Sea-Up

The Sea Upwelling Company Inc. dba Sea-Up

www.sea-up.life

505-231-7508

Topics

About Us

The Problem

Our Solution

Results

Implementation

Financial Model

Urgency

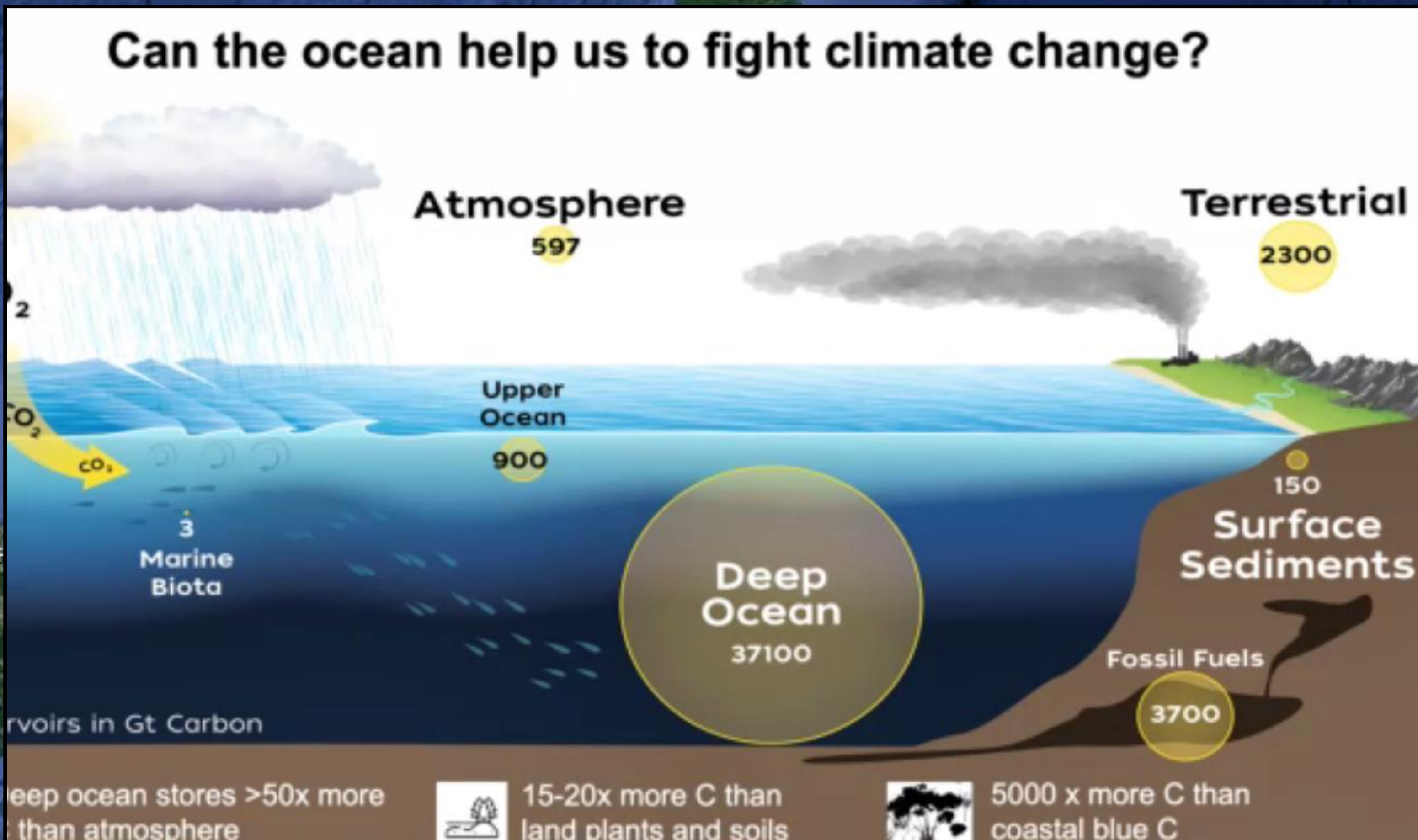
Technical Details

Sea-Up

About

Us

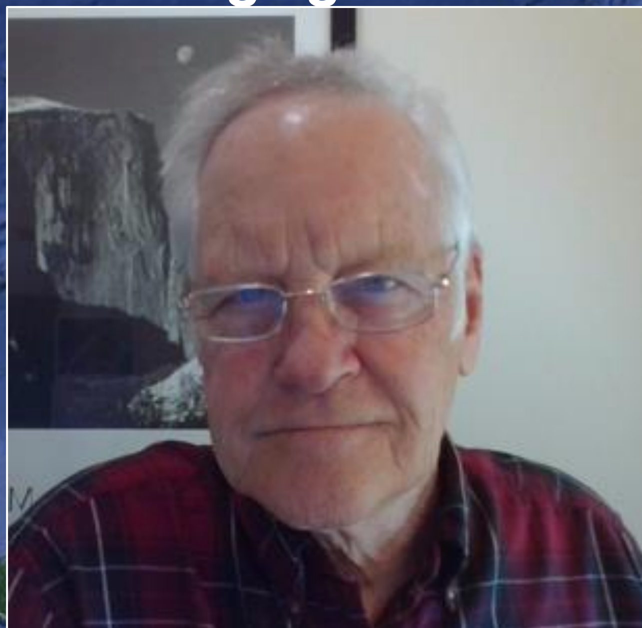
Marine Carbon Dioxide Removal (mCDR).



Source: WHOI

About Sea-Up.

Philip Kithil
Managing Director



Climate Visionary

Serial Entrepreneur.
Inventor.
BA/MBA Economics.

phil@sea-up.life

Philip Fullam, PE
Chief Engineer

Climate Executor

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

phil@designimprovement.com

Sea-Up

Our Wave-driven Pump

Sea-Up

Production

Buoy: fiberglass shell, foam filled, steel backbone.

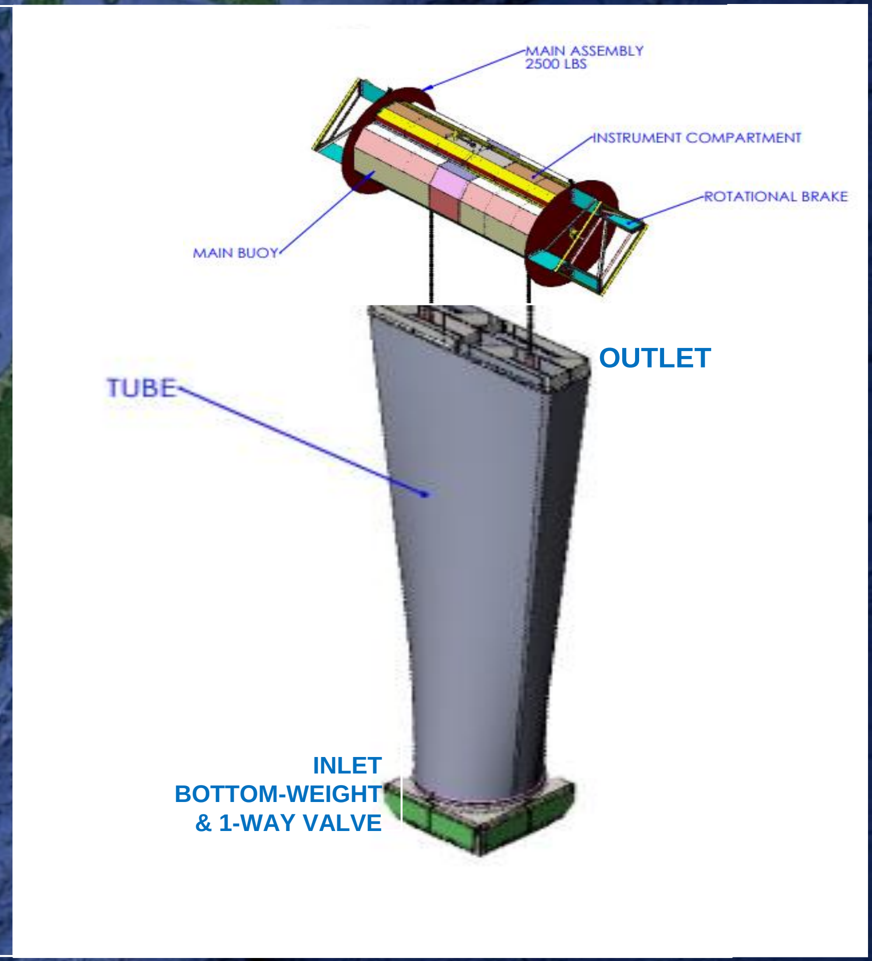
Electronics: Off-the-shelf parts, controller, standard assembly.

Ropes: Dyneema.

Outlet: sheet metal fabrication.

Tube: edge-stitched panels of Dyneema woven fabric.

Bottomweight/valve: sheet metal fabrication.

