# The Role Carbon Capture and Storage (CCS) in GHG reduction

INTERNATIONAL
CCS KNOWLEDGE
CENTRE

Presented By: Corwyn Bruce

July 23, 2019

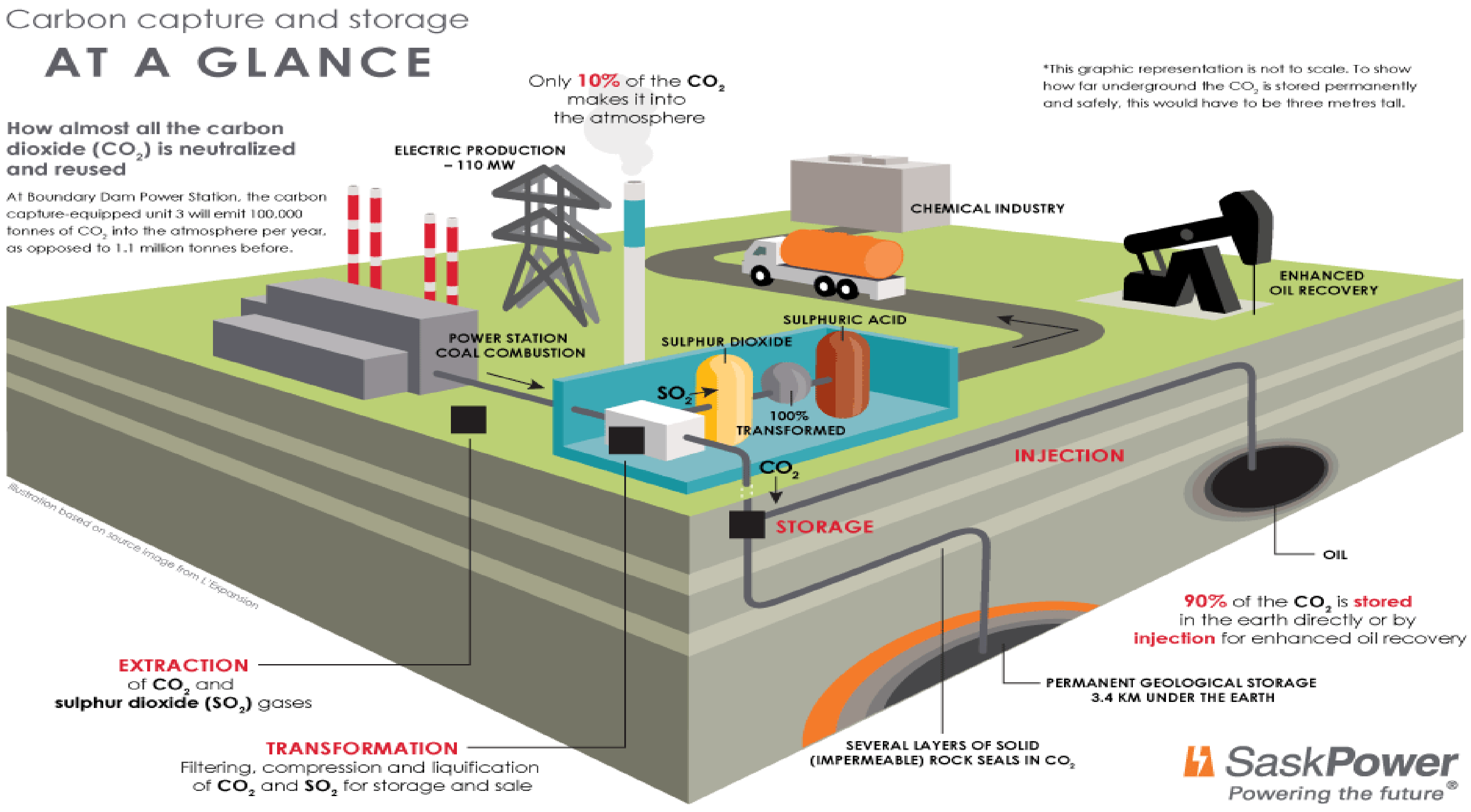
# Outline

- Carbon Capture and Storage Defined
- Boundary Dam 3 -Review of the project and it's performance
- International CCS Knowledge Centre
- Shand 2nd Generation CCS Study
- Bio-Energy With CCS - BECCS

INTERNATIONAL
CCS KNOWLEDGE
CENTRE

ccsknowledge.com

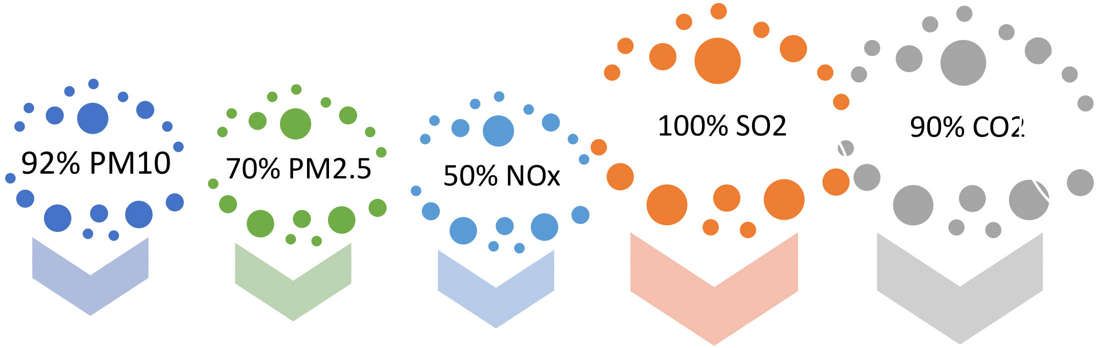
# Full Chain Carbon Capture and Storage



## Overview of the BD3 Project

The project consisted of two major parts:

1) refurbishment of the power unit and
2) capture facility construction




**Refurbishment** included a complete replacement of the steam turbine and generator, which were at their end of life, to provide adequate steam extraction to the capture facility while maximizing the output of the power plant.

**Capture** involves taking out other components before the amine removes the $CO_2$. Nominal capture 1 Million Tonnes Year

## Overview of the BD3 Project

- Projected approved in 2011, as the lowest cost option for electricity supply at the time
- BD3 went on line October 2014
- Projected 90% capture rate and 30 yr plant life extension
- Initial investment = approximately CDN$1.5 billion
- CO2 is used for EOR or sequestered at Aquistore

