Symbiotic Systems for The Future of Energy, Water, and Food

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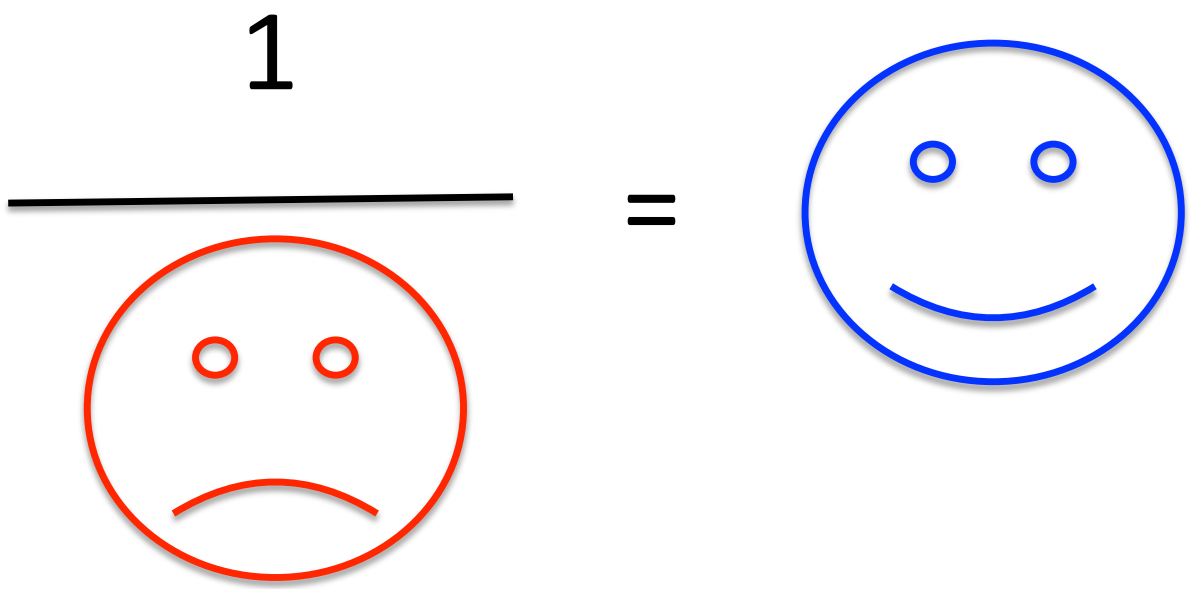
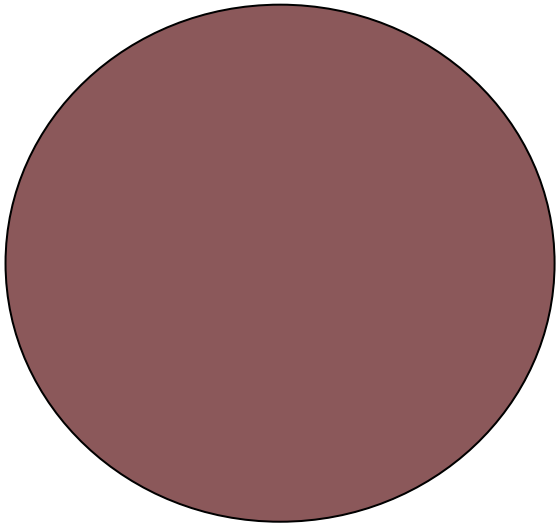


1/(Doom & Destruction)

- Insert doom & destruction, planet dying, must ***save***, there can be a ***bright*** future, the answer is blowing in the ***wind***, just need to think *symbiotically*, slide here

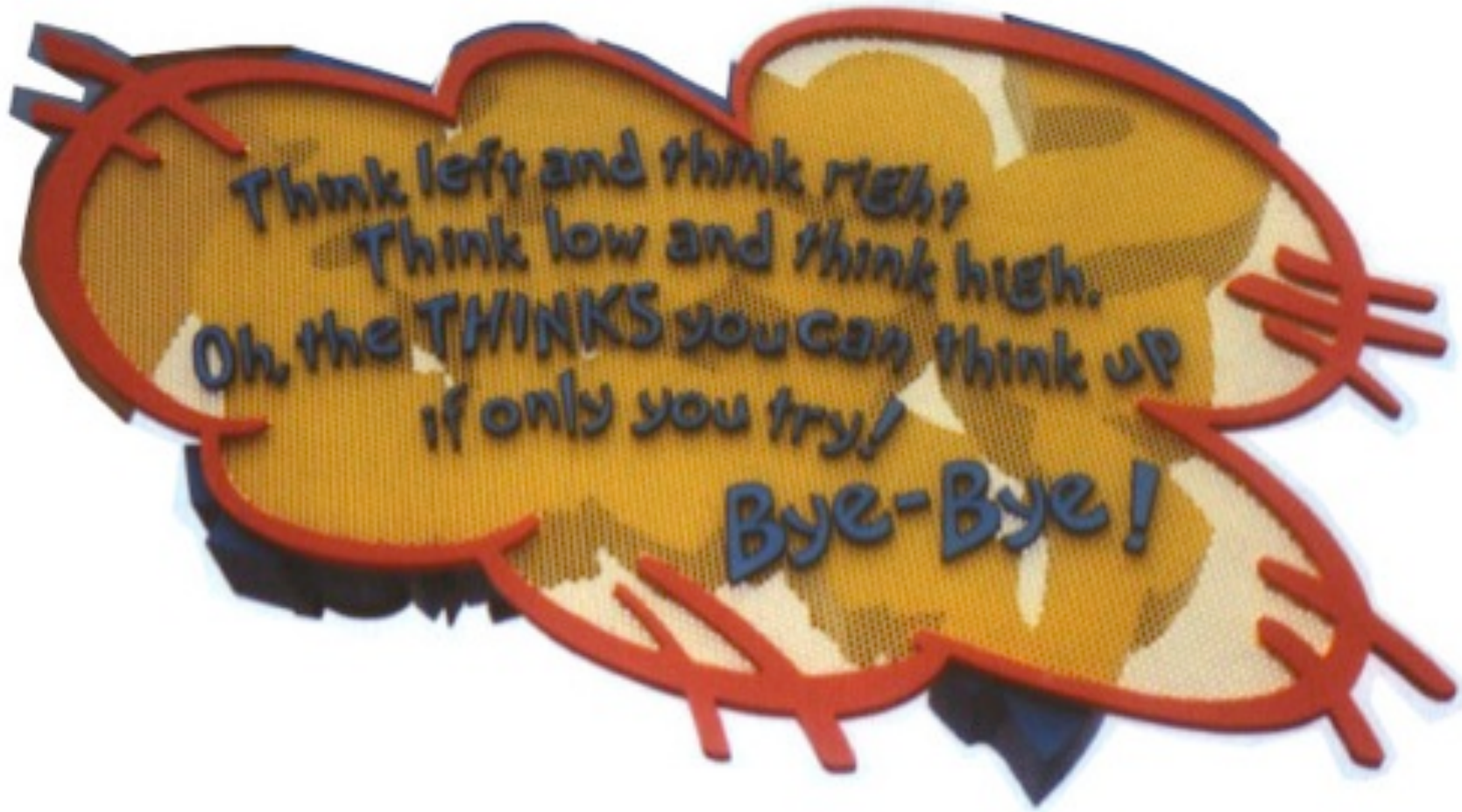
Ghostbusters: Required viewing for all leaders of all types!



