2018 Sustainability Lab Project

Presented by:

Meghan Wright
Lee Stroman
Nicolas Favier
Ivy Willyams

May 17, 2018

MIT MANAGEMENT SLOAN SCHOOL

Contents

Problem Statement

Allagash produces CO2 during the beer fermentation process and would like to reduce these emissions to <u>zero.</u>

- Allagash currently purchases approximately 300 tonnes or 600,000 lbs of CO2 per year mainly for beer carbonation from an ethanol plant in NY
- CO2 recovery has typically been performed by larger breweries and is rarely implemented by craft breweries
- Our analysis will help Allagash better understand feasible pathways for CO2 recovery from the fermentation process to be used for carbonation.

Company Sustainability

"From our beginning as a one-person operation in 1995, Allagash has focused on being an environmentally and socially responsible member of the community. " [15]

Reducing CO2 emissions feeds into their overall goals of reducing waste and using less resources.

Executive Summary

Under current conditions, a recovery system is not financially feasible. At present, Allagash consumes 50% more CO_2 than it is able to recover through its beer fermentation process. If Allagash were to install a CO_2 recovery system under current conditions, they would need to continue purchasing CO_2 from their supplier at a cost of $0.22/lb in order to supplement their recovered CO_2, yielding negative financial results. The ratio of recovered CO_2 to consumed CO_2 must increase to at least 85% in order to make the project financially feasible.

If a CO2 recovery system were installed, Allagash would only reduce the CO2 emissions generated by transportation of purchased CO2, which at present produces ~29 tonnes of CO2 per year. Allagash will not reduce overall emissions through CO_2 recovery because (1) their supplier produces CO_2 as a byproduct and would either find a new buyer for Allagash's non-purchased CO_2 or emit it into the atmosphere and (2) Allagash's recovered CO_2 will still be released into the atmosphere during the beer consumption stage.

Key Insights

- Allagash needs to hit 85% production/consumption CO_2 ratio to be financially feasible
- CO_2 offsets are a short term solution
- CO_2 production monitoring will help Allagash to better understand their production and consumption of CO_2

Methodology

Planning

- Stakeholder Mapping within Allagash
- Identify information sources and potential case studies
- Adjust project plan as needed

Data/Info Gathering

- Current State Analysis – Allagash Manufacturing process
- Case Studies (Maui Brewing, Pentair Haffmans, Lolo Peak Brewing etc.)
- Recovery technology and benchmarking
- CO_2 Research (Market Analysis, regulations/standards)

Analysis Phase

- CO_2 lifecycle map and casual loop diagram
- Financial Analysis (DCF)
- Carbon Footprint analysis
- Feasibility study

Deliverables

- Financial and production model to assess feasibility and track CO_2 consumption and production in the future
- Alternative CO_2 reduction strategies assessment
- Final model and presentation

Analysis Frameworks

Framework / Analysis	Description / Purpose	Limitations
Incremental Cash Flow Analysis	Analyzes difference between current state and future state with CO_2 recovery system. Determines NPV.	Reliability and availability of financial assumptions (quotes provided by technology suppliers)
Causal Loop Diagram	Maps broader CO_2 network and potential feedback loops resulting from CO_2 recovery.	Simplified model and therefore for informational purposes only. Dependent on system boundary chosen.
Production Analysis Tool	Develops understanding of current CO_2 production / consumption rates and enables future predictions.	Data is limited and currently collected manually.
Carbon Offset Calculations	Develops understanding of how Allagash donations reduce / offset CO_2 emissions.	Based on averages and estimated potential CO_2 reduction. Limited data on actual reduction.
Simplified Lifecycle Assessment	Develops better understanding of CO_2 footprint from Allagash beer production (scope 1, 2 and 3)	Limited data available and based on New Belgium Brewing LCA assumptions.

MIT MANAGEMENT SLOAN SCHOOL
ALLAGASH BREWING COMPANY

Understanding the craft beer CO2 recovery landscape

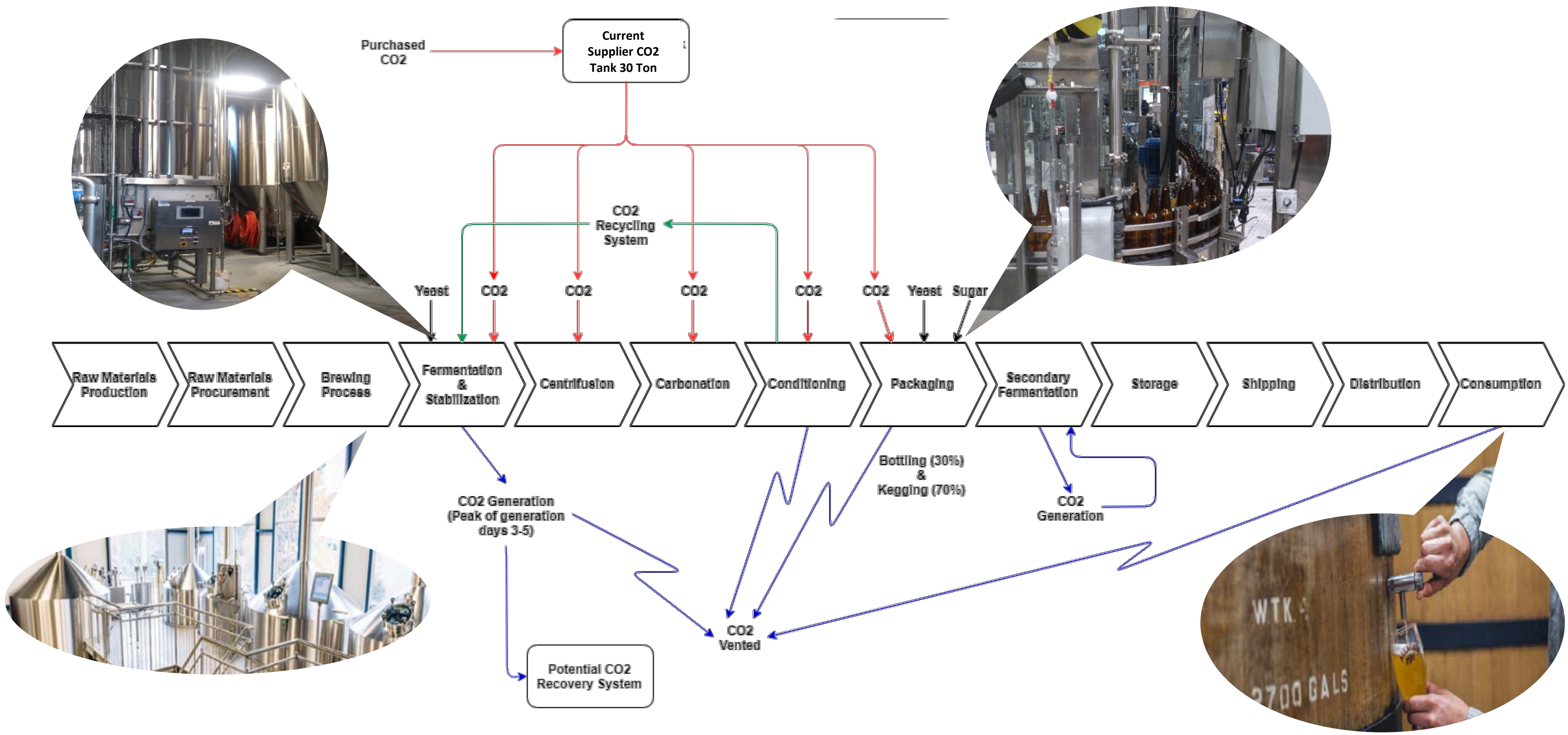
Brewing Company	Location	Annual Beer Production (Barrels)	CO2 Purchased (tonnes/y)	CO2 Recovery Potential	Technology Partner	Installation Date
Allagash Brewing Company	Portland, Maine	100,000	300	150 tonnes/y	TBD	TBD
Maui Brewing Company	Honolulu, Hawaii	53,000[1] (capacity to produce 100,000 in future[2])	Not available	Up to 600,000 lb/y[3] (300 tonnes/y)	Vendor 1	Installation in progress
Alaskan Brewing Company	Juneau, Alaska	150,000 (2013)[4]	Not available	783,000 lb/y (2009)[5] (500 tonnes/y)	The Wittemann Company (acquired by Union in 2013)	1998[5]
Widmer Brothers Brewery	Portland, Oregon	450,000[6]	Not available	Not available	Vendor 2	Sep 2017[7]
Matt Brewing Company (Saranac and other brands)	Utica, New York	500,000 (2014)[8]	Not available	545kg/h system[9] ~3500-4000 metric tonnes/y (estimate)	Pentair Haffmans through ICC Engineering	Q4 2016[9]
Brewery Vivant	Grand Rapids, Michigan	5,105[10]	19.6[10]	6.2 tonnes/y[10]	CASEQ[11]	Installation in progress
Lolo Peak Brewing Company	Lolo, Montana	1,200 Barrels[12]	Not available	70,000 ft^3/y (3.6 metric tonnes/y)[12]	COBrew[12]	Q4 2017

<u>Notes:</u> Less recent data is marked with the appropriate year. ICC Engineering provides turnkey project management and installation (not a technology supplier).

