Carbon Capture and Storage

Washington February 2011

A CANADIAN CLEAN ENERGY OPPORTUNITY

ICO2N

About ICO_2N

ICO_2N: Forefront of CCS in Canada

The ICO_2N Group addresses challenges and solutions to how large-scale CCS can be deployed in Canada

Wide range of industry participants

Air Products Canada Inc.
ConocoPhillips Company
Imperial Oil Ltd.
Statoil Canada Ltd.
Total E&P Canada Ltd.
BP
Enbridge Inc.
Nexen Inc.
Suncor Energy Inc.
TransAlta Corporation
Canadian Natural Resources Ltd.
Husky Energy Inc.
Shell Canada Energy
Syncrude Canada Ltd.

Grounded analysis

- Leading CCS technology analysis
- Integrated CCS economics

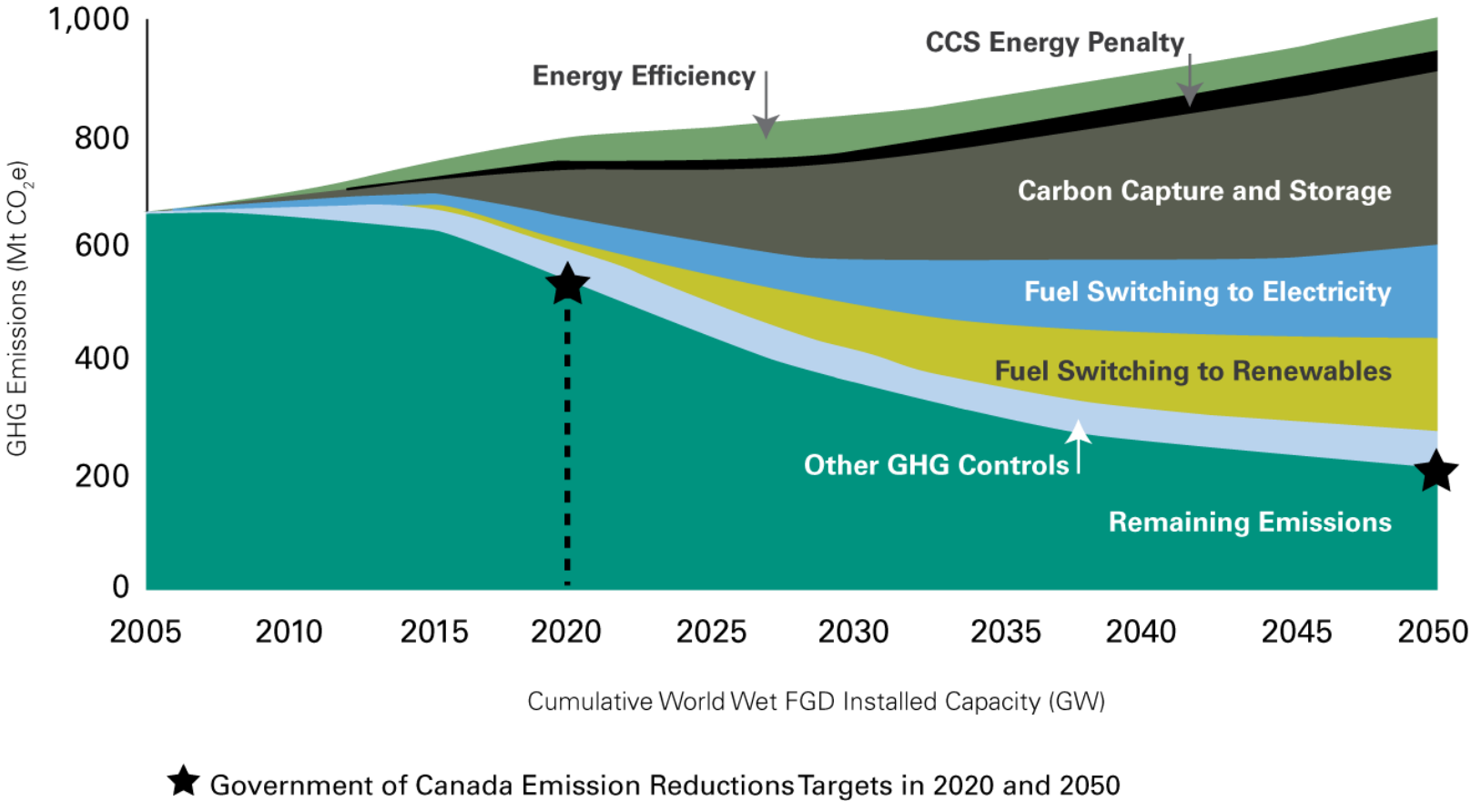
CCS policy leadership in Canada

- Source of thoughtful CCS information for 5 years

CCS in Canada

