IEA Bioenergy
Technology Collaboration Programme

Overview of CCU Technology Types Assessment Study for 1.5 MWth Biomass District Heating Plant in Ottawa, Ontario

Small biomass district heating, WP2 Case Study Report

Contribution of IEA Bioenergy Task 32 to Inter-Task Project (ITP) Management of biogenic CO_2: BECCUS Phase 2

October 2025

IEA Bioenergy: Task 32 Biomass Combustion

Confederation Heights Central Heating and Cooling Plant, Ottawa, Ontario, Canada. © Public Services and Procurement Canada (PSPC)

Overview of CCU Technology Types

Assessment Study for 1.5 MWth Biomass District Heating Plant in Ottawa, Ontario

Small biomass district heating, WP2 Case Study Report

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Index

Preface

Bioenergy combined with carbon capture and utilisation or storage, also known as bio-CCUS or BECCUS is a concept that has been discussed in climate change mitigation research for quite some time. However, implementation has only become the subject of serious consideration within governments and private actors within the last 5 years. The reasons for this are largely related to four factors that are somewhat entwined: a) an emerging awareness of the need for BECCS and other negative emissions technologies if there is to be any chance for the Paris 1.5°C target to be reached, b) increased interest in buying carbon negative or neutral products and value of biogenic CO_2, c) rising CO_2 prices, and d) the rapidly decreasing costs of electricity generation from solar & wind (and expectations of similar developments for electrolysers) that have made BECCU options based on power-to-X technologies more cost-effective.

In light of this, identifying and implementing approaches for how BECCUS systems can be deployed and integrated in ways that maximise benefits in terms of climate change mitigation - as well as in terms of energy system integration and sustainability ambitions more broadly - is highly important.

BECCUS INTER-TASK PROJECT

Phase I

During the 2019-2021 triennium, IEA Bioenergy Task 40 worked together with Tasks 36, 44 and 45 on an inter-task project called *Deployment of BECCUS value chains* that focused on understanding the opportunities for, and obstacles to, deployment of BECCUS in different sectors. Focus was on trying to cut across the full set of factors that determine successful deployment, from technology readiness, to business model viability and design of policy and regulatory frameworks.

Phase I findings

Factors determining successful deployment of BECUSS include technology readiness, business model viability, upstream supply chain set up, and current and expected public policy design. The investigations indicate that while the majority of the required individual BECUSS technology components can largely be considered proven, there is still R&D needed into finding models for on-the-ground deployment. Supply chain set up and possibly alterations of existing supply chain concepts are important. Many concepts are looking for viable business models for the captured carbon. Thus far, the focus is on utilising rather storing the carbon. Lack of governance with corresponding support measures and regulations for carbon storage pose a challenge. A synthesis report summarising phase I findings as well as publications covering case studies topical reports, and system studies can be found on the IEA Bioenergy, Deployment of BECCUS value chains website[1].

Phase I suggestions for further work

Research and development are still required to identify models of on-the-ground deployment that make the most sense from techno-economic and climate perspectives. This includes aspects such as specific designs, deployment scales and choice of site locations. In addition, there are many questions remaining when it comes to process and supply chain integration as well as policy design and implementation. Answers to the above questions can assist in addressing key and most complex questions, i.e., *in a given situation should biogenic CO2 be*

[1] https://www.ieabioenergy.com/blog/task/deployment-of-beccus-value-chains/

sequestered, or utilised? Which type of facilities (i.e., bioenergy installations) shall best provide BECCS and/or BECCUS under certain criteria (economics, CO_2 emissions mitigation potential etc.)? What are the main challenges for commercialising BECCUS projects, and the lessons learnt thus far? How to monetise the carbon negative products that bioenergy can deliver? How to govern the different energy system services when targeting a high level of CO_2 emissions mitigation? And related to this, what factors and parameters should guide this decision-making process?