CO2 Production

ANALYSIS

Allagash produces and consumes CO2



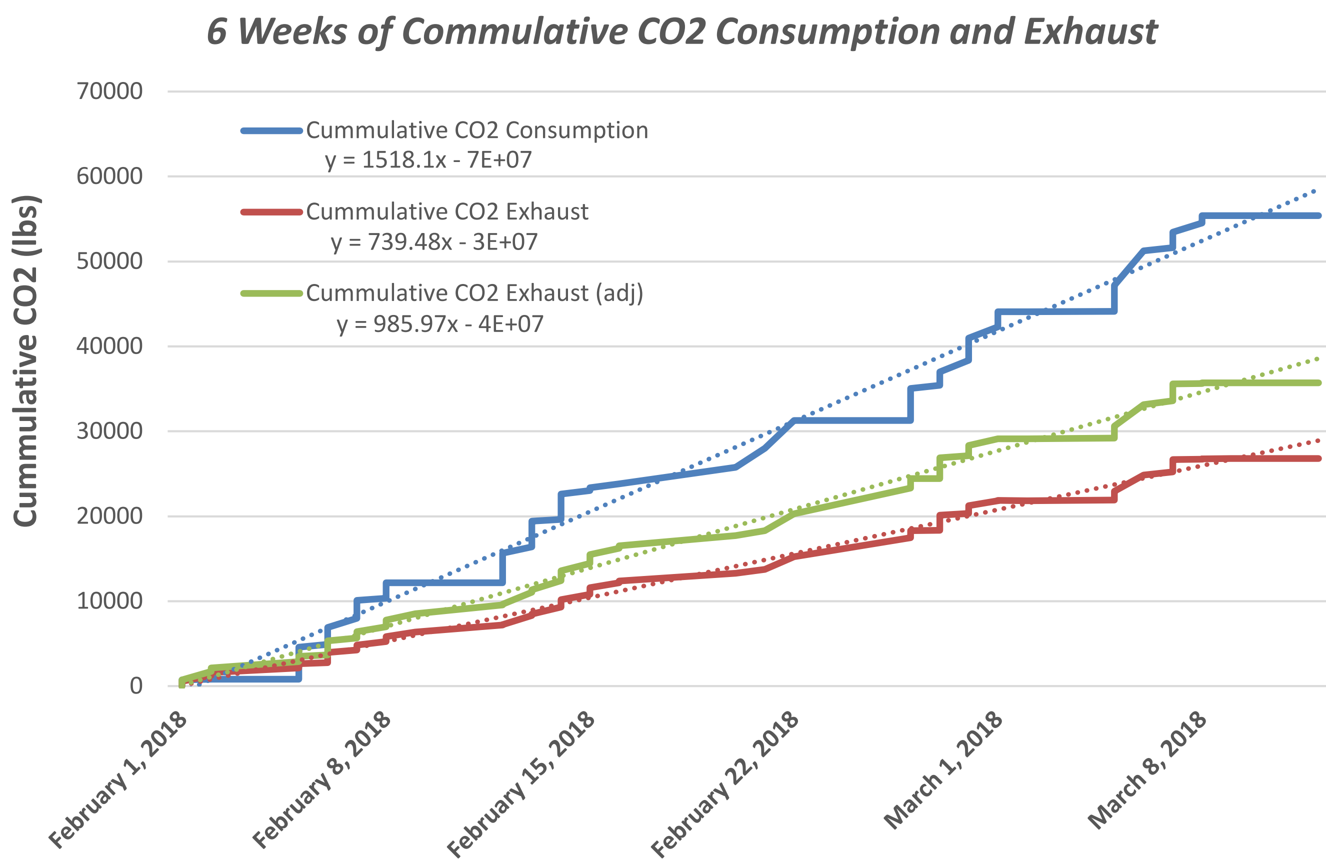
CO2 that is used for carbonation will eventually be exhausted at the consumer level.

MIT MANAGEMENT SLOAN SCHOOL

ALLAGASH BREWING COMPANY

Allagash consumes more CO2 than it produces

- Exhaust measures the CO_2 production from fermentation on the 75% of tanks connected to the central exhaust line
- All other tanks vent to atmosphere via a hose and bucket
- The adjusted exhaust estimates CO_2 production if all exhaust was captured
  – *65% of consumption is produced*



Allagash currently consumes CO2 at a rate double the exhaust rate

MIT MANAGEMENT SLOAN SCHOOL   ALLAGASH BREWING COMPANY

Monthly Production Analysis

Week	# Batches	CO2 Estimated (lbs)	CO2 Exhaust	CO2 Exhaust/Estimate Ratio	CO2 Use	Exhaust/Consumption Ratio
1	24	6,224.1	5,017.9	0.81	10,434	0.48
2	24	6,224.1	6,114.1	0.98	14,479	0.42
3	24	6,224.1	4,193.8	0.67	5,547	0.76
4	24	6,224.1	4,406.3	0.71	12,818	0.34

*the exact CO2 estimate formula is still being defined

This analysis template can be used to:

- Monitor trends associated with the weekly production schedule
- Identify how changes in process changes to production impact the exhaust and consumption of CO2
- Track progress on improving the estimate/exhaust yield and the ratio of exhaust to CO2 consumption

MIT MANAGEMENT SLOAN SCHOOL ALLAGASH BREWING COMPANY

CO2 Estimate in Production Planning

Tank	Inspected	Sanitized	Style	Yeast Notes	Brew #	Batches	Weight	Lay Base Water			End Chill	Brewer Initials	QC Notes	Other Notes	CO2 Production Estimate (lbs)
								Projected	Actual						
								Date/Time	Date/Time	Delay	Date/Time				
B13	df	df	White	....	14664	1	3475	1/29/2018 5:00	1/29/2018 5:00	0:00	1/29/2018 11:40	..	...	...	809.6
					14665	2	3475	1/29/2018 7:20	1/29/2018 7:30	0:10	1/29/2018 14:03				0
					14666	3	3475	1/29/2018 9:40	1/29/2018 10:00	0:20	1/29/2018 16:35				0
					14667	4	3475	1/29/2018 12:00	1/29/2018 12:35	0:35	1/29/2018 19:04				0
					14668	5	3475	1/29/2018 14:20	1/29/2018 15:10	0:50	1/29/2018 21:37				0
					14669	6	3475	1/29/2018 16:40	1/29/2018 17:40	1:00	1/30/2018 0:10				0
					14670	7	3475	1/29/2018 19:00	1/29/2018 20:05	1:05	1/30/2018 2:36				0
					14671	8	3475	1/29/2018 21:20	1/29/2018 22:35	1:15	1/30/2018 4:58				0
B8	hg	hg	white	...	14672	9	3475	1/30/2018 0:00	1/30/2018 1:20	1:20	1/30/2018 8:18				809.6
					14673	10	3475	1/30/2018 2:20	1/30/2018 3:45	1:25	1/30/2018 10:31				0
					14674	11	3475	1/30/2018 4:40	1/30/2018 6:10	1:30	1/30/2018 12:56				0

- This analysis estimates the CO2 production from fermentation and helps estimate how the CO2 exhaust volume can change with production rate.
- Tool is easily integrated into the existing production planning sheet (shown above) by adding the right column

The production planning tool will help to evaluate how much CO2 will be produced

Fermentation Production vs. CO2 in Final Product

Theoretical CO2 Exhaust Production	$\frac{368\ kg - CO_2}{70\ bbl} \cdot \frac{1\ bbl}{117\ L} = 0.045\ kg/L$

$$\geq$$

Average Carbonation Level of Final Product	$2.5\ \text{volumes} - CO_2 \cdot \frac{1.92\frac{g}{L}}{1\ volume} \cdot \frac{1\ kg}{1000g} = 0.0048\ kg/L$

