continues to be economically attractive, this approach will drive pipeline network development. Transport of CO_2 to saline formations will likely not take place before EOR opportunities have been exhausted. The approach taken is summarized in the flowchart. The timing of the phases was determined based on CO_2 emission reduction targets such as those offered by the International Energy Agency (IEA) [2] or studies detailing the effects of stabilizing atmospheric CO_2 concentrations at predetermined levels such as 450 or 550 ppmv [3].

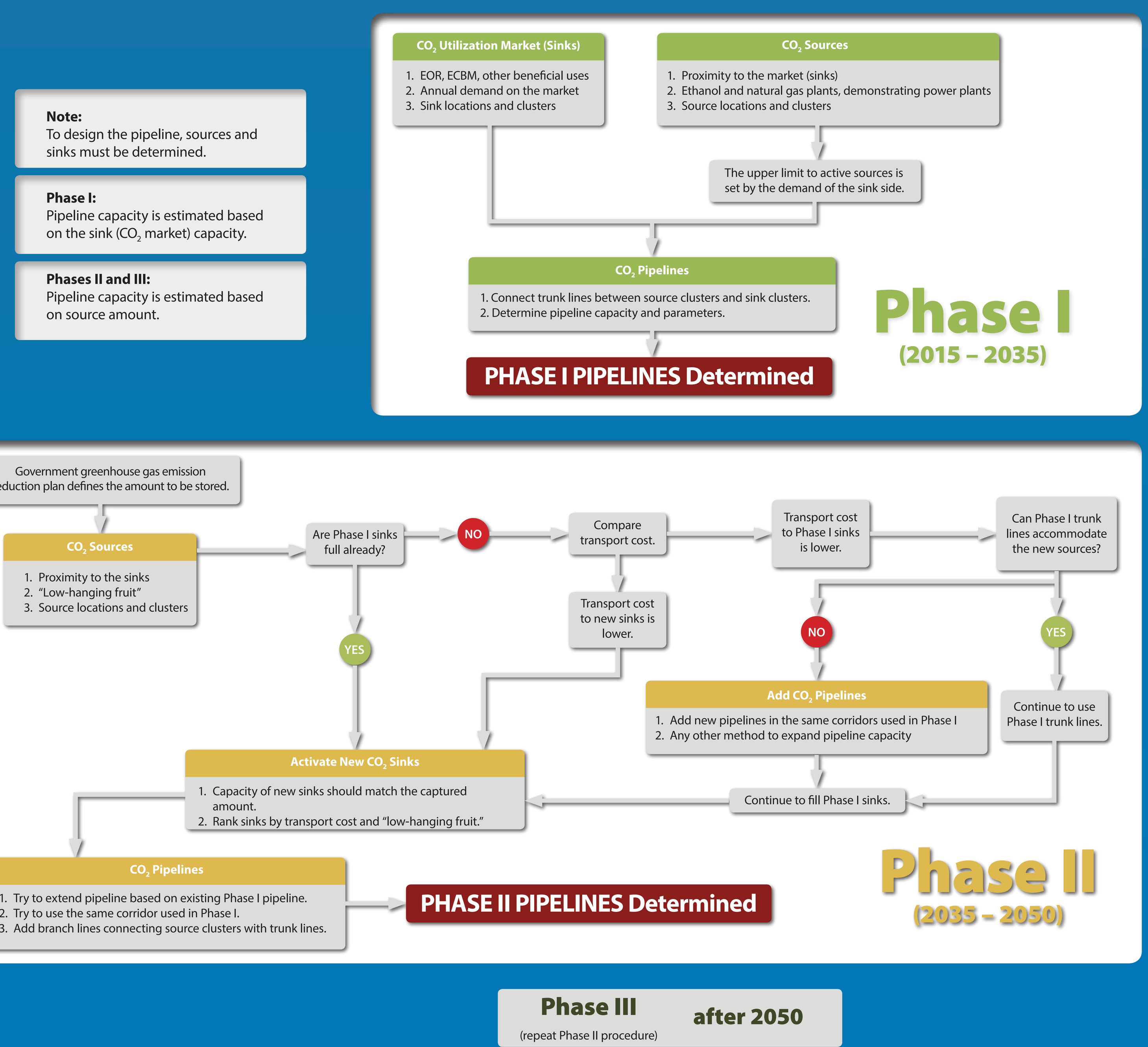
Evaluation

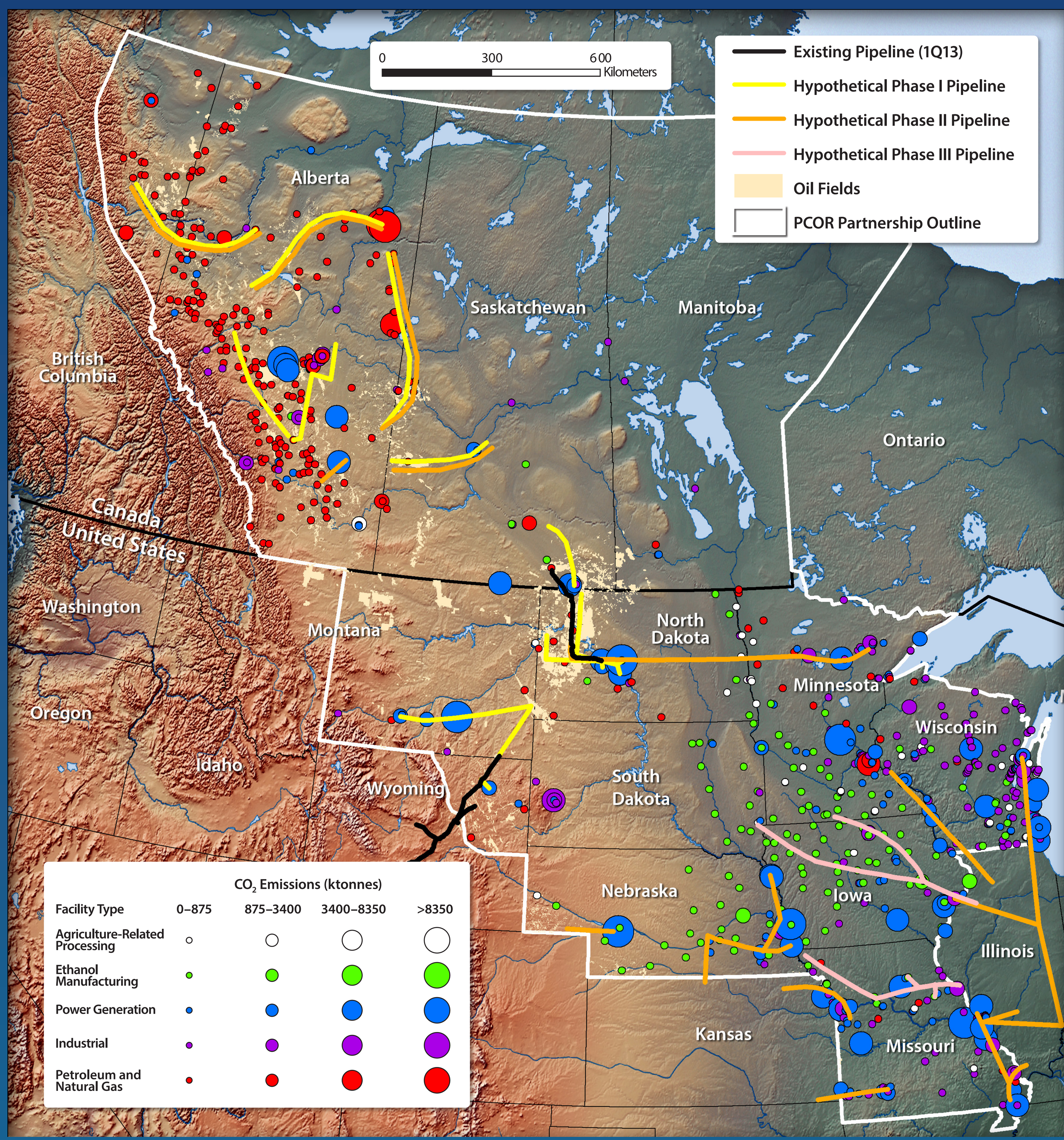
The methodology was tested to evaluate its usefulness by using it to estimate a hypothetical phased pipeline network for the PCOR Partnership region. Key features included the following:

- **Phase I – from 2015 to 2035**
  - Storage in EOR applications
  - CO_2 from relatively close gas-processing facilities and any utilities that choose to be early adopters
  - Combination of judiciously sited hypothetical pipelines linking source clusters to a sink/sink cluster and one-to-one pipelines transporting CO_2 between one CO_2 source and a specific storage target
  - Possible incorporation of existing pipelines into the hypothetical pipeline network
- **Phase II – from 2035 to 2050**
  - CO_2 from additional power plants and larger industrial facilities as well as the gas-processing and ethanol facilities for which the value of the CO_2 exceeds the cost to compress and transport it
  - Geologic sinks consisting of EOR sites as well as nearby deep saline formations
- **Phase III – beginning in 2050**
  - CO_2 from the remainder of the larger coal-fired power plants and larger industrial facilities
  - Target geologic sinks added at this point being the deep saline formations
  - Smaller hypothetical networks that serve specific areas when linking does not make economic sense

Results