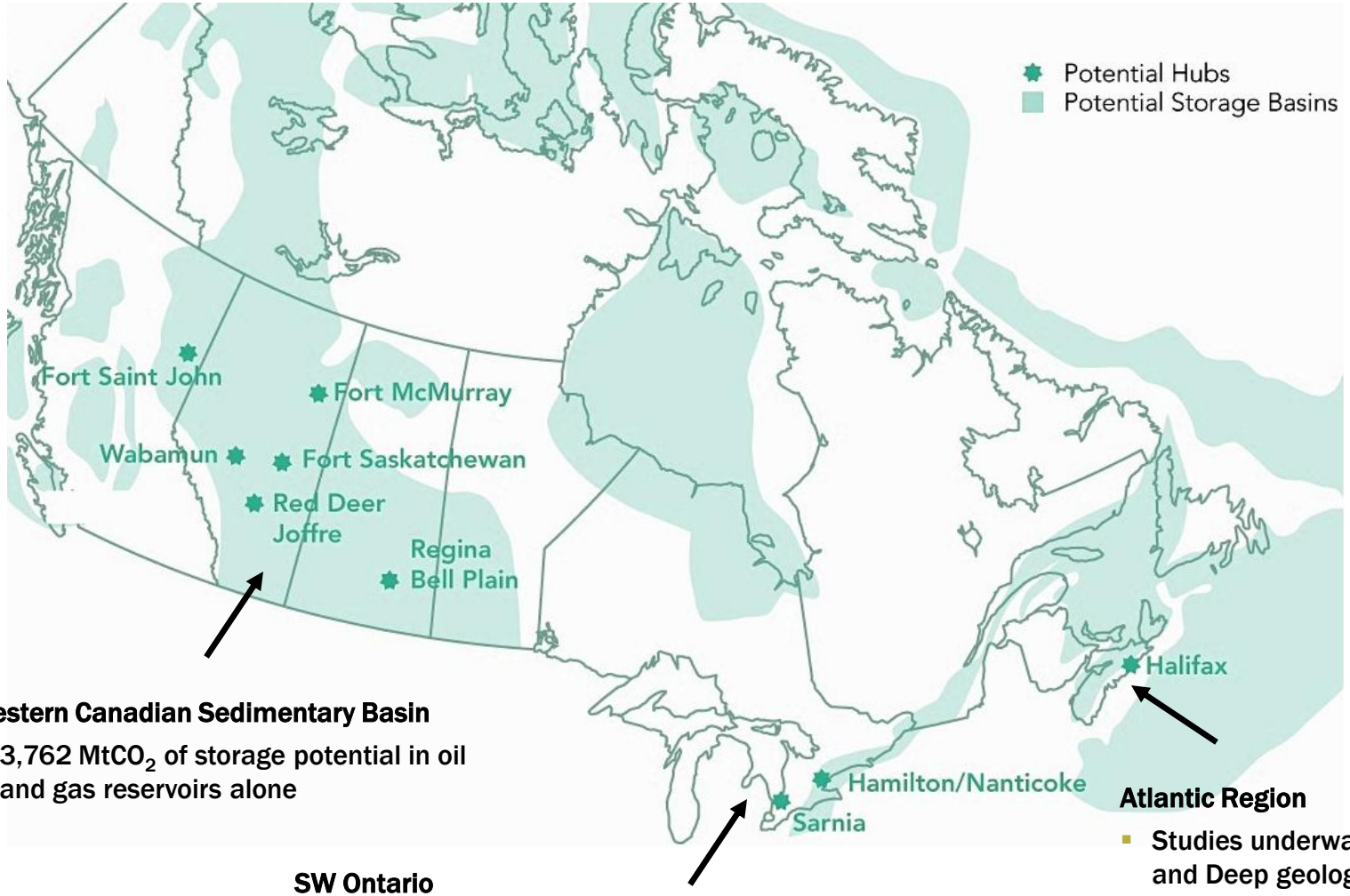
A Strategic Investment for Canada

GHG Reduction Diagram for Canada – Aggregate Wedges



Source: NRTEE 'Achieving 2050: A Carbon Pricing Policy for Canada", 2009

Long-Term Vision of CCS Across Canada



Western Canadian Sedimentary Basin

- 3,762 $MtCO_2$ of storage potential in oil and gas reservoirs alone

SW Ontario

- Work to delineate storage potential in Hamilton to Sarnia corridor required

Atlantic Region

- Studies underway into coal and Deep geologic reservoir storage

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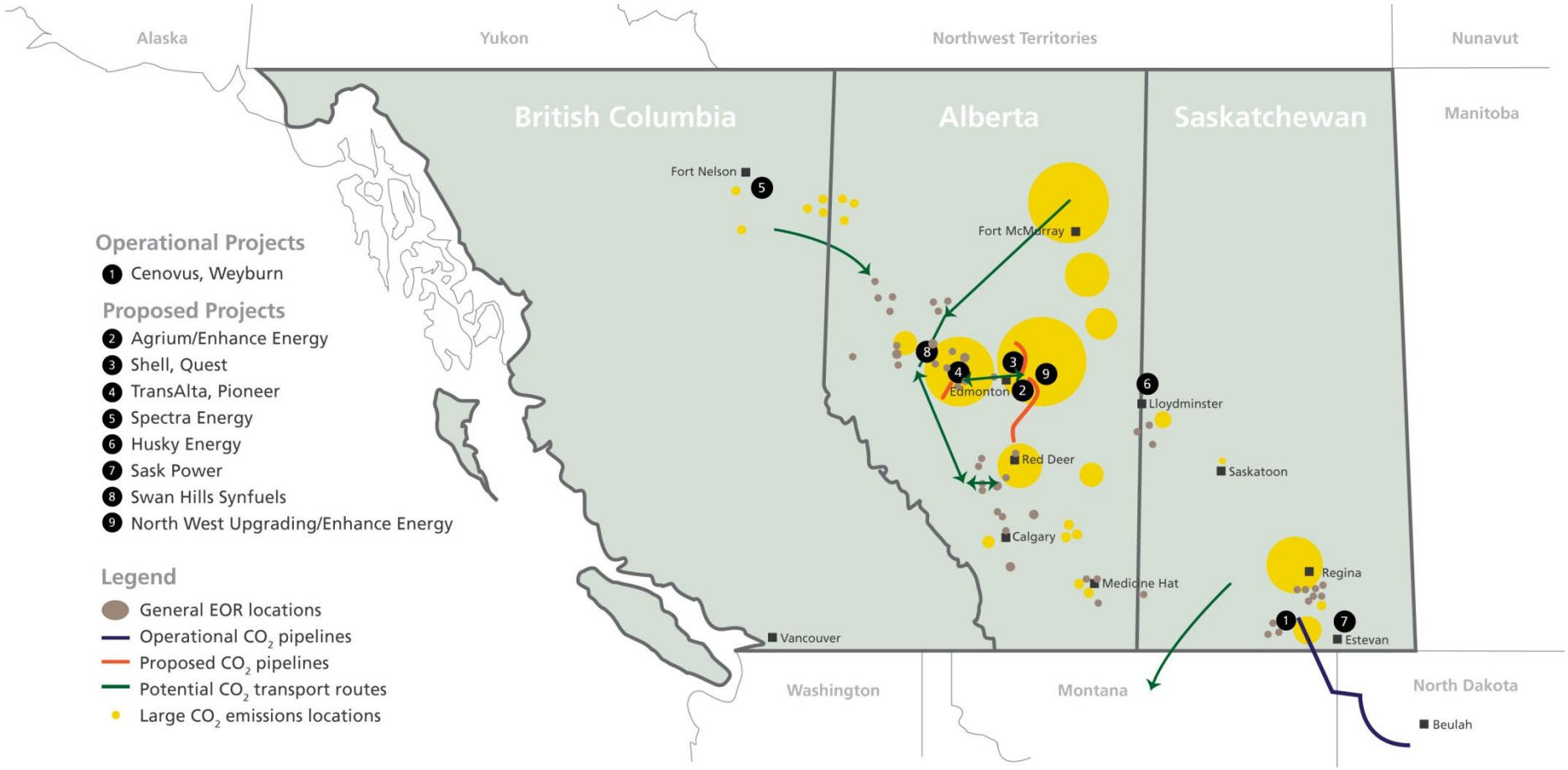
Vision for Western Canada



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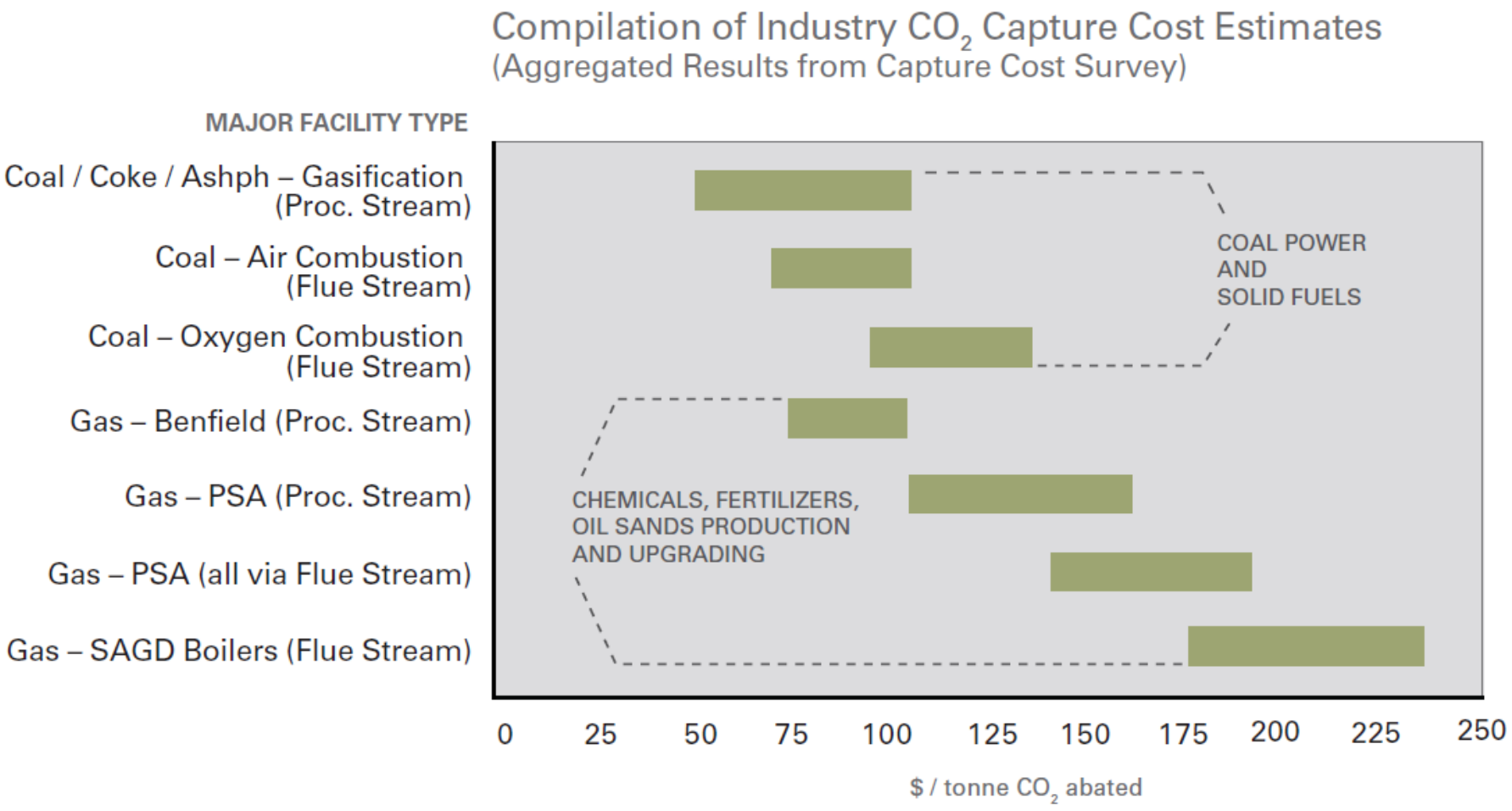
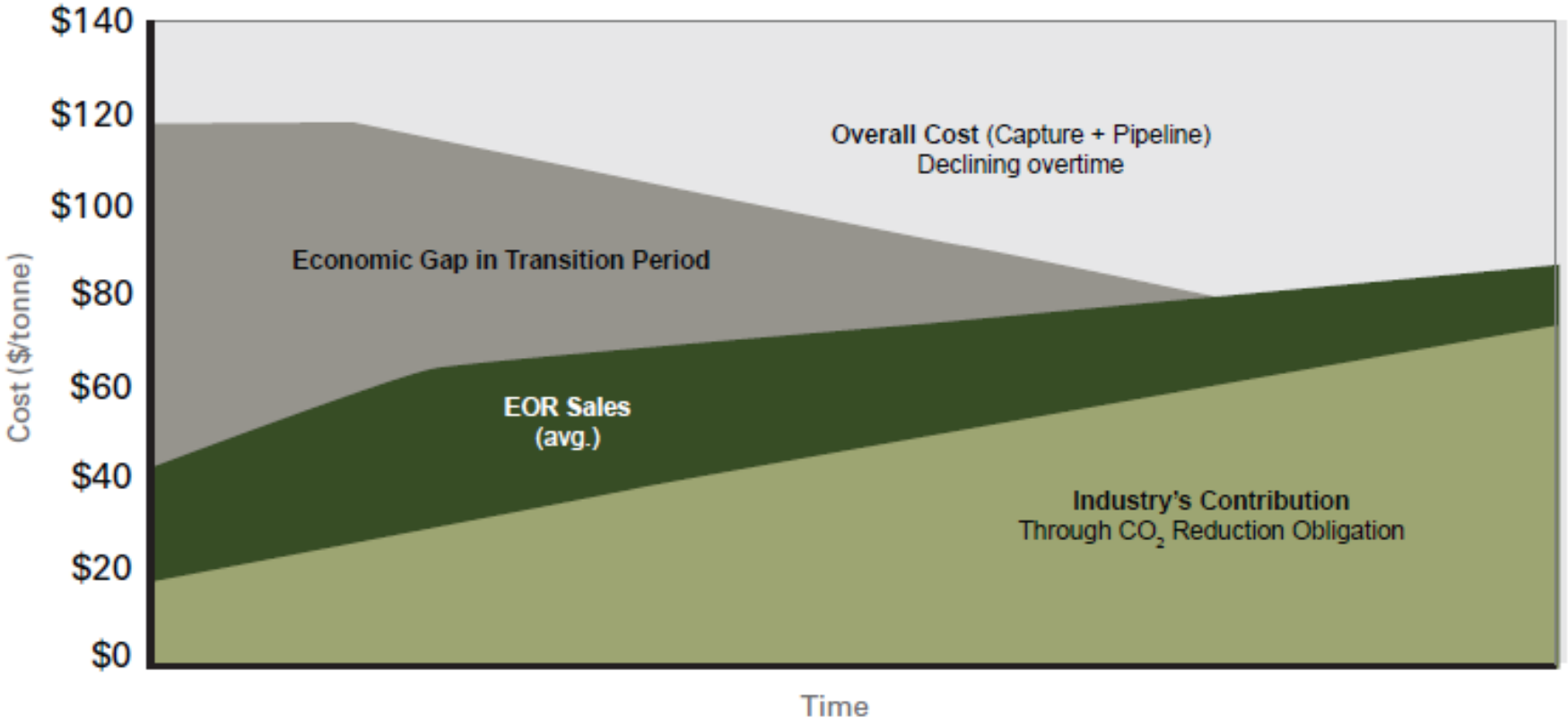
CCS Economics

