

# ASIA CLEAN ENERGY FORUM 2017



THE FUTURE IS HERE: ACHIEVING UNIVERSAL ACCESS AND CLIMATE TARGETS

Manila 5-8 June, 2017

## Sustainable Building Materials Grown in Seawater



Scott Countryman, Executive Director, The Coral Triangle Conservancy, (dba Reeph)

- Acknowledgements to Dan Millison, Transcendery, LLC and Dr. Thomas Goreau President, Biorock Technology Inc.



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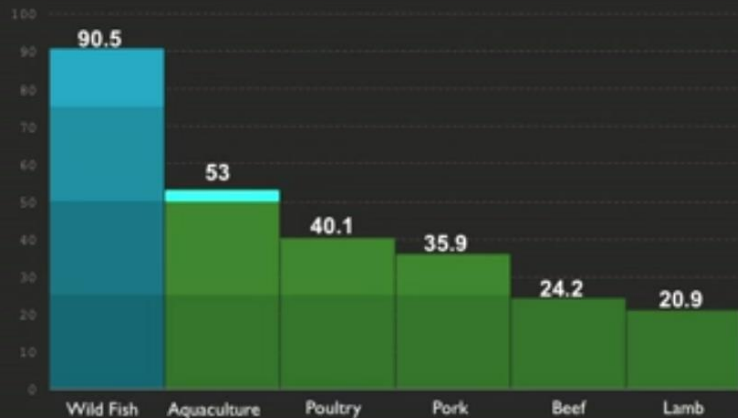
Charter Group September/October 2005 © JS Callahan 2009

	<p><b>2050</b></p> <p>IS THE YEAR EXPERTS SAY WORLD FISHERIES EXPECT TO COLLAPSE</p>		<p><b>\$50B</b></p> <p>1/5 OF FISH ARE CAUGHT ILLEGALLY RAKING IN AN EST. \$50B A YEAR</p>
	<p><b>80%</b></p> <p>THE WORLD'S FISH STOCKS ARE ALREADY FULLY EXPLOITED</p>		<p><b>90%</b></p> <p>OF PREDATORY FISH: TUNA, SHARKS, SWORDFISH, COD &amp; HALIBUT ARE GONE!</p>
	<p><b>300,000</b></p> <p>WHALES AND DOLPHINS ARE KILLED EACH YEAR VIA BY-CATCH</p>		<p><b>8M SQUARE MILES</b></p> <p>THE GREAT PACIFIC GARBAGE PATCH IS 2X LARGER THAN THE UNITED STATES!</p>



## Wild Fish is Most Cost Effective Animal Protein

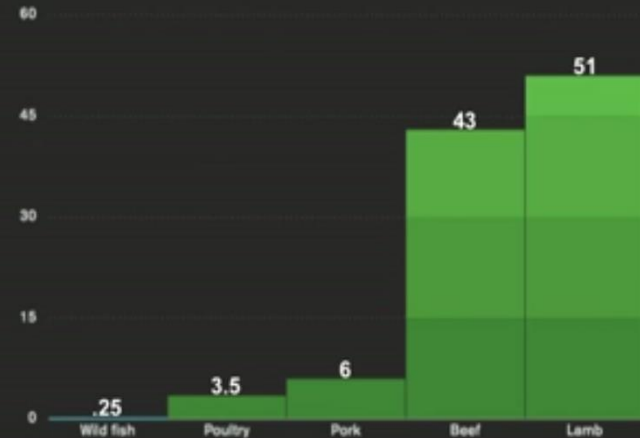
Metric tons per \$100,000



Source: FAO / Sea Around Us Program

## Wild Fish Uses Least Amount of Water in Production

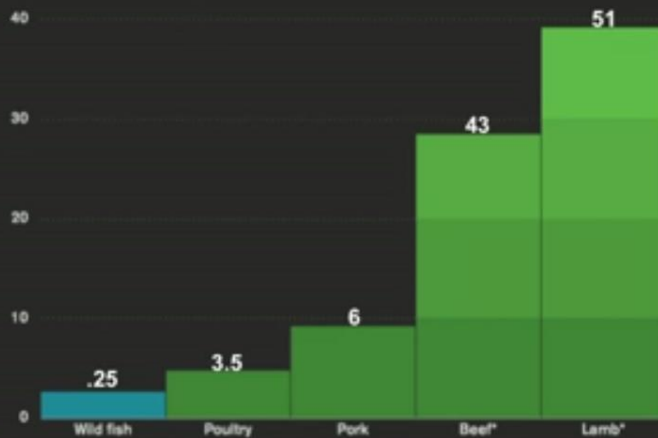
1,000 liters of water per kilogram of protein produced



Source: Pinstrup 2004

## Wild Fish is Lowest Producer of Greenhouse Gases

Kilograms of CO<sub>2</sub> per kilogram of protein



\* Includes methane as CO<sub>2</sub> equivalent

Source: Environmental Working Group / UNITEF

## Wild Fish Benefits Include Health

Potential health impacts of switching from red meat to fish

Heart Disease

24%

Cancer

25%

Obesity

5%

Sources: A. M. Berstein, et al. Circulation 2010; T. Norat, et al. JNCI J Natl Cancer Inst 2005; Y. Wang and M. Beydoun. Int J Obes (Lond) 2008

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## Coral Reef Tourism is worth \$36 Billion to the Travel Industry and Host Nations Every Year



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Arlington, Va. | May 22, 2017

- 70 countries and territories have “million dollar reefs”, or reefs that generate approximately \$1 million per square kilometer
- These reefs are generating jobs, and critical foreign exchange earnings for many small island states that have few alternative sources of employment and income.
- 4,000 dive centers, 15,000 dive sites and 125,000 hotels were used to further assess the proportion of tourism spending that can be attributed to coral reefs.
- Coral reefs can yield an average 15 tonnes of fish and other seafood per square kilometer per year.
- **And yet, nearly 60 percent of the world's coral reefs are threatened by human activity. In places like the Philippines only 1% are in excellent condition and the dual threat of climate change and ocean acidification threaten to wipe up all coral reefs within the next 35 years.**