A hypothetical pipeline network of trunk lines roughly 10,750 km in total length could transport sufficient quantities of CO_2 such that the IEA BLUE Map scenario could be met for the PCOR Partnership region by 2050 (the BLUE Map scenario is a 50% emission reduction compared to levels from the year 2000 by 2050 [2]).





Summary and Conclusions

- The PCOR Partnership's methodology for estimating preliminary phased pipeline routes appears to work reasonably well. The hypothetical phased network that was produced during a case study test of the methodology seems to agree with pipeline distance results obtained by others.
- Dooley and others estimated about 45,000 km of pipeline would be needed in the United States to meet the scenario in which the atmospheric CO_2 would be stabilized at 450 ppmv [3]. The hypothetical pipeline estimates obtained using the PCOR Partnership methodology equal 5260 km for the U.S. portion of the PCOR Partnership region. One could expect the hypothetical pipeline lengths to be less in the PCOR Partnership region because the largest sources are located relatively near the large geologic sinks.
- According to the IEA, long-term strategies are needed to cluster CO_2 sources and develop CO_2 pipeline networks such that source-to-sink transmission of CO_2 is optimized [2]. The PCOR Partnership-developed methodology could help to address this challenge.

Summary of the Hypothetical Phased Pipeline Network for the PCOR Partnership Region

	United States			Canada				
Phase	I	II	III	I	II	III	Total of Phases I and II	Total, including Phase III
km of new hypothetical pipeline, Mtonnes/yr	1078	4184	0	2520	2969	1384	10,751	12,135
CO_2 transported by new hypothetical pipeline, Mtonnes/yr	52.6	168.2	0	145.6	184.5	82.4	551.0	633.3
Capital cost of new hypothetical pipeline, $M (2009 US$)	676.5	2965.6	0	1251.0	1887.0	1136.0	6780.1	7916.1
O&M[1] cost of new hypothetical pipeline, $M (2009 US$)	3.4	13.6	0	8.1	9.0	4.0	34.0	38.0
Levelized annual cost of new hypothetical pipeline, $M (2009 US$)	79.6	348.0	0	145.6	222	132	795.2	927.2

[1]Operating and maintenance.

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