- Reduction in CO2 used in non-final product applications can help Allagash attain a exhaust/consumption ratio that makes a recovery system financially feasible

Fermentation produces ~10% of the CO2 required for final product carbonation

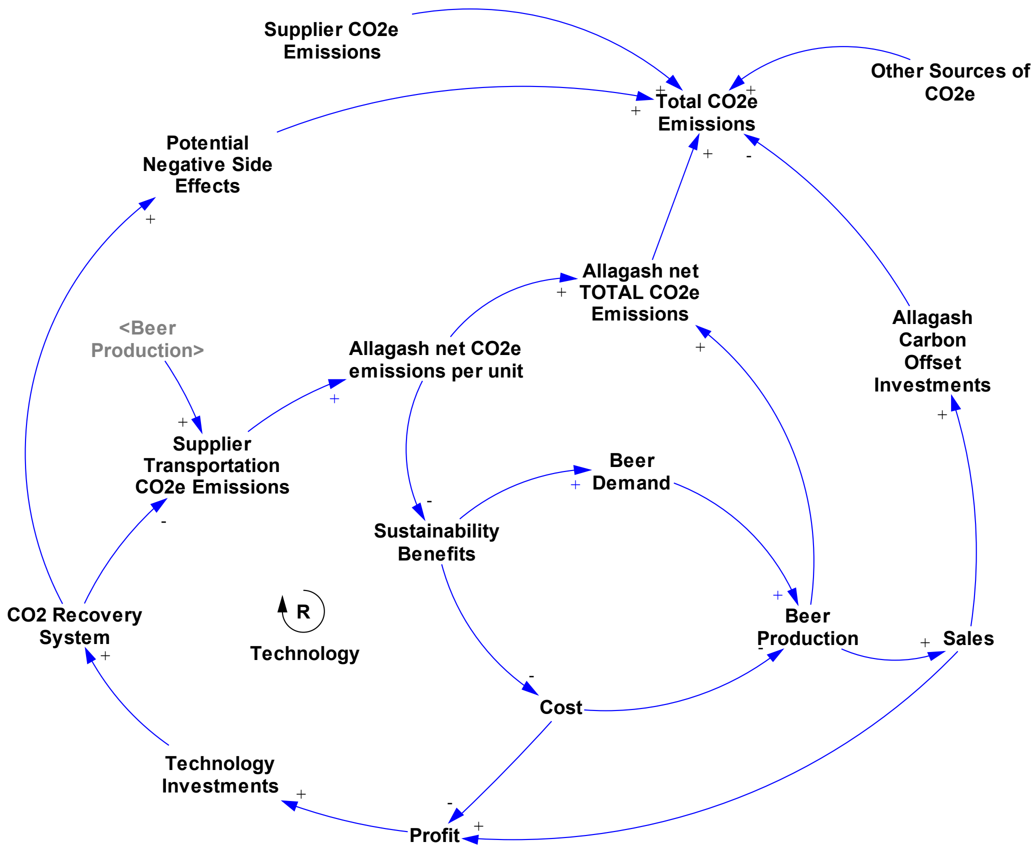
MIT MANAGEMENT SLOAN SCHOOL ALLAGASH BREWING COMPANY

CO2 Recovery

ANALYSIS

CO2 emissions on a broader level

Causal Loop Diagram:



Where:

+ Positive Relationship

- Negative Relationship

- Allagash and its current CO2 supplier contribute to the total CO2e emissions.
- By implementing a CO2 recovery system Allagash will eliminate or reduce CO2 purchases reducing the CO2e emissions due to transportation. However, due to the nature of the supplier process, CO2 not purchased will still be vented to the atmosphere or sold elsewhere.
- Recovered CO2 will still be vented to the atmosphere either during beer consumption or during bottling and cleaning processes.
- Allagash is helping to reduce CO2e emissions by some of its philanthropy initiatives (e.g. Window Dressers).

Allagash will not reduce overall emissions through CO2 recovery but it can reduce CO2e emissions from the transportation of purchased CO2

CO2 emissions on a broader level

Allagash will not reduce overall emissions through CO2 recovery but it can reduce CO2e emissions from the transportation of purchased CO2

$$\text{glucose} \xrightarrow{\text{yeast}} \text{ethanol} + \text{carbon dioxide}$$

$$C_6H_{12}O_{6(aq)} \xrightarrow{\text{yeast}} 2C_2H_5OH_{(aq)} + 2CO_{2(aq)}$$

[13]

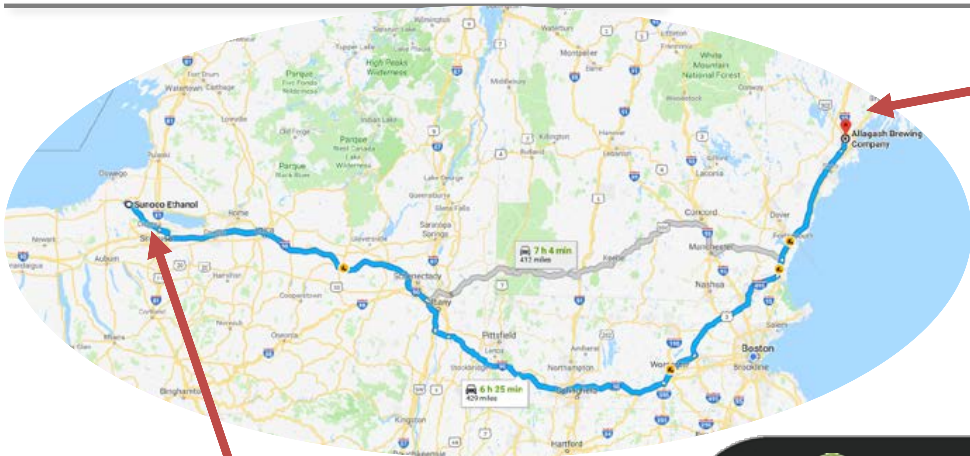
Byproduct of ethanol production

Unsold CO2 gets vented into the atmosphere with other byproducts such as steam

- Allagash's CO2 supplier is an ethanol plant.
- CO2 is a byproduct from ethanol production
- If Allagash stops buying the CO2 from that plant, the CO2 will still be released into the atmosphere as the plant still needs to produce ethanol

[13] Source: Pass my Exams - Chemistry

Allagash can reduce CO2e from transportation through CO2 recovery

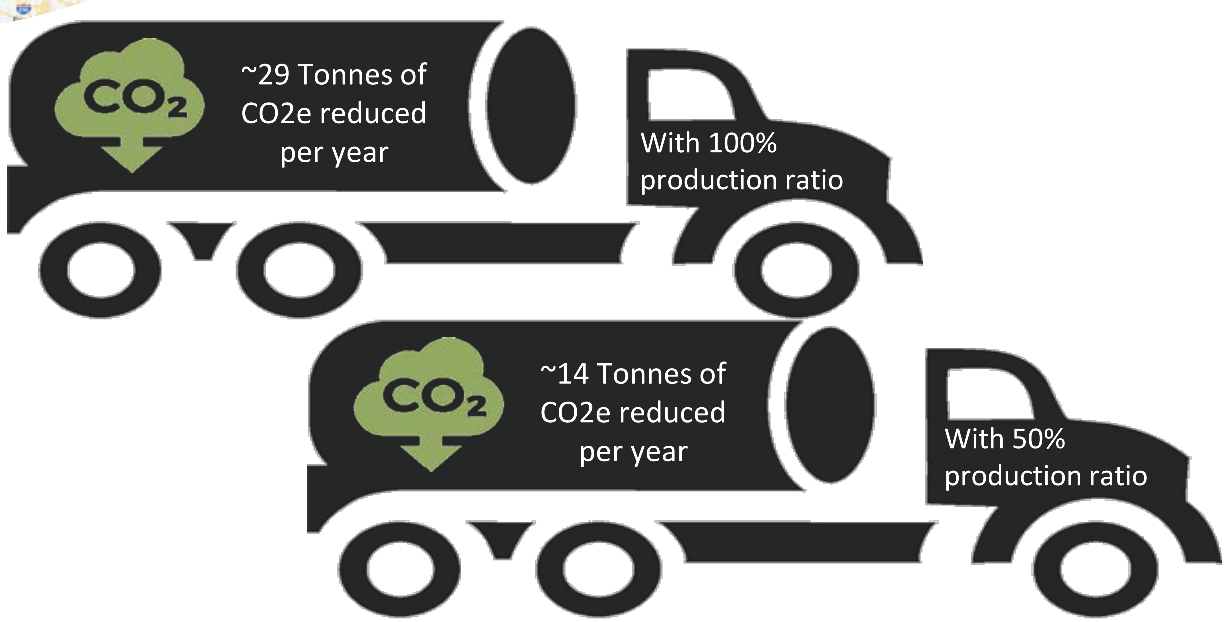


Allagash Brewery

Ethanol Plant in NY which Produces CO_2 as a by-product

428 miles per trip
21 two-ways trips per year

6.4 miles per gallon
10.16 kg CO2e per gallon



Reduction in CO2e due to transportation is proportional to the ratio between recovered CO_2 and Allagash's CO_2 consumption requirement

