Energy Recovery from CO_2 Expansion at BIFoR FACE

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Project Outline

Emergent Layer - Deliverables

To produce and present a business case to upgrade the CO2 expansion methods based on research.

Canopy Layer - Methodology

- Calculate the maximum energy released through carbon dioxide expansion and the heat required.
- Select a viable method of extracting work from the expansion of the CO2.
- Research local heat sources to vaporise and warm the CO2 to ambient conditions.
- Develop a cost and environmental impact focussed business case to upgrade the facility.

Understory Layer - Objectives

The aim of showing the feasibility of reducing the electrical consumption at BIFoR FACE will be achieved by:

- Generating electricity from the expansion of CO_2.
- Reducing the electrical energy requirement for heating.

Forest Floor - Background

- The current fumigation system, designed in the 1990s, uses electrical heat exchangers.
- During fumigation, more than 200 tonnes of air-CO_2 mixture is used daily.
- The average annual electrical consumption is 220,000 kWh, costing approximately £35,000 per year.
- The plan is to elevate atmospheric CO_2 every growing season until 2026.

Maximum Energy Calculation

Considering high pressure liquified carbon dioxide as cryogenic energy store. Using initial and final temperature and pressure of CO_2 at BIFoR, theoretical maximum work output from expansion (exergy) calculated as **574 kWh per day** during fumigation.

Water Heat Source

- Water density means large potential for energy extraction.
- Local proximity to Shropshire Union Canal Main Line.
- Heat extraction from 6 tonnes of water to produce required daily energy.
- Flow determined by movement of water through locks.

Ground Heat Source

- Fluid pipes buried underground.
- Less annual variation in energy production.
- High initial costs and environmental damage.

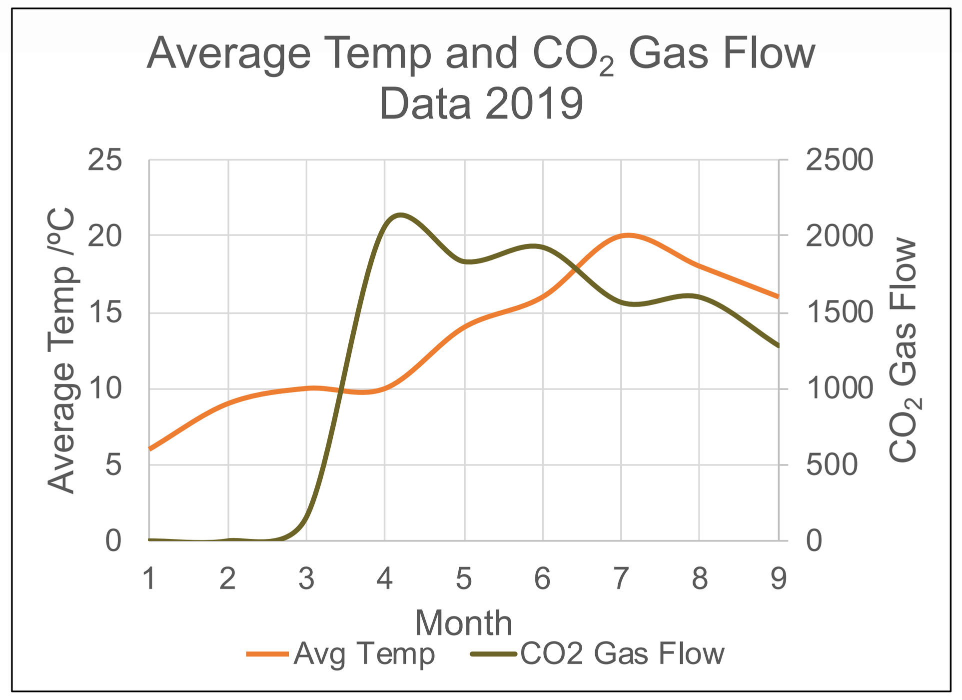
Solar Collector

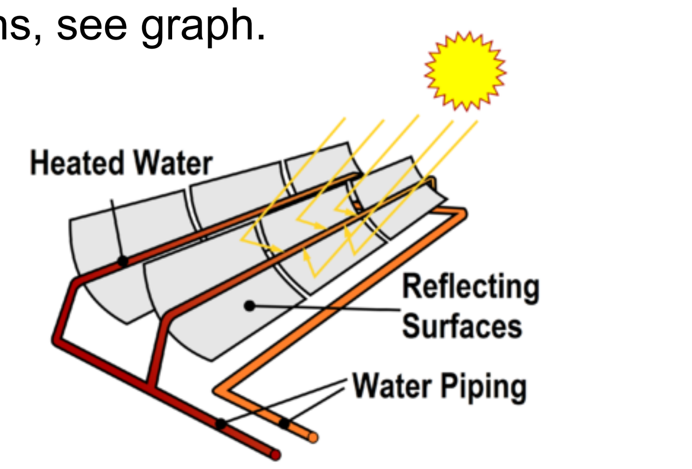
- Greatest efficiencies at temperatures close to ambient.
- Open land adjacent to Mill Haft Forest potential location.
- Low cost and minimal environmental damage.