*'WHAT WE DO IN THE NEXT 10 YEARS  
WILL DETERMINE THE FATE OF OUR  
OCEANS FOR THE NEXT 10,000 YEARS'  
-Sylvia Earl*

# Mission and Objectives of Venture

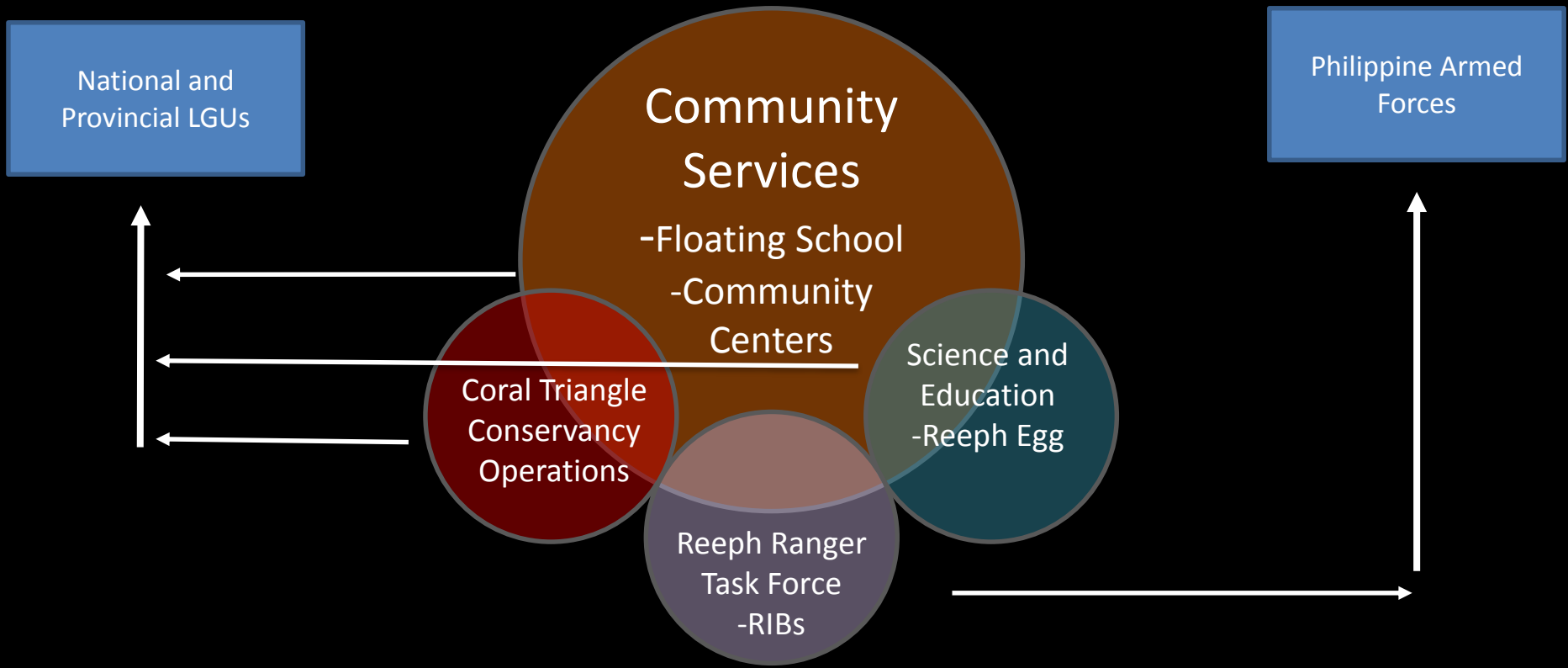


## The Coral Triangle Conservancy

Is a not for profit philanthropic venture based in the Philippines campaigning to establish networks of ecosystem sized marine protected areas while pioneering new technologies and social programs to end overfishing.

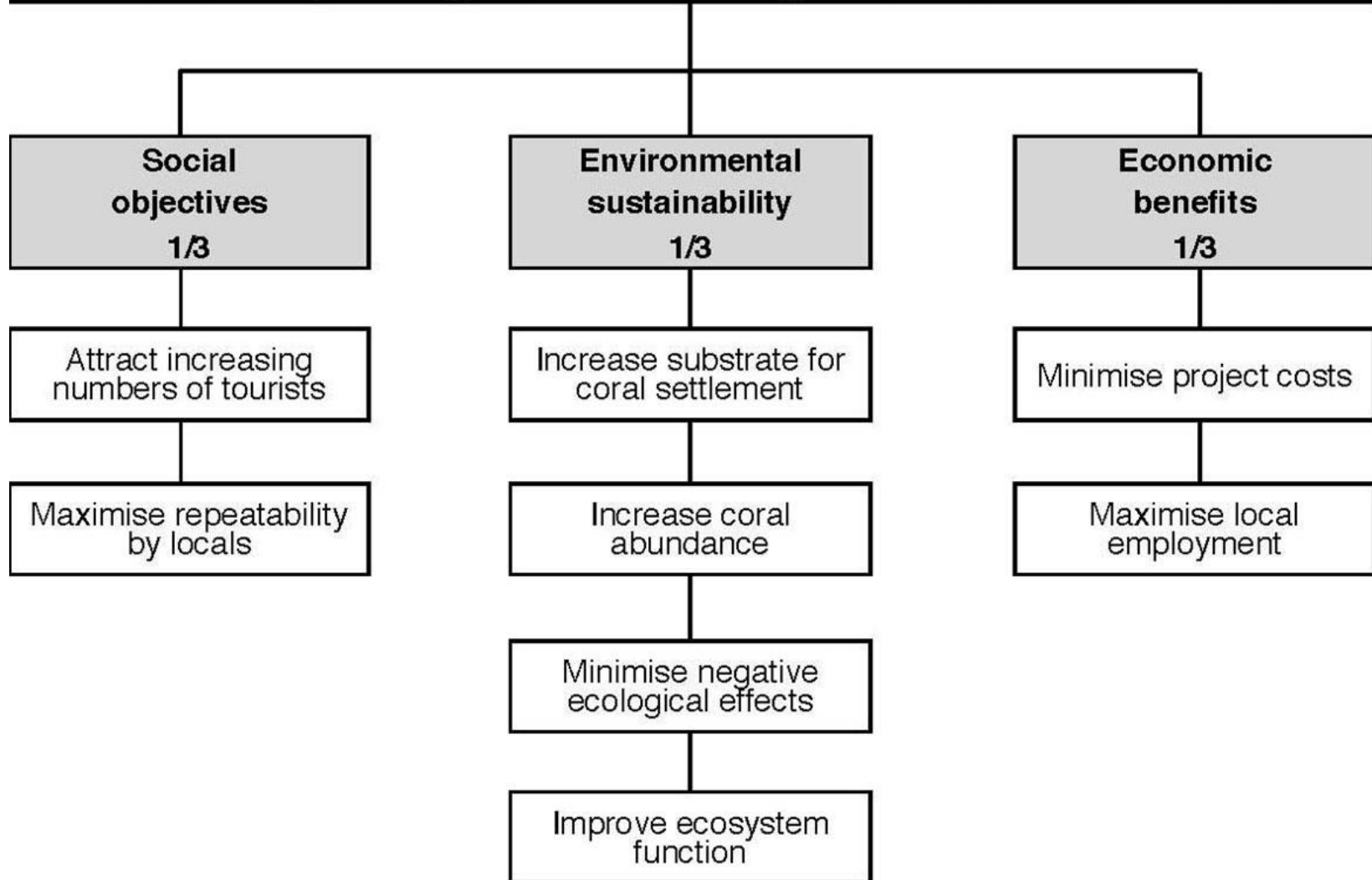
Our programs seek to increase awareness of the importance of coral reefs and then seed and incubate locally managed businesses that create economic incentives for conservation activities.