MIT MANAGEMENT SLOAN SCHOOL — ALLAGASH BREWING COMPANY

CO2 recovery projects yield negative financial results

Summary

- Incremental cash flow analysis was performed to determine incremental NPV of a CO2 recovery project (difference between current state and potential future state)
- Two quotes were provided to Allagash from Vendor 2 and Vendor 1 for CO2 recovery systems
- Recovery system pay back of 2-3 years is required; similar to other capital projects undertaken by Allagash
- Allagash would need to purchase the CO2 cryotank it currently leases from its current CO2 supplier in order to be able to store their own recovered CO2 in the tank

Quote	Contract Type	Payment Terms	Incremental NPV after 5 years	Cost of CO2 Emissions Reduction	Pay Back Met?
Vendor 2	Lease with ownership of system after 7 years	\$0.19/lb CO2 captured or minimum \$9k/month No installation cost	-\$151k	\$2,100/tonne	✗
Vendor 1	Purchase	Upfront capital investment of \$473.1k not incl. freight, installation	-\$242k	\$3,400/tonne	✗

Both projects result in negative NPV for Allagash and a high cost of CO2 emissions reduction

MIT MANAGEMENT SLOAN SCHOOL

ALLAGASH BREWING COMPANY

Key Financial Assumptions

The following assumptions are common in both projects:

- Cash flow analysis is performed over 5 years (difficult to plan for growth beyond even 3 years)
- NPV is calculated for the first 5 years without a terminal value, to enable Allagash to assess whether project pays back in the required 2-3 years
- A lifetime NPV with terminal value is also calculated separately but carries greater uncertainty
- CO_2 requirement grows 5% per year for the first 5 years, followed by 2% for the purpose of terminal value calculation
- The discount rate recommended by Allagash is 5%
- Cryotank lease payment remains constant in scenario where Allagash continues to purchase CO_2/lease cryotank from current supplier
- Recovery project is on line in 2019
- Cryotank is purchased from current supplier at $40k for recovery project
- Operating costs (electricity, water, glycol) are 10% of CO_2 purchase cost in current state (suggested by Stan at CASEQ)
- Additional 24 man hours of recovery system maintenance labor required per year at $20/h
- CO_2 production (recovery) is 50% of what is required by Allagash
- CO_2 requirement deficit is filled by continuing to purchase some CO_2 from current supplier
- The CO_2 purchase cost with current supplier is unchanged despite the reduced purchase amount

The Vendor 2 Lease to Ownership Model

Incremental Cash Flow Analysis

Quote: **Vendor 2**

	Current State	Actual	Projected					Extended Projection (Recovery System Owned)			
		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
CF in		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CF out	CO2 purchase	$ 133,228	$ 139,889	$ 146,884	$ 154,228	$ 161,939	$ 170,036	$ 173,437	$ 176,906	$ 180,444	$ 184,053
	CO2 purchase growth (%)		5%	5%	5%	5%	5%	2%	2%	2%	2%
	Cryotank lease	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877
	Cryotank lease growth (%)		0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	$ 144,105	$ 150,766	$ 157,761	$ 165,105	$ 172,816	$ 180,913	$ 184,314	$ 187,783	$ 191,321	$ 194,930
Net CF		$ (144,105)	$ (150,766)	$ (157,761)	$ (165,105)	$ (172,816)	$ (180,913)	$ (184,314)	$ (187,783)	$ (191,321)	$ (194,930)
PV CF			$ (150,766)	$ (150,248)	$(149,755)	$(149,285)	$(148,838)	$ (144,415)	$ (140,126)	$ (135,968)	$ (131,936)
NPV (after 5 years)			$ (748,892)								
NPV (after recovery system would be owned)			$ (1,301,337)								

	CO2 Recovery Project	Actual	Projected					Extended Projection (Recovery System Owned)			
	COD 2019	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	CO2 Requirement (lb)	601,470	631,544	663,121	696,277	731,091	767,645	782,998	798,658	814,631	830,924
	Average CO2 Required (lb/h)		72	76	79	83	88	89	91	93	95
	CO2 Requirement Growth (%)		5%	5%	5%	5%	5%	2%	2%	2%	2%
	CO2 Produced (lb)		315,772	331,560.34	348,138	365,545	383,823	391,499	399,329	407,316	415,462
	Average CO2 Produced (lb/h)		36	38	40	42	44	45	46	46	47
	CO2 Produced Growth (%)		5%	5%	5%	5%	5%	2%	2%	2%	2%
	Difference		(315,772)	(331,560)	(348,138)	(365,545)	(383,823)	(391,499)	(399,329)	(407,316)	(415,462)
CF in	CO2 Sale Price ($/lb)			$0.22	$ 0.22	$ 0.22	$ 0.22	$ 0.22	$ 0.22	$ 0.22	$ -
	CO2 Sale Price Growth (%)				$ -	$ -	$ -	$ -	$ -	$ -	$ -
	CO2 sales		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CF out	CO2 cost from ICC			$ 0.19	$ 0.19	$ 0.19	$ 0.19	$ 0.19	$ 0.19	$ 0.19	$ -
	Recapture system capital investment		$ -							$ 1	
	Cryotank purchase		$ 40,000								
	CO2 purchase (through recovery)		$ 139,889	$ 108,000	$ 108,000	$ 108,000	$ 108,000	$ 108,000	$ 108,000	$ 108,000	$ -
	CO2 purchase (Matheson)			$ 73,442	$ 77,114	$ 80,970	$ 85,018	$ 86,719	$ 88,453	$ 90,222	$ 92,026
	Maintenance Labor (24hrs per year)			$ 480	$ 480	$ 480	$ 480	$ 480	$ 480	$ 480	$ 480
	Recovery System Electricity, Water, Glycol Use			$ 14,688	$ 15,423	$ 16,194	$ 17,004	$ 17,344	$ 17,691	$ 18,044	$ 18,405
	Total		$ 179,889	$ 196,610	$ 201,017	$ 205,644	$ 210,502	$ 212,542	$ 214,623	$ 216,747	$ 110,912
Net CF			$ (179,889)	$ (196,610)	$ (201,017)	#######	$(210,502)	$(212,542)	$ (214,623)	$ (216,747)	$ (110,912)
PV CF			$ (179,889)	$ (187,248)	$(182,328)	$(177,643)	$ (173,180)	$(166,532)	$ (160,155)	$ (154,038)	$ (75,069)
NPV (after 5 years)			$ (900,288)								
NPV (after recovery system is owned)			$(1,456,084)								

Terminal Value (Projecting After Recovery System is Owned)

Long term growth rate	2%
Incremental CF in 2027	$ 85,698
Terminal Value	$ 2,856,610
Discounted Terminal Value	$ 1,933,466

Inputs

Discount Rate	5%
Sell CO2 (0 for no or 1 for yes)	0
CO2 Production/Consumption	0.5
CO2 Transportation Savings (tonnes/y)	28.5
CO2 Cost	$0.22

Outputs

Incremental Net Present Value (NPV) after 5 years	$ (151,000)
Incremental NPV + Terminal Value	$ 1,779,000
ROI (NPV - Capital Investment / Capital Investment)	-478%
Estimated CO2 Transportation Savings (tonnes/y)	14.3
Cost of CO2 Reduction ($/tonne)	$ 2,100

The lease agreement with Vendor 2 results in a negative NPV of -$151k in the first 5 years and the estimated cost of CO2 reduction is $2,100/tonne.