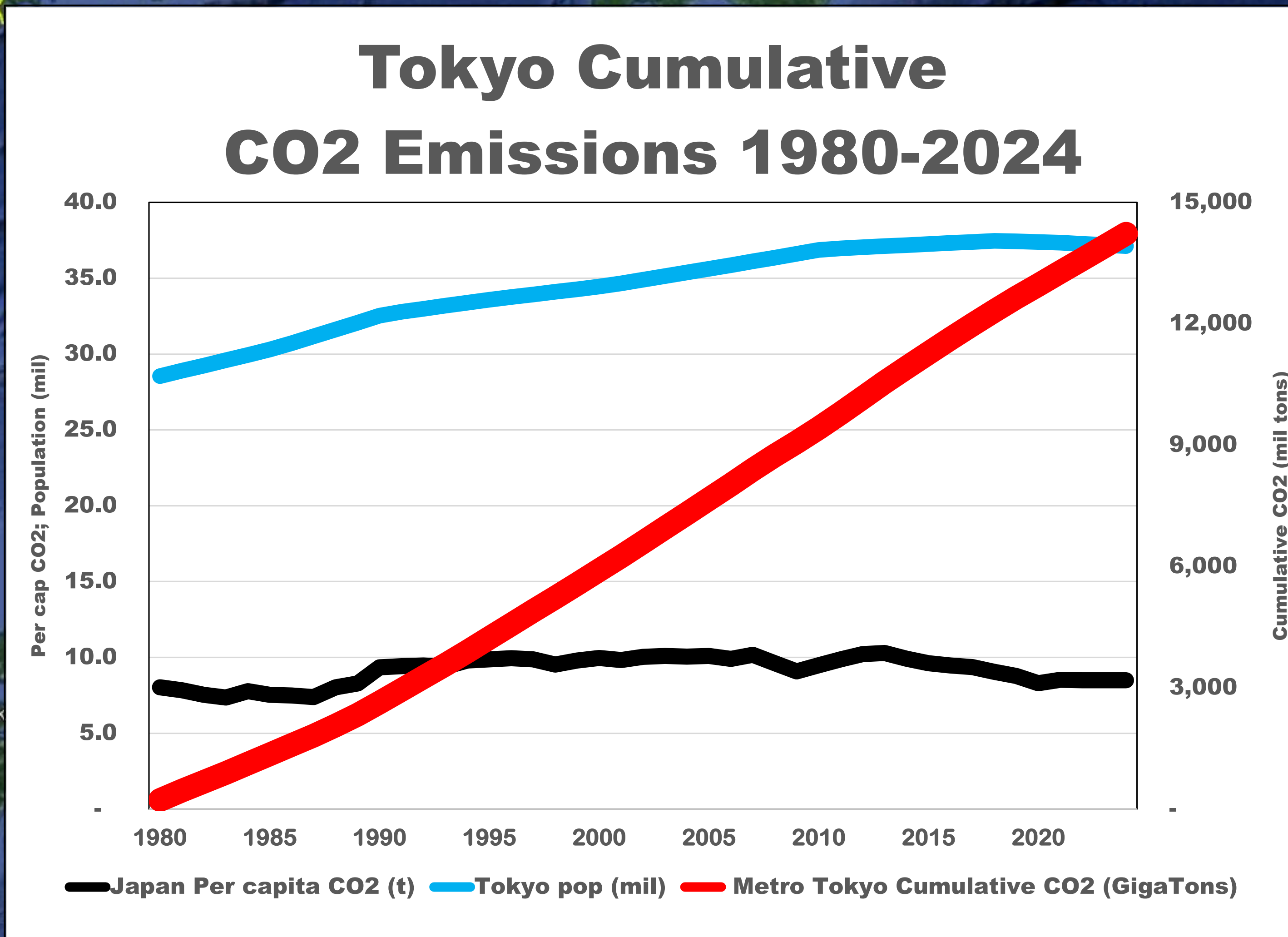


Sea-Up

The

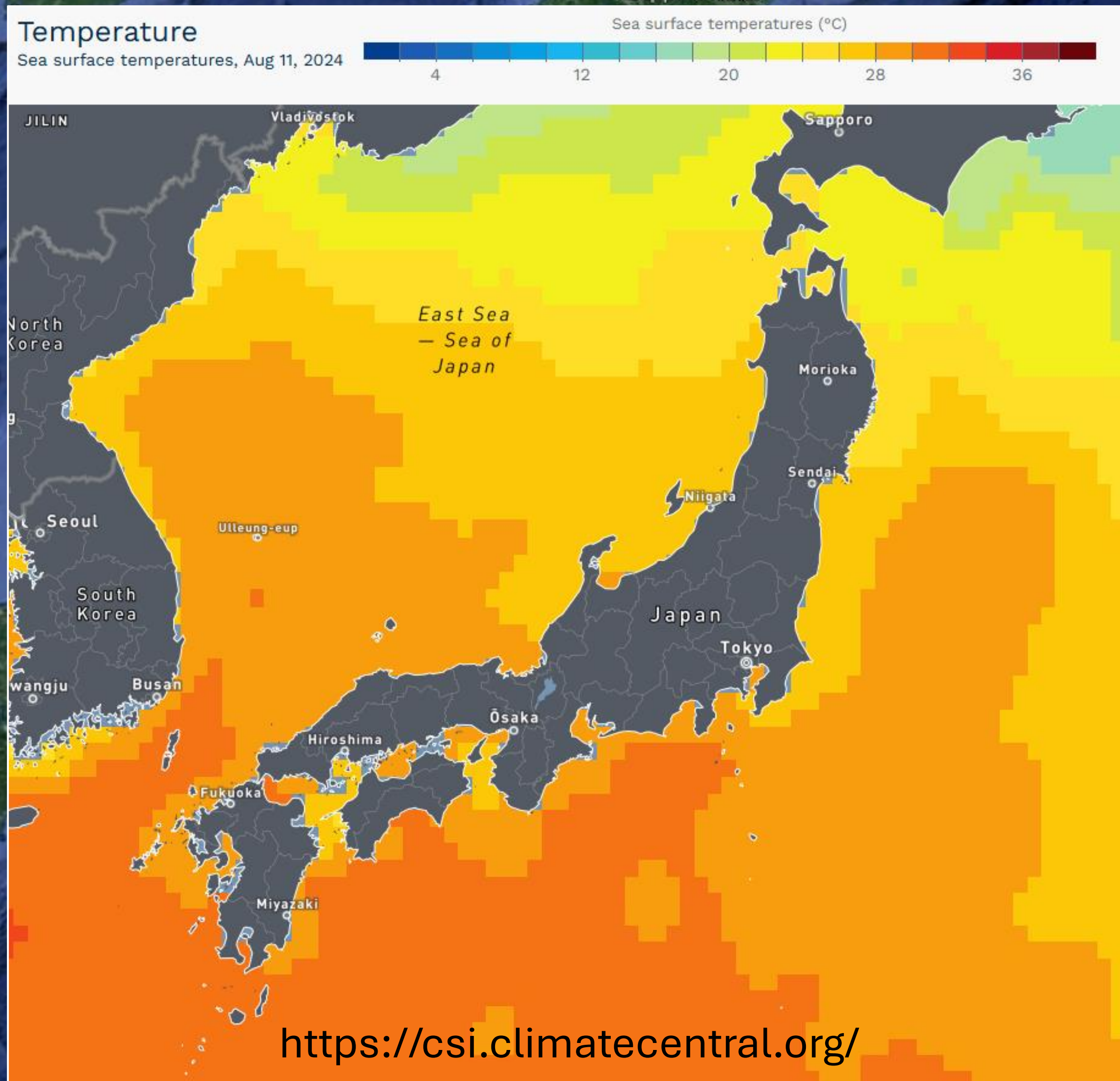
Problem

Cumulative CO2



Sea-Up

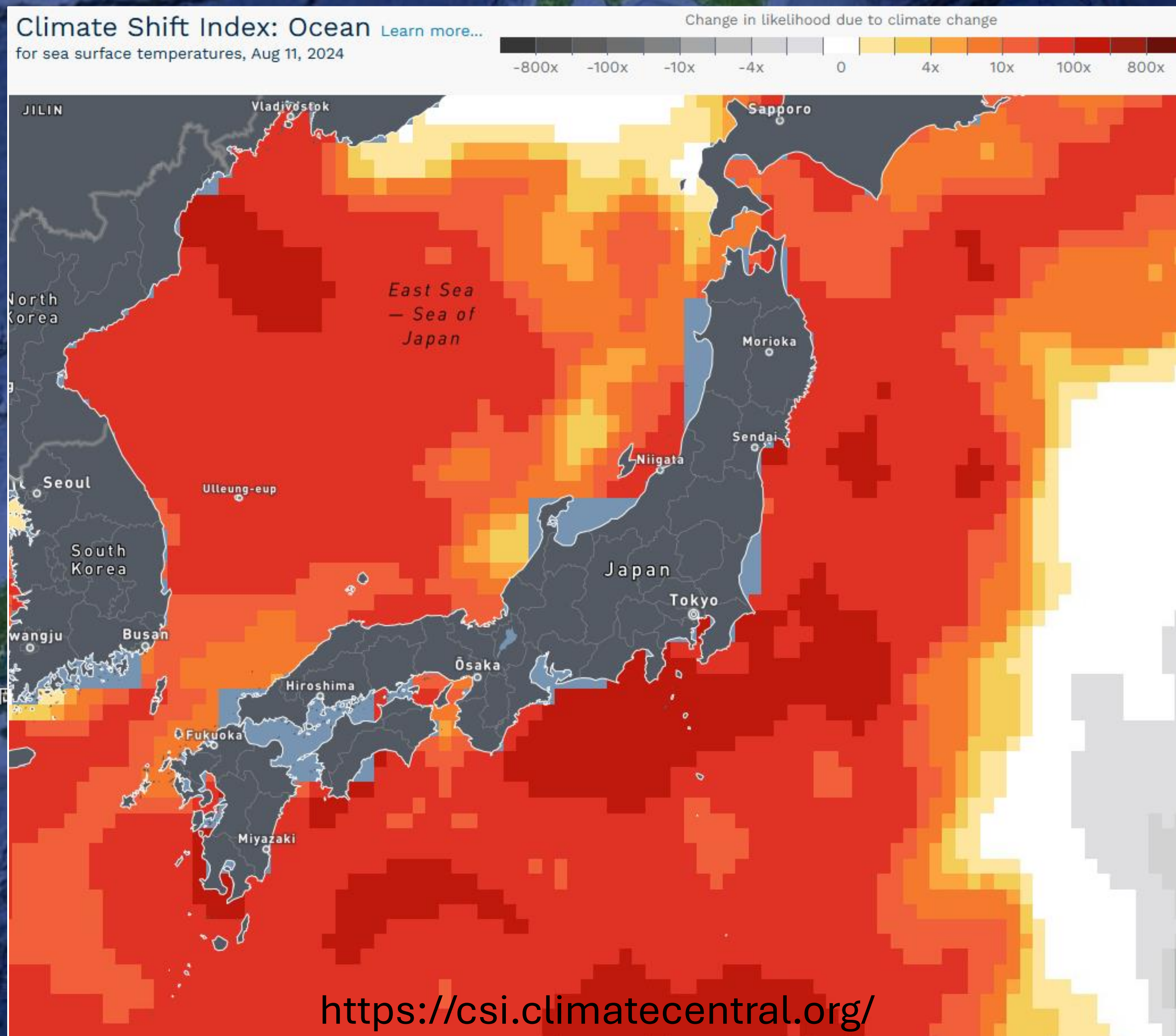
