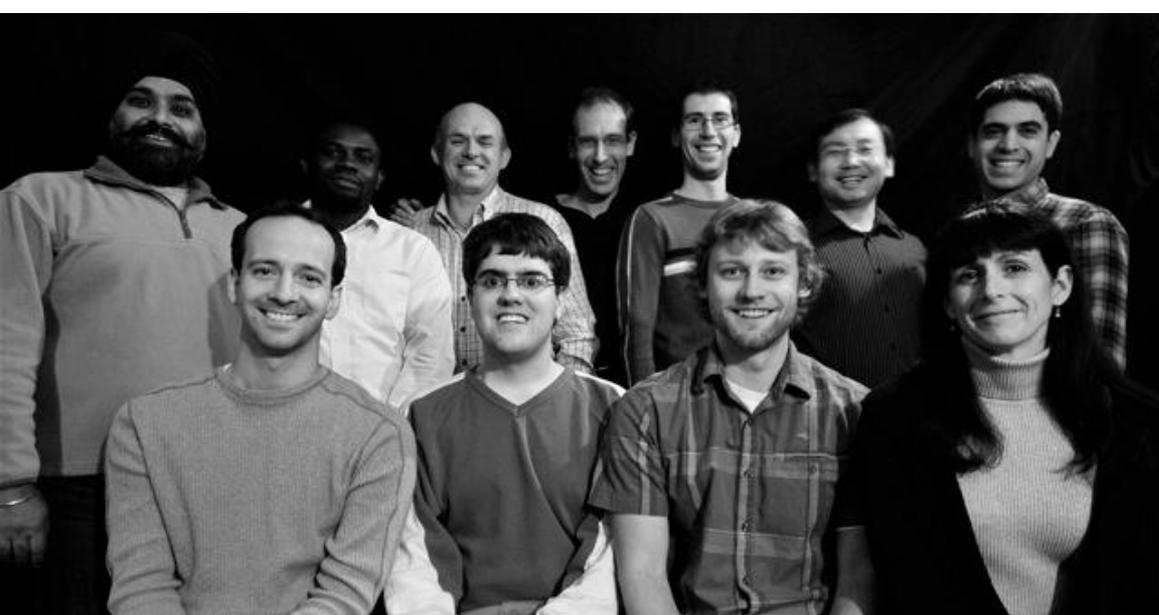




Carbon  
Engineering

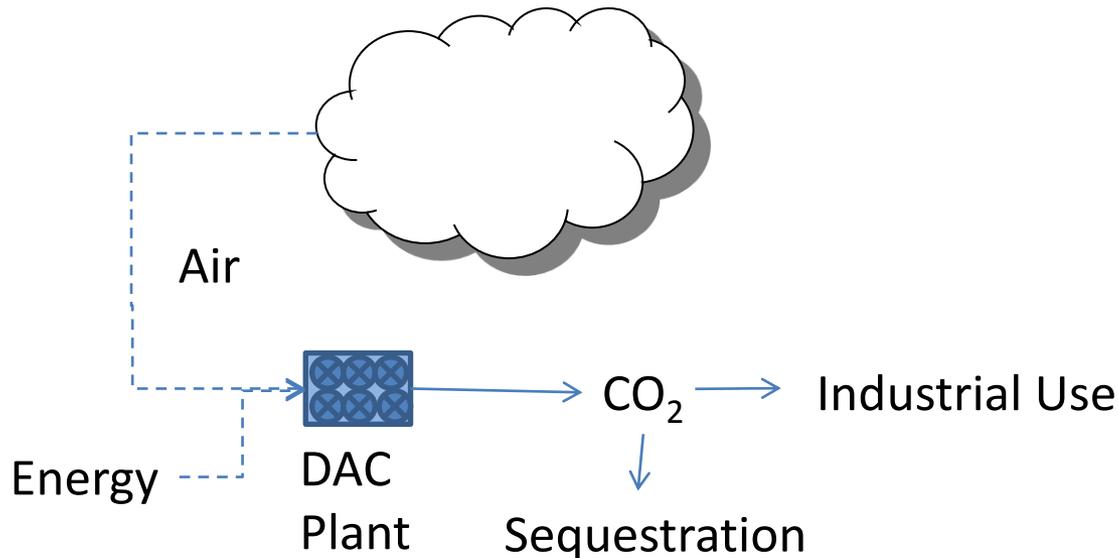


# Carbon Engineering Ltd

- Calgary Based Company
- Privately funded early stage company formed in 2008
- 11 employees; scientists & engineers
- CE is developing a CO<sub>2</sub> Direct Air Capture Technology based on proven and scalable industrial processes bound together with unique IP
- CE Strategy to commercialise the DAC technology with specific focus on enabling the production of low carbon intensity hydrocarbon fuels.