CCS Costs


Compilation of Industry CO_2 Capture Cost Estimates
(Aggregated Results from Capture Cost Survey)
MAJOR FACILITY TYPE
Coal / Coke / Ashph – Gasification (Proc. Stream)
Coal – Air Combustion (Flue Stream)
Coal – Oxygen Combustion (Flue Stream)
Gas – Benfield (Proc. Stream)
Gas – PSA (Proc. Stream)
Gas – PSA (all via Flue Stream)
Gas – SAGD Boilers (Flue Stream)
COAL POWER AND SOLID FUELS
CHEMICALS, FERTILIZERS, OIL SANDS PRODUCTION AND UPGRADING
0
25
50
75
100
125
150
175
200
225
250
$ / tonne CO_2 abated

A Case for Partnership

Conceptual Portrayal of CCS Economics



Provincial and Federal leadership is needed during the transition period

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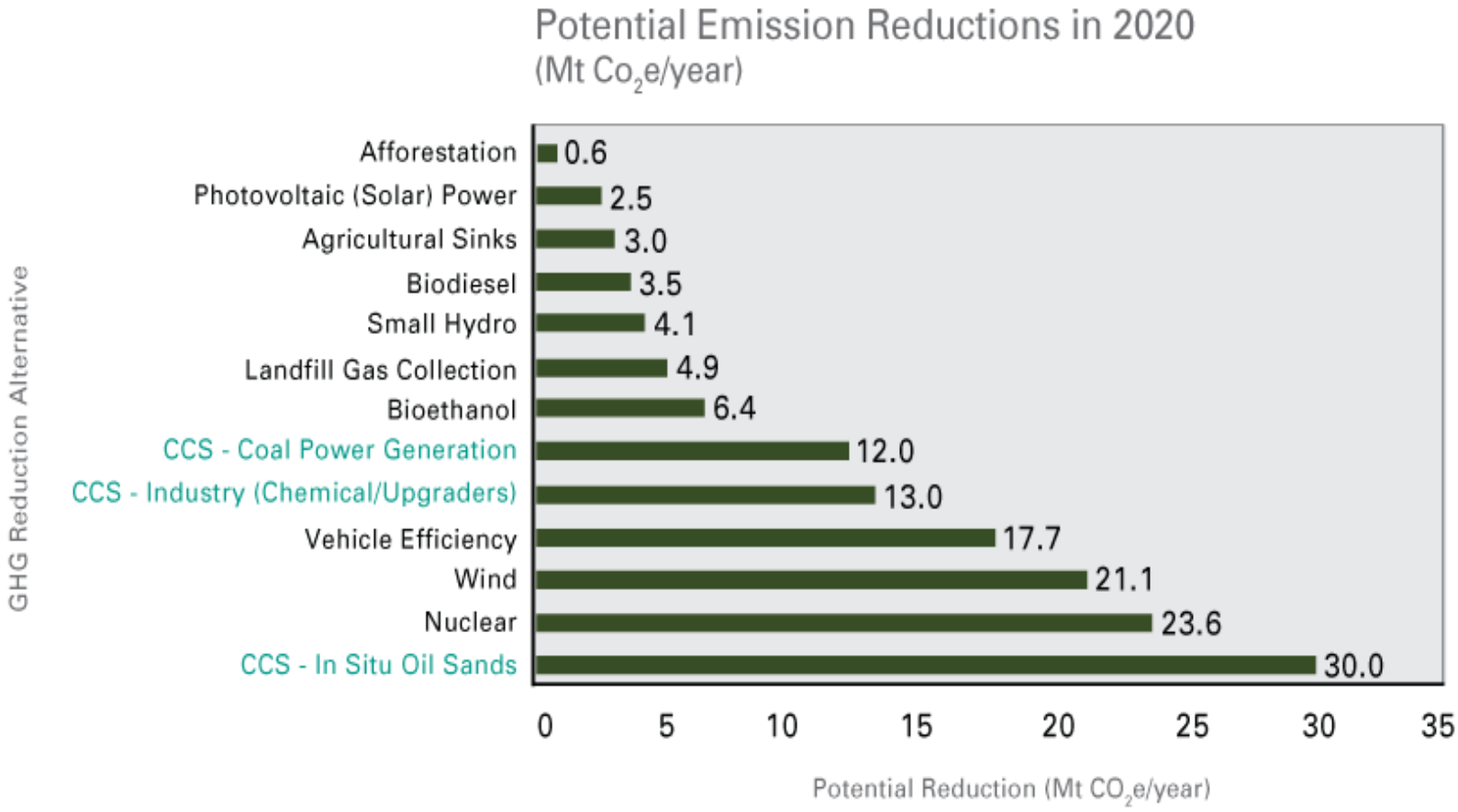
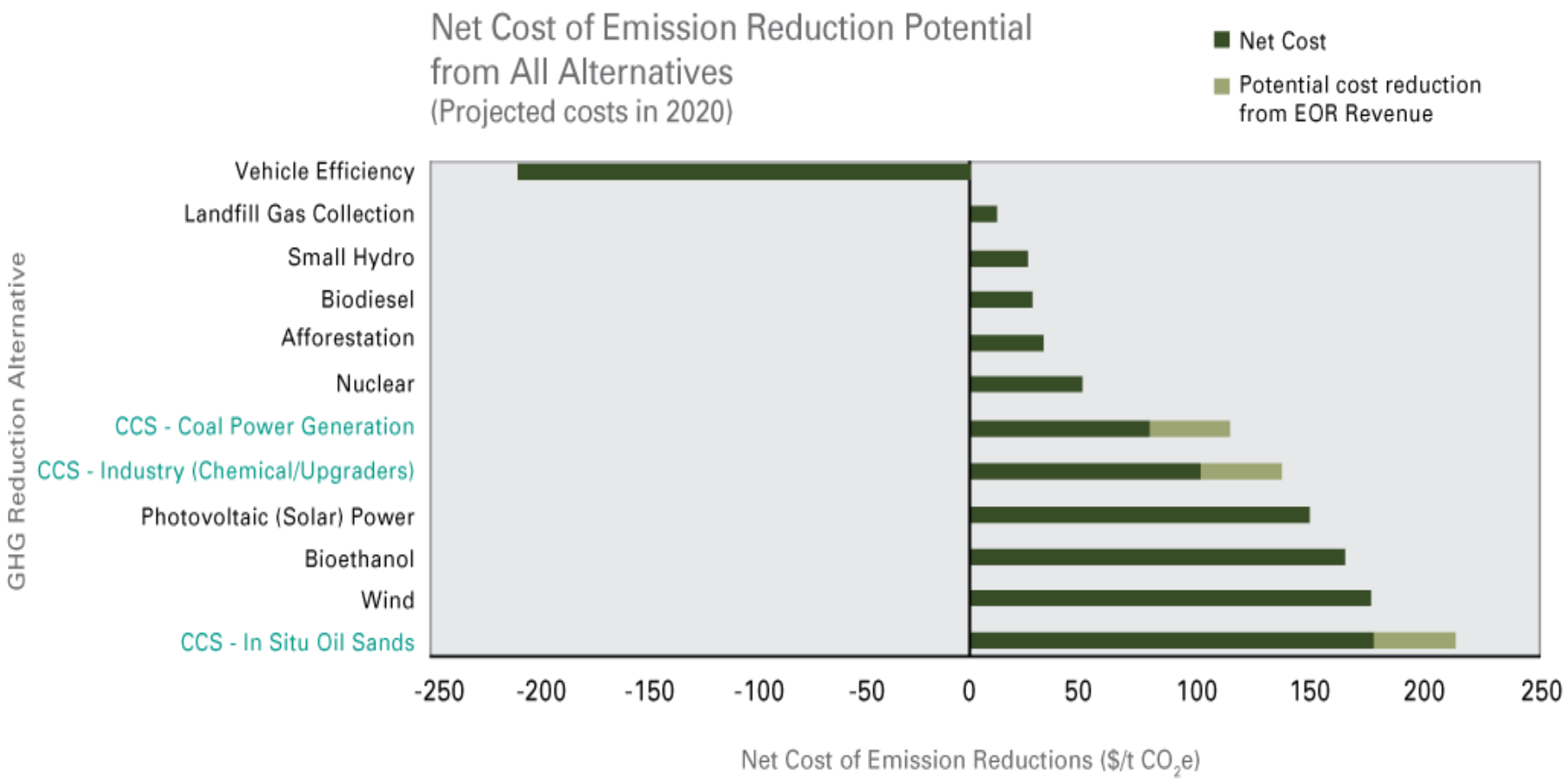
CO_2 Reduction Options – Volume