Oops, will we do it again?
We will NOT be able to say we are innocent!

YES they can!

Dr. Seuss
An inspiration for all ages for all the ages



What Future Have We?

For the money spent on wars in the last decade we could have had >500 GW of CO2-free 24/7/365 electric power !!

What would the Prophets do with the next Two Trillion Dollars?

YES WE CAN SAVE THE PLANET, ECONOMY, & US

We do not have to be victims of Silly Human Intransigent Thinking "LOGIC" !

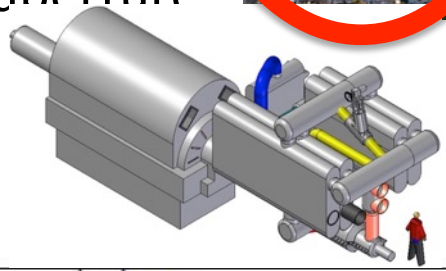
Energy is *KEY* to EVERYTHING

Everything is the *KEY* to energy

- Materials can catalyze white swan events
- Automation drives down cost of renewables and storage
  - Just as cell phones enabled bypassing land lines…
  - Incremental advances will creep us to the tipping point…
- Symbiotic relationships will help create tipping points
  - Solar energy farms *with* energy storage, hydroponic farming
  - Offshore wind *with* fish farms, energy storage, uranium mining
  - Hydrocarbons *with* nuclear (spent fuel disposal)
  - Seawater pumped hydroelectric *with* reverse osmosis
  - Saving Planet *with* Education

Solar *with* Energy Storage

- CSPonD (Concentrated Solar Power on Demand)
  - Alex Slocum & Masdar Institute currently building demo machine
- Combines reception/storage in tank of molten salts
- Mirrors across hillside focus sunlight through tank aperture
- Sunlight absorbed through volume of molten salt
  - Short term: generate steam
  - Long term: supercritical CO2 cycle



- Low cost & durable
- No need for back-up power
- No expensive pumps and plumbing

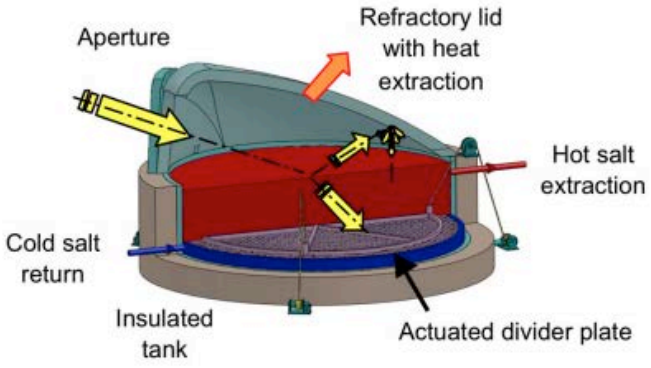
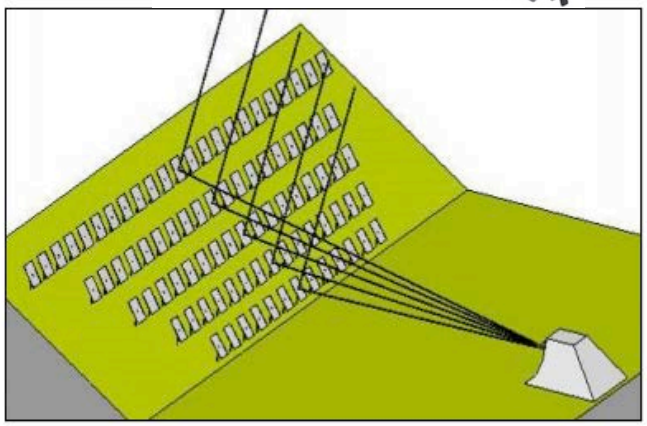