MIT MANAGEMENT SLOAN SCHOOL

ALLAGASH BREWING COMPANY

The Vendor 1 Purchase Model

Incremental Cash Flow Analysis

Quote: Vendor 1

	Current State	Actual 2017	Projected 2018	2019	2020	2021	2022
CF in		$ -	$ -	$ -	$ -	$ -	$ -
CF out	CO2 purchase	$ 133,228	$ 139,889	$ 146,884	$ 154,228	$ 161,939	$ 170,036
	CO2 purchase growth (%)		5%	5%	5%	5%	5%
	Cryotank lease	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877	$ 10,877
	Cryotank lease growth (%)		0%	0%	0%	0%	0%
	Total	$ 144,105	$ 150,766	$ 157,761	$ 165,105	$ 172,816	$ 180,913
Net CF		$ (144,105)	$ (150,766)	$ (157,761)	$ (165,105)	$ (172,816)	$ (180,913)
PV CF			$ (150,766)	$ (150,248)	$ (149,755)	$ (149,285)	$ (148,838)
NPV			$(748,892)				

Inputs	
Discount Rate	5%
Sell CO2 (0 for no or 1 for yes)	0
CO2 Production/Consumption	0.5
CO2 Transportation Savings (tonnes/y)	28.5
CO2 Cost	$0.22

Outputs	
Incremental Net Present Value (NPV) after 5 years	$ (242,000)
Incremental NPV + Terminal Value	$ 1,951,000
ROI (NPV - Capital Investment / Capital Investment)	-147%
Estimated CO2 Transportation Savings (tonnes/y)	14.3
Cost of CO2 Reduction ($/tonne)	$ 3,400

	CO2 Recovery Project COD 2019	Actual 2017	Projected 2018	2019	2020	2021	2022
	CO2 Requirement (lb)	601,470	631,544	663,121	696,277	731,091	767,645
	Average CO2 Required (lb/h)		72	76	79	83	88
	CO2 Requirement Growth (%)		5%	5%	5%	5%	5%
	CO2 Produced (lb)		315,772	331,560	348,138	365,545	383,823
	Average CO2 Produced (lb/h)		36	38	40	42	44
	CO2 Produced Growth (%)		5%	5%	5%	5%	5%
	Difference		(315,772)	(331,560)	(348,138)	(365,545)	(383,823)
CF in	CO2 Sale Price ($/lb)			$0.22	$ 0.22	$ 0.22	$ 0.22
	CO2 Sale Price Growth (%)				0%	0%	0%
	CO2 sales		$ -	$ -	$ -	$ -	$ -
	Total		$ -	$ -	$ -	$ -	$ -
CF out	Recapture system capital investment		$ 473,100				
	Freight		$ -				
	Union Engineer Transport/Lodging		$ -				
	Installation, foundation etc.		$ -				
	Cryotank purchase		$ 40,000				
	CO2 purchase (Matheson)		$ 139,889	$ 73,442	$ 77,114	$ 80,970	$ 85,018
	Maintenance Labor (24hrs per year)			$ 480	$ 480	$ 480	$ 480
	Recovery System Electricity, Water, Glycol Use			$ 14,688	$ 15,423	$ 16,194	$ 17,004
	Total		$ 652,989	$ 88,610	$ 93,017	$ 97,644	$ 102,502
Net CF			$(652,989)	$ (88,610)	$ (93,017)	$ (97,644)	$ (102,502)
PV CF			$(652,989)	$ (84,391)	$ (84,369)	$ (84,348)	$ (84,328)
NPV			$(990,426)				

Terminal Value (Projecting Beyond 5 Years)

Long term growth rate	2%
Incremental CF 2023	$ 79,980
Terminal Value	$ 2,665,986
Discounted Terminal Value	$ 2,193,313

The purchase agreement with Vendor 1 results in a negative NPV of -$242k in the first 5 years and the estimated cost of CO2 reduction is $3,400/tonne. This is still an optimistic result because other capital investments are not known (freight, installation etc.)

Maui Brewing Company Case Study

Maui Brewing Company, Hawaii

- Currently installing a CO_2 recovery system from Vendor 1 and estimated to produce roughly half the number of barrels of beer as Allagash
- An interview was conducted with the brewery to gain insights into estimated project cost and other assumptions
- Its recovery system from Vendor 1 is approximately twice the size of the Vendor 1 system quoted to Allagash, but it will be the first Vendor 1 system installed in the US and therefore has a reduced capital cost
- Its CO_2 purchase cost is 3x higher than Allagash due to the high cost of transporting CO_2 to Hawaii
- Maui does not produce enough CO_2 to cover all CO_2 consumption in the brewery
- Maui has a roadmap to reduce CO_2 consumption to be in line with CO_2 production (recovery)
- Remaining assumptions were based on similar financial analysis for Allagash

Quote	Contract Type	Payment Terms	Estimated Incremental NPV after 5 years	Estimated Pay Back
Vendor 1	Purchase	Upfront capital investment of ~$500k inclusive	$276k	3.5 years ✔

A positive NPV is estimated for Maui Brewing Company since it displaces higher CO_2 purchasing costs and their recovery system has a lower capital investment

CO2 recovery can be financially feasible under conditions

Sensitivity Analysis

- Sensitivity analysis demonstrates how projects could be potentially feasible for Allagash from a financial standpoint
- The goal was to create realistic scenarios by adjustment of 1-2 variables in combination
- Meeting 85% of CO2 requirement (as opposed to 50%), was set as a goal so that the adjustment to other variables would be less extreme; this would also reduce CO2 purchasing requirements
- These scenarios achieved approximately $17-19k incremental NPV thus demonstrating a minimum feasible case

Quote	Contract Type	Sensitivity Performed
Vendor 2	Lease with ownership of system after 7 years	CO2 production is now 85% of what is required for consumption (instead of 50%)
Vendor 1	Purchase	CO2 production / consumption is 85% Total capital investment reduces to $410k
Vendor 1	Purchase	CO2 production / consumption is 85% CO2 purchase cost increases by 15% ($0.22/lb to $0.25/lb)

Increasing the ratio of CO2 recovered to CO2 required for consumption will assist in making projects financially feasible

MIT MANAGEMENT SLOAN SCHOOL
ALLAGASH BREWING COMPANY

CO2 Offset

ANALYSIS

Corporate Social Responsibility (CSR) Initiatives

Window Dressers

- Non-profit organization that brings volunteers together to improve the comfort of homes, lower heating costs, and reduce CO_2 emissions by producing low-cost insulating window inserts[14]
- After placing an order, trained volunteers will measure the windows. The customer will then need to participate in a local Window Dressers Community Workshop where the inserts are made taking them back home at the end of the workshop[14]
- Window Dressers provide up to 10 pine inserts per year at no charge to low-income families only asking them in exchange participation in the Community Workshop[14]

Window Dressers
INSULATING WINDOW INSERTS

[14] Source: http://windowdressers.org/

MIT MANAGEMENT SLOAN SCHOOL
ALLAGASH BREWING COMPANY

Corporate Social Responsibility (CSR) Initiatives

Window Dressers

INSULATING WINDOW INSERTS

Window Insulators[14]

Window Dressers Community Workshop[14]

[14] Source: http://windowdressers.org/

MIT MANAGEMENT SLOAN SCHOOL

ALLAGASH BREWING COMPANY

CSR Initiatives

Allagash and Window Dressers

- Allagash has partnered with Window Dressers as part of its initiative: “Give where you live”
- They help by providing space for the Community Workshops and by donating each year to the organization
- Donations help low-income families to access to insulations for their houses
- Allagash is looking to have fewer but closer NGO partnerships over the next few years to be able to increase their impact
- CO_2 offset for window dressers is based on Allagash providing donations which allows more free inserts to go out that otherwise would not go out

INSULATING WINDOW INSERTS

CSR Initiatives

ALLAGASH

Partnership

Window Dressers

INSULATING WINDOW INSERTS

Space for the Community Workshops

Donations

~25 Tonnes of CO2e reduced per year

Allagash's partnership with Window Dressers reduces the release of up to 25 tonnes of CO2e per year

Window Dressers reduces CO2 and saves money

- An average house has 10 windows*[14]
- The average life of an insert is 5 to 10 years[14]
- The fuel consumption for heating an insulated house decreases by 105 gallons per year*[14]
- This translates to an energy bill cost reduction of $270 per year on average*[14]
- The average cost for a window insert is between $20-$45[14]
- The investment in window inserts is a NPV positive project (considering Allagash donations and potential users' savings), creating between $277 and $317 of value per year

Allagash donations help to reduce CO2e emissions and allow low-income families to save money

[13] Source: http://windowdressers.org/

* Results obtained from Allen Armstrong (Mechanical Engineer, member of the Portland Climate Action Team and Window Dresser's volunteer) calculations.

