Sea of Japan

### Japan Seea we et Up Osaka 大阪

Fukuoka 福岡

ichun 长春市

LIN

orea

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### The Sea Upwelling Company Inc. dba Sea-Up www.sea-up.life 505-231-7508

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Hakodate 函館

Sea of Japan

Fukuoka 福岡



About Us The **Problem Our Solution** Japa Results OTokyo 東京 .Osaka Aug **Financial Model** Urgency **Technical Details** 

# About

Us

#### Marine Carbon Dioxide Sapporo 札幌 Removal (mcDR). Can the ocean help us to fight climate change? 평양 Terrestrial Atmosphere 597 2300 2 Upper 0 Ocean 900 c0, 150 Surface Marine Sediments Deep

rvoirs in Gt Carbon eep ocean stores >50x more

than atmosphere

Biota

15-20x more C than R land plants and soils

5000 x more C than coastal blue C

Fossil Fuels

3700

Source: WHOI

Ocean 37100

### chun tá About Sea-Up LIN

Philip Kithil Managing Director

#### Hakodate Mai Philip Fullam, PE Chief Engineer



•Tokyo 東京

**Climate Executor** 

Manufacturing – SolidWorks™. Materials Science. Makes things work. BSME/MBA.

phil@designimprovement.com

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phil@sea-up.life

**Climate Visionary** 

### Chun Our Wave-driven Pump LIN Sapporo #Life



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## chun I Production

Buoy: fiberglass shell, foam filled, steel backbone.

Electronics Off-the-shelf parts, controller, standard assembly.

Ropes: Dyneema.

**Outlet: sheet metal fabrication.** 

Tube: edge-stitched panels of Dyneema woven fabric.

Bottomweight/valve: sheet metal fabrication.



Sapporo 札博



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# The

# Problem

## Gumulative CO2

### Tokyo Cumulative CO2 Emissions 1980-2024



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### chun Climate Index Sapporo 札幌

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### chun ts TOKYO Flood Risk (2030) IN Sapporo 批提

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https://csi.climatecentral.org/

## Frishing 10.6MT

Osaka 大断



#### index-220.pdf (maff.go.jp)

Sea of Japan

Seafood Sufficiency

13% Fukuoka 福岡

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**O**Tokyo 東京

<3.0M





Source: Food Balance Sheet (the Ministry of Agriculture, Forestry and Fisheries)

Note: Self-sufficiency rate (%) = (Domestic production volume / Total supply for domestic consumption) × 100 Total supply for domestic consumption = Domestic production volume + Import volume - Export volume ± Increase/decrease in inventory



# Solution

## Wave-driven Upwelling.

Inputs: 1. Ocean waves 2. Sunlight

> 2m diameter 500m depth

#### 1 moving part



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## IN Nutrients/Depth Profile.



### Chun Scientific Basis. LIN Sapporo #Life

#### Reference

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Hakodate 函館 Tons CO2 removed\*

Karl et al (2008): Nitrogen fixation-enhanced 156 carbon sequestration in low nitrate, low chlorophyll seascapes. Jurchott et al (2023): Artificial Upwelling—A 96 **Refined Narrative** Wu et al (2023): Carbon dioxide removal via macroalgae open-ocean mariculture and 141 sinking: an Earth system modeling study Chen/Taylor (2024): Modeling Carbon 1,233 **Dioxide Removal via Sinking of Particulate Organic Carbon from Macroalgae Cultivation** 3,000 The Climate Foundation (website) \*Per km<sup>2</sup>/year

## Wide Area Benefits

Sea of Japan

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Osaka 大阪

Fukuoka 福岡

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Each pump drifts with open-ocean currents 100% powered by ocean waves.

