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# Design of a Process for Direct Air Capture in Nova Scotia

## Project Background

Increased industrial activities and the combustion of fossil fuels has led to the high concentrations of carbon dioxide ($CO_2$) found in the atmosphere. $CO_2$ emissions are considered a leading contributor to climate change. To help mitigate the harmful impacts of $CO_2$ emissions, direct air capture (DAC) technology has been identified as the most efficient method of permanently removing $CO_2$ from the atmosphere.

The purpose of this project was to design a process for DAC located in the Province of Nova Scotia and assess the feasibility through an economic and safety/sustainability analysis.

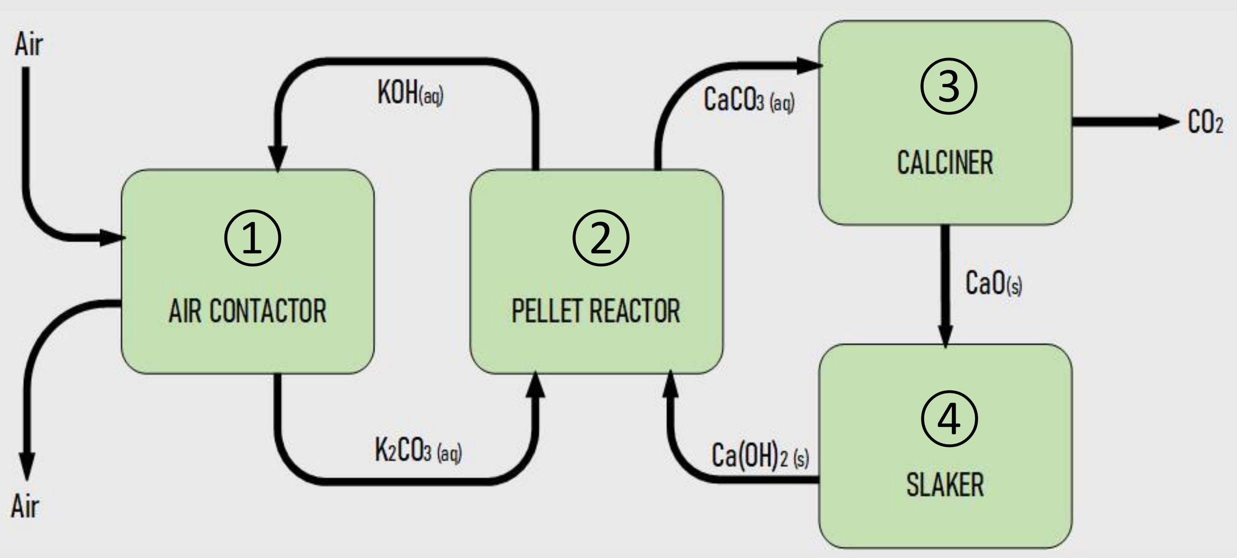
## Design Objectives

The following are key objectives for the proposed design:

- ☑ The plant must be located within Nova Scotia
- ☑ The process should allow for continuous operation, running for 8000 hours/year
- ☑ The $CO_2$ product stream should have a purity of at least 95%
- ☑ The process must result in negative emissions

## Process Overview

After conducting an in-depth literature review, the chosen approach consisted of the use of KOH as the solvent and a quick lime cycle. The process is as follows:




① $CO_{2\,(g)} + 2KOH_{(aq)} \rightarrow H_2O_{(l)} + K_2CO_{3\,(aq)}$

② $K_2CO_{3\,(aq)} + Ca(OH)_{2\,(s)} \rightarrow 2KOH_{(aq)} + CaCO_{3\,(s)}$

③ $CaCO_{3\,(s)} \rightarrow CaO_{(s)} + CO_{2\,(g)}$

④ $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2\,(s)}$

## Details of Design

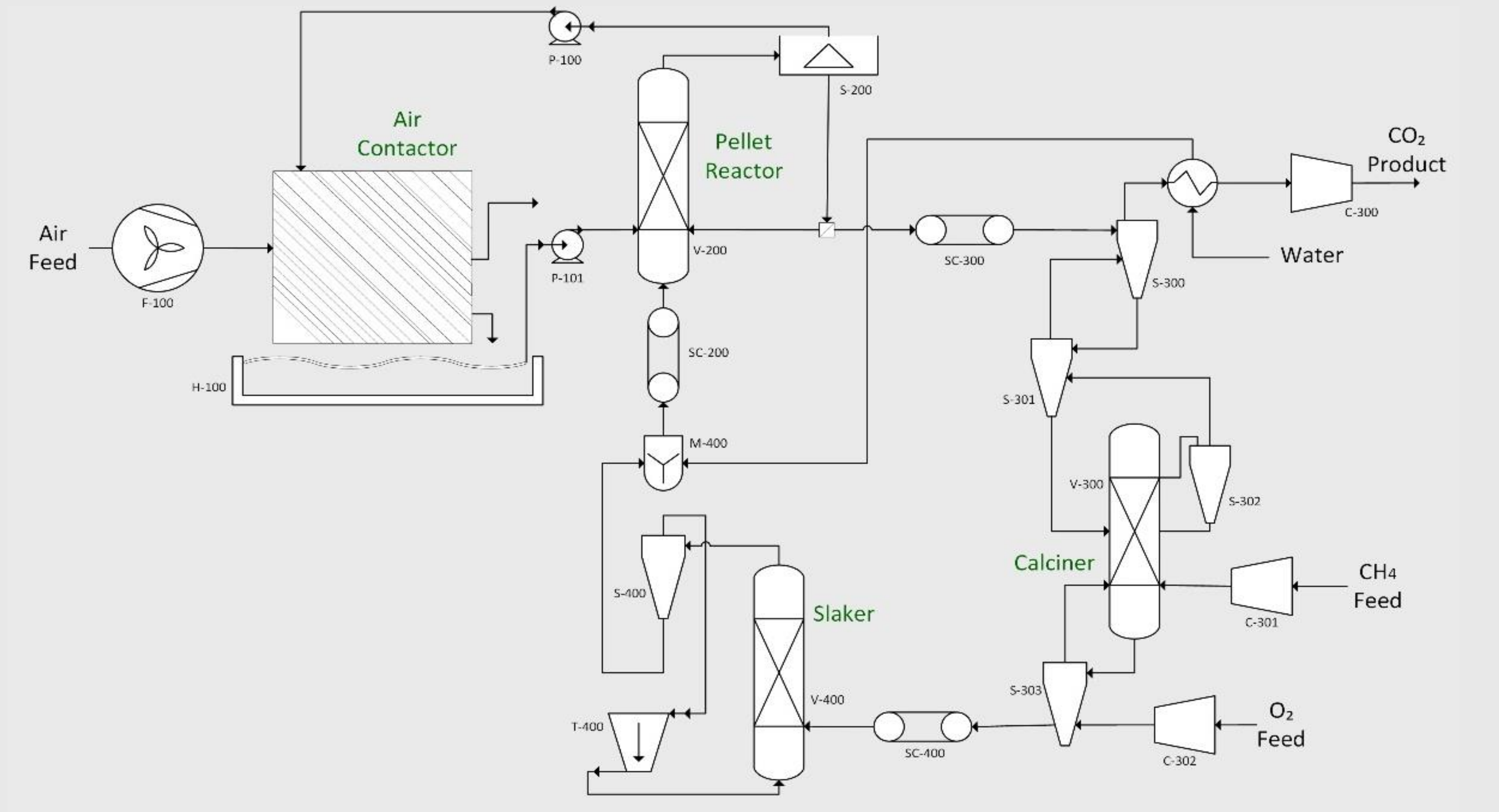



Figure 1 – Process flow diagram for the preliminary design of the proposed DAC process

### AIR CONTACTOR

The air contactor contains a large fan that pulls air into a packing that selectively reacts $CO_2$ with the flowing KOH. The air contactor has a $CO_2$ conversion of 91.4% to form $K_2CO_3$ that is fed into the pellet reactor.