Window Dressers reduces CO2 and saves money

Window Insultations Cost per Tonne
Unit of analysis: 1 Window insulator

		Total	Window Duration (Years) 1	2	3	4	5
Allagash	Window Insulator Cost (CAPEX) ($)	$ 30	$ 6	$ 6	$ 6	$ 6	$ 6
	Energy Savings ($)	$ -	$ -	$ -	$ -	$ -	$ -
	Net Income	***$ (30)***	***$ (6)***	***$ (6)***	***$ (6)***	***$ (6)***	***$ (6)***
Insulator Receive	Investment ($)	$ -	$ -	$ -	$ -	$ -	$ -
	Energy Savings ($)	$ 135	$ 27	$ 27	$ 27	$ 27	$ 27
	Net Income	***$ 135***	***$ 27***	***$ 27***	***$ 27***	***$ 27***	***$ 27***
	CO2 Savings (kg CO2e)	377.68	75.54	75.54	75.54	75.54	75.54
	CO2 Savings (Tonnes CO2e)	*0.38*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*
Allagash Cost per Tonne CO2			$ 81	$ 81	$ 81	$ 81	$ 81
Insulator Receiver Cost per Tonne of CO2			$ (357)	$ (357)	$ (357)	$ (357)	$ (357)
Combined Cost per Tonne of CO2			$ (277)	$ (277)	$ (277)	$ (277)	$ (277)

Inputs

Average Cost of a Window Insulation	30.43	$/window
Average Energy Savings per House	105.00	Gallons/House/Year
Average GHG emissions per unit of fuel	10.16	kg CO2e/gallon
Fuel Type	Home Heating	and Diesel Fuel (Distillate)
Average Windows per House	10	Windows/House
Average $ Savings Per House	270	$/House/Year
CO2e emissions for the Construction of the insulator	25.70	kg CO2e/window
Insulator Transportations emissions	5.45	kg CO2e/window

Outputs	Window Duration 5 Years	10 Years
Allagash Cost per Tonne CO2	$ 81	$ 40
Insulator Receiver Cost per Tonne of CO2	$ (357)	$ (357)
Combined Cost per Tonne of CO2	$ (277)	$ (317)

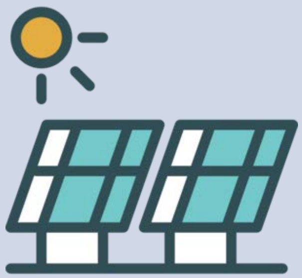
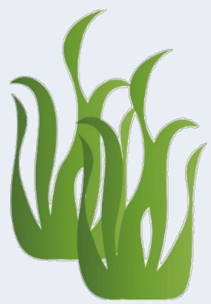
		Total	Window Duration (Years) 1	2	3	4	5	6	7	8	9	10
Allagash	Window Insulator Cost (CAPEX) ($)	$ 30	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3	$ 3
	Energy Savings ($)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Net Income	***$ (30)***	***$ (3)***	***$ (3)***	***$ (3)***	***$ (3)***	***$ (3)***	***$ (3)***	***$ (3)***	***$ (3)***	***$ (3)***	***$ (3)***
Insulator Receive	Investment ($)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Energy Savings ($)	$ 135	$ 27	$ 27	$ 27	$ 27	$ 27	$ 27	$ 27	$ 27	$ 27	$ 27
	Net Income	***$ 135***	***$ 27***	***$ 27***	***$ 27***	***$ 27***	***$ 27***	***$ 27***	***$ 27***	***$ 27***	***$ 27***	***$ 27***
	CO2 Savings (kg CO2e)	377.68	75.54	75.54	75.54	75.54	75.54	75.54	75.54	75.54	75.54	75.54
	CO2 Savings (Tonnes CO2e)	*0.38*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*
Allagash Cost per Tonne CO2			$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40
Insulator Receiver Cost per Tonne of CO2			$ (357)	$ (357)	$ (357)	$ (357)	$ (357)	$ (357)	$ (357)	$ (357)	$ (357)	$ (357)
Combined Cost per Tonne of CO2			$ (317)	$ (317)	$ (317)	$ (317)	$ (317)	$ (317)	$ (317)	$ (317)	$ (317)	$ (317)

Allagash cost per tonne is greater than the average but only because Allagash is not perceiving any of the benefits of the investment done with that donation. When combining Allagash donation with the benefits of the donation the combined cost per tonne is negative, which means that investing in the insulators is actually creating value rather than being a cost.

MIT MANAGEMENT SLOAN SCHOOL

ALLAGASH BREWING COMPANY

Other Alternatives for CO2e Offsets

Other potential initiatives for CO2e emissions offsetting	Potential CO2e savings per $ of capital investment*
 Solar Energy	0.33 kg CO2e savings per $ invested**
 Microalgae Production	0.30 kg CO2e savings per $ invested**

These projects require more capital investment and space than Allagash has available

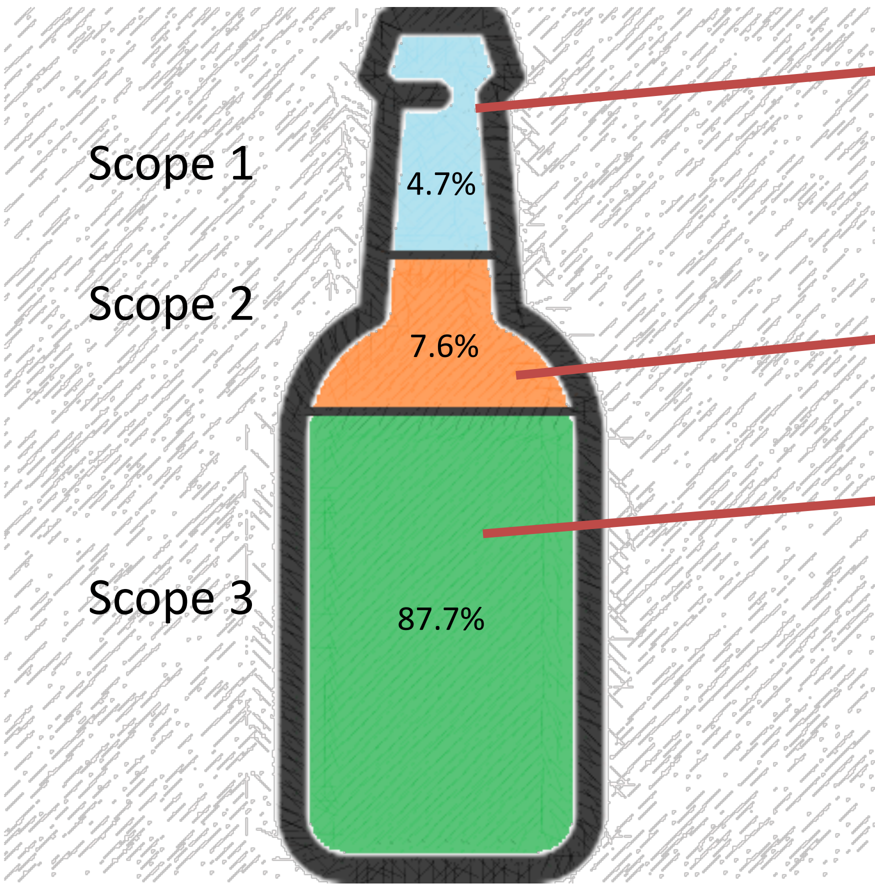
* Calculations do not include neither operational costs nor potential earnings from the operation. Only based on capital investment for an average facility.
** Rough estimations of potential CO2e savings of the mentioned initiatives. Further research should be done to get more precise results

CO2 Lifecycle Assessment of Allagash Beer

- A lifecycle assessment (LCA) analysis can identify the environmental impact of a product from its raw material production to its consumption
- A simplified LCA was done to visualize the CO2e emissions associated with Allagash beer
- This analysis is based on a similar analysis done by New Belgium Brewery[15]
- Some of the emissions were calculated based on Allagash information while others were just extrapolated based on Allagash's yearly production using New Belgium Analysis as reference

[15] Source: Sustainability Brochure – New Belgium Brewing Company

Simple CO2 Lifecycle Assessment of Allagash Beer



- Natural Gas 7.86 Tonnes CO2e per year
- Fugitive 525.71 Tonnes CO2e per year
- _Vehicle Fleet 165.96 Tonnes CO2e per year*_