# BOUNDARY DAM


THE WORLD'S 1ST INTEGRATED LARGE SCALE POST-COMBUSTION CCS FACILITY

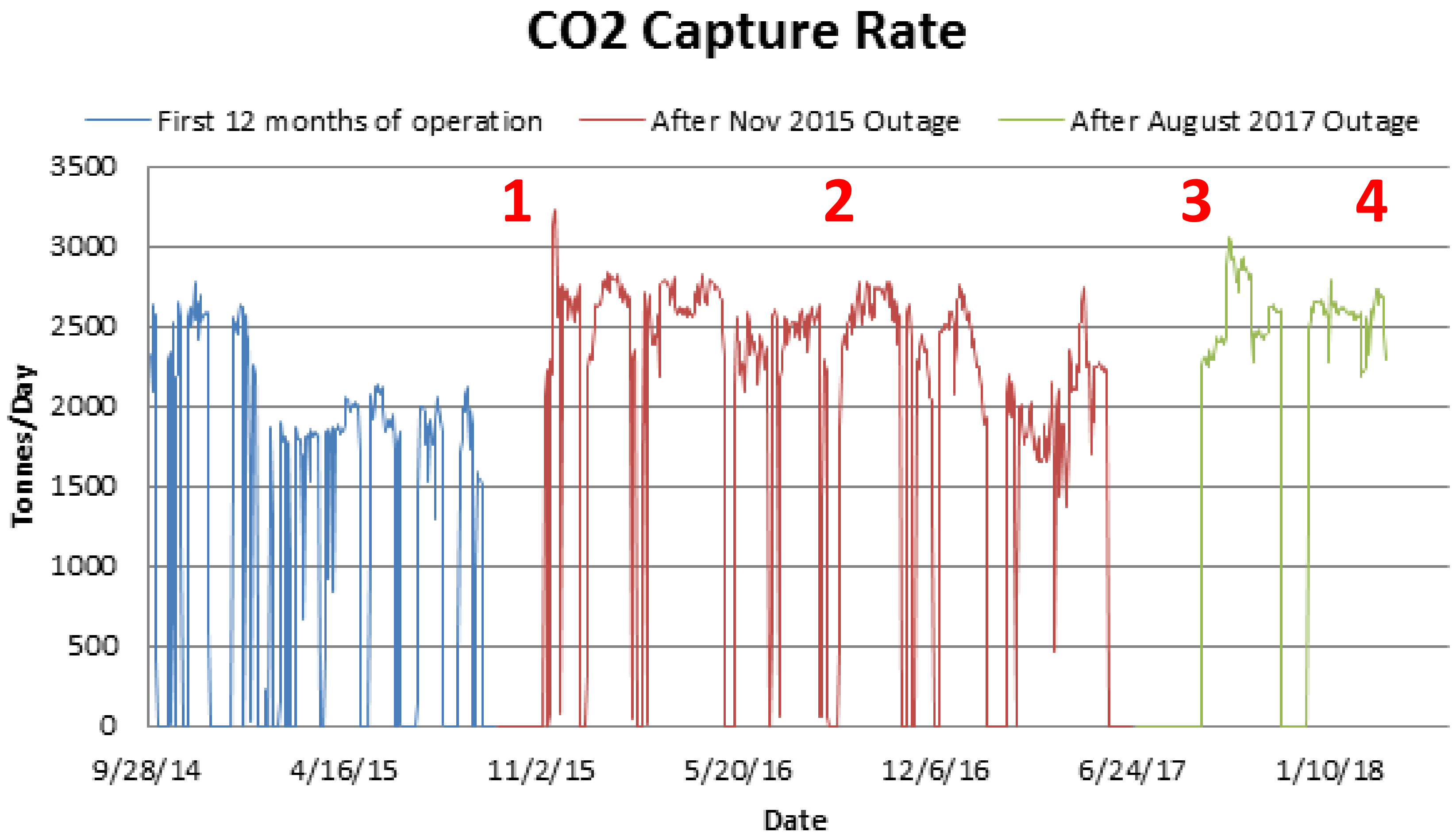
INTERNATIONAL CCS KNOWLEDGE CENTRE

ccsknowledge.com

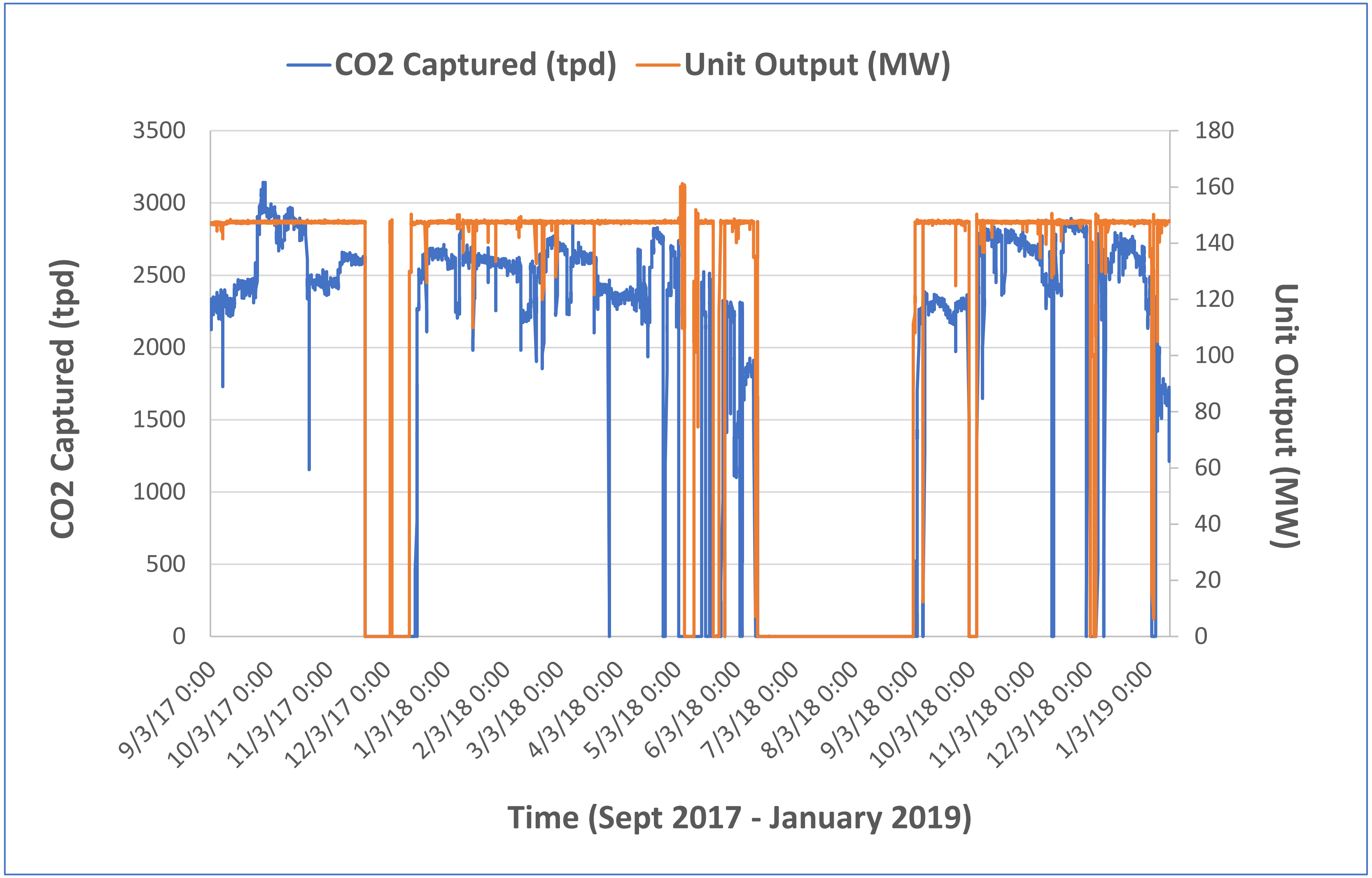
## BD3 Operational Milestones

1. Operated at design capacity (3200 t/day) for 3 days
2. Capture of 800Kt of $CO_2$ between Nov ‘15 - Oct ‘16
3. Total capture of 2Mt by Mar ‘18
4. Operation of the capture facility 98.3% of the time Jan - Apr ‘18.