### PELLET REACTOR

The pellet reactor process consists of a circulating fluidized bed reactor and a sedimentation centrifuge. A slurry of 30 wt% $Ca(OH)_2$ from the slaker and aqueous $K_2CO_3$ solution from the air contactor are fed into the bed. These components undergo the exothermic reaction with a conversion rate of 90% to generate $CaCO_3$ particles no larger than 588 µm in diameter. The particles are heated to 300°C before being sent to the calciner.

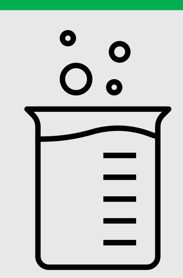
### CALCINER

The calciner is an oxygen-fired circulating fluidized bed reactor that plays a critical role in the regeneration of the captured $CO_2$ from $CaCO_3$. Methane is fed at a flow rate of 1.6 kg/s to maintain the reactor temperature of 900°C such that 98% $CO_2$ is regenerated.

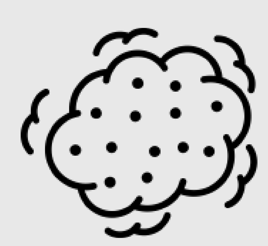
### SLAKER

The slaker is composed of a bubbling fluidized bed reactor, where the CaO hydration reaction is carried out at a temperature of 350°C. The reaction is carried out with a conversation rate of 85%, with the resulting $Ca(OH)_2$ mixed into slurry before being recycled back to the pellet reactor for regeneration.