- Adiabatic expansion reduces gas temperature.
- Heating required to avoid saturation and sublimation of gaseous carbon dioxide.

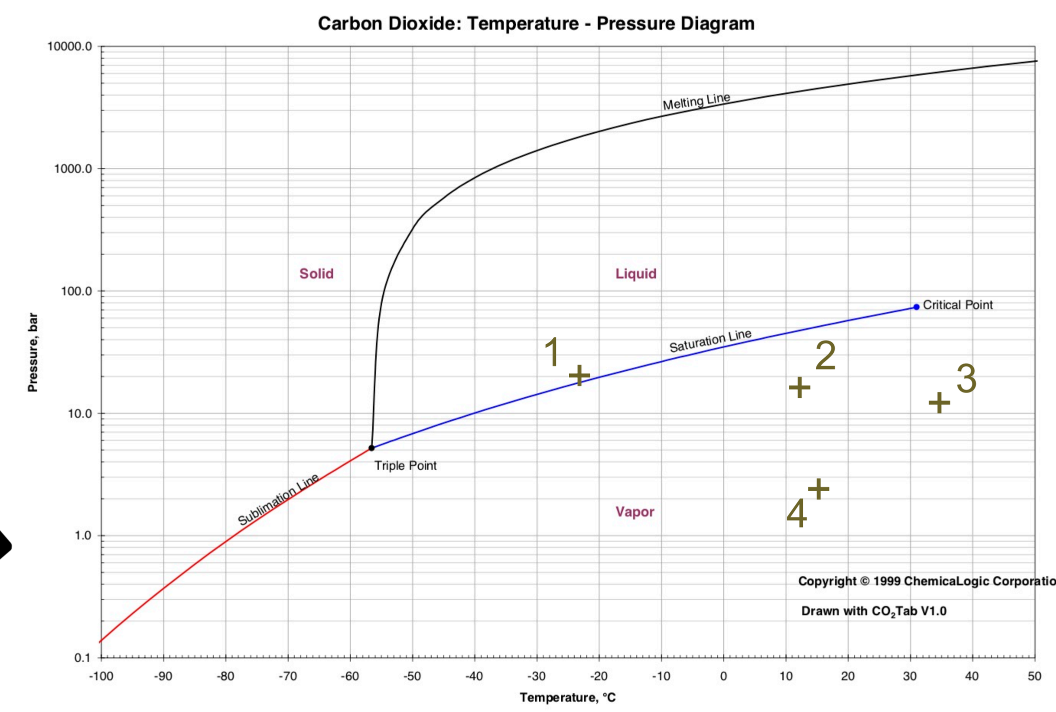
Solar Collector

- Solar radiation focussed to heat fluid, either liquified carbon dioxide or heat exchange fluid.
- Greatest efficiencies at temperatures close to ambient.
- Low initial and maintenance costs.
- **2.3% reduction in energy** usage at BIFoR in 2018, resulting from warmer average temperatures.
- CO_2 fumigation greatest during warmest months, see graph.



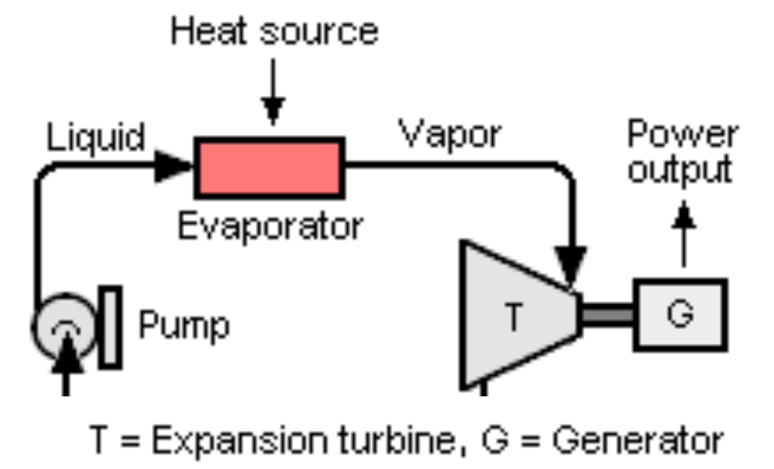


Focussed solar collector diagram courtesy of Energy Education



Carbon dioxide temperature-pressure of current system, diagram courtesy of ChemLogic