- _Electricity 1,131.57 Tonnes CO2e per year*_

- _Corporate Transportation 45.26 Tonnes CO2e per year*_
- CO2 Purchases 301.36 Tonnes CO2e per year
- Customer Use 56.33 Tonnes CO2e per year
- _Malt 875.08 Tonnes CO2e per year*_
- _Retail 1,101.39 Tonnes CO2e per year*_
- _Distribution 1,885.95 Tonnes CO2e per year*_
- _Barley 2,549.80 Tonnes CO2e per year*_
- _Glass 6,291.52 Tonnes CO2e per year*_

Most of the CO2e emissions generated by beer are Scope 3 and associated with the beer supplies

* Estimates based on the LCA done by New Belgium Brewery. Source: New Belgium Brewery 2017 Sustainability Report

RECOMMENDATIONS & ROADMAP

Recommendations

Immediate Action

- Focus on CO_2 offsets: Window Dressers
- Develop strategy to close CO_2 production/consumption gap
- Open negotiation dialogue with CO_2 recovery system suppliers

Intermediate Action

- Improve production processes to reduce CO_2 consumption
- Small capital projects that will increase CO_2 recovery

Long-term Action

- Install CO_2 recovery system
- Become self sustainable on CO_2
- Explore potential business opportunities to sell excess CO_2 to other local breweries

Future Analysis

- Complete exhaust vs. consumption analysis following any major production, forecast or capital improvement changes
  - Identify the any change in the gap between consumption and exhaust rates
  - Forecasted exhaust can help assess future emissions for capture

- Temporary monitoring of CO_2 consumption processes where feasible will help identify feasible areas for reduction in consumption and provide insights into where CO_2 is used most in the production process.

- CO_2 recovery becomes financially feasible based on current analysis if it can cover 85% of CO_2 consumption with exhaust from fermentation

- Continuous monitoring assists with assessing the impact of potential offsets on net CO_2 emissions

References

1. Murar, K., “Maui Brewing Co.: paving the way for Hawaii brewers since 2005”, Pacific Business News, 2018, https://www.bizjournals.com/pacific/news/2018/02/22/maui-brewing-co-paving-the-way-for-hawaii-brewers.html
2. Bohlool, K., “Behind the Beer at Maui Brewing Co.”, Maui Now, 2016, http://mauinow.com/2016/07/22/behind-the-beer-at-maui-brewing-co/
3. “First CO2mpact Brew Sold to Innovative Maui”, Union Engineering, 2017, https://union.dk/news-pr/all-news/first-co2mpactbrew-sold-to-maui/
4. Berlinger, J. “Beer-Powered Brewery Saves $450,000 A Year”, Associated Press, 2013, http://www.businessinsider.com/beer-powered-brewery-saves-450000-a-year-2013-2
5. Becker, D., “Alaskan Brewing – A New Release and Brewhouse Innovation”, The Full Pint – Craft Beer News, 2009, https://thefullpint.com/beer-news/alaskan-brewing-a-new-release-and-brewhouse-innovation/
6. “The Brewery”, Widmer Brothers Brewing, 2018, https://widmerbrothers.com/brewery/info
7. D.J., “Widmer Brothers Brewing Installs CO2 Recovery System”, BrewPublic, 2017, https://brewpublic.com/beer-news/widmer-brothers-brewing-installs-co2-recovery-system/
8. Eisenberg, D., “F.X. Matt to Expand in Utica”, BevNET, 2014, https://www.brewbound.com/news/f-x-matt-to-expand-in-utica
9. George, M., “Matt Brewing Company to replace and upgrade CO2 recovery system”, CraftBeer, 2016, https://www.craftbeer.com/news/brewery-news/matt-brewing-company-replace-upgrade-co2-recovery-system
10. “Brewery Vivant’s 2017 Sustainability Report”, Brewery Vivant, 2017, https://www.breweryvivant.com/reports/2017%20Beer%20The%20Change%20Report.pdf

References

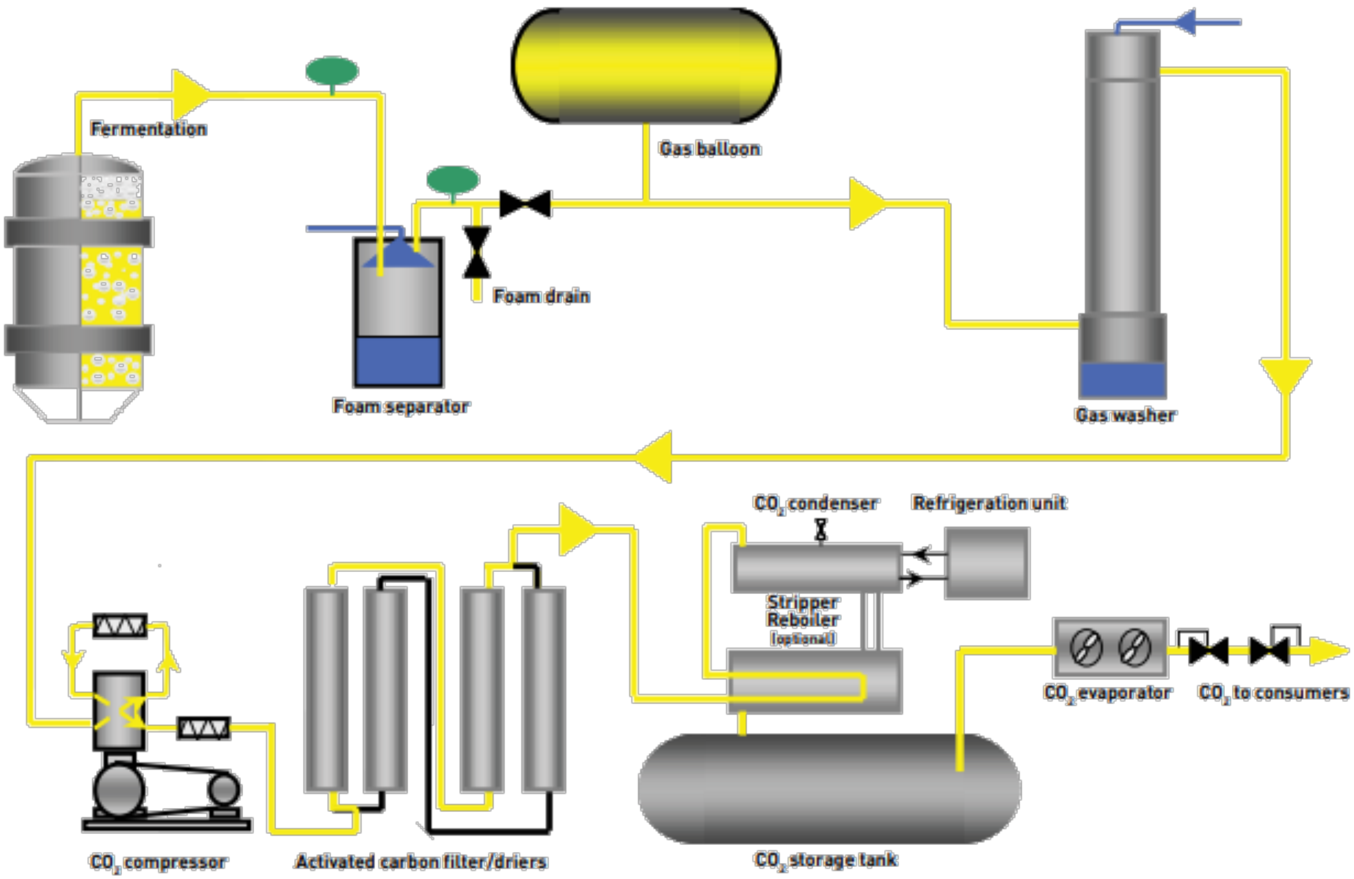
11. Kent, S., “Raising a glass to greener beer: Former GR Current director helps craft brewers cut carbon emissions”, Rapid Growth, 2015, http://www.rapidgrowthmedia.com/features/111915grcurrentbeercarbonemissions.aspx
12. “Sustainability”, Lolo Peak Brewing Company, 2018, http://lolopeakbrewery.com/sustainability/
13. Pass my exams Chemistry, 2018, http://www.passmyexams.co.uk/GCSE/chemistry/producing-ethanol-by-fermentation.html
14. Window Dressers, 2018, http://windowdressers.org/
15. “Sustainability Brochure”, New Belgium Brewing Company, 2017, https://www.newbelgium.com/docs/default-source/sustainability/2017sustainabilitybrochure.pdf?pdf=sustainabilityreport
16. U.S. Departmen of Energy, National Energy Technology Department, Carbon Dioxide Enhanced Oil Recovery, 2010, https://www.netl.doe.gov/file%20library/research/oil-gas/CO2_EOR_Primer.pdf
17. Wilson, M. H., Groppo, J., Placido, A., Graham, S., Morton III, S. A., Santillan-Jimenez, E., Shea, A., Crocker, M., Crofcheck, C., Andrews, R., CO2 recycling using microalgae for the production of fuels, 2014, https://link.springer.com/content/pdf/10.1007%2Fs13203-014-0052-3.pdf
18. Global CCS institute, CO2 reuse technologies, 2018, https://hub.globalccsinstitute.com/publications/accelerating-uptake-ccs-industrial-use-captured-carbon-dioxide/1-co2-reuse-technologies
19. American Fire Technologies, Fire Suppression Systems, 2018, https://www.aft.net/products/fire-suppression/c02