***Trend of higher capture rate and reduced outages over time***



# BD3 Performance Continued



# BD3 Performance: Exceeding Federal Coal Emissions Regulations

CLEANER

**1100 t/GWh** = Lignite Coal Plant

**550-500** = Current Natural Gas Plant

**420** = Canadian Regulations on Coal Plant

**375-400** = New Natural Gas Plant

**300-325** = Wind (with peakers)

**120-140** = CCS on Boundary Dam 3*

*Name plate capacity

## Introduction: *The International CCS Knowledge Centre*

**THE INTERNATIONAL CCS KNOWLEDGE CENTRE**

Facilitates in an advisory role
Based on expertise and lessons learned

**"Real world" considerations for using CCS are important.**

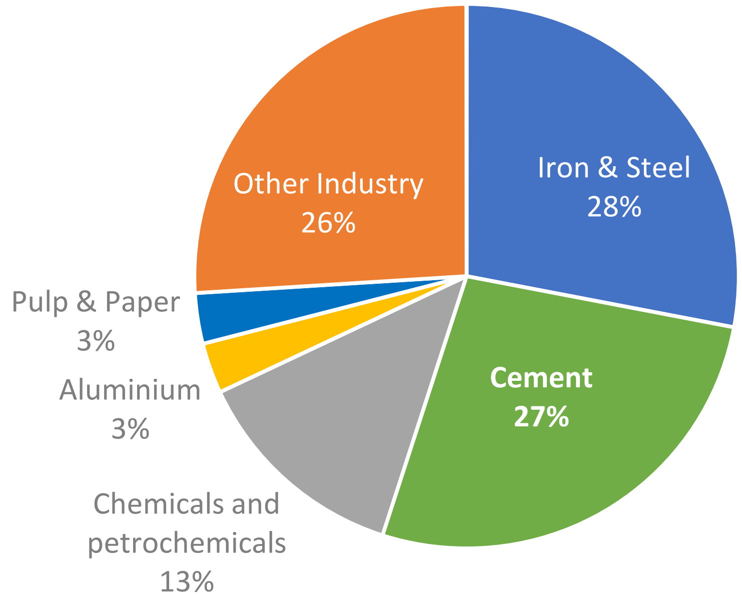
**We can collaborate to:**

- Stimulate development
- Bring down costs
- Promote greater knowledge exchange


ccsknowledge.com

# Application to Industrial Emissions

## Direct industrial $CO_2$ emissions (2014)



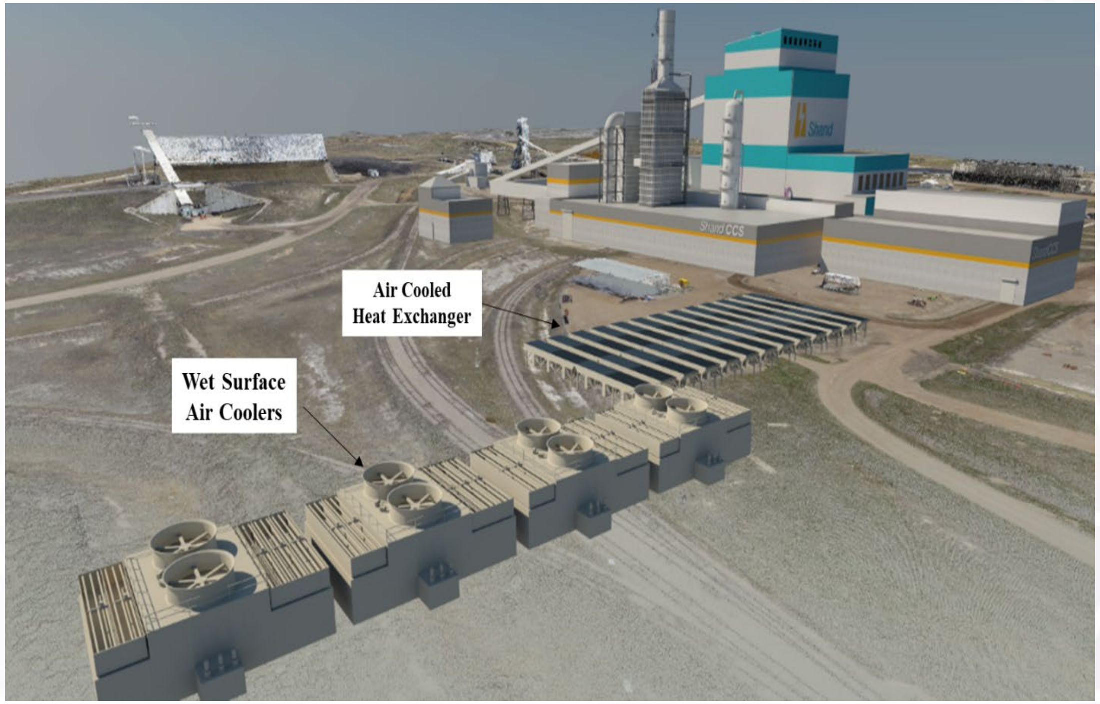

*Information on this slide is sourced from International Energy Agency, Energy Technology Perspectives 2017*

***Industrial $CO_2$ emissions represent 24% of global $CO_2$ emissions at 8.3 Gt $CO_2$ (2014)***

- Lessons learned from operational experience at Boundary Dam CCS Facility and findings from the Shand CCS Feasibility Study can be applied to other industrial sources of emissions
- Size and layout considerations / integration are key considerations
- Costs can be saved with $CO_2$ infrastructure hubs, cost recovery with EOR, modularization and byproduct sales decisions
- Optimization is still required for particular flue gas characteristics to save operating costs

## Introduction: *The Shand CCS Feasibility Study*

- The Shand CCS Feasibility Study was undertaken to evaluate the economics of a CCS retrofit and life extension on what was believed to be the most favorable host coal fired power plant in SaskPower's fleet.
- Demonstrates the value of lessons learned.
- Collaboration between Mitsubishi Heavy Industries (MHI), Mitsubishi Hitachi Power Systems (MHPS), SaskPower and The International CCS Knowledge Centre (Knowledge Centre).



## The Cost of CCS

### *Capital Costs reductions* of the next CCS facility are expected at *67%*

- The Shand CCS project would produce the second, full-scale capture facility in Saskatchewan with a design capacity of 2 million tons of $CO_2$ capture per year – twice the initial design capacity of BD3.
- Reductions in capital costs have been evaluated and are projected at 67% less expensive than they were for BD3 on a cost per tonne of $CO_2$ basis. This extensive reduction may be attributed to:
    a) lessons learned from building and operating BD3,
    b) construction at a larger scale using extensive modularization, and
    c) integration advantages afforded by the bigger 300MW units steam cycle.

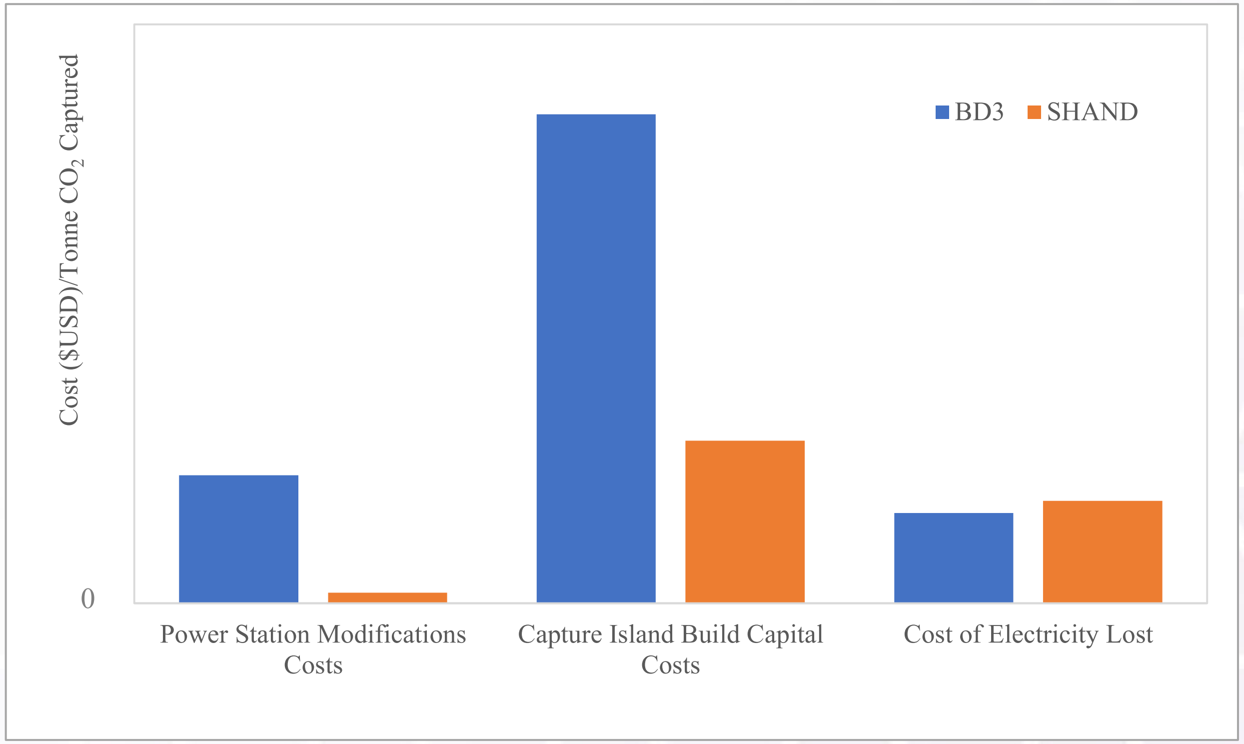



***Figure 2.*** **Cost reduction of the Shand 2nd generation CCS facility as compared to the BD3 project**

# The Cost of CCS

## The Calculated Cost of Capture from the Shand CCS Facility would be *$45US/tonne of $CO_2$*

- Economies of scale contribute to cost savings realized by moving to the larger 300 MW unit
- Factors considered when calculating the Levelized Cost Of Capture (LCOC) included:
  - 30-year sustained run-time of the power plant
  - capture island capital costs
  - capture island OM&A and consumables costs
  - power island modifications costs
  - cost of the power production penalty assuming purchasing of power lost due to $CO_2$ capture-related generation losses at costs consistent with new Natural Gas Combined Cycle (NGCC) power supply