SST



https://csi.climatecentral.org/

Sea-Up

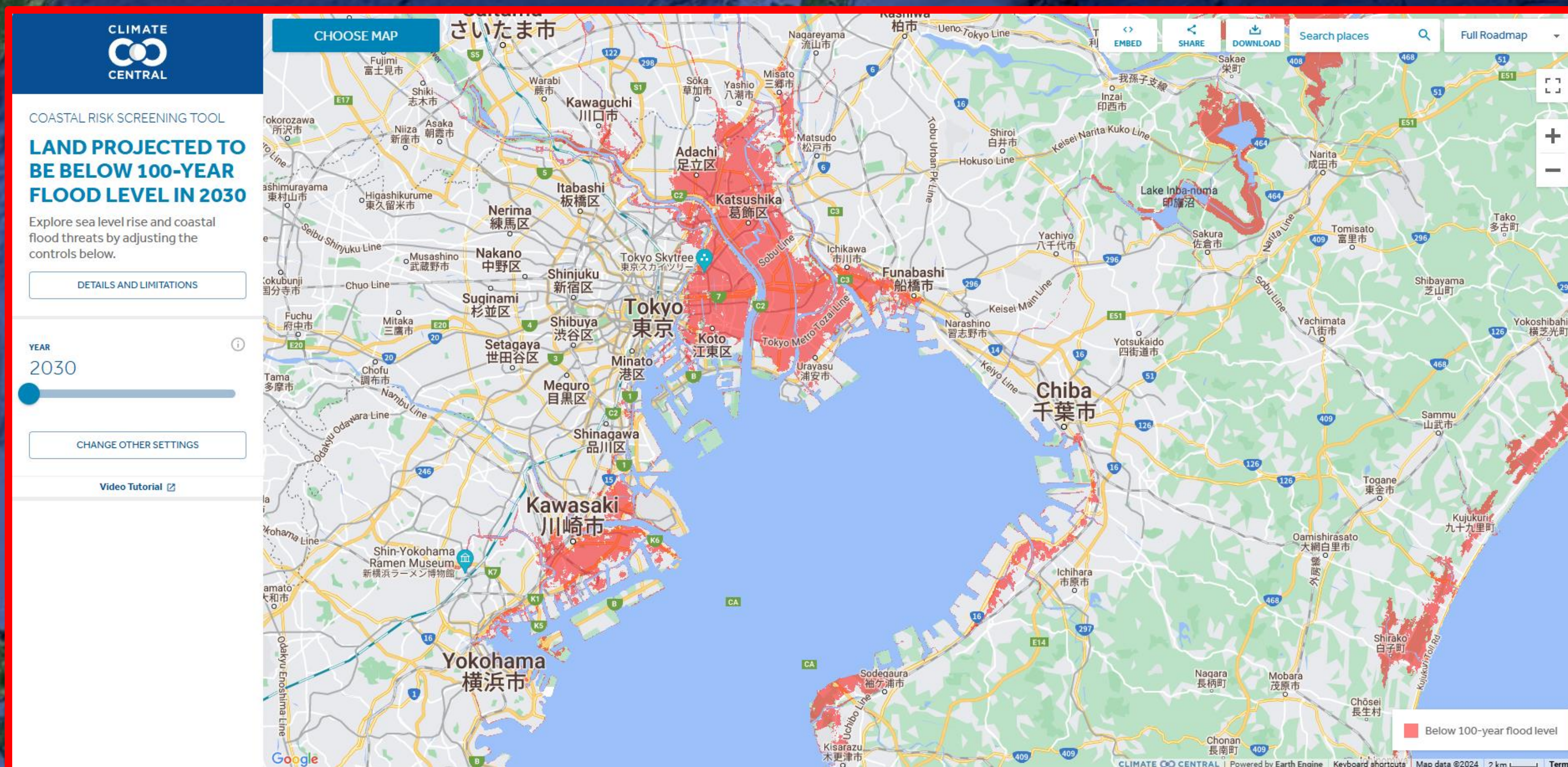
Climate Index



https://csi.climatecentral.org/

Sea-Up

Tokyo Flood Risk (2030)