MIT MANAGEMENT SLOAN SCHOOL

ALLAGASH BREWING COMPANY

APPENDIX

CO2 Recovery Technology Overview



MIT MANAGEMENT SLOAN SCHOOL
ALLAGASH BREWING COMPANY

Technology Review

Vendor	Proven Technology	Craft Breweries Using the Technology
PENTAIR UNION	✓	MAUI BREWING CO, SARANAC
PIONEERENERGY	✗	
CASEQ TECHNOLOGIES life. upcycled.	✗	Brewery Vivant
CO BREW	~	Lolo Peak Brewing Company — Mountains. Rivers. Beer.

Potential Markets for CO2

Reuse Technology	Reduce Net CO2 Generation	Reason
Enhanced oil recovery	✗	CO2 allow tertiary recovery of wells increasing well productivity[16]. This promotes the use of non-renewable resources making them more affordable increasing net CO2 generation
Microalgae production	✓	Microalgae production allow the recapture of CO2[17]. Then algae can be used to generate oil that can be used to develop biodiesel, creating a renewable source of energy
Wine making	✗	CO is used as a seal gas to prevent oxidation of the wine during maturation[18]. That gas is then vented into the atmosphere either through the bottling process or once the bottle is opened.
Food processing, preservation and packaging	✗	CO is used for various applications in the food industry, including cooling while grinding powders such as spices and as an inert atmosphere to prevent food spoilage[18]. This CO2 is also eventually released into the atmosphere

Potential Markets for CO2

Reuse Technology	Reduce Net CO2 Generation	Reason
Fire suppression technology	✓	CO2 extinguishes a fire by removing the oxygen from the surrounding area, and for local application type systems, breaks the fire triangle by removing the heat[19]. By avoiding a fire to spread out CO2 used as extinguisher reduce net CO2 emissions into the atmosphere.
Refrigerant gas	✗	CO is used as the working fluid in refrigeration plant, particularly for larger industrial air conditioning and refrigeration systems[18]. That CO2 is contained in the cooling equipment however, it will eventually be released into the atmosphere. Moreover, cooling equipment use considerably amount of energy which depending on the source might create more CO2 emissions.
Beverage carbonation	✗	Carbonation of beverages with high-purity CO[18]. However, this CO2 gets released into the atmosphere during and after consumption
Greenhouse	✓	CO is provided to greenhouses to maintain optimal CO concentration and maximize plant growth rate[18]. This creates a net reduction of CO2 in the atmosphere that would potentially be released but many years in the future when plants die.

Interviews - Allagash

Role	Takeaways
Head of Marketing In-Person Interview on 4/6/2018	• "Sustainability is embedded into the company culture." • "Sustainability adds to the Allagash brand, but is not there for the brand."
Director of HR Phone Interview on 4/6/2018	• "Employees are motivated to come up with sustainability-related projects rather than just implement them from the top-down." • "Part of the hiring process is looking for people who like beer, the outdoors, and protecting the environment."
Philanthropy Program Manager Phone Interview on 4/25/2018	• "Allagash provides community grants during Spring and Fall for Maine non-profits." • "We are looking to partner with fewer organizations and make those relationships deeper and more impactful." • "We are also open to exploring customer engagement opportunities."

Interviews - Allagash

Role	Takeaways
Brewmaster In-Person Interview on 4/6/2018	• "The amount of CO_2 produced in the fermentation process depends on sugar content in recipe. Our White recipe will be different than our Triple recipe." • "The bulk of our fermentation goes through bunker tanks (70-80%) which are connected to the central CO_2 exhaust line." • "We use CO_2 primarily to move beer, purge conditioning tanks, and maintain the O_2 free environment in the keg and bottling lines."
Finance Director In-Person Interview on 4/6/2018	• "Capital projects are split into essential projects and dream projects. CO_2 recapture is considered a dream project, meaning it is not critical." • "Lease with CO_2 supplier could be a challenge to break."
Quality Manager In-Person Interview on 4/6/2018	• "Quality of recaptured CO_2 would need to be monitored."

Interviews - Allagash

Role	Takeaways
Founder, CEO Phone Interview on 4/9/2018	• "If a system is purchased, we would want to purchase from a well-known, reliable company." • "Given the climate of decreasing growth in craft brewing industry, we must take economic benefits into account when assessing sustainability projects."
Head of Sales Phone Interview on 4/9/2018	• "Sustainability projects do not necessarily need to have an impact on Sales, as long as it is not hurting sales."

Interviews – CASEQ Technologies

Role	Takeaways
Founder, CEO Phone Interview on 3/12/2018	• "CO_2 recovery is not a revenue generator, it is a cost savings technology." • "There are several risks small brewers face in installing CO_2 recovery systems. First, cost. Brewers need to producing more than 500k gallons a year in order for the systems to be cost effective. Second, it is a large capital investment. Third, there is a possibility of growing out of the recovery system. To ease these risks, CASEQ provides 5-year leasing terms. The lease payment is a 30% discount on what a brewer paid for CO_2 purchase the previous year." • "CASEQ provides maintenance on installed systems." • "Increases in electricity costs for running the recovery system are not large enough to offset cost savings from CO_2 purchasing."

Interviews – Maui Brewing Co.

Role	Takeaways
Founder Phone Interview on 4/17/2018	• "We plan to install a Pentair Union recovery system in May 2018. The system can handle 200 lb of CO_2/hr." • "The primary motivator for installing recovery system is the price of CO_2 in Hawaii (\$0.60/lb) which is much higher than Allagash's price of CO_2 (\$0.22/lb)" • "We received a low cost for their recovery system (including freight, installation) because we are early adopters." • "We are producing less CO_2 (80 lbs/hr) than we are consuming (100 lb/hr) so will continue to purchase CO_2 in the interim while they bring on the other 15 percent of their capacity." • "We are working on a plan to reduce our production to consumption ratio."

Interviews – Window Dressers

Role	Takeaways
Allen Armstrong (Mechanical Engineer, member of the Portland Climate Action Team and Window Dresser's volunteer) Phone Interview on 4/20/2018	• "Most houses in Portland, Maine do not have modern windows on them." • "Window inserts gives better results over single windows." • "Inserts can help owners to save 105 gallons of fuel per year due to building heating loss prevention, which represents a reduction on their bills of $270 per year." • "A study done over 50 buildings allow to get the above results, where: A total of 420 house windows + 80 windows for institutional building where considered in the calculations 50% building heating was gas (90% efficiency). 25% of building heating was old oil burners (75% efficiency) and 25% was new oil burners (85% efficiency). 80% of the windows were single pane and 20% were double pane. 54 Million BTU saved in double pane case and 767 million BTU saved in single pane case Total savings on CO2 70tons of CO2. (for all the houses in the calculation) The cost of energy used was 1.89 cents per 100 ft3 of gas".

Production CO2 Calculation Assumption

- 368 kg/70 bbl tank is from Allagash and based on recipe
- Bunker tanks only produce the White beer in the near future
- The exhaust is measured in cubic feet, so use standard atmospheric conditions for conversion to weight
  - 8.741 ft^3/lb CO_2
  - Temperature swings experienced within the facility won't impact the density of the gas enough to make a difference in weight
- The production week is defined by Monday AM to the following Monday AM

MIT MANAGEMENT SLOAN SCHOOL

ALLAGASH BREWING COMPANY