Turboexpander



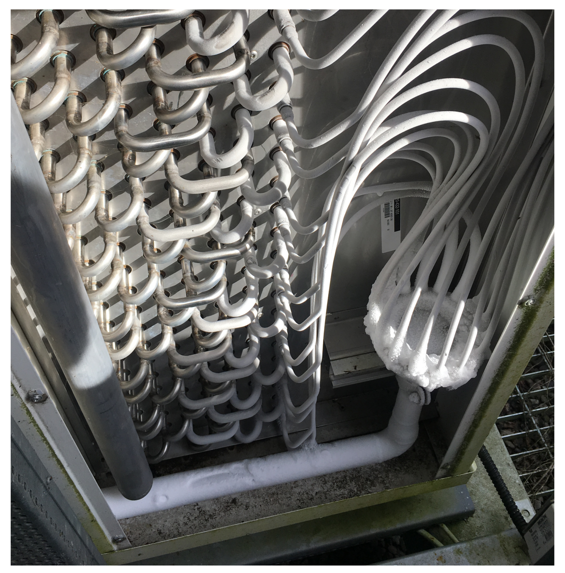
Schematic diagram of turboexpander. Diagram courtesy of Wikiwand

- High pressure fluid (CO_2 from storage tank) vaporised in evaporator by heat exchanger.
- High pressure vapour undergoes isentropic expansion in turboexpander.
- Work output from turbine used to generate electricity.
- Utilises energy removed from system during depressurisation.
- Greater energy output for high temperature difference.

Current System at BIFoR

Storage Tanks

- 3 CO_2 storage tanks
- Liquefied CO_2 storage
- 1. Pressure 1725 kPa
- 1. Temperature -22ºC



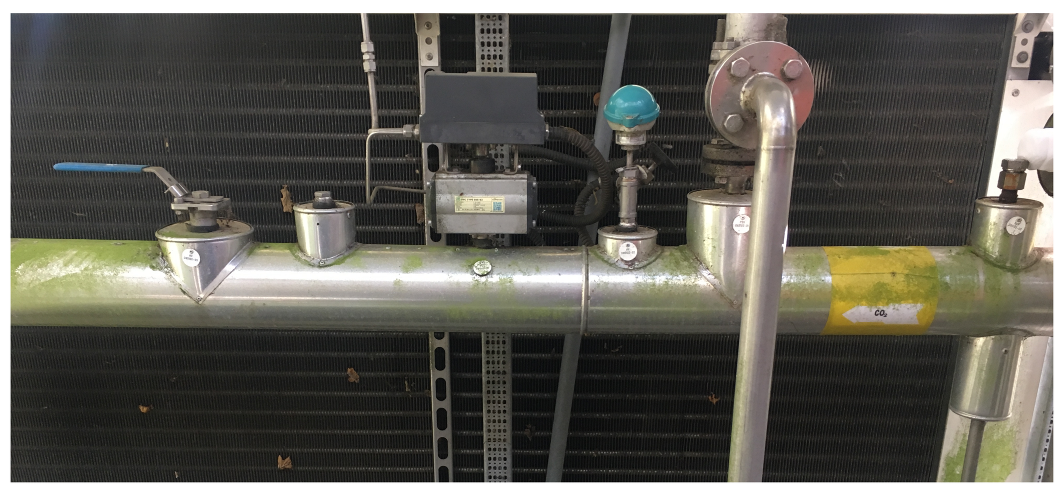
Kelvion Searle evaporator fans and side profile of heat exchanger tubes

Evaporators

- Carbon dioxide vapourised
- 4 units, each with 2 fans
- Kelvin Searle KME commercial evaporator
- Use heat from ambient air
- Capacity 1.5 tonnes per hour per unit
- Heaters used alternately to prevent ice accumulation
- 2. Pressure 1725 kPa
- 2. CO_2 Temperature 12.8ºC
- Ambient temperature 14ºC
- Currently fans in wrong direction to utilise benefits of solar heating

Super Heater

- Increases CO_2 temperature from 12.8ºC to 60ºC
- Highest electricity requirement of all system components



Pipes connecting carbon dioxide evaporators, super heater and decompressors. Flow controlled via pneumatic actuators

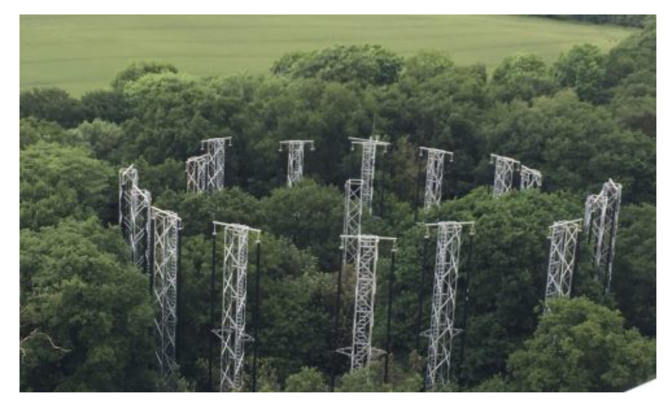
Decompressor

- Two stage system
- 3. Stage 1 - Pressure 1500 kPa
  - Temperature 35ºC
- 4. Stage 2 - Pressure 250 kPa
  - Temperature 15ºC

Pipes transporting CO_2 air mixture, elevated from forest floor

Plenum

- Gaseos CO_2 transported to plenum through metal pipes
- Ambient temperature
- CO_2 mixed with air at array location
- CO_2-air mixture released to maintain 547.7ppm CO_2 level target



One of the Arrays. Image courtesy of BIFoR