# What is the Direct Air Capture of CO<sub>2</sub>?

- The Capture of large quantities of CO<sub>2</sub> from ambient air for industrial applications and/or sequestration.
- Differs from CCS in that it can be **located independently of a point source of CO<sub>2</sub>** such as flue gas – different commercial proposition
- DAC can be **deployed almost anywhere** producing CO<sub>2</sub> close to the point of use



# Why capture atmospheric CO<sub>2</sub>?

## Challenges

- Concentration of CO<sub>2</sub> in the air is very low - 500 ppm CO<sub>2</sub> processed in DAC compared to > 5% in post combustion gasses
- Very large volumes of air must be ingested to produce industrial quantities of CO<sub>2</sub>
- Production cost/ton for DAC CO<sub>2</sub> will be higher than for natural sources and CCS

## Opportunities

- **Environmentally:** DAC can address the 60% of total CO<sub>2</sub> emissions that doesn't come from point sources
- **Strategically:** DAC CO<sub>2</sub> is **Carbon Negative** therefore products made from DAC CO<sub>2</sub> are considered to have much lower carbon intensity - commercial premium
- **Commercially:** DAC CO<sub>2</sub> offers opportunity to produce low carbon intensity fuels from CO<sub>2</sub> EOR, emerging Biofuels technology and longer term as part of the commercialisation of large scale air to fuel technology.



# CE Air Contactor Prototype

- Located in Calgary
- Proven 100 Kg per day CO<sub>2</sub> capture
- Next stage; 500 t/year fully integrated DAC Pilot Unit