# Reeph Integrated MPA Management Service Mix



# Triple Bottom Line

**MAIN GOAL: improve degraded reefs for ecological and socio-economic benefits**





# Reeph Egg: Coastal Fishing Watch



Emanta floating school



Ree.ph EGG



Community managed mineral accretion reef

Egg Ree.ph aims to encompass Science, Education and Fisheries Monitoring – all in the one box.

## Marine Science Educational Program

- *Emanta* Solar Floating School
- Practical learning through field excursions
- Citizen science monitoring programs
- Community managed electric mineral accretion Reeph

## Fisheries Resource Monitoring

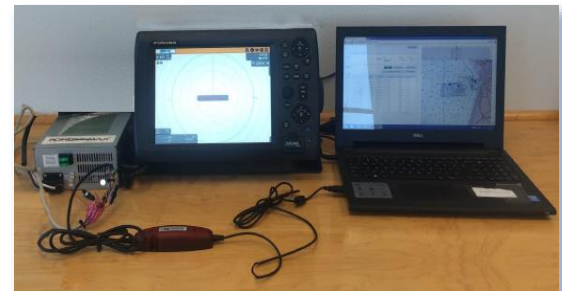
- M2 AI Enhanced RADAR
- Day and night-time marine patrols with FLIR and NVG
- Underwater Acoustic Monitoring
- Fish Landing Surveys
- Long Range Autonomous Drones and UAVs

## Marine Science and Environmental Monitoring Program

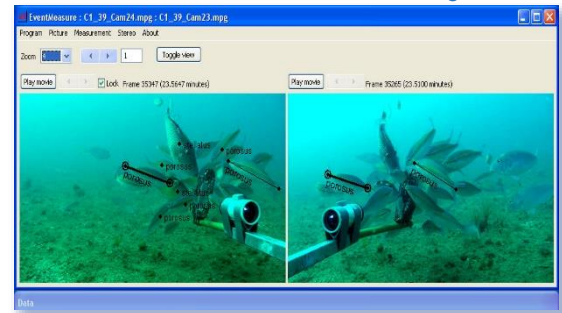
- Fish Monitoring
- Habitat Mapping
- Reef Check Diver Surveys
- Water Quality Monitoring Program