Comparison of Canadian GHG reduction options undertaken by The Delphi Group



CO_2 Reduction Options – Cost

Comparison of Canadian GHG reduction options undertaken by The Delphi Group



Economics of Common Carrier

A 400 km CO_2 Pipeline Example

Option 1: Build in phases	Capital Cost	Pipeline Capability (t / day)	$ / t Cost
Point & Shoot Pipeline (Phase I)	$400 M	20,000	
Point & Shoot Pipeline (Phase II)	$400 M	20,000	
Total	$800 M	40,000	$10/t

Option 2: Build for capacity	Capital Cost	Pipeline Capability (t / day)	$ / t Cost
Build in one phase	$500 M	40,000	$6/t

Economies of Scale: Centralized design and pre-building is significantly more cost effective than point and shoot CCS solutions.

Canadian Overview

Important Steps Have Been Taken

Federal government

- ~$1.3 billion for CCS supporting studies and demo projects
- Clean Energy Dialogue with the United States

Alberta government

- $2B towards deployment of 4 projects by 2015
- Groundbreaking CCS legislation:
  - Assumption of long-term liability
  - Establishment of long-term stewardship fund
  - Address pore space ownership

Saskatchewan, British Columbia & Maritimes

- Advancement of several large-scale CCS projects
- Study work to understand underground storage potential

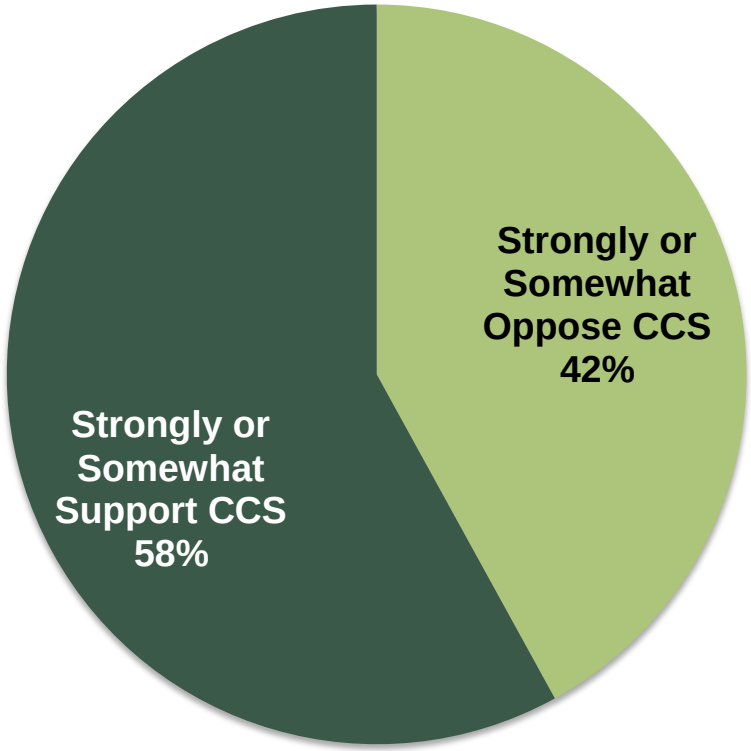
Canada's CCS Projects

Project	Location	Project Type	Volume
1. Shell Scotford Upgrader	Edmonton, Alberta	• Bitumen Upgrader • Post- combustion amine solvent	• 1 Mt/yr • EOR & Sequestration
2. TransAlta Pioneer	Wabamum Lake, Alberta	• Coal-fired power plant • Post-combustion chilled ammonia	• 1 Mt/yr • EOR & Sequestration
3. Enhance Pipeline	Industrial Heartland, Alberta (3 facilities)	• Large-scale CO_2 pipeline • CO_2 from fertilizer plant & bitumen upgrader	• 1.7 Mt/yr initially • Pipeline for up to 14Mt • EOR
4. Swan Hills Synfuels	White Court, Alberta	• In-situ coal gasification • (syngass for 300MW of co-generation)	• 1.3 Mt/yr • EOR
5. SaskPower Boundary Dam	Estevan, Saskatchewn	• Coal-fired electricity power plant • Post Combustion Amine	• 1 Mt/yr • EOR
6. Spectra Energy	Fort Nelson, British Columbia	• Capture at a natural gas plant	• 1 Mt/yr • EOR & Sequestration

Public Acceptance

National public opinion polling in 2010

Question: "I personally support CCS projects"



Source: Ipsos Reid for Shell and TransAlta, 2010

Supporting Work Must Continue

The First Projects

- Ensure they advance

CCS Regulatory Work

- Progress CCS regulations on operations, liability and long-term stewardship

Climate Change and CCS Policy

- Ensure that it will work to advance CCS deployment
  - Climate change policy must work to incentivize CCS deployment
  - Avoid building inefficiencies into regulations that act as barriers to future CCS projects;
- Recognition that sector specific performance standards are not enough to drive early CCS

Supporting Work Must Continue

Economics and Incentives

- Advance understanding on what large-scale CCS deployment will require
- Fill gaps on participation as part of a next wave (including oilsands, coal and broader group of players);

System Integration

- Transition from the first ‘point and shoot lines’ to a bigger picture system;
- Common carrier approach and pipeline integration/optimization

Ongoing study work

- Purity Specification Project – a global study to develop CO_2 purity and contaminants standards

If major emissions reductions are to be achieved, then CCS must still be considered a long-term priority

Thank You

For more information:

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Contact:

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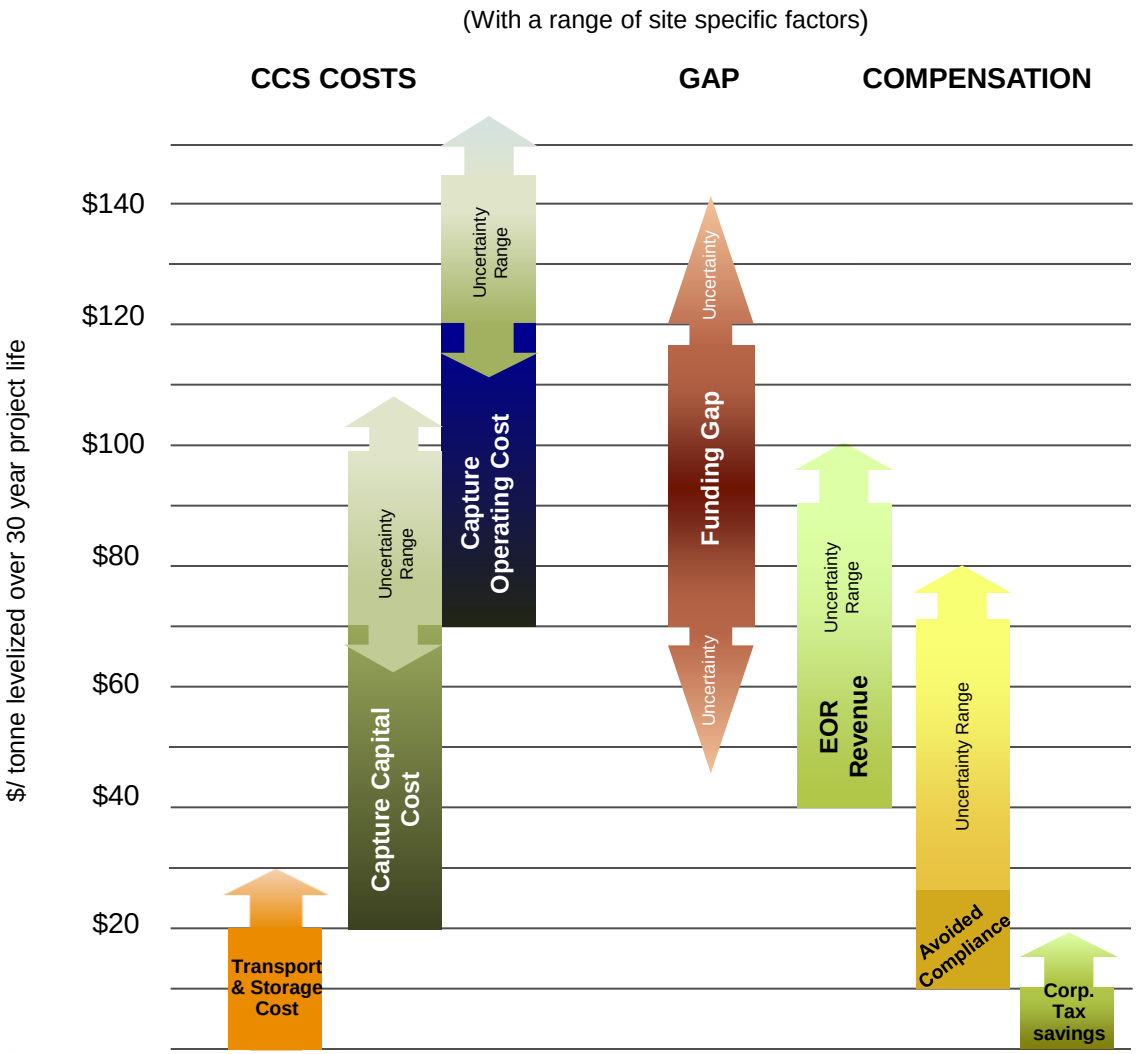
ICO$_2$N Members:

Air Products Canada Inc.
Canadian Natural Resources Ltd.
Enbridge Inc
Imperial Oil Ltd.
Shell
Suncor Energy Inc.
Total E&P Canada Ltd.
BP
ConocoPhillips Company
Husky Energy Inc.
Nexen Inc.
StatoilHydro Canada Ltd.
Syncrude Canada Ltd.
TransAlta Corporation

Supplementary Information

Conceptual CCS Economics



Costs of CCS system components are variable and site specific. Key drivers are:

- **Pipeline** – Distance of transport and pipeline size
- **Capture** – Facility specifics and chosen capture technology
- **EOR** – Productivity of EOR field
- **Compliance** – Strictness of government regulations
- **Tax Savings** – Individual corporate finances and economic loss associated with respective CCS operation

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Transition Period is Essential

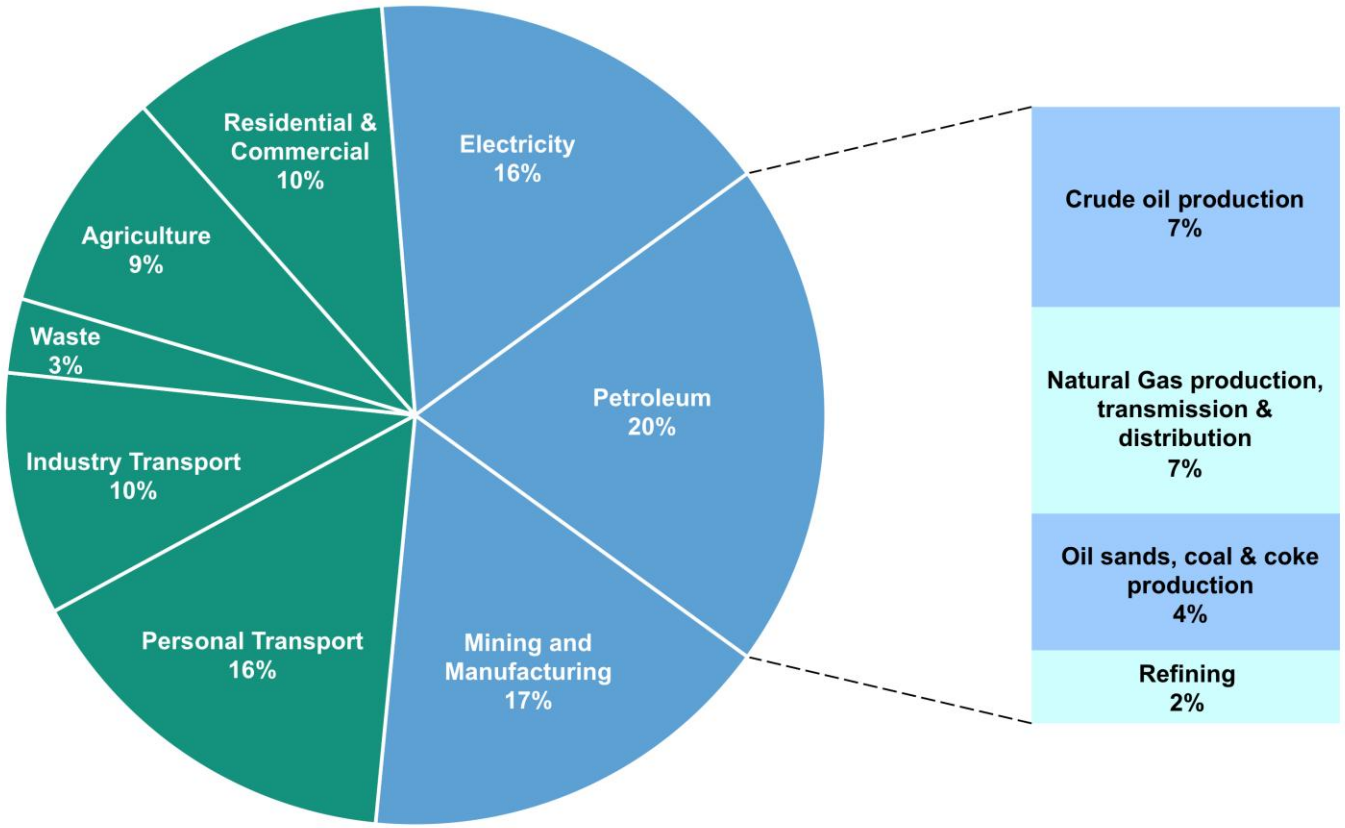
Multiple Business Risks:

- **Economics**
  - Gap
  - Development of new CO_2 markets
- **Investment Risk**
  - Large capital expenditures
  - Policy uncertainty
- **Technology Risk**
  - A new way to use technology
  - Early adoption may not pay