Phase II

Phase II of the BECCUS Inter-Task Project is more diverse in its scope, with a stronger emphasis on cross-sector and cross-country learning about implementation of BECCUS projects using different energy conversion processes (WP2-WP4). A further goal is to shed some light on the effects of the integration of BECCUS facilities and systems within the overall energy system and its interaction with other energy system services (WP5). In addition, although we tend to refer to "BECCUS" as a unified concept, we also emphasise and analyse the important differences between BECCS and BECCU, not least from the perspective of potential business models and policy development (WP6). An understanding of the impacts of BECCUS on overall climate system in terms of potential for CO2 mitigation is addressed (WP7) and all different aspects covered are analysed jointly and policy recommendations provided (WP8). This approach allows for a systemic consideration of how to take different BECCUS applications to deployment, thereby building upon, but going beyond, Phase I. IEA Bioenergy Task 40 works together with Tasks 32, 33, 34, 36, 44 and 45.

Report Summary

The study on hand identifies the most suitable option(s) for carbon capture and utilization (CCU) technologies for a small biomass district heating demonstration plant. As a reference facility, the 1.5 MWth Biomass District Heating Plant in Ottawa, Ontario has been further assessed when adding a carbon capture plant to the site and considering different options for utilizing the biogenic carbon. The assessment performed by Natural Resources Canada (NRCan) and took into account the technology readiness of capture technologies and utilization.

An initial technology scan identified nearly 50 CCU technologies (20 post-combustion capture, 21 utilization, and 7 combined capture and utilization). These technologies were ranked according to their technology readiness level (TRL). Carbon capture technologies were required to achieve at least TRL 7 while CO_2 utilization technologies were required to achieve at least TRL 6. The assessment study considered oxy-combustion, chemical looping combustion and cryogenic carbon capture under capture technology options.

In terms of technology development, amine capture technology has been demonstrated for CO_2 capture from natural gas or coal (TRL 8 - 9), but less for biomass flue gas (TRL 7). TRL for all other capture technology types was identified at a maximum of TRL 7 with greater potential of reaching higher TRL levels soon.

For all technology types assessed, additional power consumption was associated with CO_2 capture. Adsorption and absorption technology types require additional steam for regenerating adsorbent or solvent, while hot water is likely sufficient for regenerating carbon capture media for non-amine-based technology type

The detailed technology option analysis study performed by NRCan concluded that capture technology options exist that can meet the CO_2 target for the reference facility, Confederation Heights wood chips district heating and cooling demonstration plant. These

capture technologies will require additional power consumption, and heat integration of new facilities with the current plant. CO_2 capture technology options are not expected to bring additional complexities to the operation of the existing plant.

Overview of Carbon Capture Technology Assessment Study for 1.5 MWth Biomass District Heating Plant in Ottawa, Ontario

Background

CCU technologies are viewed as part of Canada's broader strategy to achieve net-zero emissions by 2050 and position the country as a leader in sustainable and innovative technologies (Natural Reosurces Canada, 2023). Beyond the key goal of reducing GHG emissions, CCU technologies are considered within a broader sustainability goal of reducing the carbon intensity of industrial processes and supporting the transition to a low-carbon economy.

As part of the Canadian federal government's Greening Government Strategy, Natural Resources Canada was asked by Public Services and Procurement (PSPC) to undertake a study to identify the most suitable option(s) for carbon capture and utilization (CCU) technologies for a small biomass district heating demonstration plant. The assessment primarily focused on evaluating CO_2 capture and capture with utilization pathways, given that the reference site conditions were deemed unsuitable for permanent CO_2 storage (Atkinson, 2019).

The study was seen as central in support of advancing CCU technologies for biomass district energy plants by demonstrating that their implementation consumes minimal area, is retrofittable, meets safety regulations, and is beneficial to central heating and cooling plants and for the end users. It was also seen as advancing bioenergy innovation and creating job opportunities in the green technology sector.

Technology and concept description

BIOENERGY TECHNOLOGY

The heating and cooling plant at Confederation Heights Campus in Ottawa, Ontario supplies low temperature hot water to a district heating network comprised of 15 buildings in the Confederation Heights Campus. The plant includes a 1.5 MW_{th} boiler designed to fire locally sourced graded wood chips and a natural gas boiler. The wood chip boiler is designated as the primary boiler, and the natural gas boiler as secondary boiler which is used either as a backup boiler or to augment the primary boiler, depending on the district heating hot water demand. The only flue gas treatment is particulate removal via a multicyclone and conventional baghouse on the primary boiler.

