Case Study

Reducing the Carbon Footprint of Orange Juice

Porifera's confidential customer is one of the largest vertically integrated global producers of orange juice and concentrate, processing about 20% of the orange juice in the world. The customer's juice extractors process 100,000 oranges per minute. That's enough to make about two thousand tons of orange juice each working day.

The orange juice is processed into a "Not from Concentrate" (NFC) product or into a 65 Brix concentrate, referred to as frozen concentrated orange juice (FCOJ). The NFC and FCOJ are shipped to consumers all around the world.

Though the FCOJ's carbon footprint has only half of the carbon footprint of NFC, is easier to handle, and less expensive to deliver, NFC has retained a dominant share of the market. NFC is preferred by most consumers due to its superior flavor, aroma and nutritional value. While the FCOJ is processed with state-of-the-art TASTE evaporators that were specifically designed to minimize impact on the quality of the concentrate, elevated processing temperatures degrade concentrate quality.

Porifera's concentration process results in a new product that's flavor, aroma and nutritional value are comparable to NFC but with the low carbon footprint and all the logistical advantages of the concentrate. In addition to transportation and refrigeration savings, Porifera's all-membrane all-electrically powered processing system reduces GHG emissions from processing juice into a concentrate by 66% compared to conventional thermal evaporators.

While Porifera's technology can reach juice concentrations as high as 68 Brix, the optimal GHG emissions reductions are achieved by going to 50 Brix for an all-electric nonthermal membrane system.

Savings for the Customer

66% GHG Reduction from Efficient Processing

The confidential customer is looking to install equipment capable of processing ~10,000 kg/hr of juice (approximately ~1/6 of their current thermal concentrate production) initially. Following a successful test demonstration at that scale, the company will implement Porifera's technology at full-scale production for all orange juice concentrate, realizing significant energy savings and superior product quality.

Stages of Implementation:	Porifera juice processing capacity installed [kg/h]	Reduction of emissions from processing	Metric tons of CO_2 saved per year
Starting system	10,091	66%	1012
Replace all current FCOJ with Porifera's Natural Concentrate	60,480	66%	6,073

CO_2 Emissions Reduction for the Planet

Potential to Reduce CO_2 Emissions by >2 Million MT per year

Pilot tests at Porifera's facilities have demonstrated that the natural concentrate produced by Porifera's technology creates a superior orange juice concentrate, which when diluted compares favorably to fresh orange juice not from concentrate (NFC).

The customer is considering converting a large amount of juice that is currently sold as NFC into a concentrate produced with Porifera's technology. This new product that competes with NFC would not only provide cost and energy savings in juice processing, but also reduce transported juice volume by 68%.

Implementation of Porifera's technology for 95% of all the juice customer processes would result in potential reduction of yearly CO_2 emission approximately 548,000 MT of CO_2. If implemented in 95% of all the orange juice production facilities in the world, the CO_2 reductions would be approximately 2.6 million of MT/year.

Source of savings:	*Full Implementation at one customer [Thousands of MT CO_2 /year]*	*Full Implementation in global orange juice industry [Millions of MT CO_2 /year]*
Maritime transport	278	1.341
Trucking	258	1.246
On-land cold storage	9	0.044
TOTAL	*545*	*2.631*

Additional Reduction of Air Pollution

Potential to Remove Emissions Equivalent to 29% World's Cars

Implementation of Porifera's technology would also significantly reduce air pollution due to the reduced requirements of storage and shipment. Shipping is by far the biggest transport polluter in the world[1] due to the use of dirtier, higher polluting fuels.

The world's 90,000 maritime shipping vessels burn approximately 370 million tons of fuel per year, emitting 20 million tons of Sulphur Oxides (SO_x). A single large ship can generate approximately 5,200 tons of SO_x pollution in a year. There are 760 million cars in the world today emitting approximately 78,600 tons of Sulphur Oxides annually. Therefore, the global shipping fleet emits 260 times more SO_x than the world's automotive fleet.

If Porifera's technology were implemented for 95% of the customer's juice, the air pollution reduction would be equivalent to removing 45 million cars from the roads. If Porifera's technology were implemented across the entire orange juice industry, the potential pollution reduction would be equivalent to eliminating 29% of the total cars in the world (~220 million cars).

[1] https://newatlas.com/shipping-pollution/11526/

Assumptions

Emissions from juice processing:

Evaporator concentrating 11 Brix to 65 Brix, using electrical energy equal to 12.72 kWh/ton of water removed and thermal energy equal to 0.33 kg of steam per kg of water removed, corresponding to 7.63 Therms/ton of water removed. For juice processing capacity of 10,080kg/h, operating for 4224h/year, this system removes 35,372 tons of water/year.

PFO Concentrator with ROX-max2 draw recovery processing 11 to 50 Brix using only electrical energy equal to 36kWh/ton of water removed. For juice processing capacity of 10,080kg/h, operating for 4224h/year, this system removes 33,211 tons of water/year.

Emissions from transportation:

To estimate the potential for GHG emission reduction from transportation it is assumed that 95% of juice that's transported as NFC today could be converted into concentrate. The reduction of transported volume is then calculated.