Floating school participants April 2017



Fisheries Resource Utilisation Monitoring



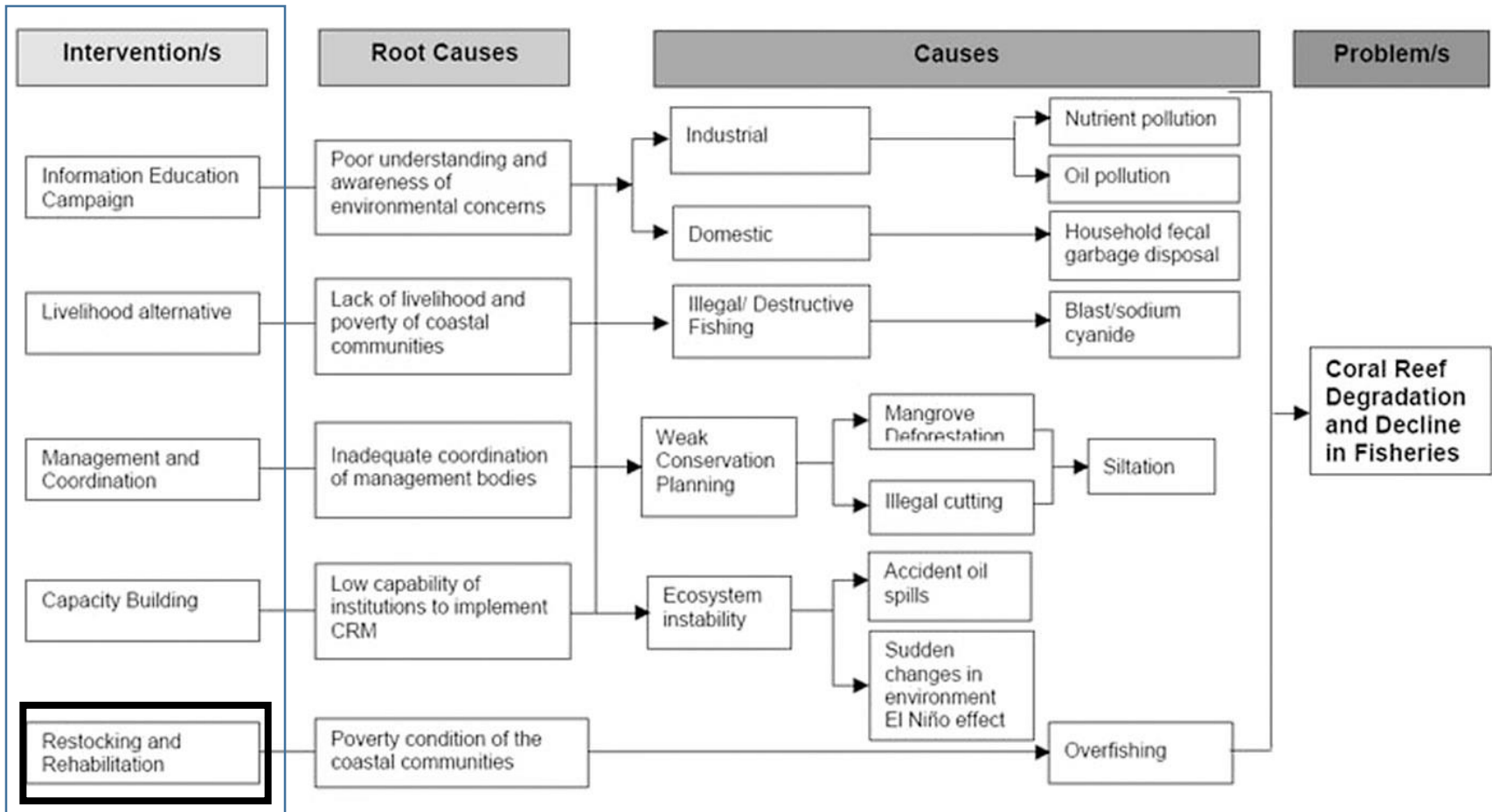
Baited Stereo Camera Fish monitoring



Anthropocene Institute



# Areas for Intervention



... the Gigatech solution for a Gigaton Problem

# Green / Modular Buildings: “AD-MIT”

Adaptation = more resilient to meteorological events

Mitigation = energy & GHG savings



T30A hotel tower built in 360 hours by Broad Sustainable Building Co. Ltd. Hunan

- **90% pre-fabricated – use Reephrock??**
- 5x more energy efficient
- Magnitude 9 earthquake resistance

<http://www.broad.org/enbroadcom/>

# Conventional cement & concrete = unsustainable

Limestone + coal

$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$

0.83 – 1.6 MWh/ton cement

0.9 tons CO<sub>2</sub>e/ton cement



Portland cement + rebar  
+ aggregate →  
Cast-in-place concrete



- No environmental dividends
- Externalities not fully priced in



# Conventional with Cleaner Production...

Limestone + coal  
 $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$   
0.83 – 1.6 MWh/ton cement  
0.9 tons CO<sub>2</sub>e/ton cement

- Quarry & mine restoration
- Convert to pumped storage



Portland cement + rebar  
+ aggregate →  
Cast-in-place concrete

- No environmental dividends
- Externalities not fully priced in

- Calera: not commercial
- Solidiatech: 70% CO<sub>2</sub> reduction – commercial?
- *Neither addresses full supply chain*

# Replace Conventional with Sustainable Process

Limestone + coal  
 $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$   
0.83 – 1.6 MWh/ton cement  
0.9 tons CO<sub>2</sub>e/ton cement



Portland cement + rebar  
+ aggregate →  
Cast-in-place concrete



- No environmental dividends
- Externalities not fully priced in

Electricity + seawater + rebar →  
grown-in-place concrete equivalent  
 $e^- + \text{Ca} + \text{CO}_2 + \text{H}_2\text{O} + \text{rebar} \rightarrow$   
 **$\text{CaCO}_3 + \text{H}_2 \text{ gas}$**   
1 MWh / ~ 1 ton CaCO<sub>3</sub>  
1 - 2 cm/year growth rates  
0 tons CO<sub>2</sub>e/ton (direct)

## ***Multiple benefits:***

- Infinitely scalable
- Climate proof, self-healing structures
- Marine ecosystem creation

W. H. Hilbertz & T. J. Goreau, 1996, Method of enhancing the growth of aquatic organisms, and structures created thereby, United States Patent Number 5,543,034, U. S. Patent Office (14pp.).

## ***Proven science and engineering***

- Cathodic protection systems widely used in petroleum industry
- Anode plus cathode of shaped rebar
- “Trickle” charge: no safety issues to divers or marine life
- Off-the-shelf materials + semi-skilled labor

Alkaline conditions that are needed for coral skeleton growth is provided by the removal of protons with zooxanthellae photosynthesis, which pulls the bicarbonate system equilibrium to the right  $2\text{HCO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{CO}_3$ . The alkalinity is then neutralized by the precipitation of calcium carbonate (aragonite) as  $\text{CO}_3$  is very unstable and immediately fuses with a  $\text{Ca}^{2+}$  ion. Because photosynthesis and calcification are physically separated, an active transport of calcium and protons is required, with ATP (adenosine triphosphate) being the energy carrier.