# Results

### Metro Tokyo Net-Zero 1980-2050!

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1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050

### **Cost Per Person Per Day**

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### Percent Tokyo 1 serving fish per day

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### **Additional Personal Income**

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# Implementation

## Deployment Sites

ikuoka 福岡

East China Sea

Shanghai 上洲

Sea of Japan

O<sub>Tokyo</sub> 東京

•Sapporo 札幌

Hakodate 函館

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618 km

Data SIO, NOAA, U.S. Navy, NGA, GEBCO Data LDEO-Columbia, NSF, NOAA Image Landsat / Copernicus



#### Example, Abore 264 Tour Bard International Contraction (Contraction) Tour Bard Abore 264 Abore

Kushiro 釧路 Kushiro 釧路町 Shiranuka 白糠町

> -819 m 29.9 km -0.7%

i com kaga ar i arei

Betsuk

Toyokoro 豐頃町

Nakasatsunai 中札内村

30hu R<sup>bio</sup>rt kubetsu 幕別町

Sarabetsu 更別村

46 km

Taiki 大樹町

Data SIO, NOAA, U.S. Navy, NGA, GEBCO Image Landsat / Copernicus

n, Avg, Max Elevation: -1019: -579, 0 m

nge Totals: Distance: 51.5 km Elev Gain/Loss: 26 \$ n. 12 m mx Sh el C 19, 20.8% Avg Slope: 3.8%, -2.8%



# Financial

# Model

### chun te Tokyo Net Zero 2050 LIN Sapporo 礼候

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oTokyo 東京

### REMOVE legacy CO2

The PEOPLE pay.
Cost-based fee.
Monthly direct bank deduction.

### REDUCE current CO2

• BUSINESSES pay.

- -15% annual CO2.
- Secured by Tokyo license to operate.



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## chun Cautionary Ramp-up

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Sea of Japan

# 2025 2026 2027 2028 2029 Pumps deployed 5 100 1,000 1,291 1,666 Image: Mark Stress Image: MarkStress Image:

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# Urgency

## The Tipping Points of Climate Change – and Where We Stand.

Johan Rockstrom

https://youtu.be/VI6VhCAeEfQ?si=z4cLVDQ5fFA1Dq98

SEAT

JULY2024

## Chun Summary Statement

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By implementing *Sea-Up*'s ocean wave-driven upwelling pumps, Metro Tokyo becomes the <u>singular global leader</u> in the fight to REMOVE and REDUCE CO2 causing climate change while restoring vast ocean areas to pristine productivity.

Hakodate 函館

Our Mission is to achieve net-zero total accumulated CO2 for Metro Tokyo looking back to 1980 and forward to 2050 and negative CO2 thereafter. No other government anywhere in the world is yet to consider (much less, implement) such a <u>farreaching program</u> as this!

Operating through our Tokyo subsidiary, *Sea-Up* also will achieve <u>food security</u> from the sea, while creating more income both in Tokyo and Japan coastal communities.

# Technical

# Details

## Chun Nutrients/Depth Profile.

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## Flow Rate ~ Wave Height/Period

		flow rate	vol/day/km	
wave ht	period	m3/s	^2	Average
1.25	6	0.65	56,520	
1.5	7	0.67	58,135	
1.75	8	0.69	59,346	59,066
2	9	0.70	60,288	
2.25	10	0.71	61,042	
models	1cm/day/km^2			10,000



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Santa Barbara

# Mixing



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Source: personal email from Jost Kemper GEOMAR-Kiel



## **Drifting Maximum Rate**

1200am 1140pm <u>/</u>1130pm 1110pm 1120pm 1100pm 1040pm 11.5 km in200 5.67 hours pm 940pm 920pm 920pm (.56 m/s) 850pm 910pm 920pm 840pm 820pm 830pm 810pm 800pm 740pm 720pm 650pm 700<mark>pm</mark> 630pm 640pm Sea-Up 6:20pm 5.41 km



#### Source: GPS on buoy 11/18/22

200m depth pump



## Solubility Calculation.

#### SCIENTIFIC METHODOLOGY.

Calculations to disentangle the biological carbon pump and the solubility pump via remote sensor measurements on the AU-pump.

Measurements needed for calculation:

- DIC surface (or calculated via surface CO2 in atmosphere, temperature and salinity)

- DIC depth
- O2 surface (or calculated via surface O2 in atmosphere, temperature
- and salinity)
- O2 depth
- NO3 depth

Assumptions and limitations:

- Redfield ratio 106 C : 16 N : 1 P of organic matter.
- Response of solubility pump does not include changes in surface alkalinity or temperature.
- Response of biological carbon pump (any increase in primary productions, export production or deep ocean storage) is strongly dependent on pipe location.
- Any carbon or alkalinity contribution via the CaCO3 counter pump is not considered.