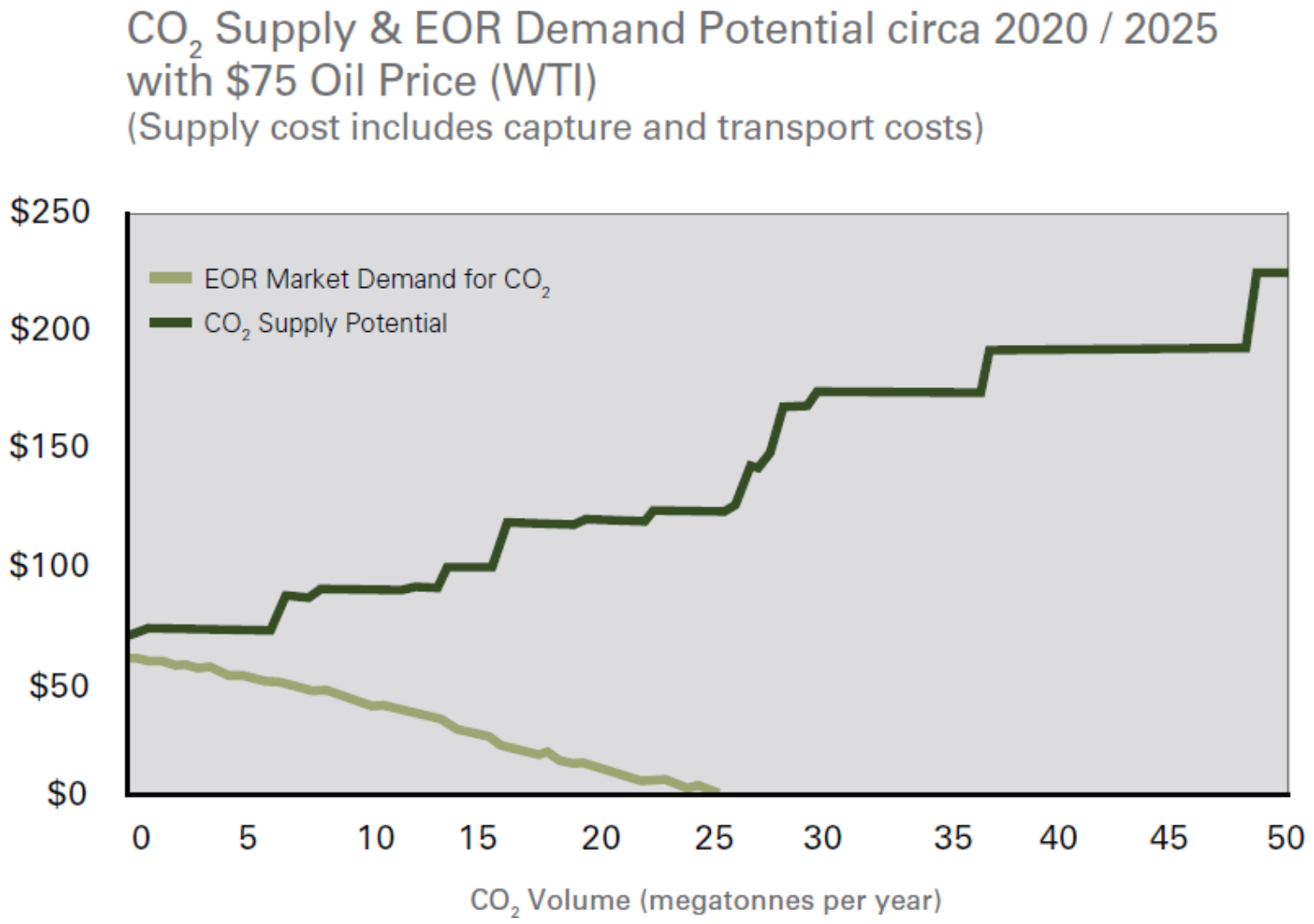
Governments and industry each have a role in moving CCS to full deployment and realizing major emissions reductions

Only Certain Industries Can Pursue CCS

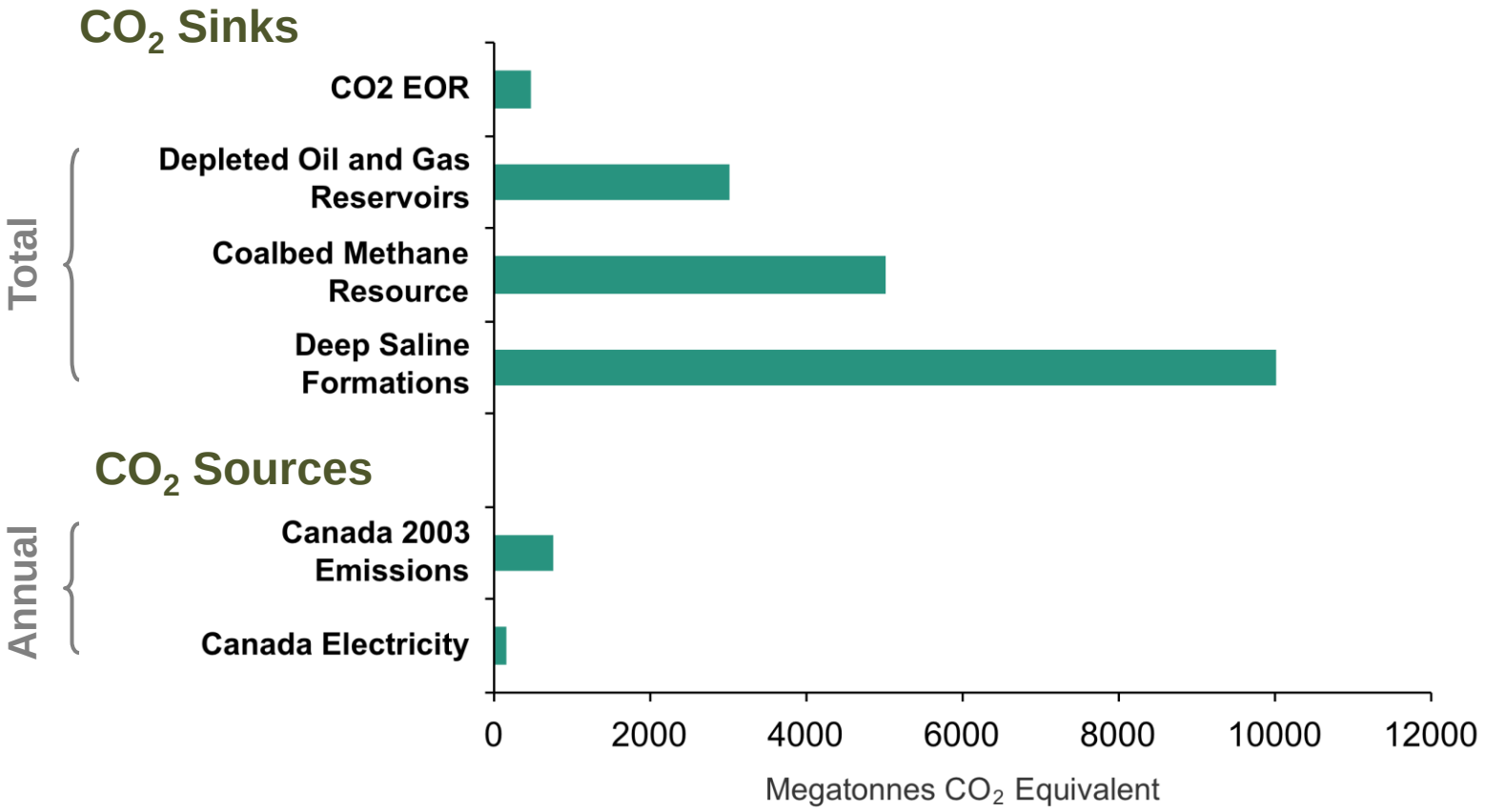
Canada's 2006 Sectoral GHG Emission Summary
Total Emissions - 721 Mt CO2 eq