1 Year : Nasugbu, Batangas

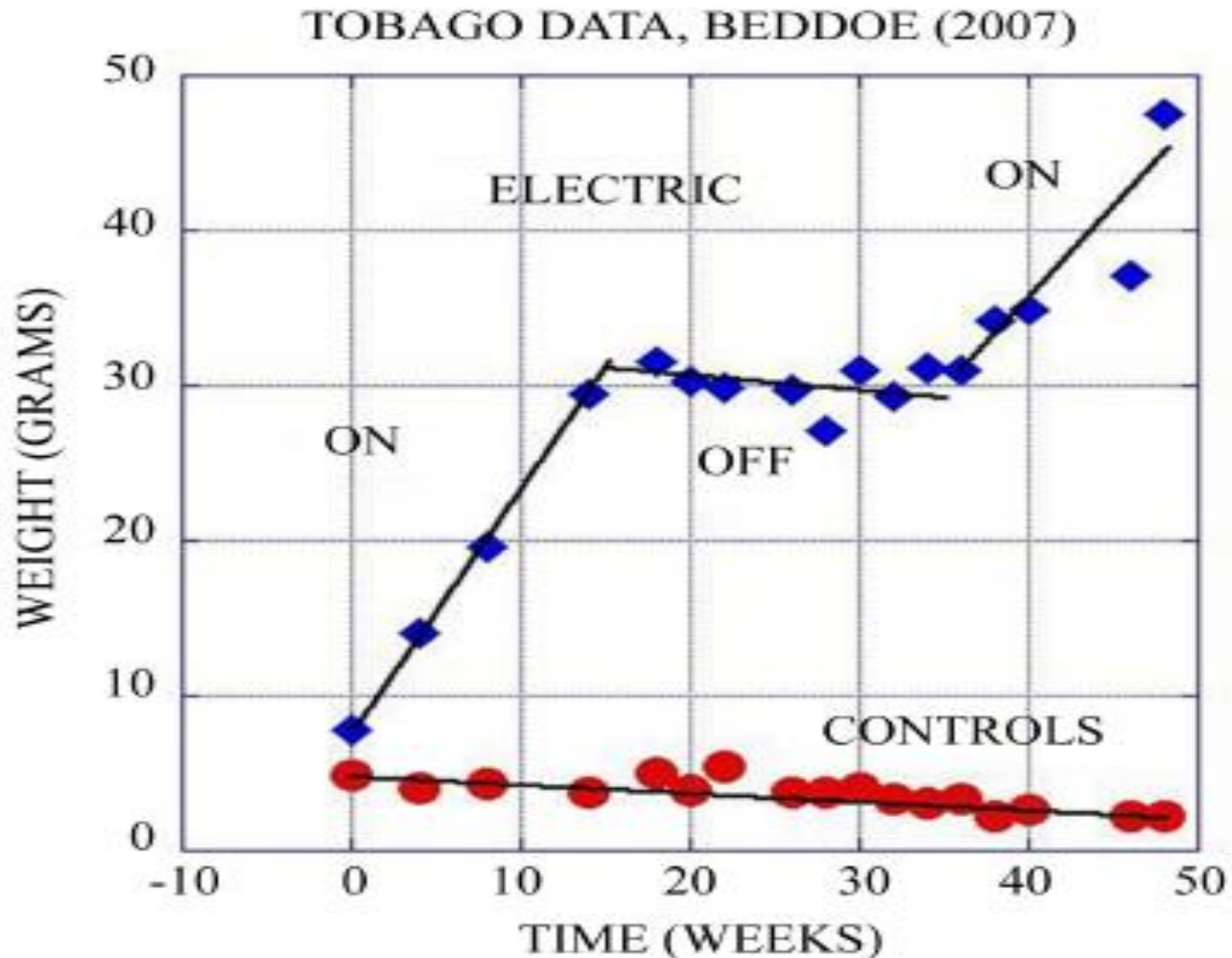




6+ Years Bali, Indonesia



# Electric reefs are resistant to acidification & bleaching & can be grown faster than the climate is changing



# EMA Checks all the Boxes

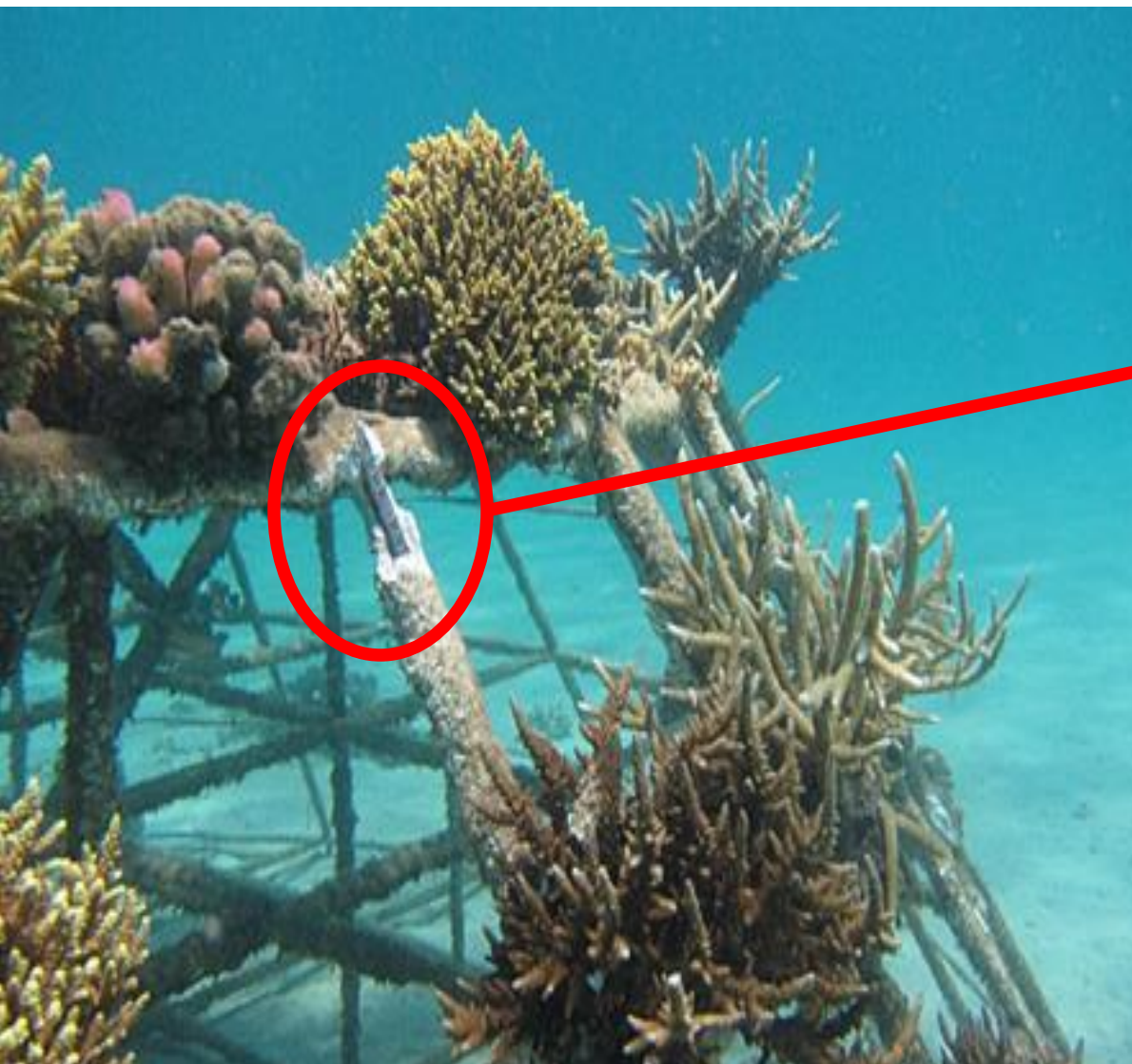
- **Quickly Rehabilitates Damaged Coral Reefs**
- **Increases Biodiversity**
- **Build resilience to Climate Change**
- **Increase abundance and food security**
- **Educates Communities**
- **Reverses shoreline erosion**
- **Improve standards of living, create economic alternatives to wildlife extraction activities, etc.**

**EMA Reephs might not cover every square meter of the ocean but they are an important element at the center of our conservation projects.**