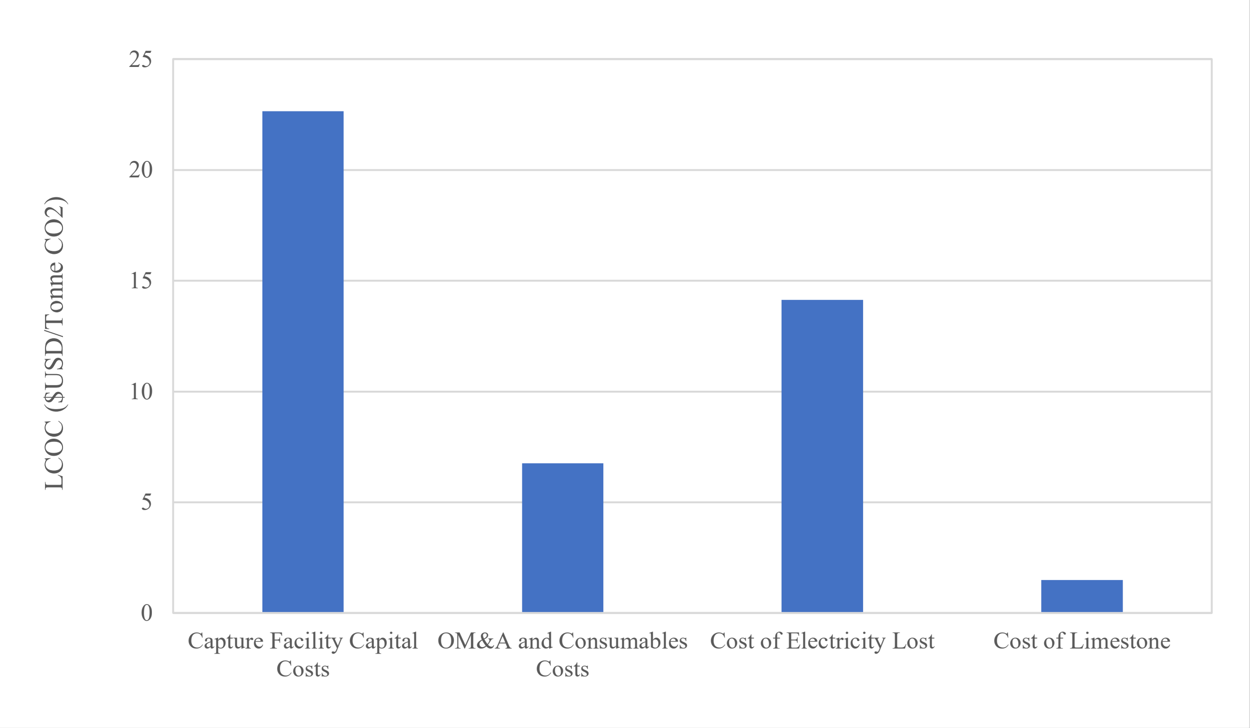



***Figure 3.*** **Cost reduction of the Shand 2nd generation CCS facility as compared to the BD3 project**

# Drivers for CCS Implementation and Key Findings of the Study

***Thermal Integration and Host Selection***

- Steam extraction to reboiler sourced from IP-LP crossover; addition of butterfly valve enables continued capture operations at reduced loads
- Use of rejected flue gas heat for LP condensate preheating using a FGC and novel condensate preheating loop configuration (3 CPHs aligned in series with LP FWHs 1 and 2) helps to reduce the energy penalty
- Overall parasitic load was determined at 22.9%