	Juice transported as Concentrate [kg/day]	Juice transported as NFC [kg/day]	Concentrate transported [kg/day]	Juice transported as NFC [m3/year]	Concentrate transported [m3/year]	Total volume transported per year [m3]
Current (65 Brix thermal+NFC)	700,000	1,300,000	118,462	451,046	32,856	483,902
Future (50 Brix PFO+some NFC)	1,900,000	100,000	418,000	34,696	118,271	152,967
					Volume reduction	330,934
						68%

Volume reduction is used to calculate potential GHG reduction and potential SOx reduction by calculating GHG emissions per m3 for maritime transport, trucking and refrigeration and SO_x emissions per m3 juice shipped.

GHG Calculation for Maritime Transport

Two methods were used: Method 1 that uses specifications of a sample maritime vessel for juice transport and Method 2 that uses emissions factors.

Method 1:

Assume transport with Gold of Brasil ship[2]:

With a length of 172 m, a width of 26 m and a draft of 9.5 m, the Ouro do Brasil is measured at 15,218 GT. It has a carrying capacity of 19,500 dwt. Around 12,300 cubic meters of orange juice concentrate or fresh orange juice can be transported in 16 cargo tanks. The propulsion power is 12,200 kW and gives the ship a speed of 20.5 knots. A shaft generator (1,580 kVA) and three auxiliary diesel generators (3 × 940 kVA) are available to generate electricity.

Total cargo carrying capacity=19500 tonnes capacity (tonnes deadweight)

Total cargo carrying capacity 12300 m^3

[2] https://second.wiki/wiki/fruchtsafttanker

Shipping Emissions per tonne-km (https://www.nature.com/articles/news.2008.574)				
Lower Bound	11	g CO2 eq/tonne-km cargp		
Upper Bound	42	g CO2 eq/tonne-km cargp		
Emissions of Bunker Fuel (https://theicct.org/sites/default/files/publications/Global-shipping-GHG-emissions-2013-2015_ICCT-Report_17102017_vF.pdf)				
CO2 intensity of fuel	3.2	g CO2/g fuel		
grams fuel used/tonne-km of goods	3.4375	g fuel/tonne cargo-km		
grams fuel used/tonne-km of goods	13.125	g fuel/tonne cargo-km		
Total energy used estimate to ship orange juice concentrate per ton-mille				
Low	0.067	tonne fuel/km traveled		
High	0.256	tonne fuel/km traveled		
Assumed shipping distance, Sao Paulo Brazil to Rotterdam & back				
Estimated distance using great circle (https://www.prokerala.com/travel/distance/from-sao-paulo/to-rotterdam-netherlands/)	20,000	km/trip		
Fuel consumed per trip				
Low	1341	tonnes fuel	0.11	tonnes of fuel/m3 capacity
High	5119	tonnes fuel	0.42	tonnes of fuel/m3 capacity
Average fuel consumption per m3	0.263	tonnes of fuel/m3 capacity		
MT CO2 produced	0.840	MT/m3		

Method2:

CO2 emmissions per ton-mile for waterborne craft	0.043	kg/ton mile
ton/m3	1.316	kg/l
Miles traveled	12,500.0	miles
CO2 emissions per m3 transported	0.704	MT/m3

Considering that the juice tankers are on the lower end of watercraft efficiency, the higher estimate of 0.840 MT/m3 is used.

GHG Calculation for Trucking:

CO2 emmissions per ton-mile for medium/heavy duty trucks	0.2967456	kg/ton mile
ton/m3	1.316	kg/l
Miles driven	2000	miles
CO2 emissions per m3 transported	0.781	MT/m3

GHG Calculation for Refrigeration:

Energy consumption [kWh/m3/year]:	64	kWh/m3/year	8-120 kWh/m3/year for on-land cold storage
Cold storage fill factor	75%		
Average refrigeration time	9	months	(shelf life 1-2 years)
Energy consumption [kWh/m3]:	64	kWh/m3	
MT CO2 produced	0.028	MT/m3	

Reduction in SOx Emissions

SOx emissions:	https://newatlas.com/shipping-pollution/11526/	
SOx emissions:	0.054	tons SOx per ton fuel
SOx emissions per m3 shipped	0.014	tons SOx per m3 shipped

Conversion factors[3,4]*:*

metric tons CO_2/kWh =0.00043

metric tons CO_2/therm =0.00531

Vehicle Type	CO2 Factor (kg / unit)	Units	GHG equivalent
Medium- and Heavy-duty Truck	1.456	vehicle-mile	1.460
Passenger Car A	0.368	vehicle-mile	0.372
Light-duty Truck B	0.501	vehicle-mile	0.507
Medium- and Heavy-duty Truck	0.296	ton-mile	0.297
Rail	0.026	ton-mile	0.026
Waterborne Craft	0.042	ton-mile	0.043
Aircraft	1.301	ton-mile	1.313

[3] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

[4] https://www.epa.gov/sites/default/files/2015-07/documents/emission-factors_2014.pdf