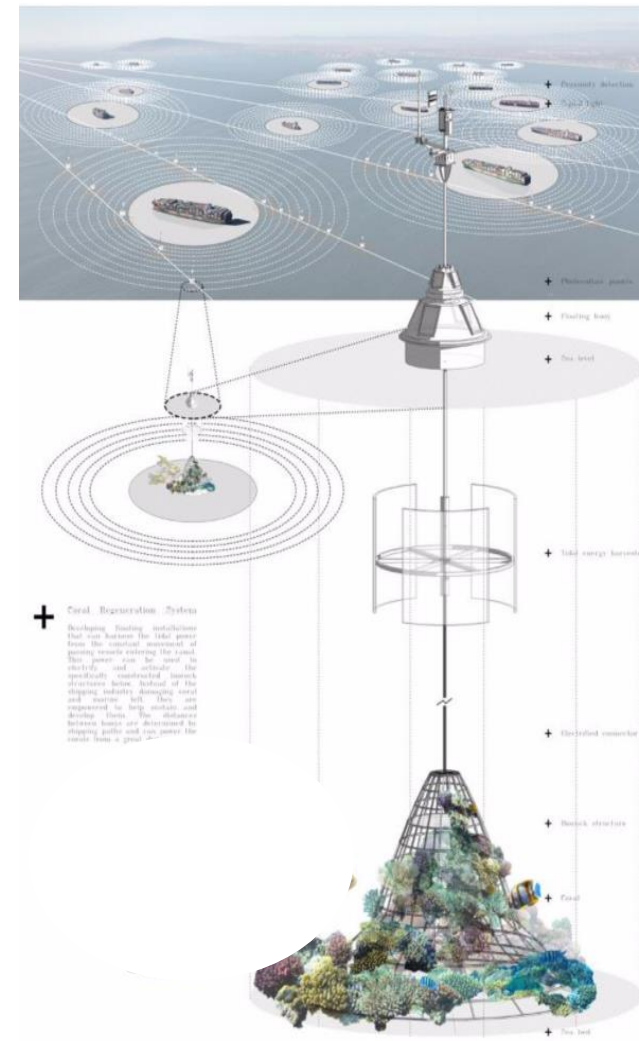
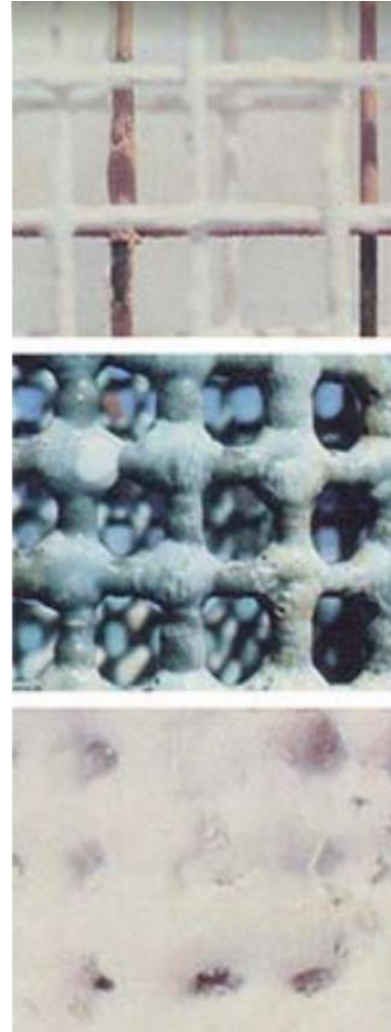
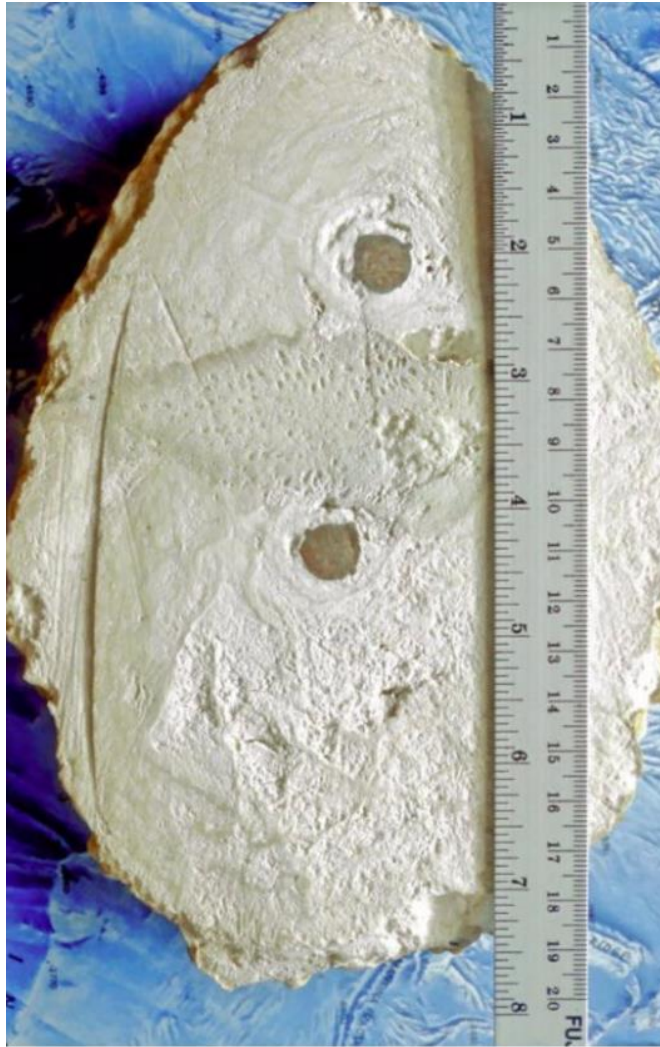
# Coral Triangle Conservancy – Nasugbu, Philippines

## “reeph” production of limestone & e-reef



Photos courtesy of Scott Countryman, Coral Triangle Conservancy: [ree.ph](http://ree.ph)

# Targeting Prefabricated Limestone Slab and Higher Value Building Products



Mineral accretion sample from Maldives which was grown electrolytically during only five years. Images from [www.wolfhilbritz.com](http://www.wolfhilbritz.com)

# Growth Rates and Density determined by Varying Voltage and Current



6 volts - 1.5 days

Clumps of mineral accretion began to form quickly on the mesh - seemingly focused on specific areas at the beginning of the experiment.