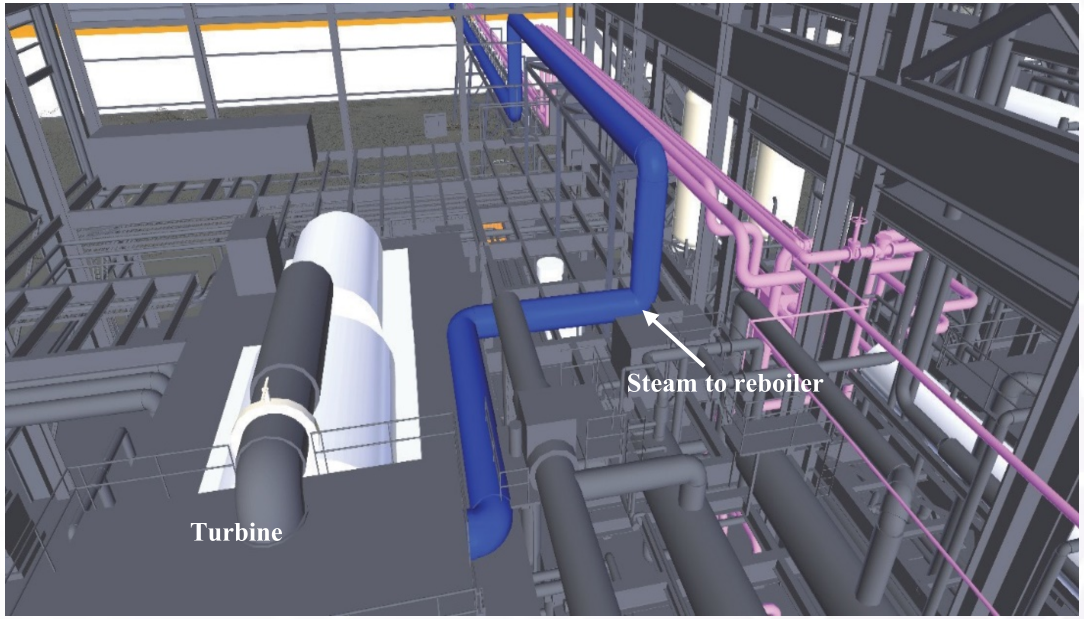



*Figure 6. Proposed butterfly valve in IP-LP crossover*

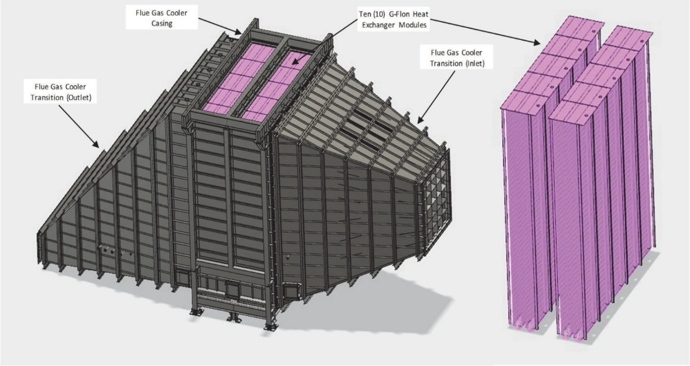



*Figure 4. Proposed FGC and modules*

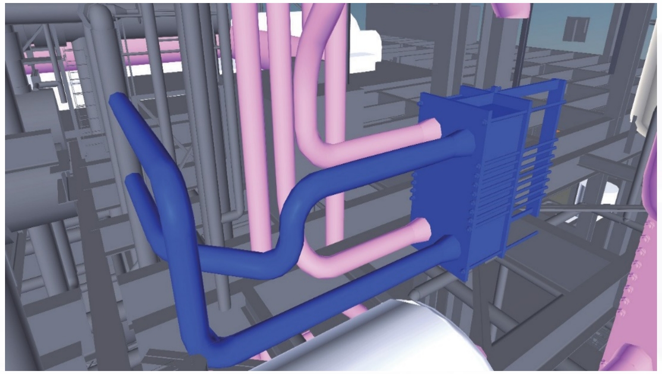


*Figure 5. Proposed installation of CPH*

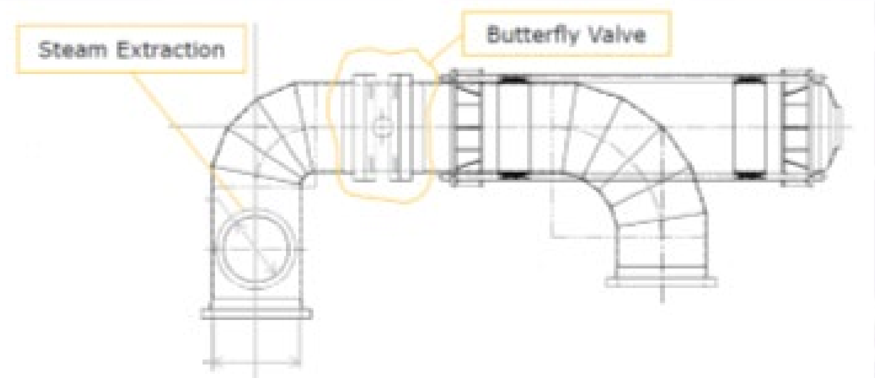



*Figure 7. Proposed steam extraction line to the reboiler*

# Drivers for CCS Implementation and Key Findings of the Study

***Heat Rejection Design Considerations***

- CCS retrofit of Shand increases the heat rejection requirement by 50%
- Shand operates as a Zero Liquids Discharge (ZLD) facility; additional water draw is not possible
- New hybrid wet surface air cooler heat rejection system consists of air cooled heat exchangers (ACHE) and wet surface air coolers (WSAC) connected in series
  - Water requirements satisfied solely by flue gas condensate
  - Designed at the 85 percentile of a 26 years survey of Estevan weather data
  - Dry cooling favored during summer months while wet cooling is dominant at cooler temperatures
  - Average colder climate in Saskatchewan shifts the annual average of heat rejection load in favour of wet cooling
  - Overall power consumption for the design case is 4.96 MWe; the annual average of 2.58 MWe which is  52% of the design case

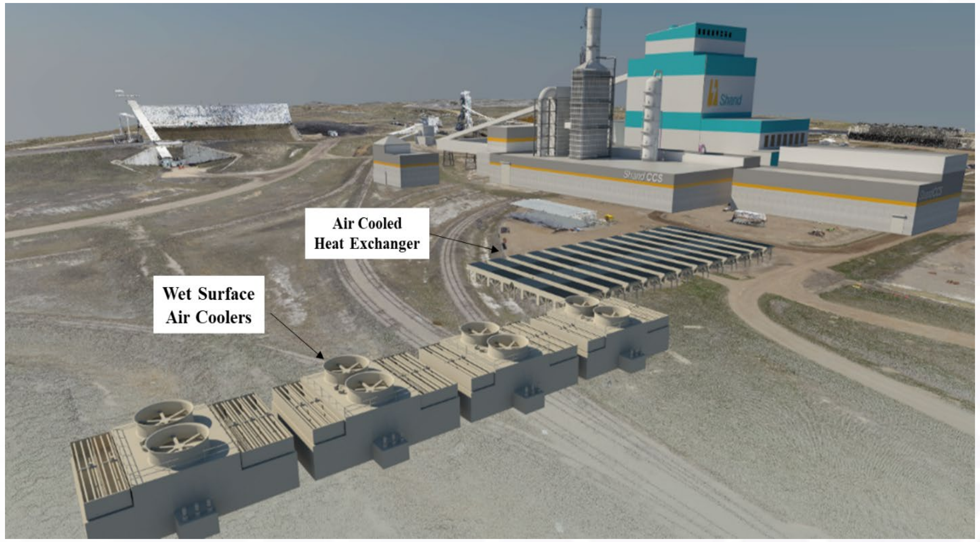



*Figure 10. Proposed new hybrid heat rejection system*

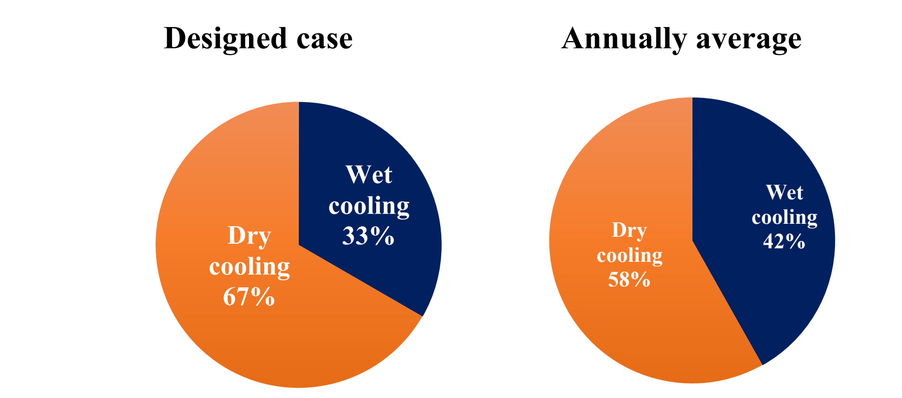



*Figure 11. Variation in annual heat reject load*

# Drivers for CCS Implementation and Key Findings of the Study

***Power Plant Reliability / Capture Plant Partial Capacity***

- "Dual mode" is a risk mitigation strategy that allows continued power plant operations when experiencing issues with the capture facility
- Diverter dampers allows partial flue gas diversion

***Grid Support and Ancillary Services***

- Load adjustments of large thermal power stations are dictated by the supply-demand balance in the electricity grid
- Viable CCS would have to maintain the flexible operating range

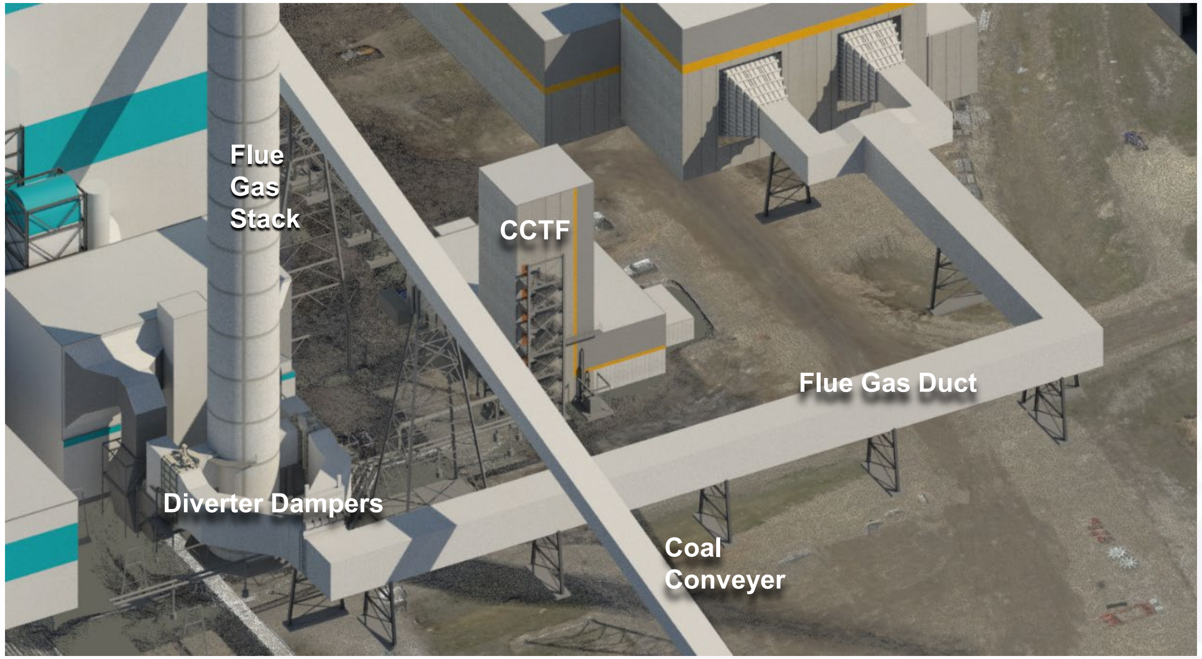



*Figure 14. Proposed flue gas supply to the capture facility*

***Plant Maintainability***

- Current coal fired power plant designs are the product of multiple generations of revision
- This level of refinement has not yet been achieved with amine based CCS facilities
- Experience at BD3 highlighted key process isolations and redundancy at selected locations in the process; these have been considered in the Shand CCS design

# Drivers for CCS Implementation and Key Findings of the Study

***$CO_2$ Market***

- $CO_2$ EOR opportunities exist within 100 km of Estevan, Saskatchewan
- Economical development of these opportunities is key to a successful CCS retrofit
- Opportunity exists to join the Shand $CO_2$ pipeline to the BD3 pipeline; this would increased reliability of $CO_2$ supply and reduce penalties associated with delivery challenges
- $CO_2$ from BD3 that is currently not sold to off-taker(s) could be used to develop the $CO_2$-use market prior to the completion of the Shand CCS facility
- Excess $CO_2$ capture volumes could be sequestered within the capacity of the existing Aquistore dedicated geological storage project.