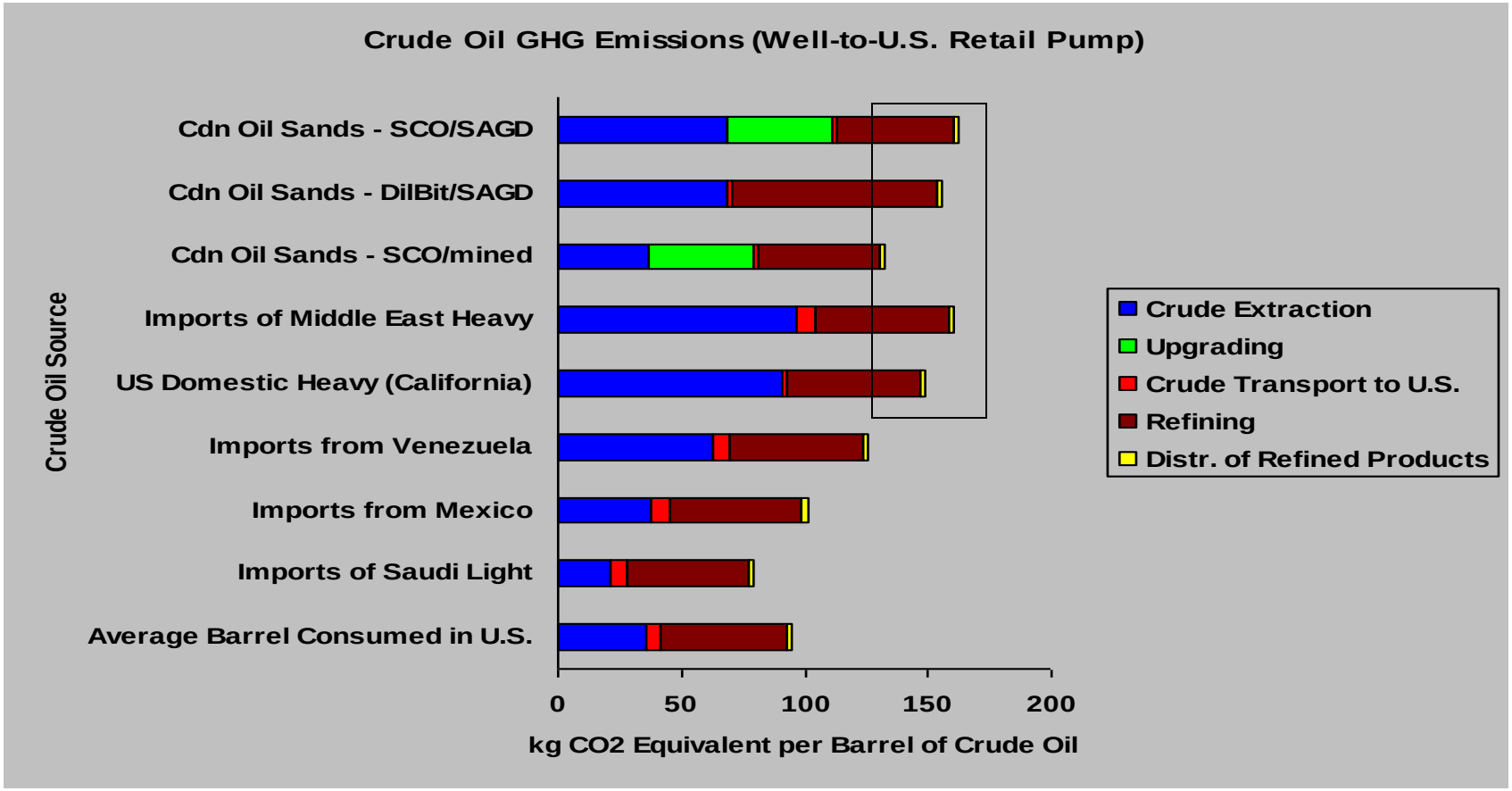
Supply and Demand



Canada's Storage Capacity



Application at Alberta's Oil Sands



Source: Cambridge Energy Research Associates (CERA). The use of this material/graphic was authorized in advance by CERA.
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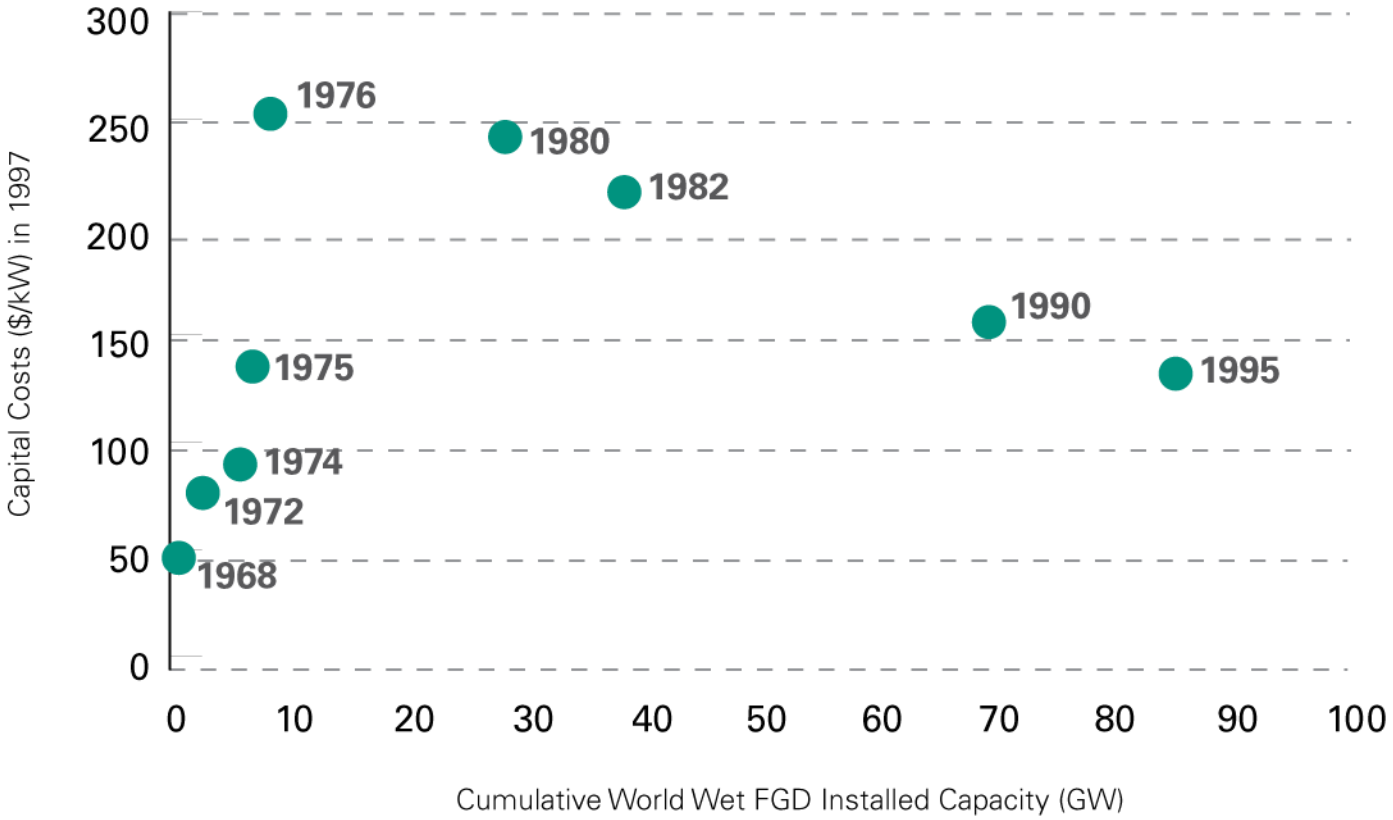
Learning Curve Improvement (slow and uncertain)

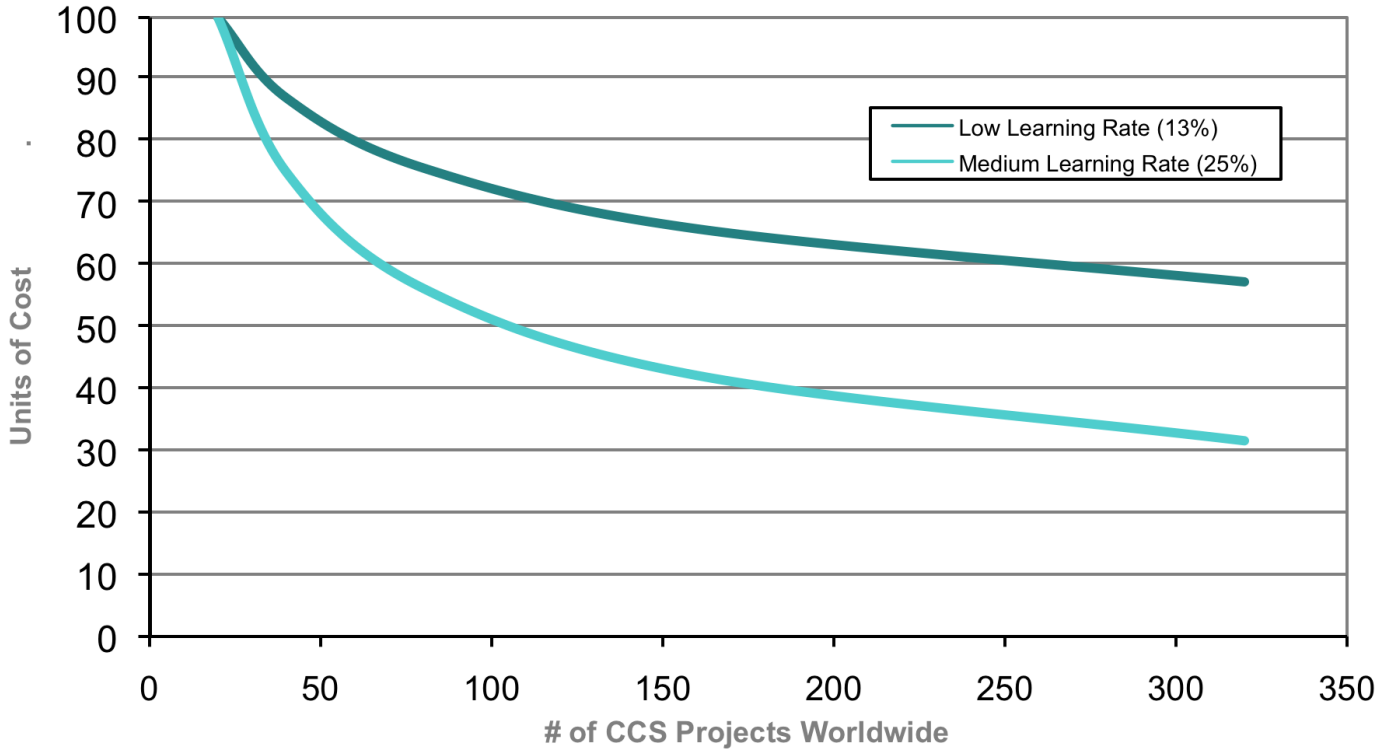
Flue Gas Desulphurization



Source: Rubin et al et al, Estimating Future Costs of CO2 Capture Systimes Using Historical Experience Curves