6 volts - 3 days

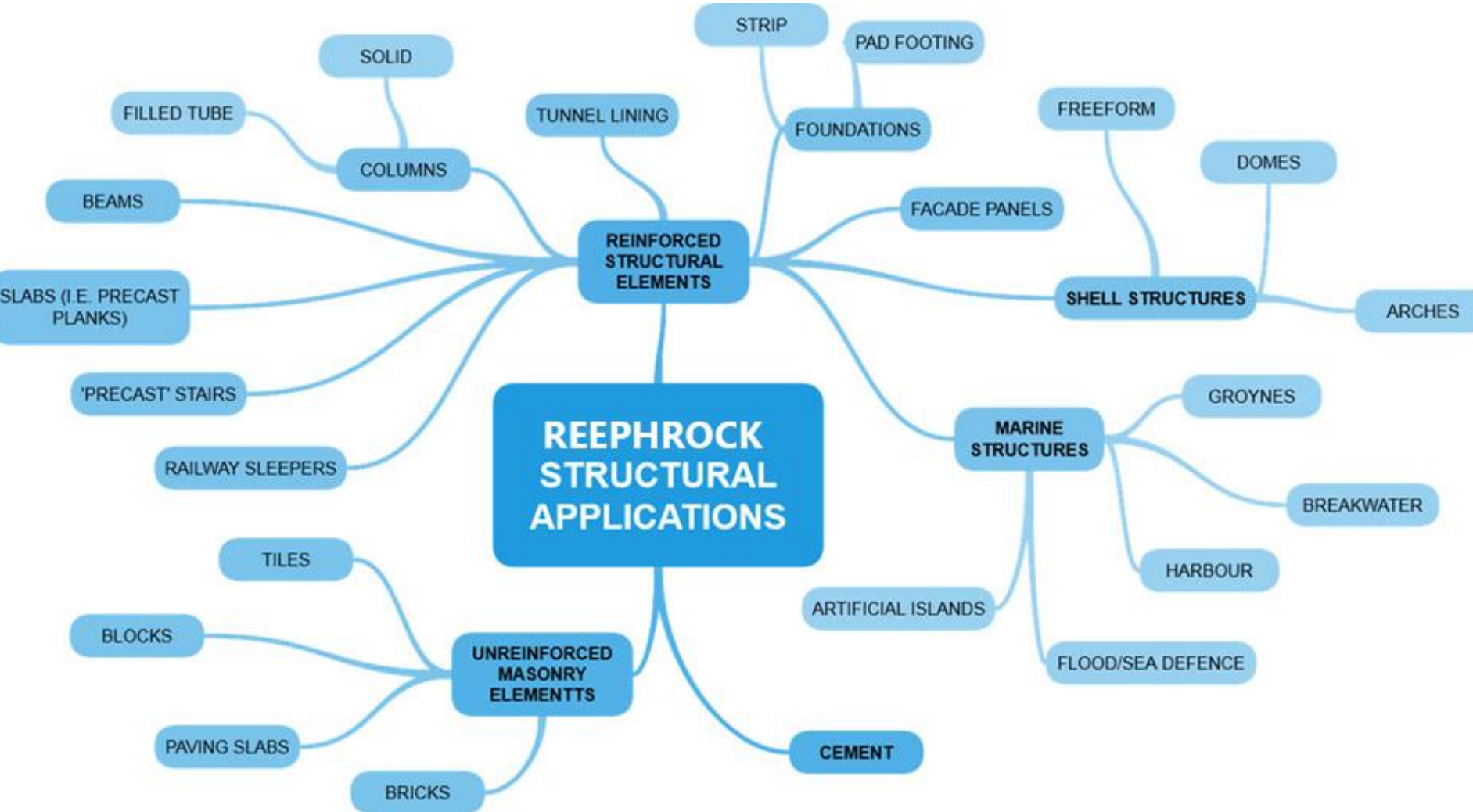
There was not much progression after 3 days, therefore I added more marine-salt to the mixture.



6 volts - 4 days

Accretion dramatically increased after adding salt, providing a thick and more even coverage of calcium carbonate deposit on the mesh - adding 10-12mm of depth to the steel mesh

# Supports marine ecosystem health, rehabilitation, & creation: *scalable* climate change adaption



Source: Coral Triangle Conservancy, ree.ph

# Global Construction Materials Market

Material	Unit Price	Break-even Electricity Cost	Comment
Concrete <sup>a</sup>	\$39 / ton	\$0.04 / kWh	Low end of utility scale solar PV <sup>d</sup>
Portland Cement <sup>a</sup>	\$75 / ton	\$0.075 / kWh	Typical range of utility-scale solar PV <sup>d</sup>
Quarried limestone – bulk <sup>b</sup>	\$160 / ton	\$0.16 / kWh	High end of on-shore power in SE Asia (except PHI)
Finished Limestone slabs <sup>c</sup>	\$649 / ton	\$0.65 / kWh	Electricity cost >> diesel generation or floating PV

Notes: <sup>a</sup> From solidiatech.com; Portland cement market is valued at \$300 Billion for 4 billion tons/year; concrete market is valued at \$1.3 Trillion for 33 Billion tons/year

<sup>b</sup> On-line price on 30 January 2017, accessed from:

<http://www.stonecontact.com/products-320404/iran-beige-gohare-limestone>

<sup>c</sup> This link to vendor selling slabs at \$30 - 50 / m<sup>2</sup>, 1.5 cm, 2 cm, and 3 cm thickness, with density > 2.56 ton/m<sup>3</sup>:

[https://www.alibaba.com/product-detail/Limestone-price-beige-limestone-limestone\\_60449241268.html](https://www.alibaba.com/product-detail/Limestone-price-beige-limestone-limestone_60449241268.html)

Unit price is \$649 - 789 / ton

<sup>d</sup> World Bank Group. 2016. Price of Solar PV Electricity in Developing Countries. World Bank, Washington D.C.



# Break-even Cost for 1 MW Solar PV-based System

Material	Unit Price	Annual Product Value	Simple Cost Recovery (years)
Concrete	\$39 / ton	\$55,152	36.3
Portland Cement	\$75 / ton	\$105,000	19.0
Quarried limestone	\$160 / ton	\$224,000	8.9
Finished limestone slabs	\$649 / ton	\$909,091	2.2
Finished limestone slabs	\$789 /ton	\$1,105,263	1.8

## Key Assumptions:

(i) 1 MWh of electricity input yields 1 ton  $\text{CaCO}_3$  (1 kWh = 1 Kg  $\text{CaCO}_3$ )

(ii) 1 MW solar PV with 4 hours per day output, 350 days per year = 1400 MWh / year = 1400 tons  $\text{CaCO}_3$  per year