Fig. 1: Section view of CSPonD receiver

Light Collected Inside Insulated Building With Open Window

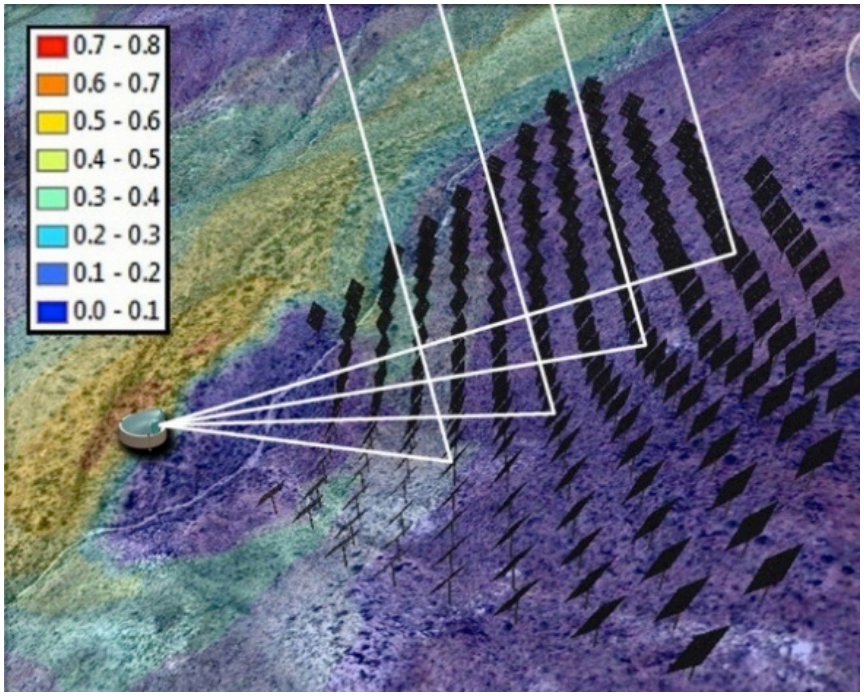


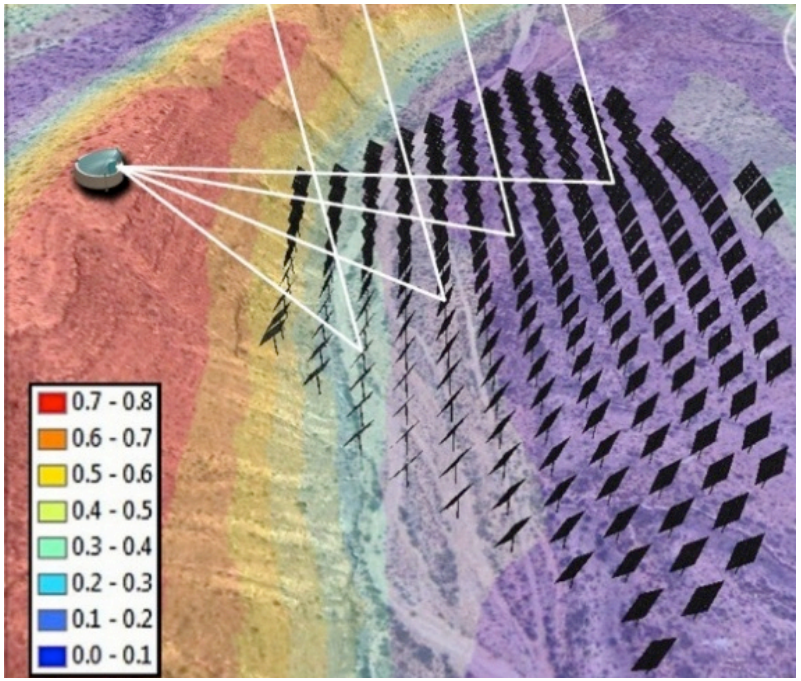
(Not to scale!)

Light Reflected From Hillside heliostat rows To CSPonD system

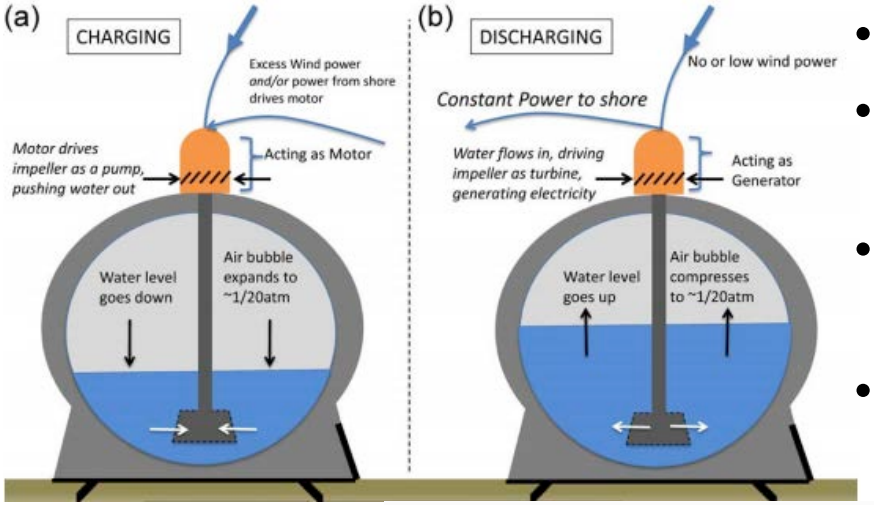
Potential Conflict-Free Sites

- Use unused portions of military basis which has no development, recreation or commercial potential
  - Assume 15% of land can be utilized, 30% is covered by heliostats, a solar-to-electric efficiency of 22%, and a 24/7 average solar insolation of 200 W/m^2:
    - White Sands site could provide 20 GW$_e$ of power 24/7.
    - Similar results are obtained for China Lake.