Table 1. Overview data bioenergy technology

Name of technology / project / company	Data / Assumptions
Combustion system by KMW Energy Group / Confederation Heights Campus Demonstration project (Ottawa, ON) / Public Services and Procurement Canada	Staged combustion technology with moving grate

Name of technology / project / company	Data / Assumptions
Feeding System	Auger based
Principal Feedstock(s)	Graded wood chips meeting CAN/CSA-ISO 17225-4 Part 4 specifications
Principal Application(s)	low temperature hot water district heating
Scale	1.5 MW_{th}
Other relevant info	The plant is equipped with multicyclone and a baghouse; Boiler emits 16 tpd of CO_2

Establishment of the project design basis included the following:

- As calculated by a process simulation in Aspen HYSYS, the 1.5 MW_{th} biomass boiler produces 668.34 kg/h CO_2, or roughly 16 tpd. 10 tpd of CO_2 will be captured, corresponding to 62% of the CO_2 in the flue gas. This capture rate was selected to allow a buffer for indirect emissions and still achieve the GHG emission reduction target of 50% identified by PSPC.
- Desired on-stream factor is 220 days per year.
- All rotating equipment drivers shall be electric.

The flue gas flow rate and composition are key elements in the design. The NRCan team used PSPC design data to simulate the performance of the boilers and determine the combustion flue gas compositions and flow rates. The flue gas became the basis of design and performance for the carbon capture plant and is presented in Table 2. Properties of available utility and support systems are summarised in Table 3.

Table 2. Wood chip boiler design basis (KMW Energy)

Process Parameter	Value	Units
Flue gas flow rate	3 156	Sm3/h
Flue gas temperature	163 – 200	°C
Pressure	0.5	kPa(g)
Flue gas composition		
Carbon Dioxide (CO_2)	10.97	% by volume
Water (H_2O)	21.62	% by volume
Oxygen (O_2)	4.91	% by volume
Nitrogen (N_2)	62.50	% by volume
Sulphur Dioxide (SO_2)	n/a	% by volume
Sulphur Trioxide (SO_3)	n/a	% by volume

Methane (CH_4)	n/a	% by volume
Flue gas composition	**Value**	**Units**
Carbon Monoxide (CO)	0.0001	% by volume
Nitric Oxide (NO)	0.0001	% by volume
Nitrous Oxide (NO_2)	n/a	% by volume
Hydrogen Sulphide (H_2S)	n/a	% by volume
Carbonyl Sulphide (COS)	n/a	% by volume
Hydrogen (H_2)	n/a	% by volume
Chlorine (Cl_2)	n/a	% by volume
Particulates	75	mg/Nm3
Other	n/a	% by volume

Table 3. Properties of available utility and support systems

Utility	Flow rate (Sm^3/h)	Temperature (°C)	Pressure (kPa(g))
Cooling water	Unknown	Unknown	465
Natural gas	Unknown	Unknown	70
Hot Water	108	110	910
Hot Water	104	150	910
Plant Air	Unknown	Unknown	640
Steam		Not available	
Electricity		575 volt, 60 Hz, 3 phase	

The objective of the NRCan study was to assess technologies for carbon capture, carbon utilization and combined capture and utilization and their costs to achieve minimum 50% net reductions in GHG emissions. Primary governance consideration required to ensure that the BECCU technology /operations sequester more carbon than the supply chains emit.

This fact sheet summarises the comprehensive assessment conducted by Natural Resources Canada (NRCan), originally completed in 2019 (Atkinson, 2019) and updated in 2024 in support of the current publication. It presents high-level findings for capture technology options in a condensed and generic manner to respect the confidentiality of the information provided by the technology suppliers. The report first provides an overview of methodology applied in the assessment study, followed by comparative assessment of capture technology types based on their technology development, environmental and economic performances, and system integration.

OVERVIEW

The initial technology scan identified nearly 50 CCU technologies (20 post combustion capture, 21 utilization and 7 combined capture and utilization). These technologies were ranked according to their technology readiness level (TRL). Carbon capture technologies were required to achieve at least TRL 7 while CO_2 utilization technologies were required to achieve at least TRL 6. The NRCan assessment study considered oxy-combustion, chemical looping combustion and cryogenic carbon capture under capture technology options, however at the time of the assessment, these options were deemed neither to have TRL <7 nor suitable for the Confederation Height site (as a brownfield project) and were excluded from the assessment. Strengths, Weaknesses, Opportunities & Threats (SWOT) analysis were performed on the technologies that met the required TRLs.