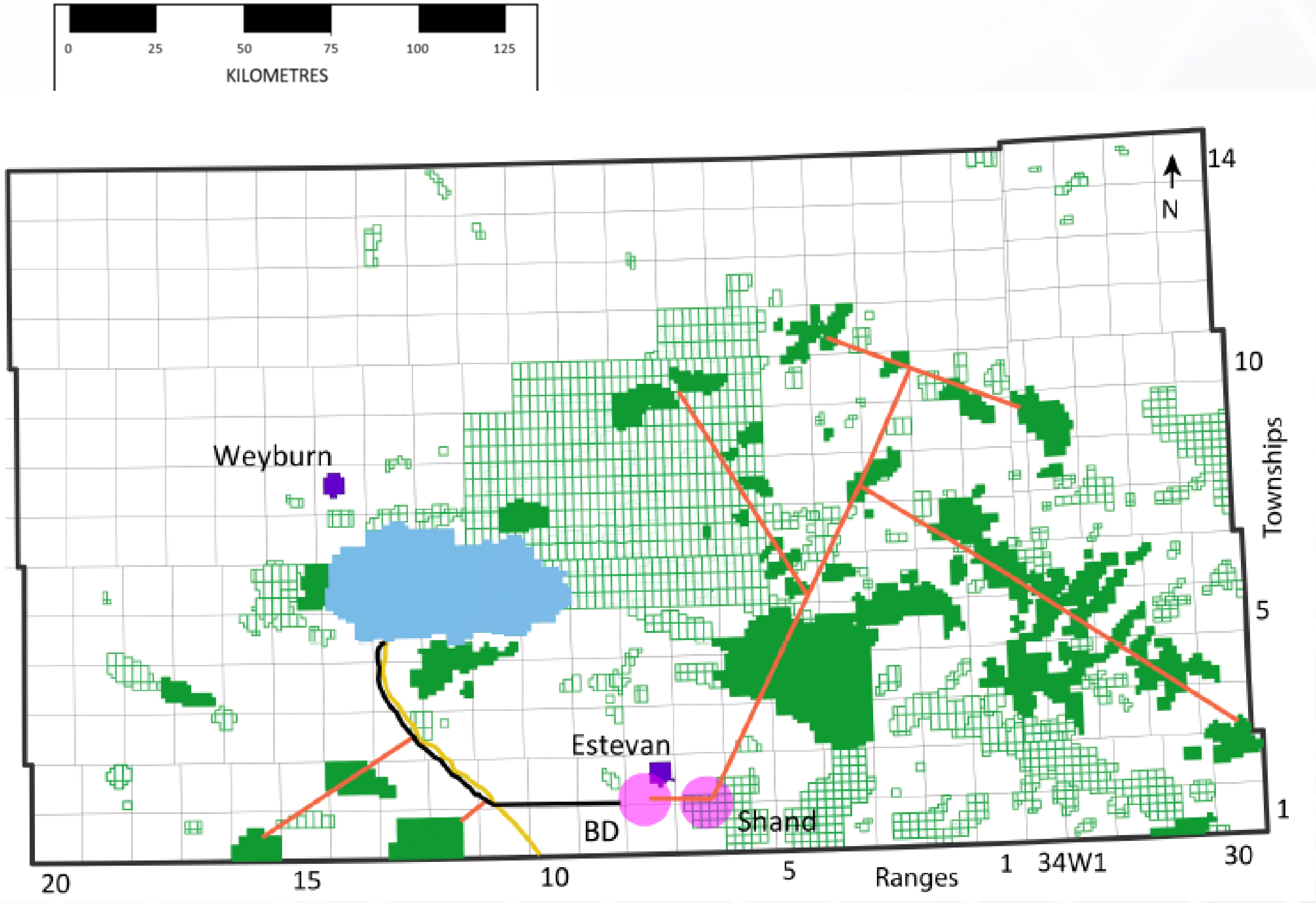



*Figure 15. Location of potential $CO_2$ EOR in south east Saskatchewan*

# Emissions Profile of a Shand CCS Retrofit

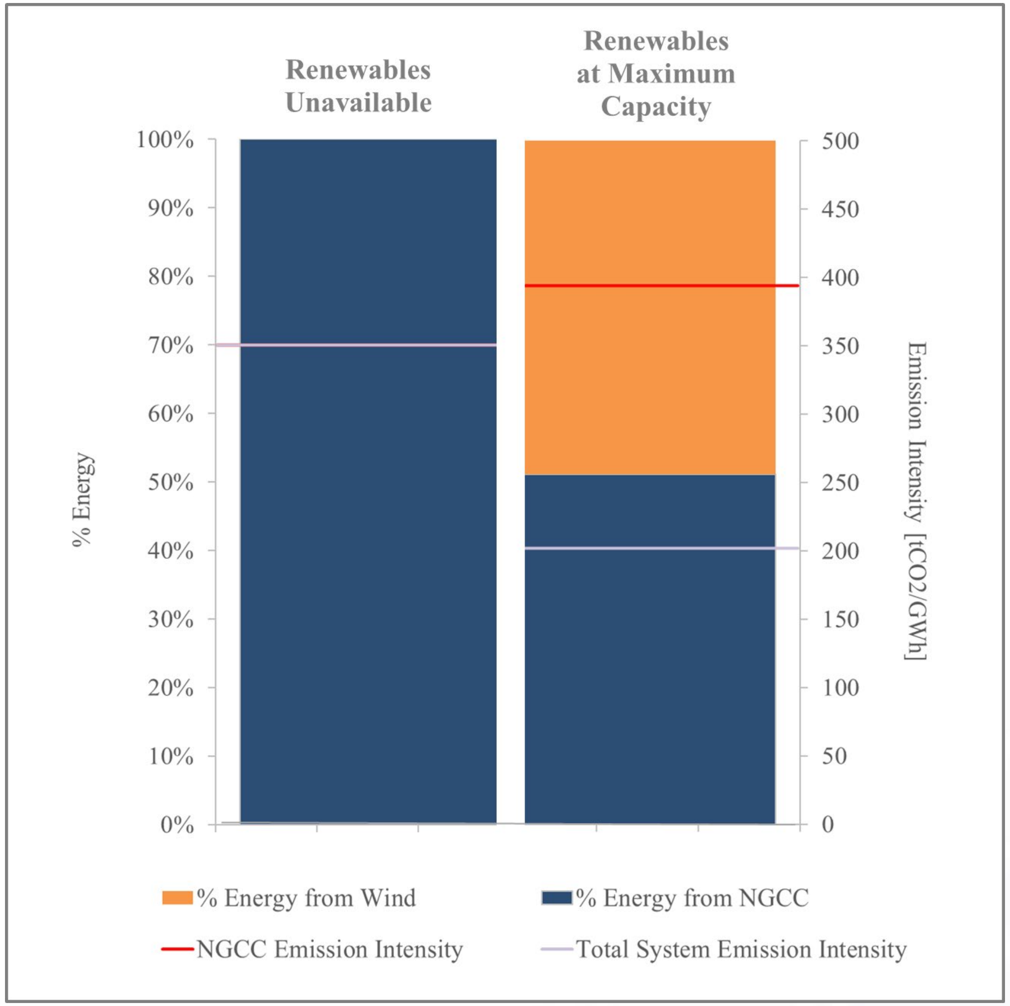



*Figure 18. Emission intensity of an NGCC plant integrated with wind*

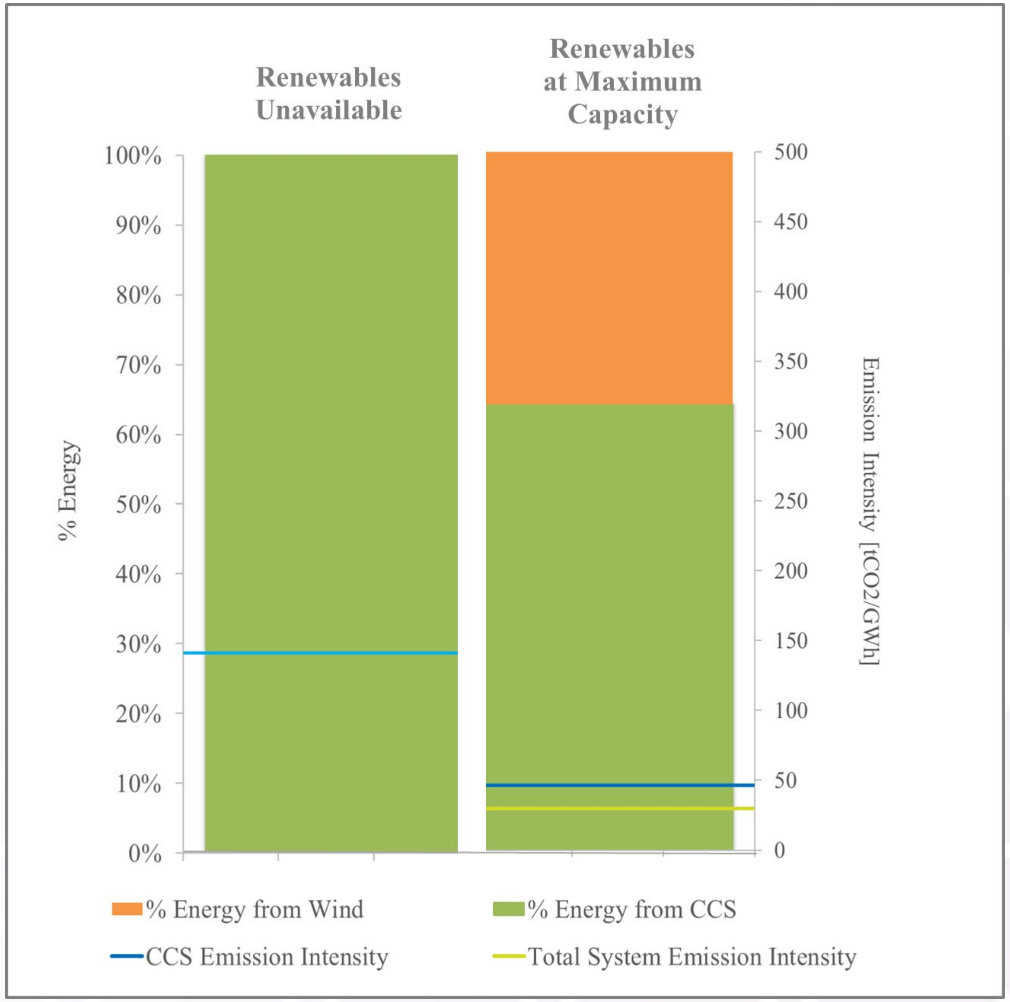



*Figure 19. Emission intensity of a CCS coal plant integrated with wind*

INTERNATIONAL CCS KNOWLEDGE CENTRE

What is CCS | BD3 CCS Facility | Expertise | Resources | News | Blog

# 2ND GENERATION CCS

## Studies

The International CCS Knowledge Centre experts spearheaded a feasibility study to retrofit SaskPower's Shand Power Station, (Shand) a 300 – M
coal-fired power plant that has double the capacity of Boundary Dam 3 CCS Facility (BD3) with a large-scale, CCS facility.

- Read Full Public Report (120 pages) - *Shand CCS Feasibility Study*, click here
- Read Compendium Document - *Summary for Decision Makers*, click here
- *Read Summary for Decision Makers in Chinese, click here*