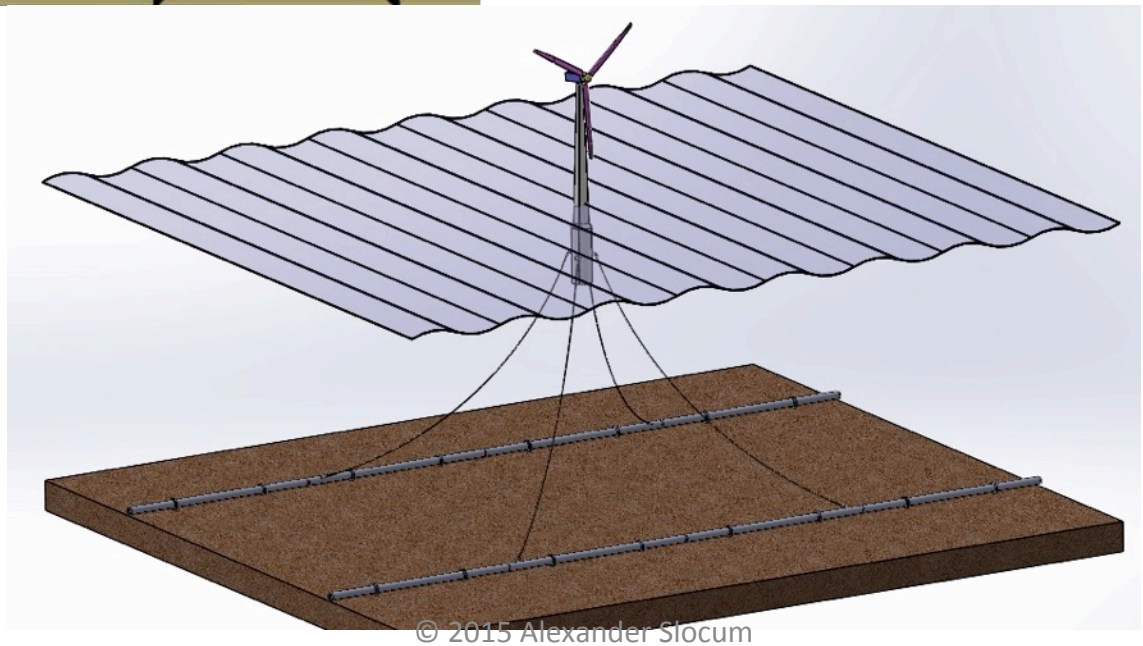




Offshore Wind *with* Pumped Hydro Storage

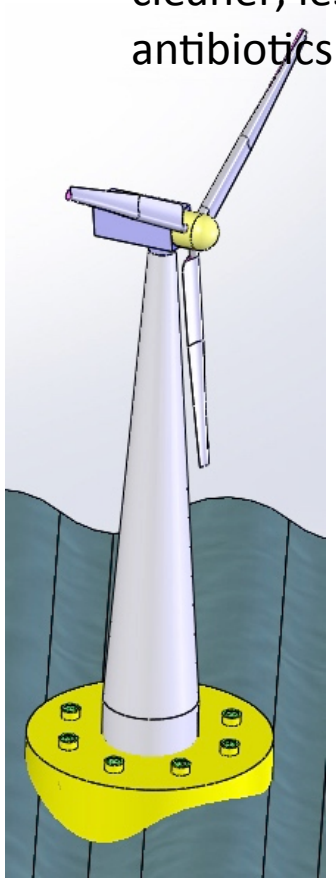


- Floating wind turbines with built-in storage
- Concrete spheres or pipes on seafloor anchor turbines and store energy
- Excess power used to pump seawater from hollow structures
- When power needed, water flow back into structure through turbine



Offshore Wind *with* Aquaculture

- Wind and Aquaculture can go hand in hand
  - Far offshore water is cleaner, less need for antibiotics



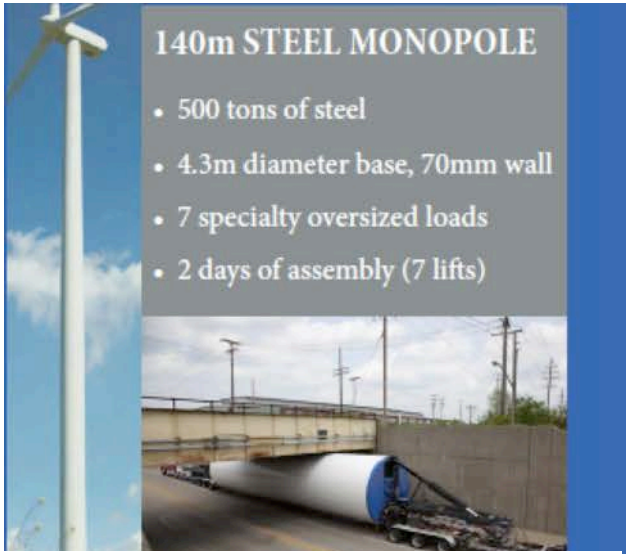
Symbiotic System Requirements		
population served	10,000,000	
kg of fish per person per day	0.2	
average electric power per person (includes industry needs) (kW)	2	
average net electric power per offshore wind turbine (MW)	2	
Percentage of population to be covered by grand challenge	50%	
Wind Farm Parameters		
People served per wind turbine	1000	
number of wind turbines required	5,000	
ocean area per turbine (km^2)	1	
rectangle ratio (length/width)	1.6	10
ocean rectangle width (km)	56	22
ocean rectangle length (km)	89	224
wind turbines installed per day	4	
years to full installation	4	
Aquaculture System		
years to mature fish from fry to harvest	1	
kg/fish	1	
fish per person per wind turbine based pen	73	
total fish to be contained in a pen supported by a wind turbine	73000	
water volume per fish (m^3)	2	1
total volume water to be encased by wind turbine based pen (m^3)	146000	73000
diameter of spherical pen to contain fish	65	52
diameter of cylindrical tank (diameter = height) (m)	57	45
Comparison with Nuclear Power		
nuclear power plant size (MW)	2000	
equivelant number of nuclear power plants	5	

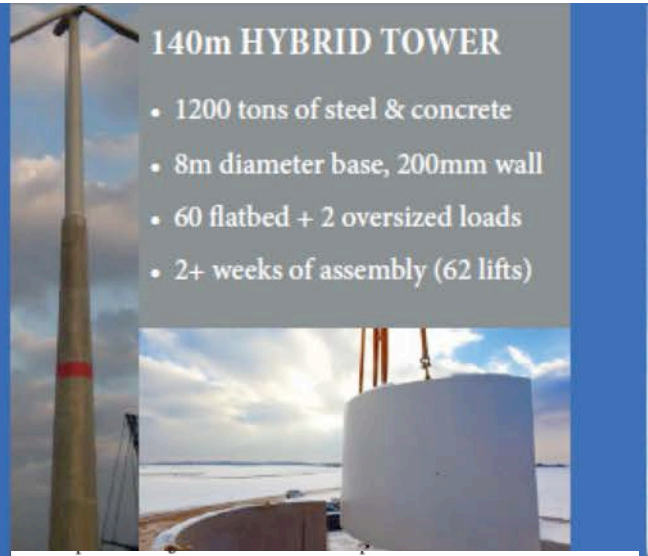
See for example: Buck, Bela H., Gesche Krause, and Harald Rosenthal. "Extensive open ocean aquaculture development within wind farms in Germany: the prospect of offshore co-management and legal constraints." Ocean & Coastal Management 47 (2004): 95-122

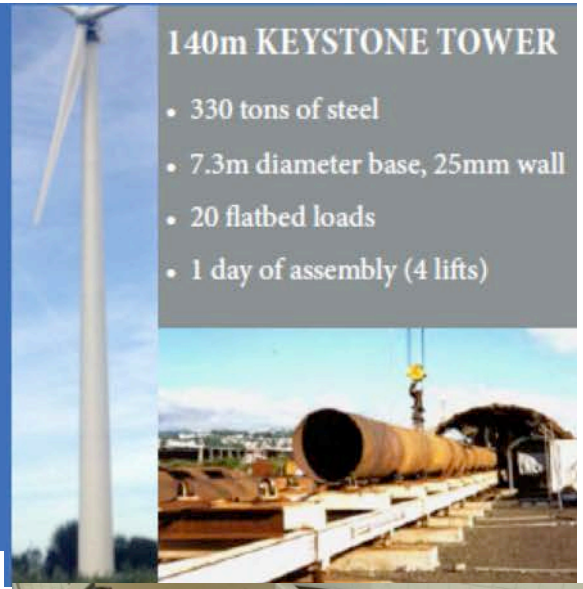
Meanwhile, in Colorado, an MIT spinoff is….