For the second level of screening, criteria comprised of: (1) the ability to demonstrate the technology at a scale of 10 tpd for CO_2 capture or 2 tpd for CO_2 utilization, (2) a commercial presence of the company in North America, (3) availability of sufficient information to complete next stage of technoeconomic assessment analysis, and (4) logistical feasibility of implementation at the heating plant. The study also considered and evaluated the integration suitability of the technologies, reactant supplies, product streams and utilities. Level 2 screening identified a total of 11 technologies: 4 capture, 4 utilization and 3 combined capture and utilization, see Figure 1.

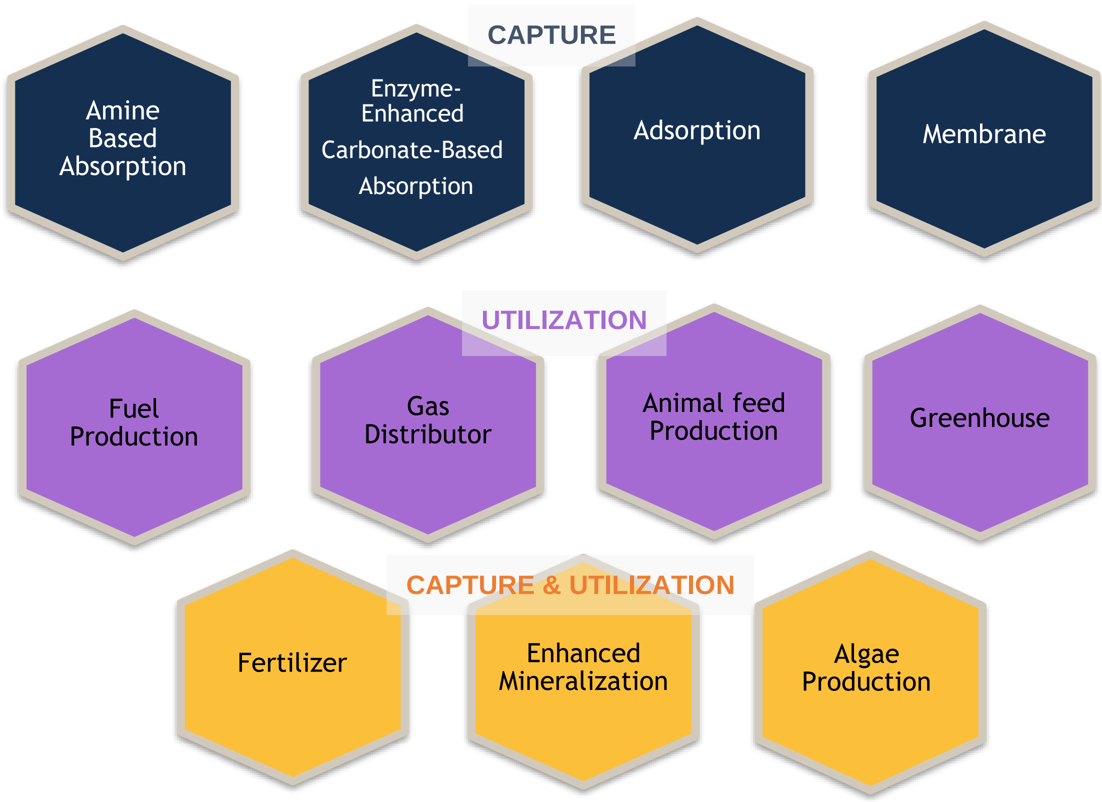

Figure 1. Types of carbon capture, utilization and combined capture & utilization technologies considered in the assessment study for Confederation Heights demonstration biomass district heating plant

Post combustion capture technology types were deemed as the most mature, i.e. TRL≥7 and easiest to add to the heating plant at the time of the assessment study; and remains one of the most mature and widely used methods for carbon capture in 2024. The carbon capture technology types included in the assessment were adsorption (temperature swing adsorption);

amine-based absorption, enzyme enhanced carbonate-based absorption; membrane. Types of utilization technologies considered in the study with TRL >6 included fuel production (methanol (MeOH) or dimethyl ether (DME)), commercial gas distribution, animal feed production and greenhouses. The types of combined capture and utilization technologies included with TRL >7 were enhanced mineralization, fertilizer and algae.