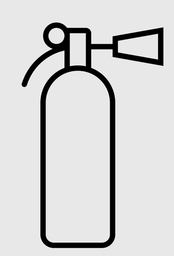
## Safety Considerations



Runaway reactions



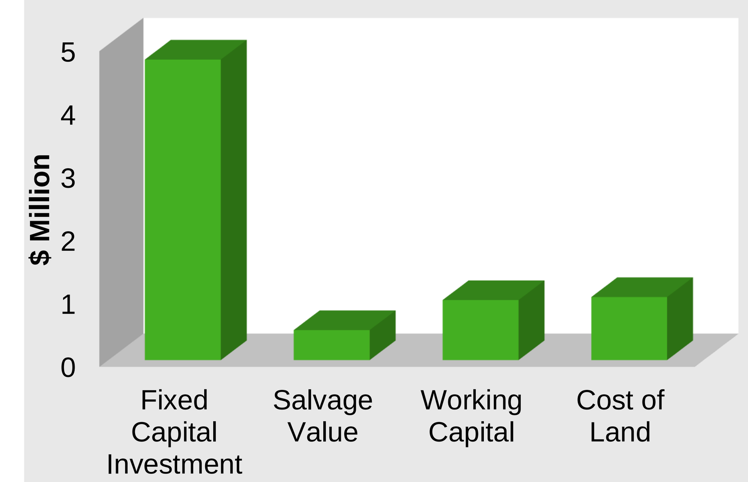
Dust formation & airborne debris

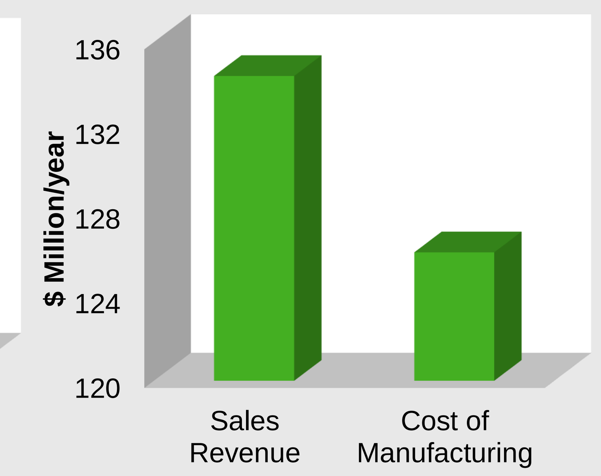


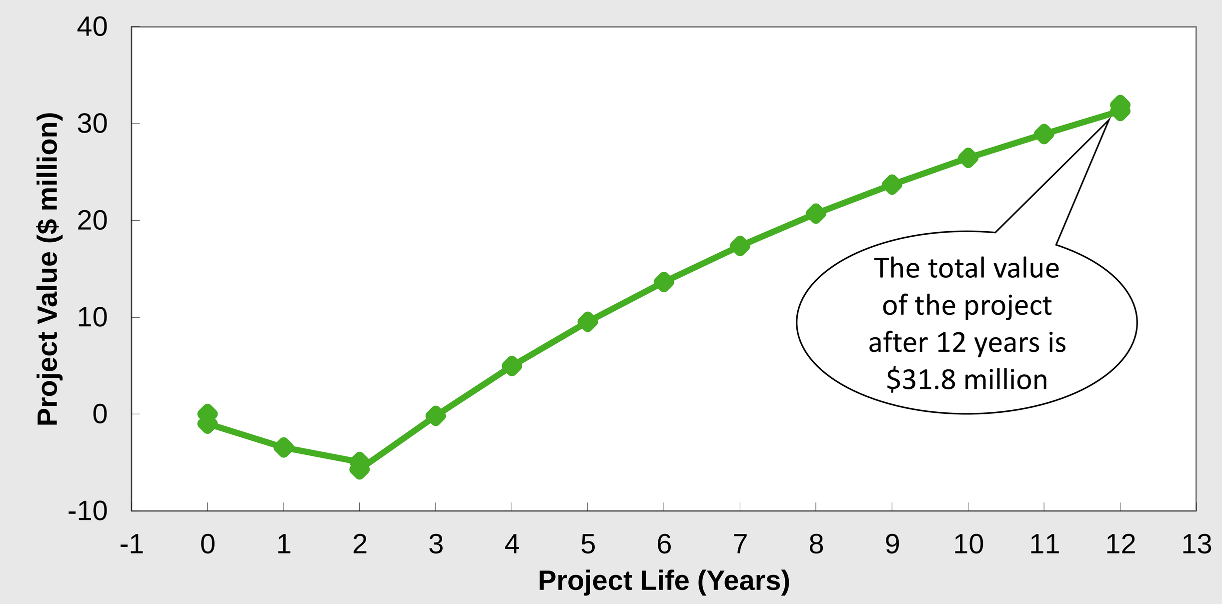
Over pressurized systems

## Energy-Use and Economics

- ❑ The process requires **1061 kW** of electricity
- ❑ **5.3 tonnes** of $CO_2$ is captured through the air contactor per hour
- ❑ **26 tonnes** of $CH_4$ is required for thermal energy per hour, making up more than **99%** of the energy requirements
- ❑ **100%** of $CO_2$ formed from combustion is captured
- ❑ For every **1 gram of $CO_2$ emitted** from the process, **217 grams are captured**




## Conclusion & Recommendations

- ❑ The process produces 97.5% $CO_2$ at 13.4 ton/hr.
- ❑ The process results in a net value of $31.8 million
- ❑ The process is carbon negative

Recommendations

- ❑ Future work use renewable energy
- ❑ Future study on noise pollution

## References

Keith, D. W., Holmes, G., St. Angelo, D., & Heidel, K. (2018). A Process for Capturing CO2 from the Atmosphere. *Joule*, *2*(8), 1573–1594. https://doi.org/10.1016/j.joule.2018.05.006

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