Read the announcement on the public release of the Shand Study.

Read What Others Are Saying about the Shand Study.

**Key Hightlights of the Shand CCS Feasibility Study (Shand Study):**

- The study shows that compared to the Boundary Dam 3 CCS project (BD3), a CCS system at Shand could see capture capital cost red
of carbon dioxide ($CO_2$) captured as well as 92% in potential savings to power plant integration capital cost.
- Based on the model, the levelized cost of captured $CO_2$ is calculated at $45US/tonne.
- Second generation CCS can capture more emissions at lower loads (i.e. power generation) such that more than a 90% capture rate
that CCS has the potential to integrate well with renewables which provide a varying load. $CO_2$ capture rate could be up to 97% at

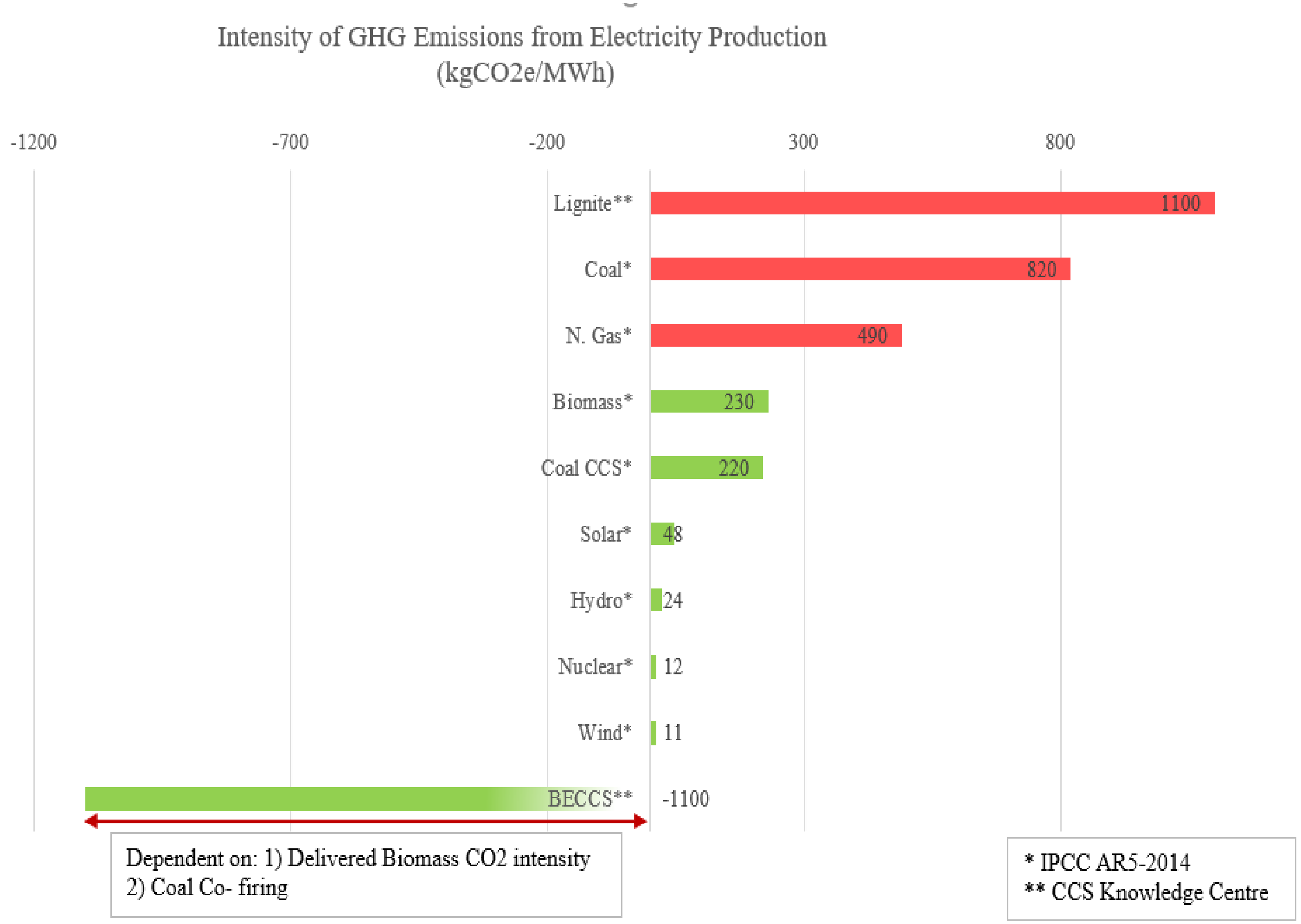
**Link to Report - https://ccsknowledge.com/pub/documents/publications/.Shand%20CCS%20Feasibility%20Study%20Public%20Report_NOV2018.pdf**