The technology options that passed Level 2 screening were further assessed for technology development, reliability, availability, CO_2 retention time, and CO_2 displacement. Lastly, a basic life cycle assessment was conducted for each technology option.

Assessment for Carbon Capture Technology Options for 1.5 MW_{th} Wood Chip District Heating & Cooling Plant

The following sections present the assessment results of the aforementioned four capture technology types.

TECHNOLOGY RELATED

For Confederation Heights biomass district heating demonstration plant, multiple operational objectives were identified and developed by NRCan in consultation with PSPC:

- technology development
- reliability, availability, maintainability
- operational flexibility
- public perception.

The study also included objectives for CO_2 end-use market opportunities, CO_2 retention time and CO_2 displacement; however, those results are excluded from this document, as these objectives are relevant to carbon utilization and combined capture and utilization technology types.

Table 4 summarizes the key results of operational objective assessment for each of the selected capture technology types.

Table 4. Assessment summary of carbon capture technology types

Key Metric	Adsorption	Enzyme-Enhanced Carbonate -Based Absorption	Amine Absorption	Membrane
TRL*	7	7	7 - 9	7
Resulting CO_2 product	95%+ CO_2(g)	99.95 % CO_2(g)	CO_2(l)	CO_2(g)/N2(g) mixture
CO_2 emission reduction [%]	30	52	43	61

Key Metric	Adsorption	Enzyme-Enhanced Carbonate -Based Absorption	Amine Absorption	Membrane
Energy req. [kWh/tCO_2]	350	350	244	382
Space required	80-100 m2	400 m2	260 m2	60 m2
Utility Requirements	air (for adsorbent conditioning); power; make-up water; low-pressure steam; cooling water or glycol (for flue gas condensation)	hot water; power; cooling water or glycol (for flue gas condensation)	power; air; steam (for solvent regeneration); cooling water or glycol (for flue gas condensation)	Power; air; cooling water or glycol (for flue gas condensation)
Feedstock & Product Streams (non-CO_2)	non-toxic carbon capture media; flue gas condensate (low pH, possibly containing some ash species)		toxic solvent; flue gas condensate (low pH, possibly containing suspended ash species)	flue gas condensate (low pH; likely containing suspended ash species)
Building/tower/ stack height	no higher than existing buildings	tower: 20-30 m; Absorption Bed fits within existing building	15 m	3 m

**TRL is based on NRCan's original assessment study (Atkinson, 2019) and updated in 2024*

It was most desirable for the technology to be provided as a packaged system with guarantees for performance and installation schedule. The "must meet" criteria for technology development objective were: (i) commercial deployment of the technology at multiple sites at 100+ tonne per day CO_2 capture, and (ii) availability of reactants, materials and components from multiple suppliers within North America. The objective of reliability, availability and maintainability (RAM) was evaluated, i.e. "must meet" conditions, if the system was (i) fully automated control and monitoring, (ii) operated with minimum intervention by operations staff, and, (iii) was operated 6 000+ hours without major upset or maintenance shutdown. The operational flexibility objective was assessed for the system ability to respond to load changes and start-up / shut down sequences as rapidly as the boiler providing flue gas to the system. The systems are required to (i) achieve turn down ratio of 30% of full load, (ii) meet GHG reduction requirements during partial load operation, (iii) have start-up time of less than 5 minutes. The public perception objective mainly aimed at the system to be a compact, modern and innovative "look and feel", and assessed poorly if reactants and by-products were hazardous to health and environment.

In terms of technology development, amine capture technology has been demonstrated for

CO_2 capture from natural gas or coal (TRL 8 - 9), but less for biomass flue gas (TRL 7). TRL for all other capture technology types was identified at a maximum of TRL 7 with greater potential of reaching higher TRL levels soon. Membrane technology type though is well-developed, it produces blend of CO_2 and N_2, likely requiring further purification downstream. In all cases, feed materials were commonly available and conventional (Table 4).