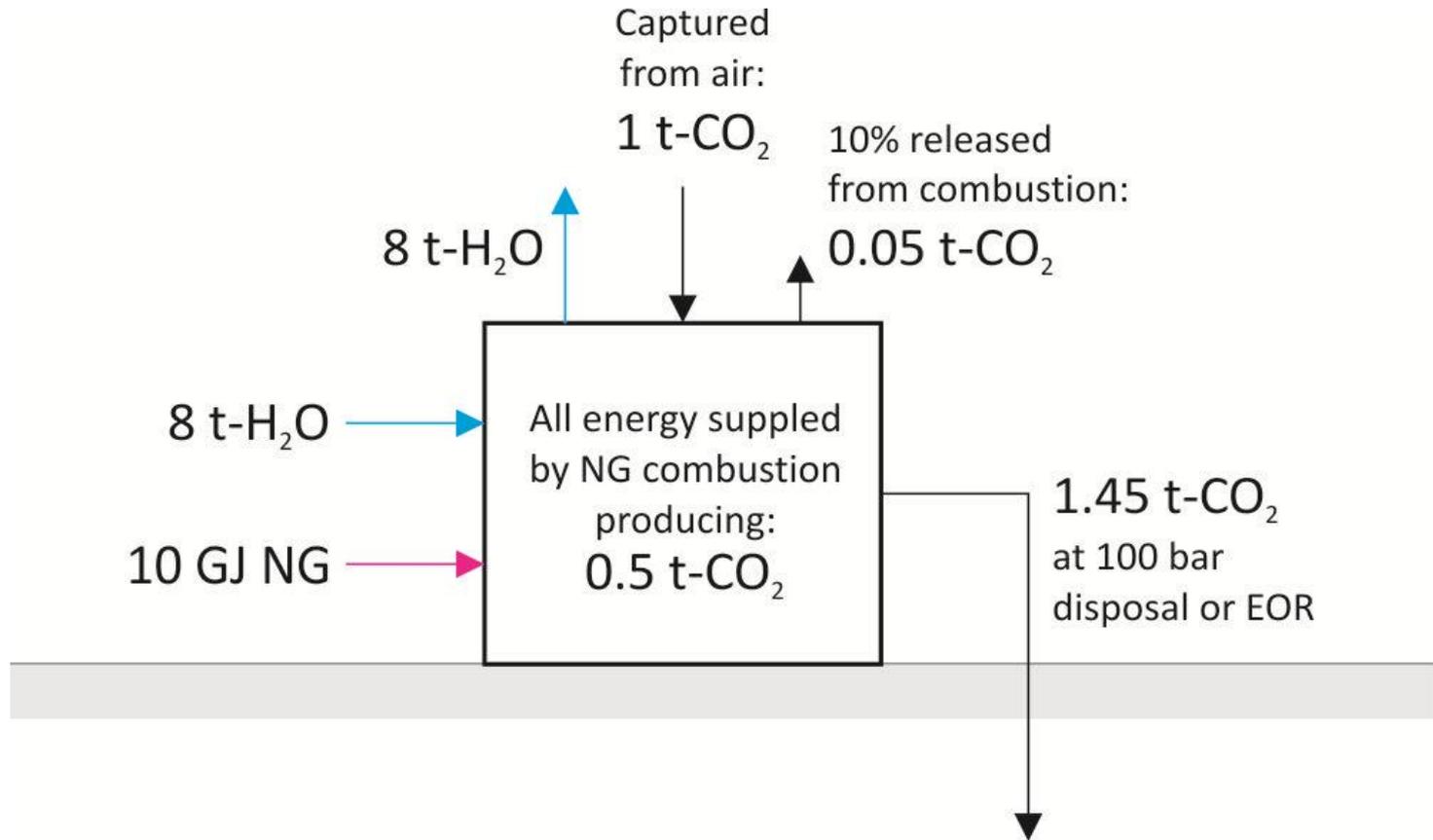


# LNG Vaporization Tower



**LNG Heating Tower**  
**~25m high x ~200m long**  
**→ Same size as 100k t CE Slab**

# DAC, Energy and Carbon Balance Schematic



## Energy for capture

Current amine technology: 3 GJ/t-CO<sub>2</sub>

NaOH thermodynamic limit: 2.5 GJ/t-CO<sub>2</sub>

Thermodynamic limit for CO<sub>2</sub> from air to 1 bar: 0.45 GJ/t-CO<sub>2</sub>

This is an illustrative schematic only. CE is looking at several different configurations, some of which use more or less and 10 GJ per ton.

# What are the markets for DAC CO<sub>2</sub>?

## DAC CO<sub>2</sub> for enhanced oil recovery

- Large and growing market for CO<sub>2</sub> (currently 50M t/year in Texas)
- Delivers lower carbon intensity oil - exploitation of existing and emerging regulatory frameworks