Learning Curve Improvement for CCS

Reduction of CO_2 Capture Costs Based on Expected Learning Rates

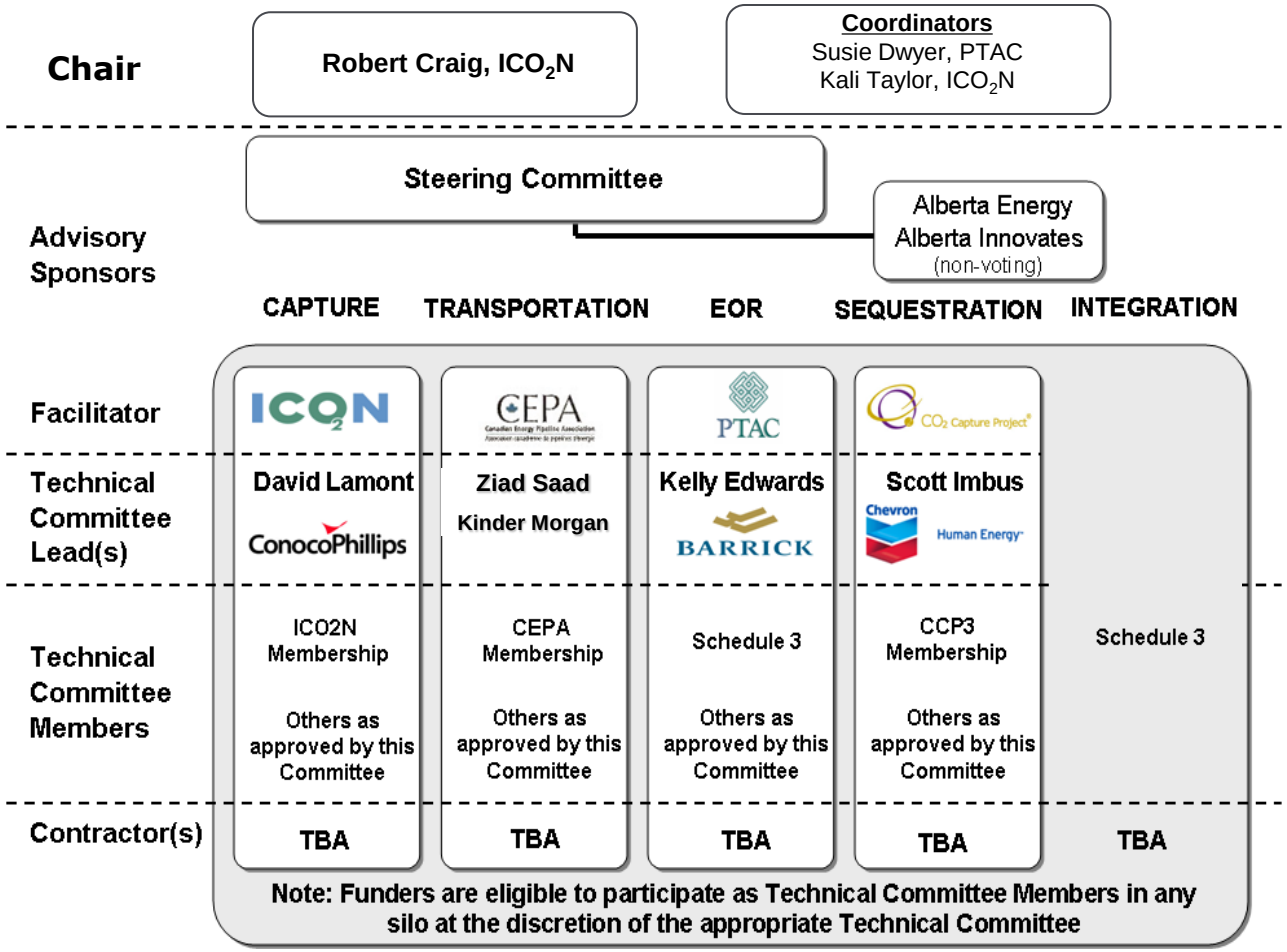


Data provided for this chart is based upon a technical study done by the IEA on estimating the future trends in the cost of CO_2 capture technologies.

Pre/post/oxyfuel combustion technologies for CO_2 capture were reviewed and an estimated range of learning curves (13%-40%) were presented.

We have used a midpoint of 25% to demonstrate potential reduction of CO_2 capture costs and have included the low rate for comparison.

Alberta CO_2 Purity Project

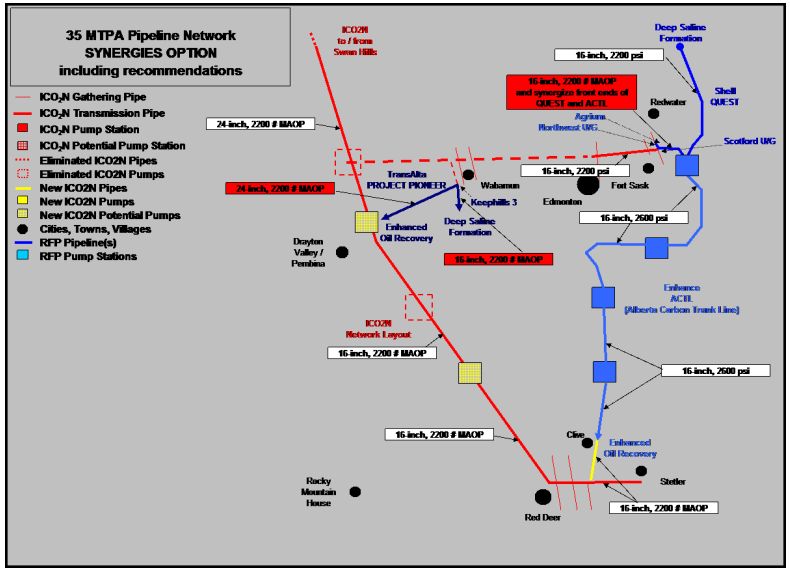


Key Accomplishments

- Steering Committee and Technical Silos meetings
- Resources deployed to move study components forward
- Project is nearing Phase I completion (March 3, 2011)

DNV Hydraulic Assessment

- Detailed pipeline design review of demo projects and linkages to longer term build up
- Defined scope, deliverables and schedule
- A technically strong proposal received from Det Norske Veritas
- $115 K overall cost poses budget challenges to ICO_2N
- Originally scheduled to start Jan. 1 and to be completed March 2011



Assess EOR and Sequestration Costs

- **Assess international studies on sequestration costs**
  - IEA, GCCSI, Worley Parsons, EPRI
- **Draw on Alberta comparators**
  - WASP, ARC, others
  - Assess full scope of storage costs (site characterization, injection well costs, ongoing monitoring and post closure monitoring
- **In discussion with Rob Lavoie of CalPetra and former WASP project manager**

Quest Project

- **Project Lead:** Shell Canada
- **Project Partners:** Athabasca Oil Sands Project

  Shell Canada (60%) Chevron Canada Ltd (205) Marathon Oil Sands L.P (20%)
- **Expected Start Date:** 2015
- **Location:** Scotford Upgrader near Edmonton
- **CO_2 source:** Bitumen Uprgrader
- **Capture Process**: Amine Solvent will capture CO_2 from hydrogen production
- **Volumes:** 1 MT CO_2/y for EOR and Sequestration
- **Public Funding:** Canada $120 Million & Alberta $750 Million

Project Pioneer

- **Project Lead:** TransAlta Corporation
- **Project Partners:** Capital Power, Alstom Canada, Enbridge
- **Expected Start Date:** 2015
- **Location:** Wabamum Lake west of Edmonton
- **CO_2 source:** Coal-fired electricity power plant
- **Capture Process:** Post Combustion Chilled Ammonia
- **Volumes:** 1 MT CO2/y for EOR and Sequestration in an Saline Aquifer
- **Public Funding:** Canada $343 Million & Alberta $431 Million

Alberta Carbon Trunk Line

- **Project Lead:** Enhance Energy
- **Project Partners:** North West Upgrader, Agrium Fertilizer
- **Expected Start Date:** 2012
- **Location:** 3 major facilities
  - Compressor facility at Agrium Complex- South of Redwater
  - A compression facility at NWU site
  - Pump station west of Bruderhiem
- **CO_2 sources:** Bitumen Upgrader and Fertilizer plant
- **Volumes:** 1.7 MT CO2/y for EOR
- **Public Funding:** Canada $63 Million & Alberta $495 Million

ENHANCE ENERGY INC.

ICON CO_2

Swan Hills Synfuels ISGC

- **Project Lead:** Swan Hills Synfuels
- **Project Partners:** To be determined
- **Expected Start Date:** 2015
- **Location:** White Court, Alberta
- **CO_2 source**: In situ coal gasification from unmineable coal seams
- **Volumes:** 1.3 MT CO2/y for EOR and syn-gas for 300 MW of co-generation
- **Public Funding**: Alberta $285 Million

Boundary Dam

- **Project Lead:** Sask Power
- **Project Partners:** Many
- **Expected Start Date:** 2015
- **Location:** Estevan, Saskatchewn
- **CO2 source:** Retro Fit of 100 MW Coal-fired electricity power plant
- **Capture Process:** Post Combustion - Amine
- **Volumes:** 1 MT CO2/y EOR
- **Public Funding:** Canada $250 Million

Spectra Energy

- **Project Lead:** Spectra Energy
- **Project Partners:** Many
- **Expected Start Date:** 2016
- **Location:** Fort Nelson, British Columbia
- **CO2 source**: Natural gas
- **Capture Process:** Extraction off produced natural gas
- **Volumes:** 1 MT CO2/y for EOR and Sequestration
- **Public Funding:** British Columbia $3.4 Million