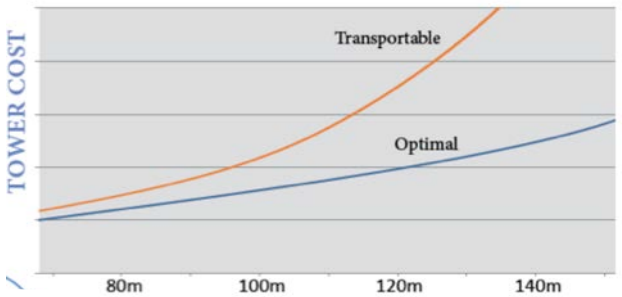
Lowering the Cost of Wind Energy by 10%

- Tall towers make class III @ 80 m sites into Class 4 sites @ 120-140m
  - Maine goes from 6 GW potential to 60 GW potential!
- Keystone Tower Systems, Inc. in-situ tapered tower manufacturing

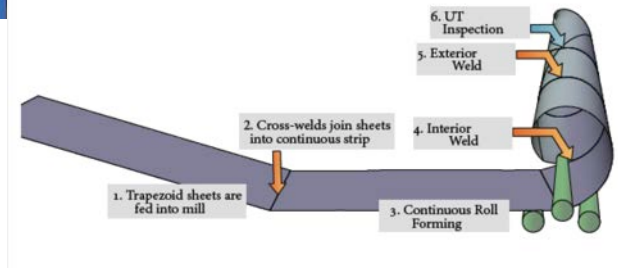


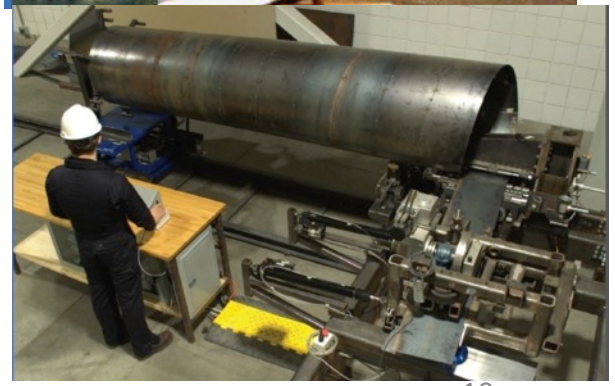






DELIVERED AND INSTALLED TOWER COST VS. HUB HEIGHT



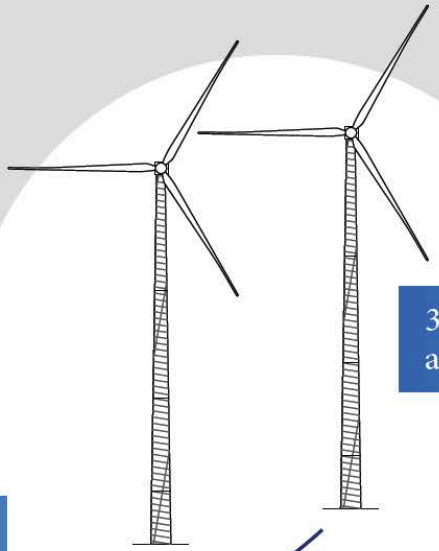


ON SITE SPIRAL WELDING

The pipe industry has already shown that on-site spiral welding is an attractive way to get around transportation limits. Keystone's innovations bring this technology into the wind industry, unlocking the potential of much taller towers.

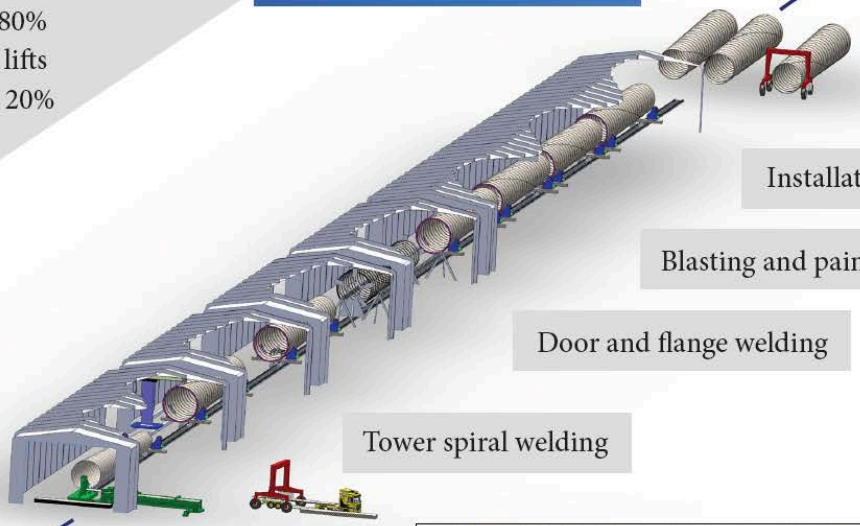
ON SITE SPIRAL WELDING ENABLES LARGE DIAMETER TALL TOWERS

- 100+ tons of steel saved per tower by increasing diameter
- Standard trucks reduce shipping costs by over 80%
- Larger tower sections enable fewer flanges and lifts
- Larger base flange reduces foundation costs by 20%
- Thinner walls allow use of lower cost steel coil rather than plate
- Locally manufactured towers may satisfy local content requirements