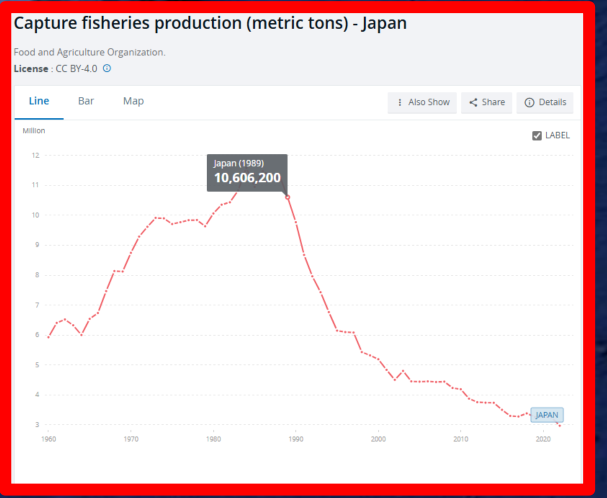


https://csi.climatecentral.org/

Sea-Up

Fishing 10.6MT

<3.0MT

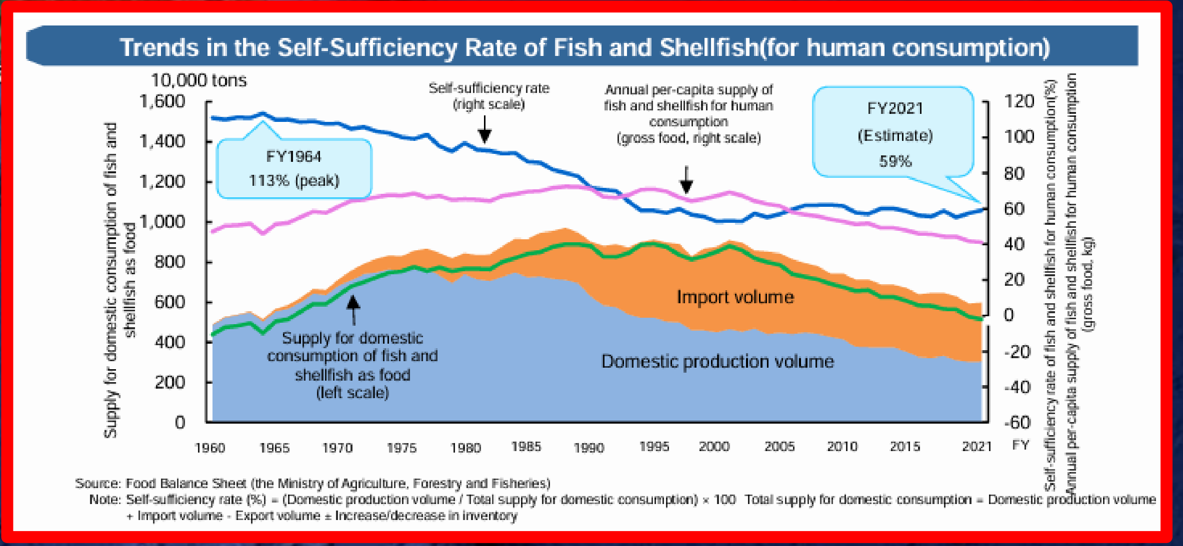


Seafood Sufficiency

113%

59%

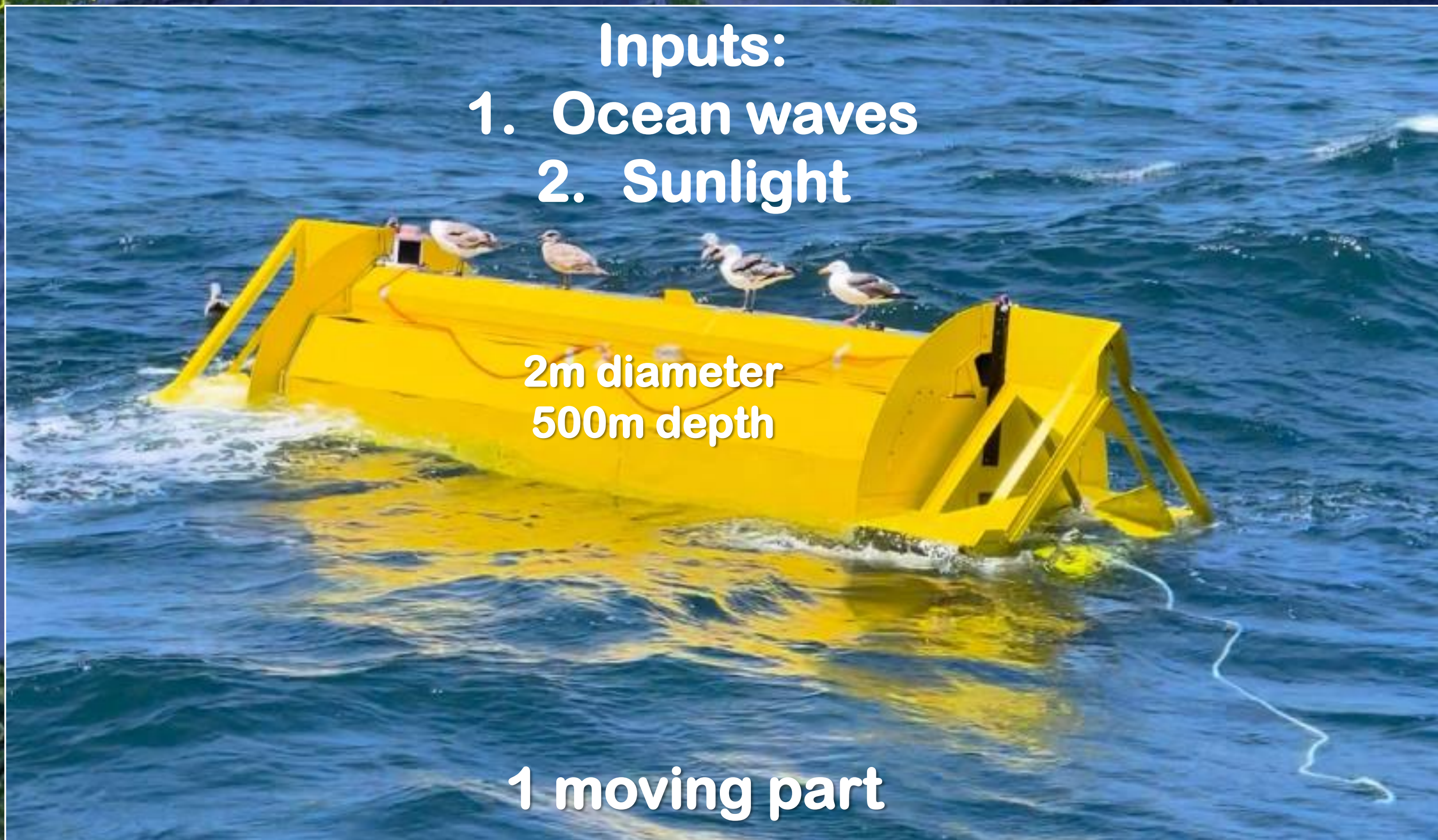
index-220.pdf (maff.go.jp)



Sea-Up

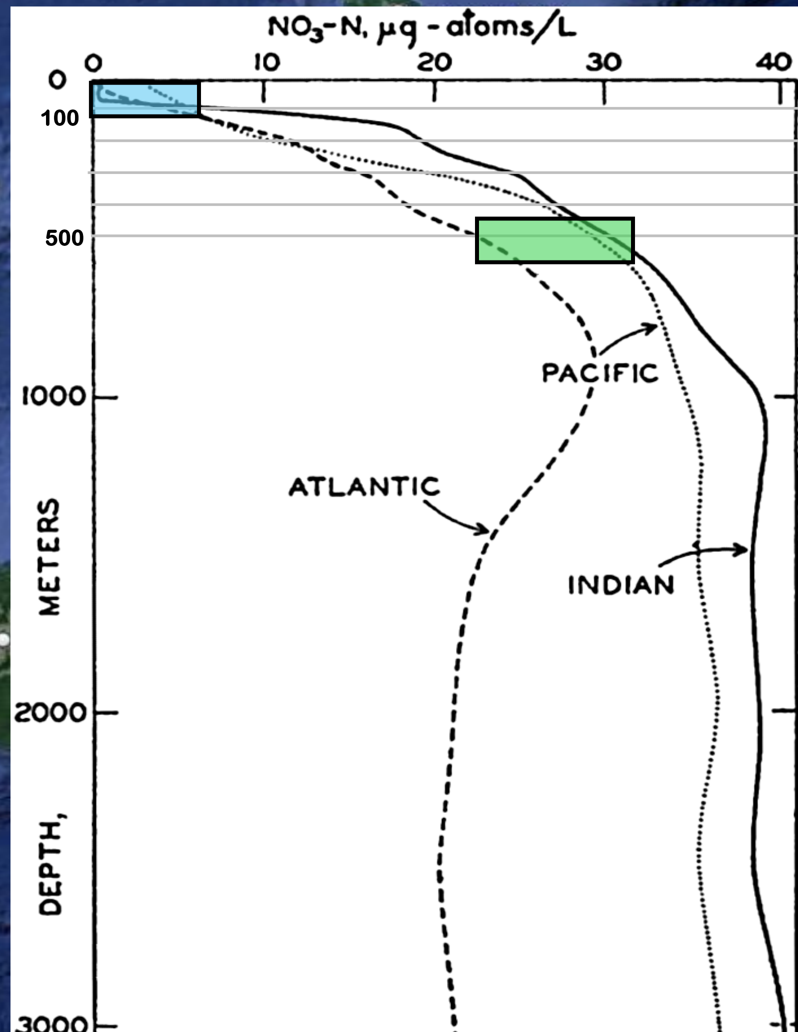
Our Solution

Wave-driven Upwelling.



Sea-Up

Nutrients/Depth Profile.



Sea-Up

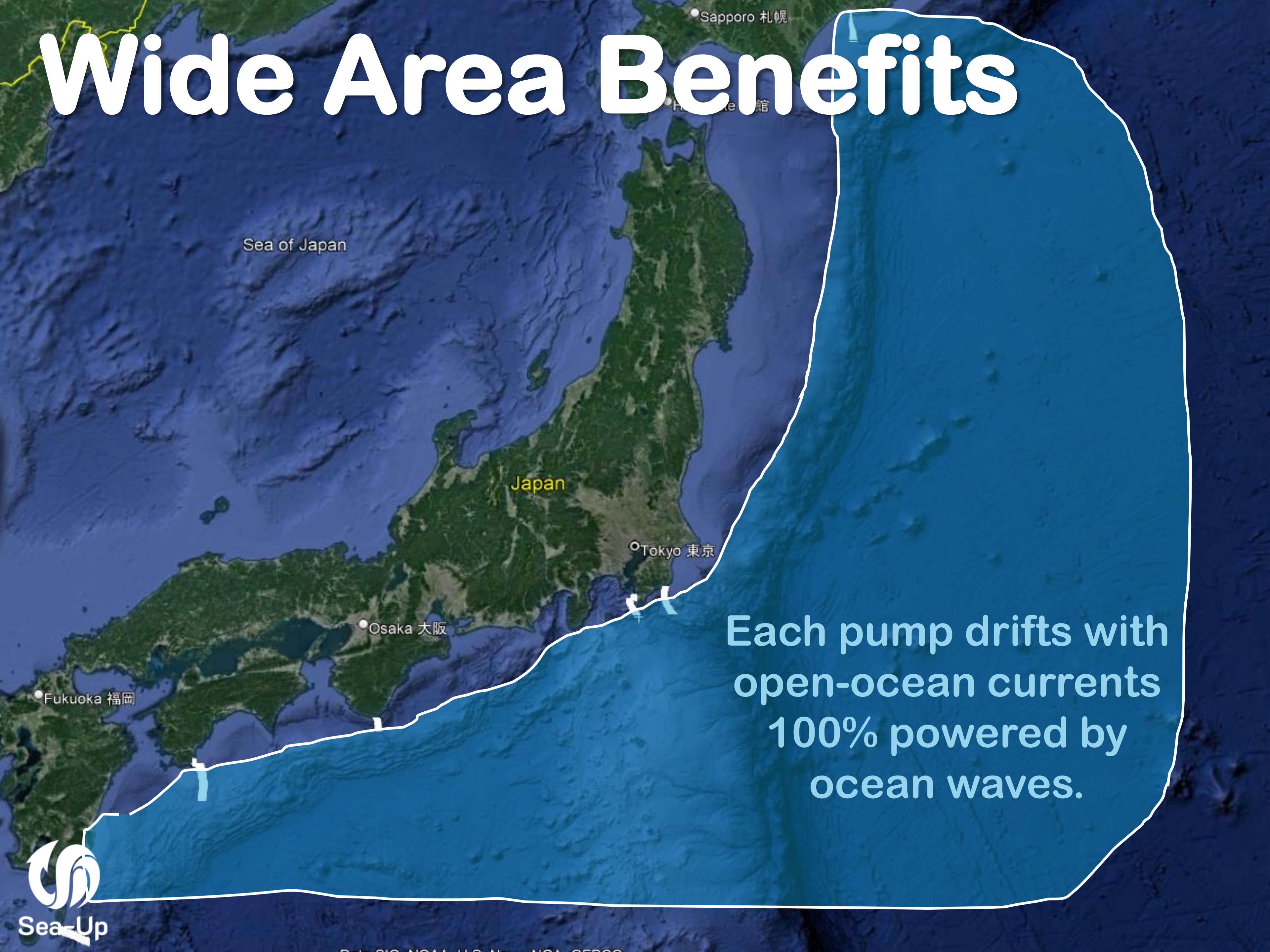
Scientific Basis.