Step by step calculation:

#### (1) Calculating Apparent Oxygen utilization (AOU)

AOU gives the amount of oxygen consumed during remineralization of pipes source water.

AOU = [max. O2 solubility at surface] - [O2 observed at depth]

(2) Disentangling total DIC and re-mineralized DIC (biological carbon pump)

Calculating C / O2 ratio for remineralization without denitrification: Organic Matter + 138O2 -> 106CO2 + 16HNO3 + 1H3PO4 + water This equation now contains O2 take up via denitrification. The ratio therefore changes to 106 C / 138 02 = 0.768. Using O2 consumption at depth calculated via AOU and applying C / O2 ratio gives the amount of remineralized DIC included in total DIC concentration at depth. [O2 mol/L from AOU] \* [0.768] = re-mineralized DIC mol/L

Santa Barbara

#### (3) Separation of preformed DIC from total DIC.

Preformed DIC concentration at pipe's source depth should be between preindustrial 275ppm and current 400ppm CO2. The difference between preformed DIC at depth and surface DIC indicates potential CO2 uptake via the solubility pump.

Total DIC(depth) – re-mineralized DIC(depth) = preformed DIC(depth)

Increase of solubility pump at surface ocean:

DIC(surface) - preformed DIC(depth) = potential DIC uptake of surface water due to solubility pump

#### (4) Calculating theoretical biological carbon pump response at surface ocean

Use previously calculated re-mineralized DIC and apply Redfield ratio to calculate re-mineralized NO3.

Total NO3 (depth) – re-mineralized NO3 (depth) = preformed NO3 (depth)

Convert preformed NO3 via Redfield ratio into CO2. This is the amount of additionally stored CO2 in algae bloom biomass assuming Redfield ratio. How much gets released into the atmosphere again due to shak w remineralization or how much is exported to depth is unknown without tracking and measuring the algae bloom.

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## Instrumentation.

### Pump Components To Calculate SP CDR & MRV

Top of buoy: Solar panels, battery pack, GPS, Satcomm, Campbell Scientific processor, USCG light



1.1 t Bottomweight and 1-way valve **Belly of buoy** 

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DIC calculated via CO2 in atmosphere, surface water temperature and salinity (CTD). O2 (from World Ocean Atlas). Load cells top of ropes.

#### Measured inside the pump outlet

(same water as 500m depth)

Flowmeters (2) DIC (calculated) O2: RBRcoda<sup>3</sup> T.ODO pCO2 (CO2-Pro) + pH (ANB) (=TA) NO3 (SUNA-V2) Salinity (from ANB) Temperature (from Argo fleet or adjust from RBRcoda<sup>3</sup> T.ODO)

## **Estimating BCP.**



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Adapted from Jürchott, M., Oschlies, A., & Koeve, W. (2023). Artificial upwelling—A refined narrative. Geophysical Research Letters, 50, e2022GL101870. https://doi.org/10.1029/2022GL101870

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## Caveats

The CO2 equilibrium calculation requires T (e.g. 22°° C.), pressure, and 2 of the following: alkalinity (e.g. 2428.3), pH, pCO2 (e.g. 420). Results are highly sensitive to these inputs. [Prof. David Hodge]

How much [CO2] gets released into the atmosphere again due to shallow remineralization or how much is exported to depth is unknown without tracking and measuring the algae bloom. [Malte Jurch of [2]]



## Comments.

I think your solubility pump with real-time sensors is exactly the kind of approach we were thinking about as we tried to explain the challenges of MRV in the WG5 document.

This is a key advantage of your proposed system compared to other mCDR approaches that have not fully considered how to do the MRV. The pH sensors we discuss would definitely be a part of this since you need the second carbon parameter.

We need a real-world demonstration that shows that you are properly capturing the signals from the pump and the resulting plume. I would anticipate that some will be skeptical of the modeled advection rate and mixing. It is important to capture those downstream signals. [Chris Sabine]