3. Tall towers are erected

2. Towers are spiral welded at the wind farm



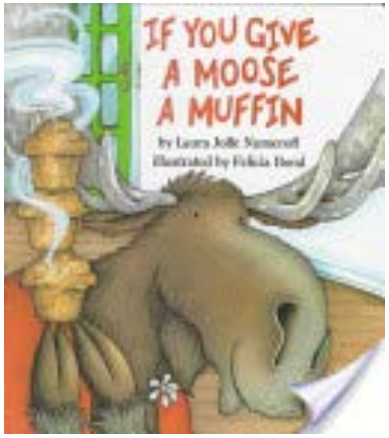
1. Steel is shipped as flat sheets

ON-SITE SPIRAL WELDING BY THE NUMBERS

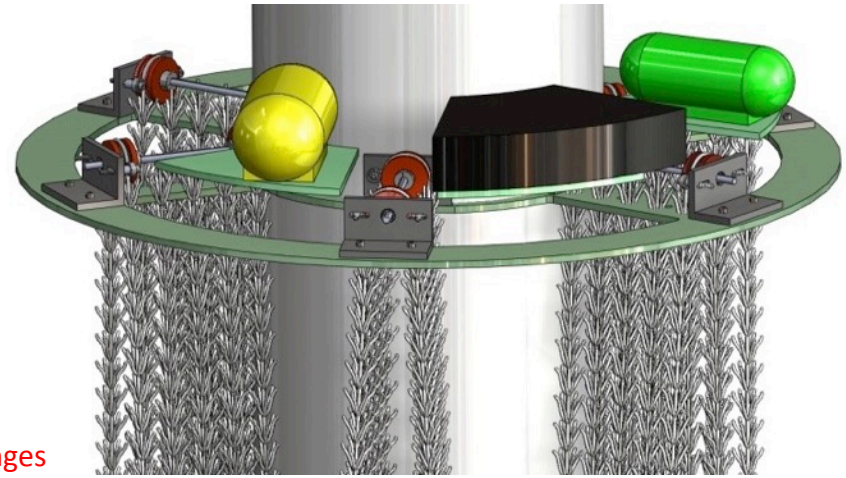
- Can be deployed at a new site in just three weeks
- Deployment justified for projects with as few as 5 towers
- Only 2 acres (1 ha) required for setup (smaller than a laydown yard)
- The mobile facility is staffed by a crew of just 30
- Towers can be produced and erected at a rate of one a day

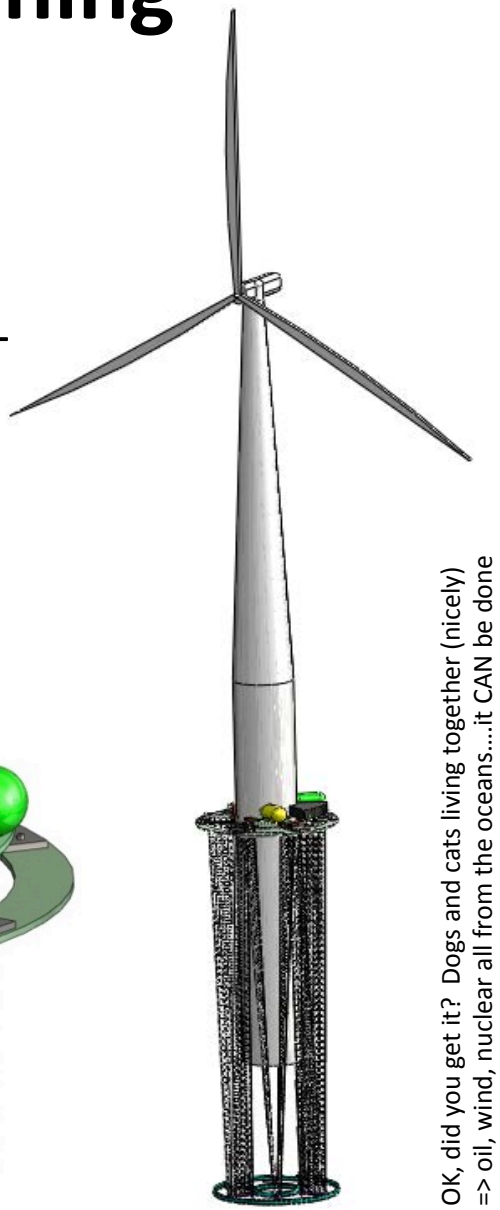
Offshore Wind *with* U Mining

- Nuclear power is a critical part of clean energy future
  - Nothing else carbon-free can provide such baseload power
  - BUT only 100 years of terrestrial uranium left
- Uranium is in ocean water in form of uranyl ions: 3-3.3µg/L
  - 4.5 billion tonnes, 1000X conventional reserves'
  - Polyethylene adsorption materials make it economical to get the uranium IF we design the right machine…
  - Symbiotic: Offshore wind turbine + extractor = ☺
- The answer my friend, is blowing in the wind….



BIG challenges require a Moose-sized approach!





OK, did you get it? Dogs and cats living together (nicely) => oil, wind, nuclear all from the oceans…it CAN be done

Hydrocarbons *with* SNF storage

- Oil got us into this mess and it can get us out…
  - Can the oil industry can be the savior of the planet?
    - Deep geographical formation mapping and deep drilling technology leaders
  - Deep Borehole Disposal
    - Bore deep horizontal holes near each reactor
    - Drop spent fuel in, curved hole to slow it down…
    - New drilling technology make it possible

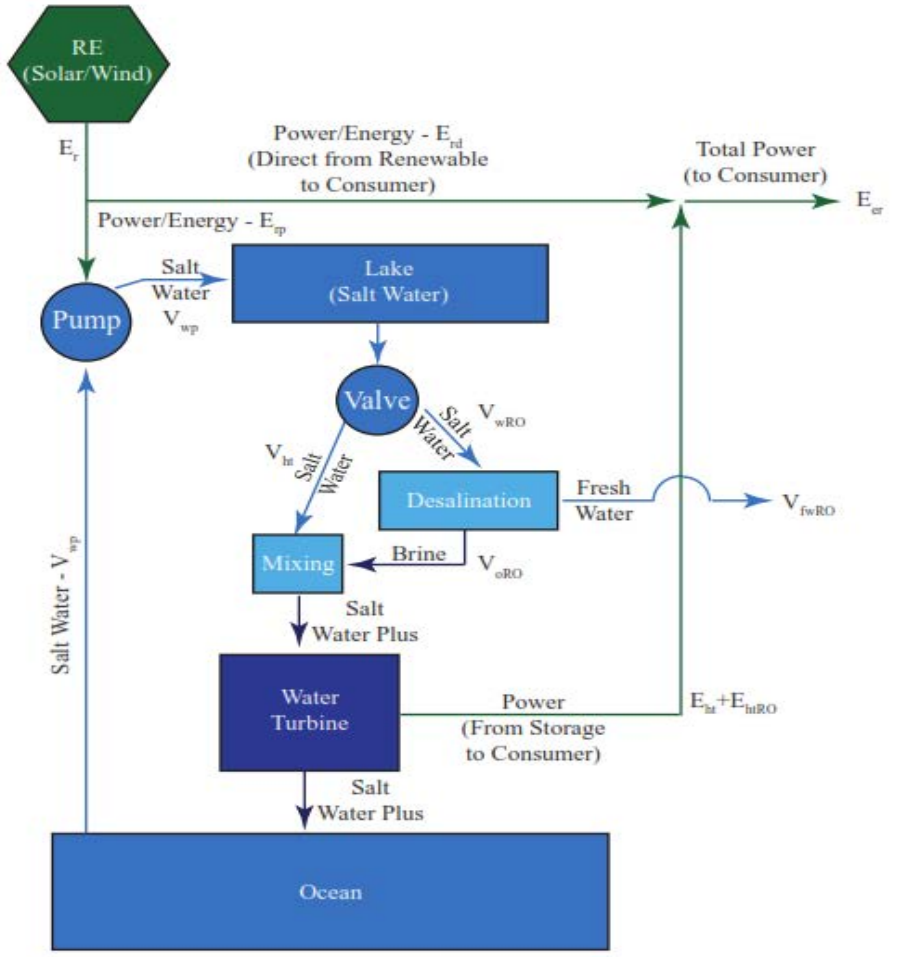
Power Plant		
Capacity (MW)	3000	3000
SNF per year per reactor (tonnes/GW)	240	240
Operating life	30	30
Total waste produced	21600	21600
Borehole disposal site		
Borehole inside diameter (m)	0.5	1
Emplacement length zone length (m)	3,000	3,000
Number of branches	4	4
Total emplaceabe volume (m^3)	9,425	37,699
Packing efficiency	1	1
Average waste and container density (kg/m^3)	5,000	5,000
Tonnes of waste emplaceable	23,562	94,248
number of power plants served	1	4