Reference	Tons CO_2 removed*
Karl et al (2008): Nitrogen fixation-enhanced carbon sequestration in low nitrate, low chlorophyll seascapes.	156
Jurchott et al (2023): Artificial Upwelling—A Refined Narrative	96
Wu et al (2023): Carbon dioxide removal via macroalgae open-ocean mariculture and sinking: an Earth system modeling study	141
Chen/Taylor (2024): Modeling Carbon Dioxide Removal via Sinking of Particulate Organic Carbon from Macroalgae Cultivation	1,233
The Climate Foundation (website)	3,000

*Per km^2/year

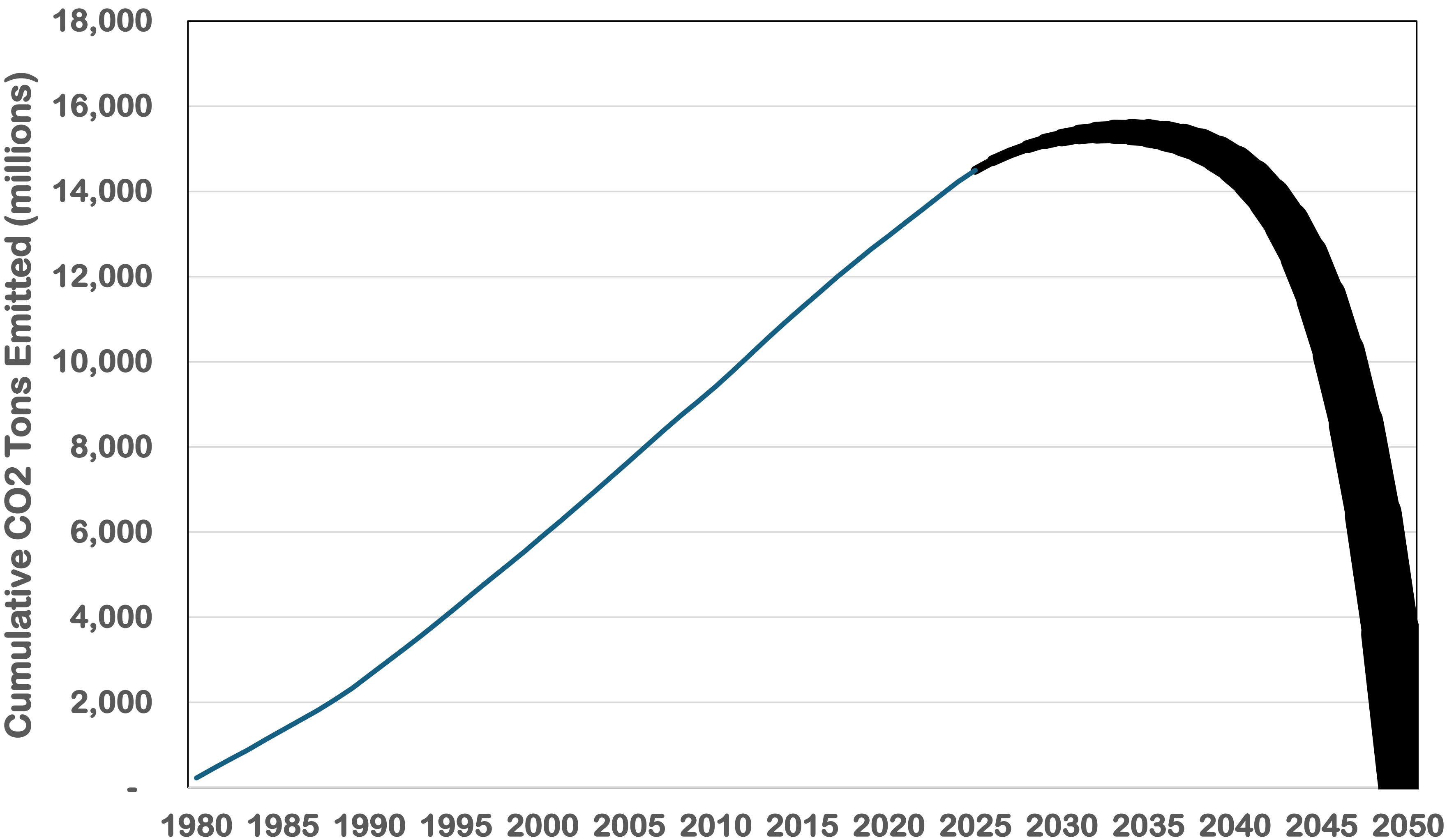
Sea-Up

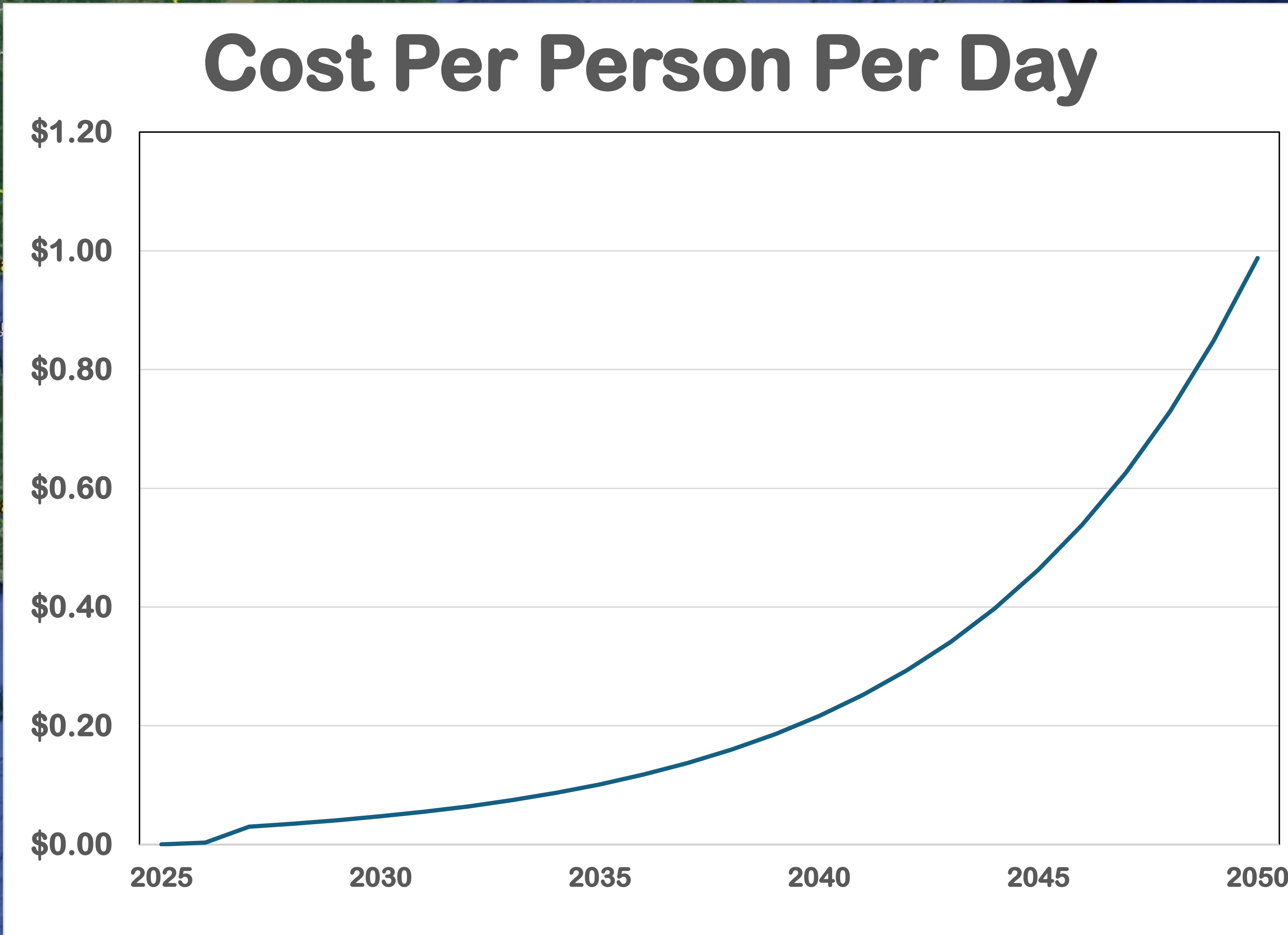
Wide Area Benefits



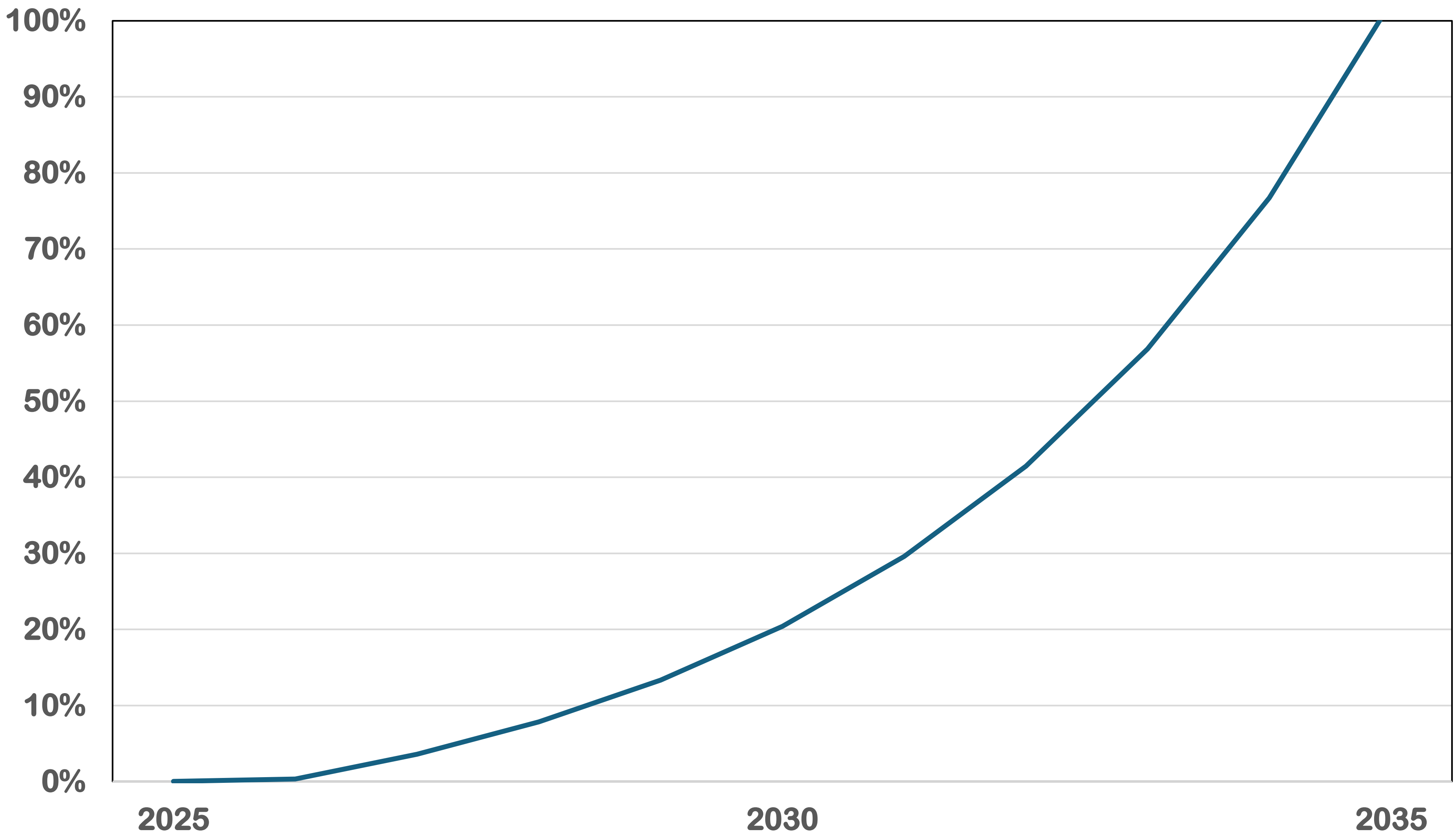
Results

Metro Tokyo Net-Zero 1980-2050!

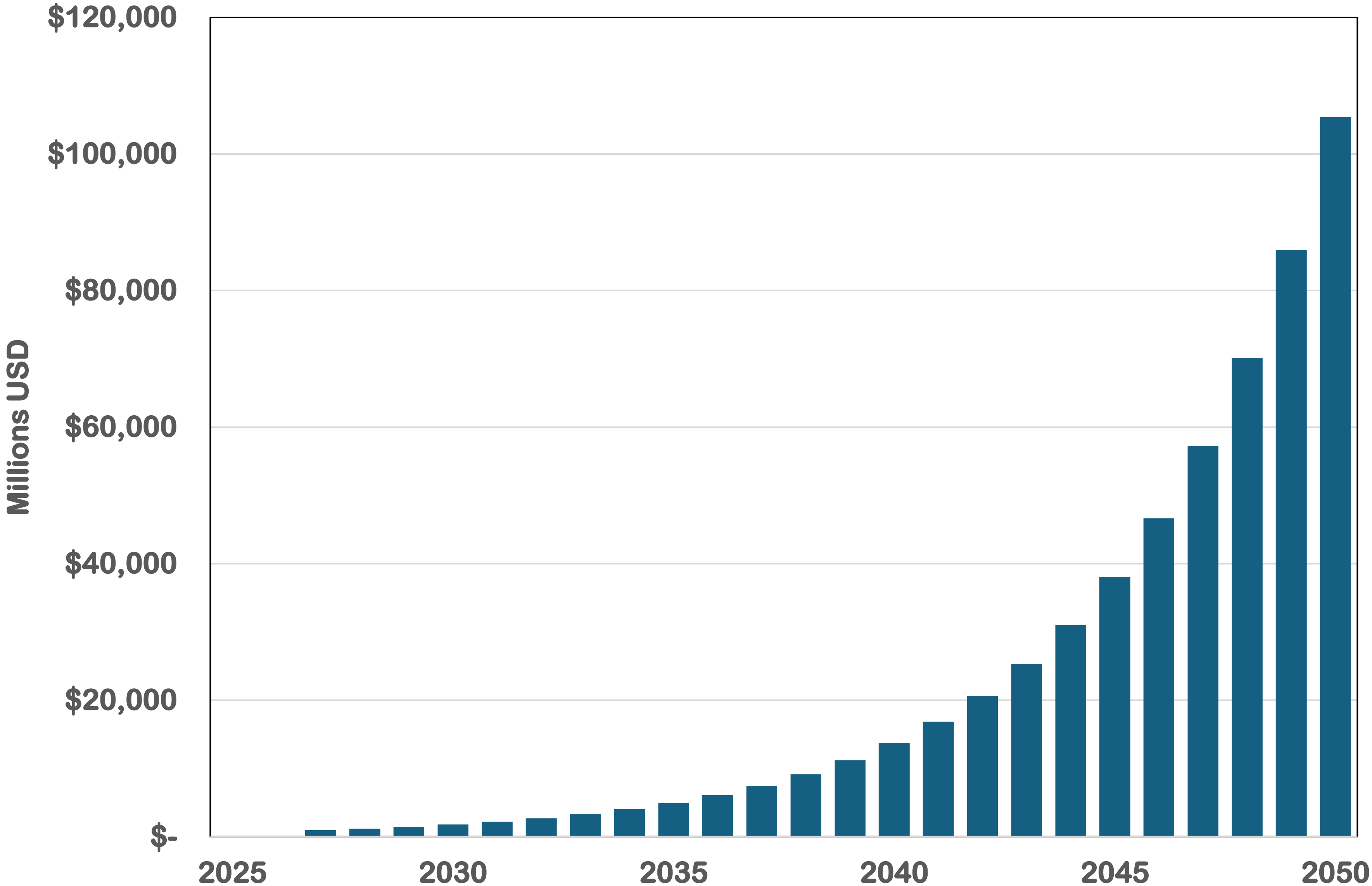



Cost Per Person Per Day
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
2025
2030
2035
2040
2045
2050