## DAC CO<sub>2</sub> for algal biofuel production

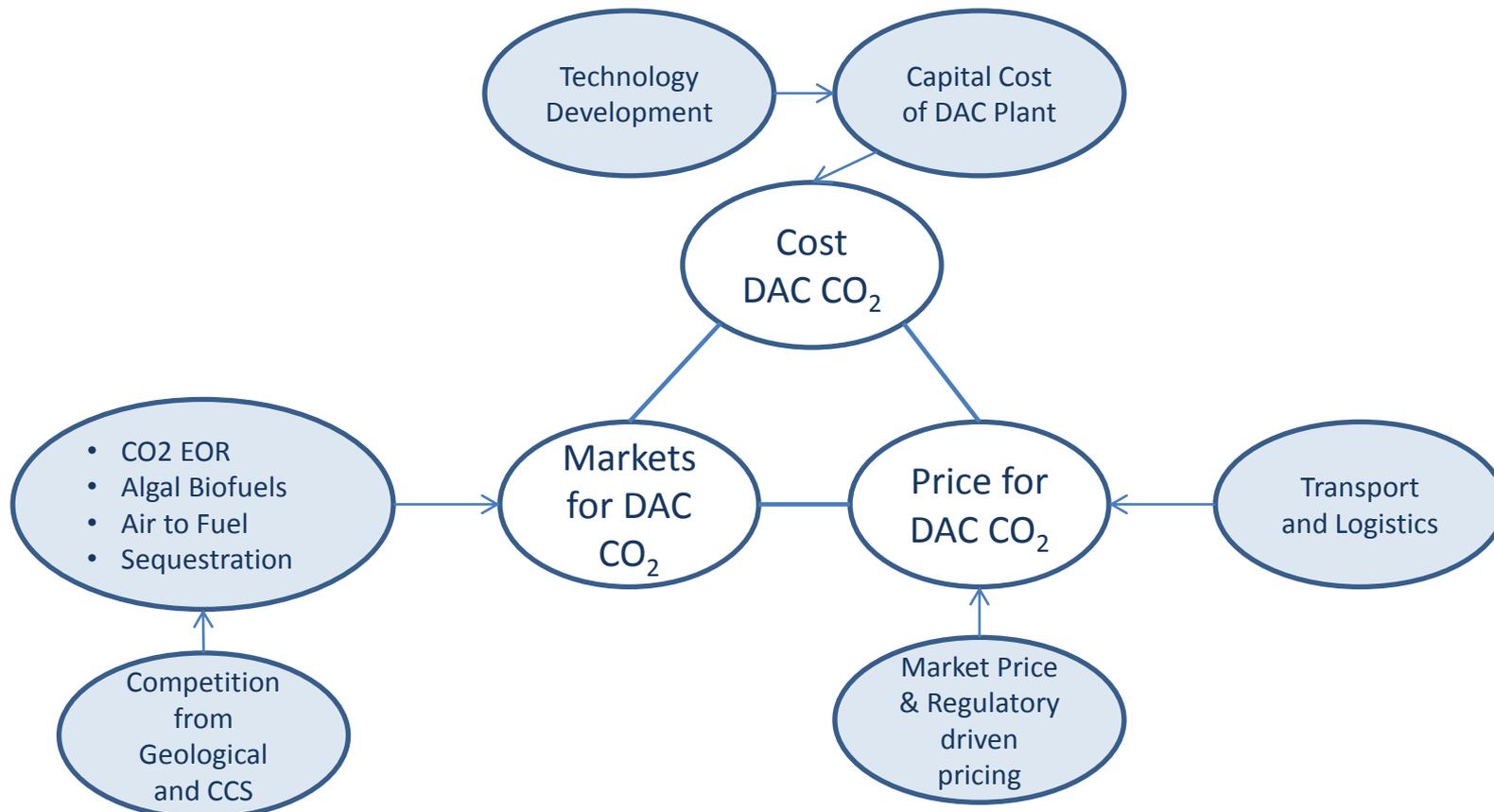
- Emerging market with rapidly developing technologies
- All have in common the requirement for CO<sub>2</sub>
- DAC offers locally produced CO<sub>2</sub> and exploitation of additional Carbon Negative value from DAC CO<sub>2</sub>

## DAC CO<sub>2</sub> for Air to Fuels production

- Longer term strategic market; non replaceable hydrocarbon fuels for aviation and remote vehicle use
- DAC CO<sub>2</sub> plus H<sub>2</sub> with energy from renewables or nuclear to produce completely carbon neutral hydrocarbon fuels

# How will DAC CO<sub>2</sub> be commercial?

- Challenge; introduce a developing technology into an undeveloped market, many factors are coming into play:



# DAC CO<sub>2</sub> for Enhanced Oil Recovery

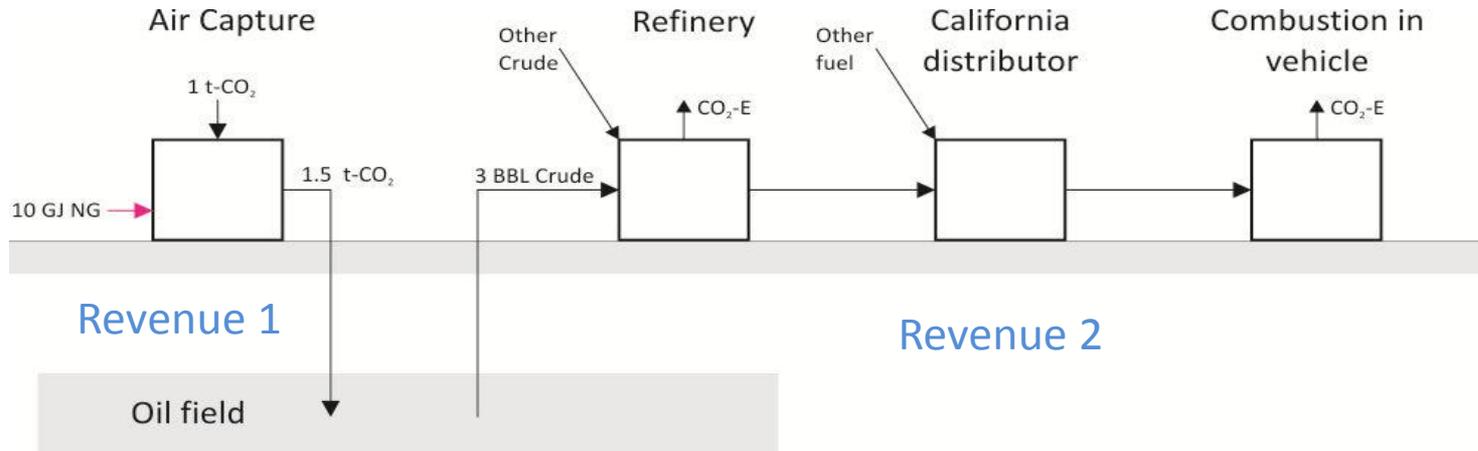
## Utilising Californian Low Carbon Fuel Standard

- LCFS effectively states that all fuels imported into California must have a Carbon intensity of less than 95 gm- CO<sub>2</sub> e/MJ on a well to wheels basis.
- Fuels that exceed this CI must be “blended” with lower CI fuels in order to achieve the LCFS specification
- The regulation is designed to progressively reduce the CI limit thereby stimulating the development, production and transportation of lower CI fuels into California.



- DAC CO<sub>2</sub> used in EOR can be used to deliver conventional oil with a lower CI than oil produced with either geologically or CCS sourced CO<sub>2</sub>
- Under the LCFS regulation this will give DAC CO<sub>2</sub> a significant price premium that increases as the CI limit is reduced.
- The European Fuel Directive and other regulatory structures will likely operate in a similar way.

# DAC CO2 revenue model



Wells-to-Wheels Carbon Intensity	Conventional Fuel Pathway	DAC with EOR Fuel Pathway
<b>CO<sub>2</sub> captured from atmosphere</b>		<b>-56.2</b>
CO <sub>2</sub> Transport		1
Crude Recovery	6.9	6.9
Crude Transport and Storage	1.1	1.1
Crude refining to Gasoline	13.7	13.7
Gasoline Transport and Storage	0.4	.4
Gasoline combustion in vehicle	72.9	72.9
<b>Well-To-Wheels Total</b>	<b>95.1</b>	<b>39.8</b>

- DAC CO2 EOR could deliver crude oil with a CI of 39.8 gm- CO<sub>2e</sub> /MJ
- This represents a highly valuable “blending” stock
- Current price equivalent for CO<sub>2</sub> is about \$20/t under the Californian LCFS
- Independent assessments indicate that this could be >\$100/t CO<sub>2</sub> within 5 years

# DAC CO<sub>2</sub> EOR Revenue

<b>Present Day</b>	<b>\$/t CO<sub>2</sub></b>
CE DAC CO <sub>2</sub> (Capex, Opex and Financing)	\$70
R1 Market Price CO <sub>2</sub>	\$45 (1.5 x market)
R2 LCFS Revenue CO <sub>2</sub> e	\$20 (current price)
R1 + R2 Total Revenue	\$65
Net	-\$5

<b>5 year horizon</b>	<b>\$/t CO<sub>2</sub></b>
CE DAC CO <sub>2</sub> (Capex, Opex and Financing)	\$70
R1 Market Price CO <sub>2</sub>	\$45 (1.5 x market)
R2 LCFS Revenue CO <sub>2</sub> e	\$100 (5 year forecast)
R1 + R2 Total Revenue	\$145
Net	\$75

# Summary

- Large Scale CO<sub>2</sub> DAC is technically viable
- CE is developing a DAC technology utilising proven industrial technology with a low technical risk
- CE will have commercial pilot plant in operation by the end of 2014
- The key markets will be in the production of low carbon intensity fuels and these are potentially huge markets
- The commercial potential of these markets for DAC is dependent on the continued development of the carbon pricing - regulatory frameworks globally.