http://www.slb.com/services/drilling/drilling_services_systems/directional_drilling/powerdrive_family/power_drive_orbit_rotary_steerable.aspx

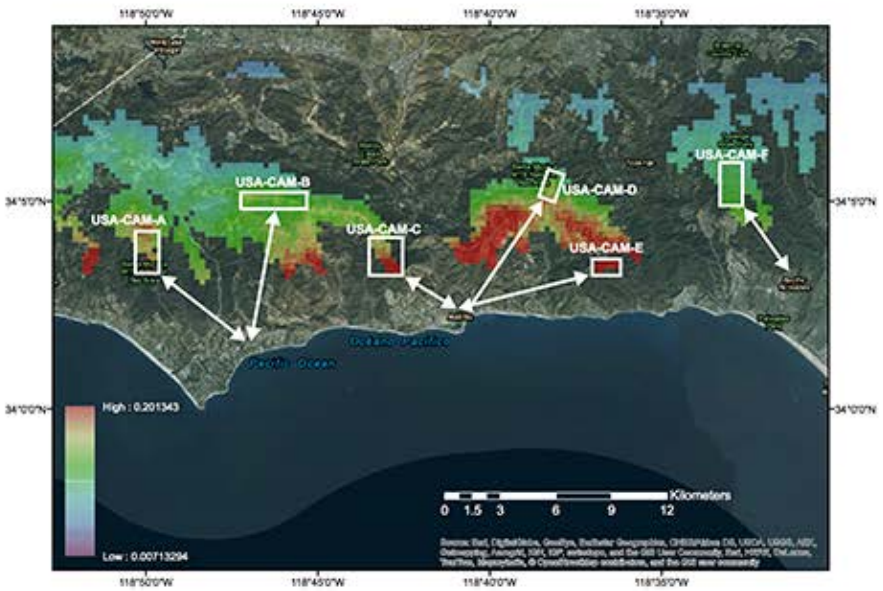
Seawater pumped hydro *with* reverse osmosis APHROS to Save California!

(and the world)

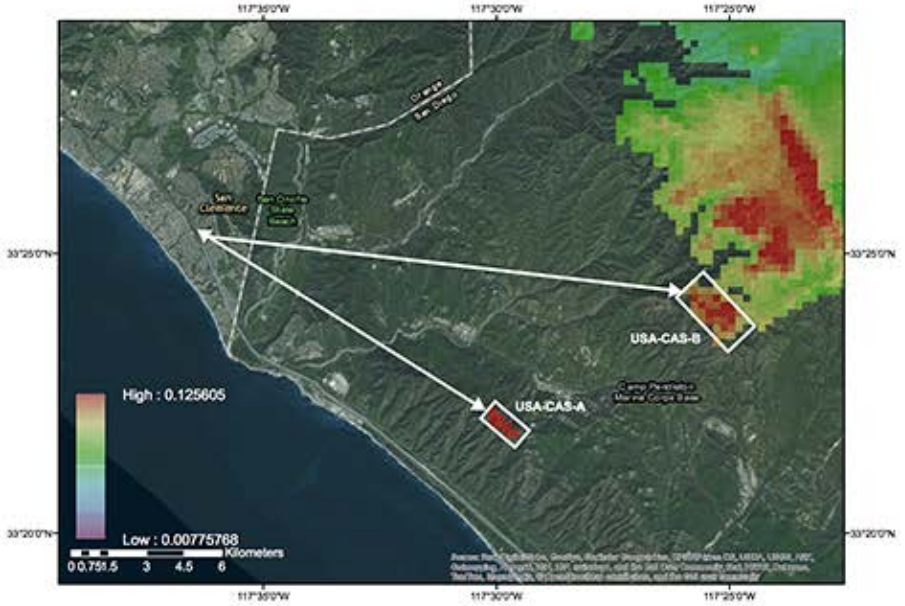
- Advanced Pumped Hydro Reverse Osmosis System
- Intelligent design ☺: Pumped Hydro Head = 500-700 m, = RO desal head.
- Many drought stricken coastal regions have mountains for upper reservoirs at this head height.
- 20m^3 water => 2kWe, 1 m^3 => 500l freshwater.
  - Brine out-flow from RO plant is readily diluted by the output from the turbine.