(iii) \$2 Million per Megawatt PV installed

# Infinite Scalability

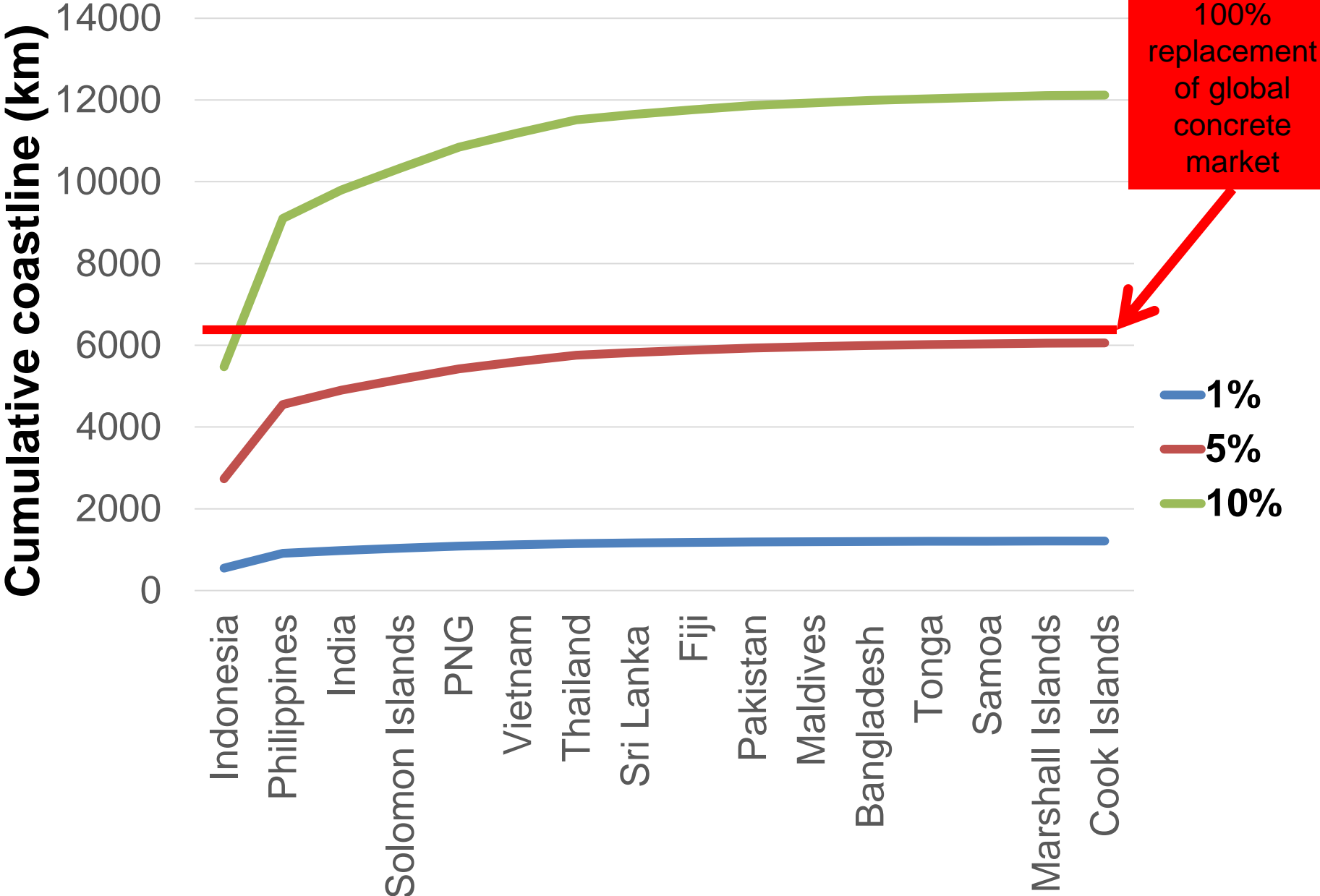
Country	Coastline (km)	Coastline needed for 100% replacement of global concrete production
Indonesia	54,716	11.7%
Philippines	36,289	17.6%

Global concrete market: 33 billion tons / 2.56 tons/m<sup>3</sup> = 12.8 billion m<sup>3</sup>  
Assuming 2 m water column, need 6.4 billion m<sup>2</sup> surface area; use a 1 km corridor... @ 1 million m<sup>2</sup> / km<sup>2</sup> → need 6400 km<sup>2</sup>  
= 0.0018% of earth's oceans

## Other ADB DMC candidates:

Cook Islands 120 km, Marshall Islands 370 km, Samoa 403 km, Tonga 419 km, Bangladesh 580 km, Maldives 644 km, Pakistan 1046 km, Fiji 1129, Sri Lanka 1340 km, Thailand 3219 km, Vietnam 3444 km, PNG 5152 km, Solomon Islands 5313, India 7000 km      TOTAL ~ 30,000 km

# Scalability



Coastline needed for 100% replacement of global concrete market

- 1%
- 5%
- 10%

# Nasugbu Site, Philippines

## e-Manta & Charge Barge for sustainable energy inputs



# Project Site at Calaca, Batangas Ready for prototype operation Adjacent to Free Power



# Business Model & Financing

- “Patient” capital: ~ \$1+ million for start-up + 2-3 years for initial production output (Breakthrough Energy Ventures?)
- Concessional finance
- Partnership with global cement producers: Cemex, Holcim, Lafarge?
- 21<sup>st</sup> century construction companies: Broad Sustainable Building Co. Ltd.
- Coastal zone disaster insurance?

# Research and Development

- Further testing required to confirm material properties – especially strength in compression and shear
- Competitive price per kg – how does this compare to concrete or steel
- Rate and quality of growth to be carefully controlled
- Conductive mesh to be used as tension strands – performs same job as rebar in reinforced concrete
- Connections between discrete elements to be considered



# One of the richest countries in the world was not able to prevent loss of ~ 1/3 of the Great Barrier Reef

*“Despite the massive death of corals from high temperature in 2016, Biorock reefs in Indonesia maintained under 24-hour power suffered no noticeable mortality at all, making it the only method that protects corals from dying from global warming.”*

*-- Thomas Goreau*

Accessed on 30 January 2017 from: <http://www.globalcoral.org/2017-gcra-plans/>



# References

Goreau, T.J. (2014) *Electrical Stimulation Greatly Increases Settlement, Growth, Survival, and Stress Resistance of Marine Organisms*, *Natural Resources*, 5, 527-537, <http://dx.doi.org/10.4236/nr.2014.510048>

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W. H. Hilbertz & T. J. Goreau, 1996, Method of enhancing the growth of aquatic organisms, and structures created thereby, United States Patent Number 5,543,034, U. S. PATENT OFFICE (14pp.).

## Additional References

- Sarah Slaughter, panel presentation on “Opportunities in infrastructure and built environment”, MIT Sloan School of Management, Cambridge, Massachusetts, 19 September 2008.
- Greg Kats, *The Costs and Financial Benefits of Green Buildings: A Report to California’s Sustainable Building Task Force* (California, 2003).
- Overview of modular buildings: <http://www.modular.org>
- For some green building activity in southeast Asia see:  
<http://www.eco-business.com/news/panahomes-pre-cast-technology-promotes-sustainable-living/>
- Broad group of companies: <http://www.broad.org/enbroadcom/>
- For additional information on electric reefs: ree.ph, globalcoral.org