# BECCS AT SHAND POWER STATION

- Shand is a 305 MW, single unit, coal-fired power plant located in Saskatchewan, Canada.
- Current federal Canadian regulations will cap $CO_2$ emissions from coal fired power plants to 420 tonnes/GWh by 2030.
- If Shand is not retrofitted with CCS it will be forced to retire prematurely
- The International CCS Knowledge Centre performed a feasibility to retrofit Shand with CCS. Results indicated a 67% reduction in capital cost per tonne of $CO_2$ in comparison to the Boundary Dam 3 and a levelized cost of $CO_2$ capture of \$45USD/tonne of $CO_2$.
- The current historically low natural gas price in North America enables fierce competition between NGCC and CCS coal fired facilities when considering the most economical means to reduce $CO_2$ emissions.
- If maximizing $CO_2$ emissions reductions is the desired outcome, a case favoring the CCS retrofit of coal and subsequent conversion to BECCS can be made

## BECCS

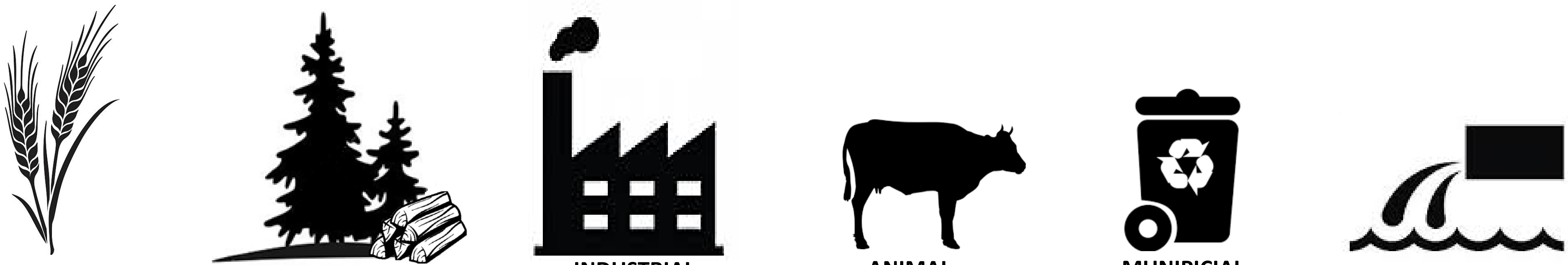
- Residual emissions are higher than true near zero emissions from sources such as solar, nuclear, wind and hydro
- **BECCS is the only option for production of electricity that will result in negative emissions**
- The actual $CO_2$ withdrawal will be dependent on the emission intensity of biomass production, transportation and preparation.
- Co-firing of coal with Biomass provides a convenient transition ability as biomass delivery systems mature.
- Maximum net effect of bioenergy with CCS is consistent with removal of about **1.1 tonnes of $CO_2$** from the atmosphere per megawatt hour of net power production



## Bio-energy from biomass

Bioenergy is energy produced from renewable, biological sources such as **biomass**. Biomass is plant material that can be turned into fuel (also known as biofuel when it is made from biological material) to supply heat and electricity. (Source: nrcan.gc.ca)

### Biomass Sources:



AGRICULTURAL CROPS & RESIDUES

FORESTY CROPS & RESIDUES

INDUSTRIAL RESIDUES

ANIMAL RESIDUES

MUNIPICIAL SOLID WASTE

SEWAGE

## Biomass Sources in Saskatchewan:

- **Agriculture Crop Residues**
  - Straws in excess of soil conservation and other requirements
  - Baled and directly transported (lower cost, limited area of supply)
  - Preprocessed prior to transport (higher cost, extends area of supply)
  - Concern over consistency of supply.

# Biomass Sources in Saskatchewan:

- **Wood pellets**
  - BC wood pellets (abundant supply, high costs per unit of energy
  - SK wood pellets (limited supply, costs are less certain as market is un-developed)

# Biomass Sources in Saskatchewan:

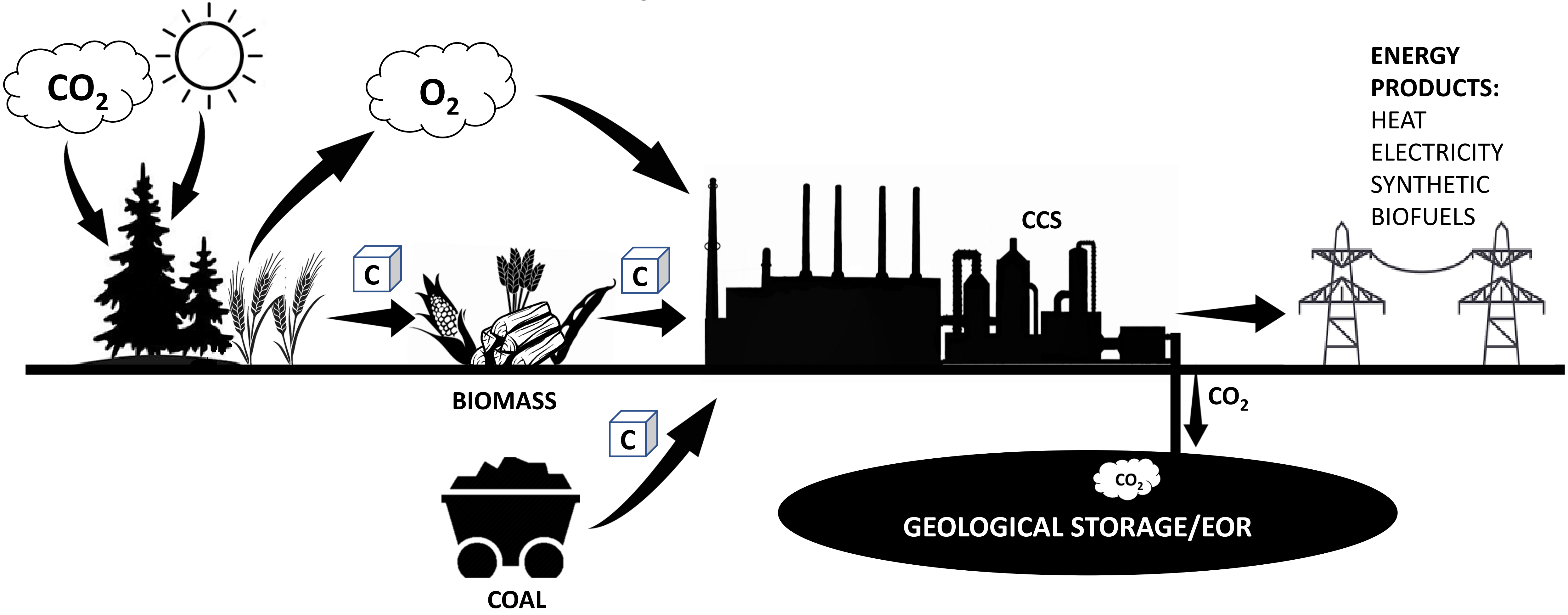
- **Purpose Grown Biomass**
  - Short rotation coppice (willow, poplar) on marginal land, or in concert with waste treatment
  - Grasses (Delivered costs are greater than straws but less than wood products)

INTERNATIONAL CCS KNOWLEDGE CENTRE

ccsknowledge.com

# BIO-ENERGY WITH CARBON CAPTURE & STORAGE

Among NET technologies, BECCS is most promising as it provides a potential solution on dealing with existing coal plant infrastructure while reducing CO2 emissions from fossil-fuel combustion.



## Conclusions

- Boundary Dam 3 CCS is reliable and optimization is on-going
- Industrial CCS will leverage lessons learned from the power sector
- A second generation CCS facility on coal is possible
  - Capital costs have been reduced by 67%
  - Calculated cost of capture would be $45US/tonne of $CO_2$
  - Emissions are significantly lower than Canadian regulations
- BECCS may represent a significant opportunity for the region

# Thank You

For more information please visit our website at:

**ccsknowledge.com**

Contact us by email:

**info@ccsknowledge.com**

Don't forget to follow us on Twitter

**@ccsknowledge**

INTERNATIONAL
CCS KNOWLEDGE
CENTRE