Percent Tokyo
1 serving fish per day



Additional Personal Income

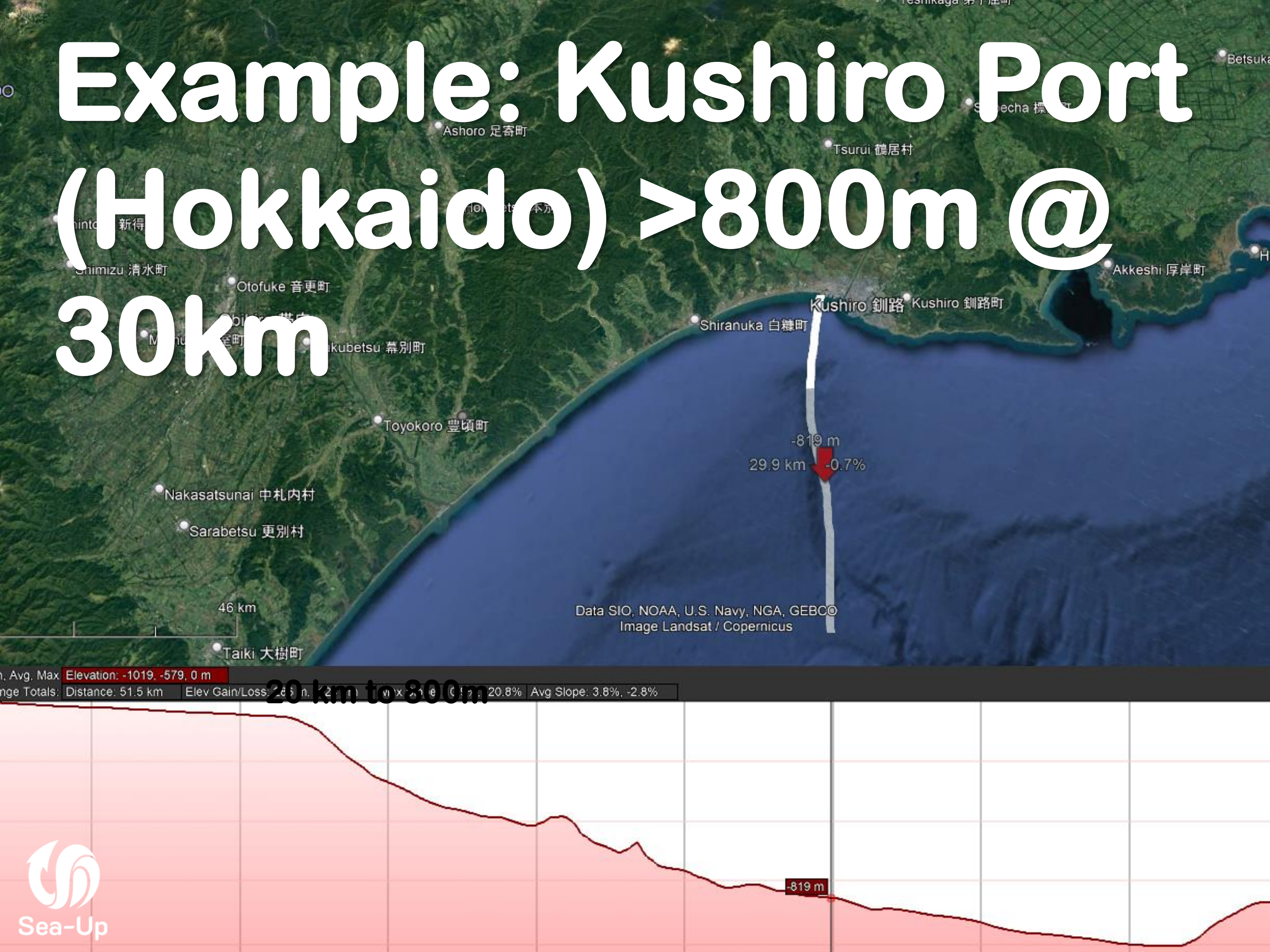


Implementation

Deployment Sites

Sea-Up

Example: Kushiro Port (Hokkaido) >800m @ 30km



20 km to 800m

Sea-Up

Financial

Model

Tokyo Net Zero 2050

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.

Sea-Up

Cautionary Ramp-up

	2025	2026	2027	2028	2029
Pumps deployed	5	100	1,000	1,291	1,666
	....Evaluation....		.......Full production......		

Sea-Up

Urgency

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

Johan Rockstrom

https://youtu.be/Vl6VhCAeEfQ?si=z4cLVDQ5fFA1Dq98

Summary Statement

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

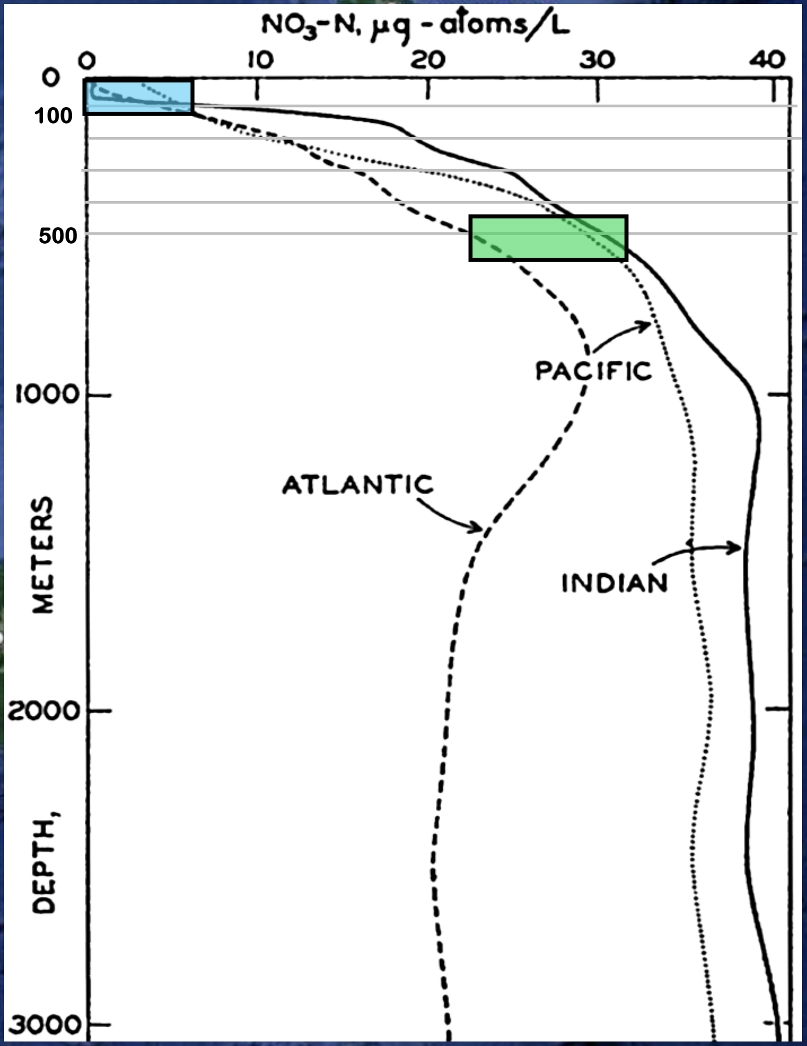
Our Mission is to achieve net-zero total accumulated CO2 for Metro Tokyo looking back to 1980 and forward to 2050 and negative CO2 thereafter. No other government anywhere in the world is yet to consider (much less, implement) such a far-reaching program as this!

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

Technical

Details

Nutrients/Depth Profile.