Considering reliability, availability, and maintainability (RAM), non-amine based and membrane technology options received the highest scores. Overall, it was determined that none of the technologies introduced operational risks from hot equipment, nor from flowing particulate matter. In regard to long term performance, data is not yet available. It would be beneficial to have more data, especially beyond 6 000 operating hours, which can provide insights into the durability and reliability of the systems over extended periods.

Regarding operational flexibility, all but amine capture systems met the objective satisfactorily, showing ability to be turned down to 30% of the full load, and meeting GHG reduction requirements during partial load. Some technology options, such as membrane and adsorption, can have start up time of several minutes, while non-amine technology option can require an hour or more. The amine capture option assessed at a low score due to the limited ability to reduce energy intensity during turndown, likely resulting in failure to meet GHG reduction requirements during partial loading.

In terms of public perception, amine based and enzyme based absorption technology options received higher scores, as they can be compact in size, and fit within the existing building (Table *4*). Amine technology types in general scored lower due to their use of reactants that are hazardous to health and environment, with the potential for those solvents to slip to the stack.

The technology assessment for Confederation Heights 1.5 MW_{th} biomass district energy demonstration sytem indicated that all capture tehcnology types were able to produce a minimum of 95% CO_2 concentration; though membrane tecnology option would require further step to purify the CO_2 concentration (Table 4).

SYSTEM RELATED

To evaluate the suitability of the technologies for installation at the Confederation Heights Heating Plant, it was necessary to understand how the boilers and CO_2 capture unit, reactant supplies, product streams, and utilities would be integrated. Integration of process equipment as well as utility needs for each technology is presented below. Opportunities for heat integration were considered, at the time of the assessment, only one company was identified to incorporate heat integration into their technology.

For all technology types assessed, additional power consumption was needed for the CO_2 capture. Adsorption and absorption technology types require additional steam for regenerating adsorbent or solvent, while hot water is likely sufficient for regenerating carbon capture media for non-amine-based technology type. All capture technology types considered in the analysis required cooling of the flue gas stream to 30-40°C. For the initial cooling from 170°C to the acid dew point a conventional convective heat exchanger can be used to recover additional heat from the flue gas. Below this temperature, condensation of moisture and removal of fine ash is required. This can be accomplished using a condensing heat exchanger or a direct contact cooler.

In general, it was expected that exploring approaches for heat integration when feasible to maximize the efficiency of the overall system will be beneficial. Examples involve potentially using waste heat for pre-heating the biomass feedstock to reduce moisture variability and improve overall system efficiency or capturing the energy from the portion of waste heat to produce hot water or pre-heat combustion air to the boilers.

ENVIRONMENTAL RELATED

Table 4 summarises the feedstock and product streams that are expected to be generated in each of the assessed capture technology types. Carbon capture media are non-toxic for adsorption and non-amine based absorption technology types. For membrane technology types, no chemicals are used. Flue gas condensates from the assessed capture technology types are expected to contain some ash species and have too low pH to discharge to the municipal sewer, therefore requiring pH adjustment prior to discharge. The study identified opportunities that advanced amines may be formulated in the future with better properties, i.e. lower toxicity and/or lower regeneration heat requirements. At the time of conducting the assessment study, advanced adsorbents were under active development, which is expected to lead to performance improvements in the short to medium term.

A basic life cycle assessment was conducted where the only metric considered was Global Warming Potential, measured in tonnes of CO_2-equivalent emitted (t CO_2eq). Emissions at each life cycle stage were considered and quantitatively assessed where possible (Table 5).

The design basis for the amount of CO_2 leaving the boiler in the flue gas was 668.3 kg/h, or 16 tpd, and the amount being captured as 417.4 kg/h, or 10 tpd, corresponding to a removal of 62% of the CO_2 from the flue gas. This meant to achieve 50% GHG emissions reduction on a life cycle basis, a technology must not produce additional emissions of more than 0.2t CO_2eq / t CO_2cap.

The LCA analysis indicated that adsorption and amine absorption technology options were more likely to exceed the threshold at which the capture target is met. In both cases, this is largely due to combustion of natural gas for sorbent/solvent regeneration. It may be possible for these technologies to meet the 50% reduction target, but it was determined that this would require re-scoping of the design to capture more than 62% of the CO_2 from the flue gas and/or capture additional CO_2 emissions from natural gas combustion. It is also possible to use alternative renewable energy sources for sorbent/solvent regeneration to reduce the reliance on natural gas and lower overall emissions.