Sea-Up

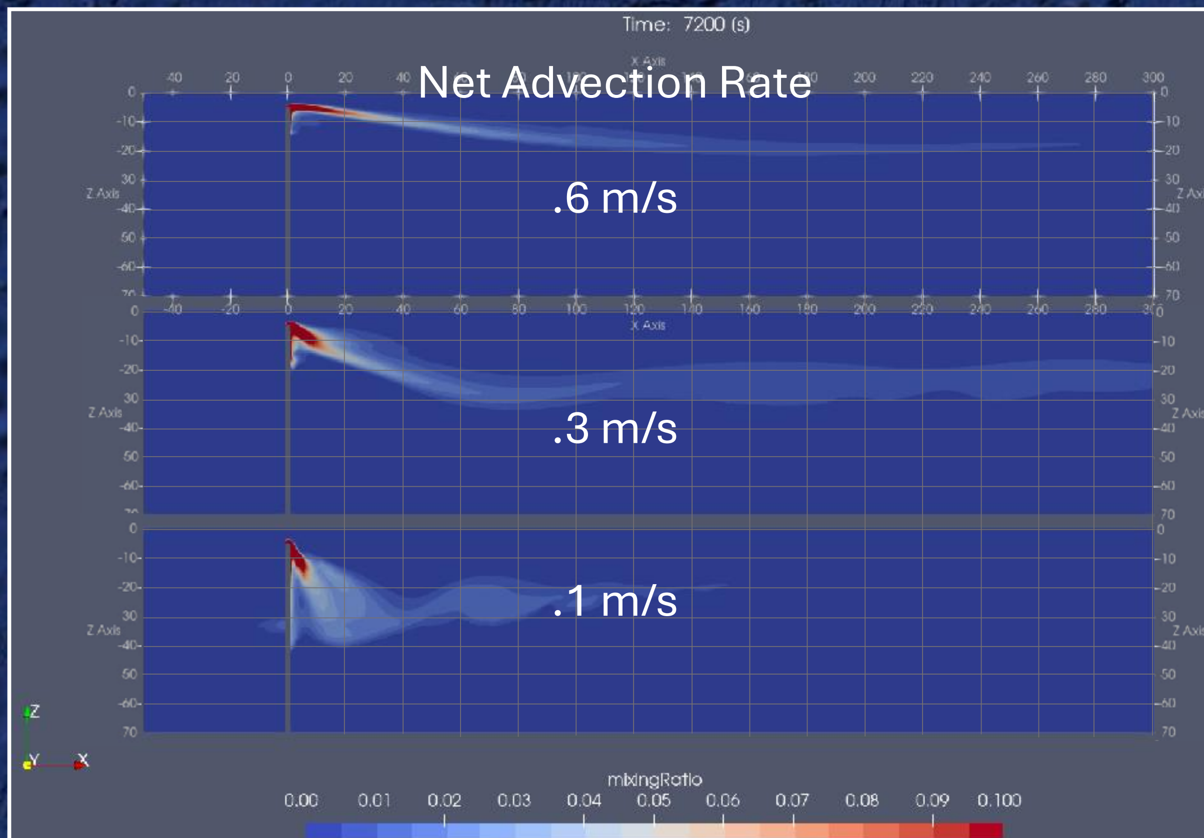
Flow Rate ~ Wave Height/Period

wave ht	period	flow rate m3/s	vol/day/km ^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

Sea-Up

Santa Barbara

Mixing



Source: personal email from Jost Kemper GEOMAR-Kiel

Sea-Up

Drifting Maximum Rate

11.5 km in 5.67 hours (.56 m/s)

Source: GPS on buoy 11/18/22

200m depth pump

Sea-Up

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 CO_2 in atmosphere, temperature and salinity)
- DIC depth
- O_2 surface (or calculated via surface O_2 in atmosphere, temperature and salinity)
- O_2 depth
- NO_3 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 $CaCO_3$ 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. O_2 solubility at surface] - [O_2 observed at depth]

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

Calculating C / O_2 ratio for remineralization without denitrification:

Organic Matter + $138O_2$ -> $106CO_2$ + $16HNO_3$ + $1H_3PO_4$ + water

This equation now contains O_2 take up via denitrification. The ratio therefore changes to 106 C / 138 02 = 0.768. Using O_2 consumption at depth calculated via AOU and applying C / O_2 ratio gives the amount of re-mineralized DIC included in total DIC concentration at depth.

[O_2 mol/L from AOU] * [0.768] = re-mineralized DIC mol/L

(3) Separation of preformed DIC from total DIC.

Preformed DIC concentration at pipe's source depth should be between preindustrial 275ppm and current 400ppm CO_2. The difference between preformed DIC at depth and surface DIC indicates potential CO_2 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 NO_3.

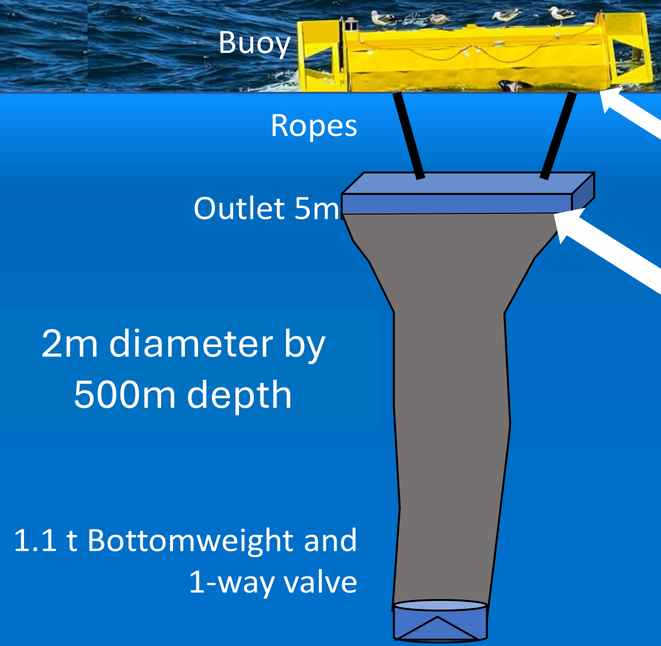
Total NO_3 (depth) – re-mineralized NO_3 (depth) = preformed NO_3 (depth)

Convert preformed NO_3 via Redfield ratio into CO_2. This is the amount of additionally stored CO_2 in algae bloom biomass assuming Redfield ratio. How much 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.

Instrumentation.

Pump Components To Calculate SP CDR & MRV

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



Belly of buoy

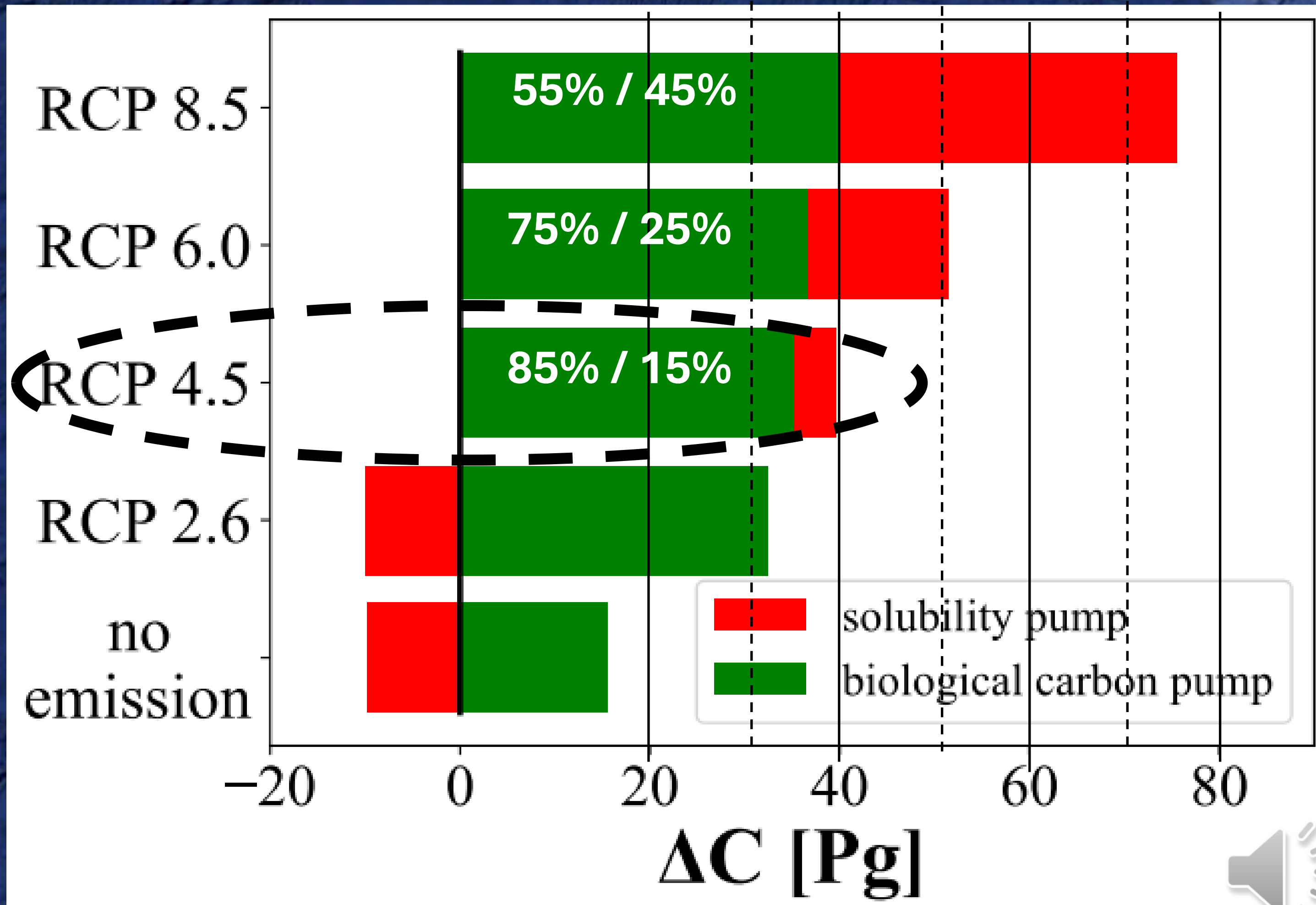
DIC calculated via CO_2 in atmosphere, surface water temperature and salinity (CTD). O_2 (from World Ocean Atlas). Load cells top of ropes.

Measured inside the pump outlet

(same water as 500m depth)

Flowmeters (2)
DIC (calculated)
O_2: **RBRcoda^3 T.ODO**
pCO_2 (**CO2-Pro**) + pH (**ANB**) (=TA)
NO_3 (**SUNA-V2**)
Salinity (from **ANB**)
Temperature (from Argo fleet or adjust from RBRcoda^3 T.ODO)

Estimating BCP.



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

Sea-Up

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 Jurchott]

Sea-Up

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]