Table 5. Summary of Life Cycle Assessment for capture technology options

Capture Technology	GWP (CO_2teq/CO_2tcap)	Key Contributors to GHG Emissions
Membrane	0.03	Major: Auxiliary Power Minor: Product Liquefaction
Enzyme-Enhanced Absorption	0.16	Major: Required boiler for Solvent Regeneration Minor: Auxiliary Power
Amine Absorption	0.32	Major: Sorbent/Solvent Regeneration NG Combustion and Production

Adsorption	0.54	Major: Sorbent/Solvent Regeneration NG Combustion Minor: Auxiliary Power and NG Production

ECONOMIC RELATED

The cost estimates presented in this section are high level budgetary estimates and meant to provide an order-of-magnitude guide to how much it might cost to deliver for each of the carbon capture options. Costs were calculated assuming a 20-year project lifetime, without including depreciation. For decision making, value for money analysis needs to be performed, including cost benefit analysis for each technology option covering initial investment, operational costs, maintenance, revenue streams and potential savings from GHG reduction; however, that was beyond the scope of the assessment study for Confederation Heights 1.5 MW_{th} biomass district heating demonstration plant.

Table 6. Summary of high-level budgetary estimates

Estimated costs and revenues (C$/tonne CO_2 captured)	Capture Technology			
	Adsorption	Enzyme-Enhanced Absorption	Amine Absorption	Membrane
CAPEX	$0.3K	$0.2K	$0.5K	$0.5K
Total OPEX	$1.1K	$0.7K	$1.1K	$1.2K
Revenue Streams - from marketable CO_2	$0.5K	$0.5K	$0.5K	$0.5K

Note. Cost values are 2019 values

Key Highlights of the CCU Assessment Study

The detailed technology options analysis conducted by NRCan concluded that viable CO_2 capture technologies exist that can achieve the target capture rates for the Confederation Heights wood chips district heating and cooling demonstration plant. Implementation of these technologies will require additional power consumption and careful heat integration of new facilities with the existing plant systems. Importantly, the addition of CO_2 capture is not expected to introduce significant operational complexities to the current plant. However, an additional refrigeration and compression unit will be required to liquefy the captured CO_2 for transport.

From an economic perspective, deployment of CO_2 capture will involve substantial capital investment as well as increased operations and maintenance costs. The additional space requirements necessitate careful planning and design to minimize impact, identify the most effective integration strategies, and ensure flexibility during installation.

In terms of environmental impact, the adoption of these capture technologies is expected to result in a significant reduction in CO_2 emissions from the facility, contributing to the demonstration plant's overall greenhouse gas mitigation objectives. The potential emissions reduction will depend on the capture efficiency of the selected technology and its integration with plant operations, with preliminary estimates indicating the capability to capture a substantial fraction of the facility's CO_2 output. Incorporating this mitigation potential into project planning not only supports environmental goals but also provides insights into optimizing the design, energy use, and operational strategies to maximize carbon abatement benefits while minimizing costs and disruptions.

Challenges in Implementing CCU for Biomass District Energy

At present, there are several challenges that need to be overcome to advance the implementation of CCU technologies for biomass district energy systems:

- **Cost**: The initial investment for CCU technology can be high. This includes the cost of equipment, installation, and ongoing maintenance.
- **Efficiency**: Achieving a high capture rate (like the 62% targeted in the study) requires advanced technology and precise control, which can be technically challenging.
- **Energy Consumption**: The process of capturing and utilizing CO_2 can be energy-intensive, potentially offsetting some of the benefits of reduced emissions.
- **Integration**: Integrating CCU technology with existing systems can be complex. It requires careful planning to ensure compatibility and efficiency.
- **Supply Chain Emissions**: Ensuring that the entire supply chain, from biomass sourcing to CO_2 utilization, results in a net reduction of GHG emissions is crucial but challenging.
- **Regulatory and Governance Issues**: Compliance with regulations and ensuring proper governance to verify that the technology is effectively reducing emissions can be demanding.
- **Public Acceptance**: Gaining public and stakeholder support for new technologies and infrastructure can be a hurdle.

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