California: Malibu & San Clemente



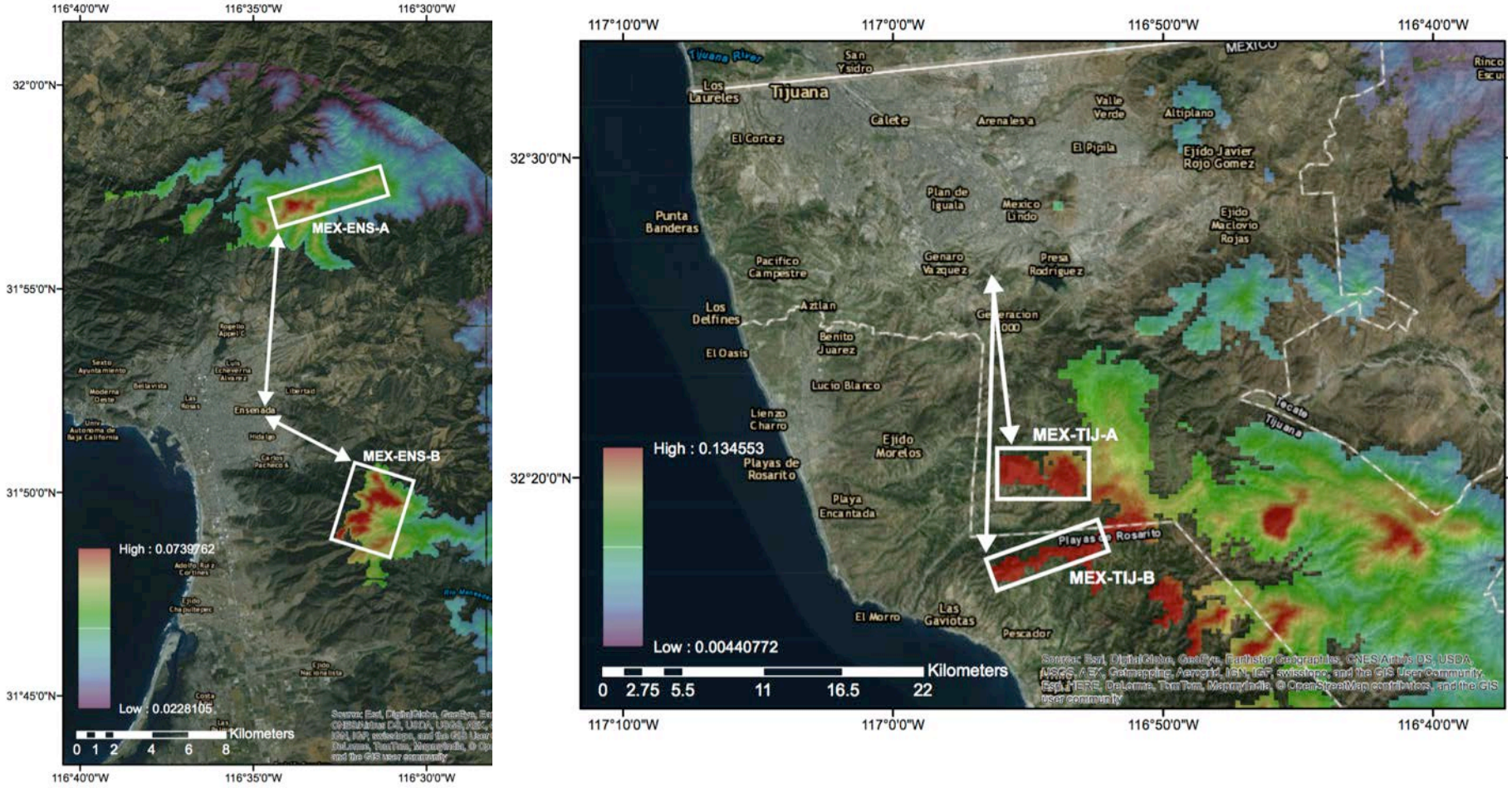
Malibu, CA, USA



San Clamente, CA, USA

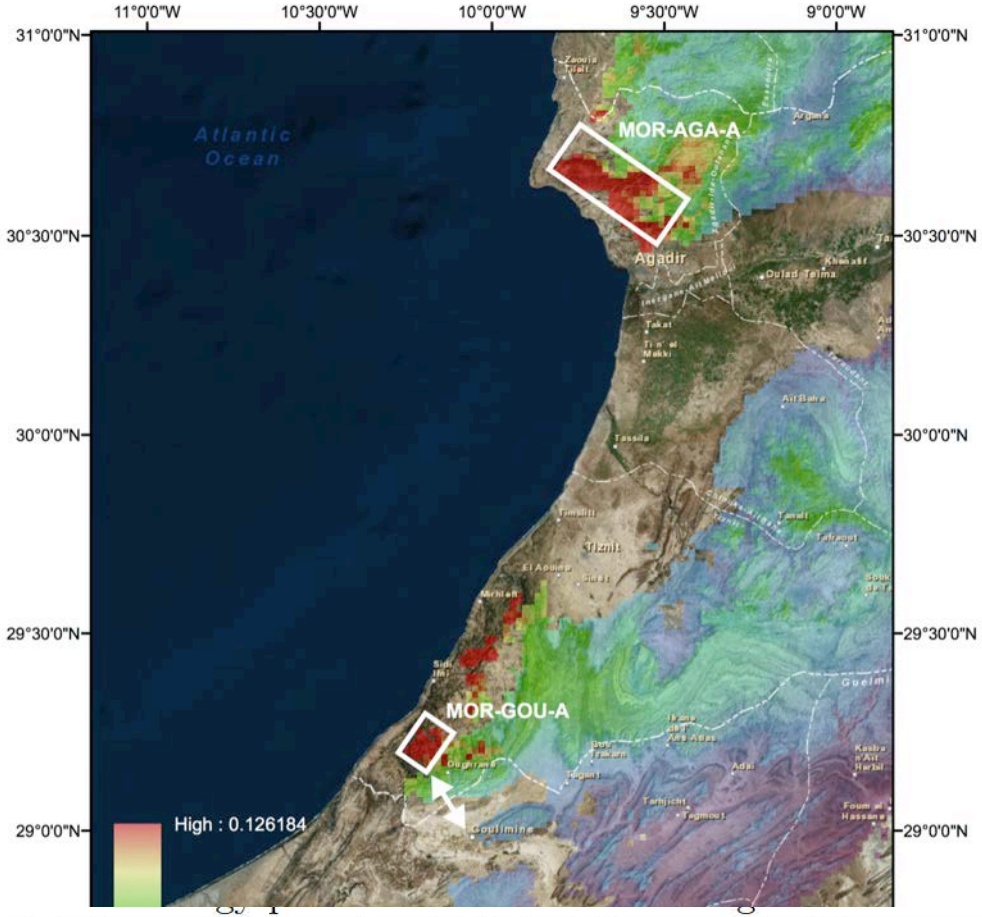
Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
USA-CAM-A	612	2.9	5.2	0.112	Malibu	5.9	119
USA-CAM-B	684	2.2	7.7	0.089	Malibu	8.8	101
USA-CAM-C	528	1.7	4.3	0.123	Malibu	3.3	59
USA-CAM-D	678	0.9	6.9	0.098	Malibu	8	42
USA-CAM-E	518	1.3	2.7	0.192	Malibu	8	44
USA-CAM-F	545	2.4	7.2	0.076	Pacific Palisades	7.9	89
USA-CAS-A	505	0.5	4.1	0.123	San Clemente	14	17
USA-CAS-B	552	2.8	13.3	0.042	San Clemente	20	104

Mexico: Ensenada & Tijuana



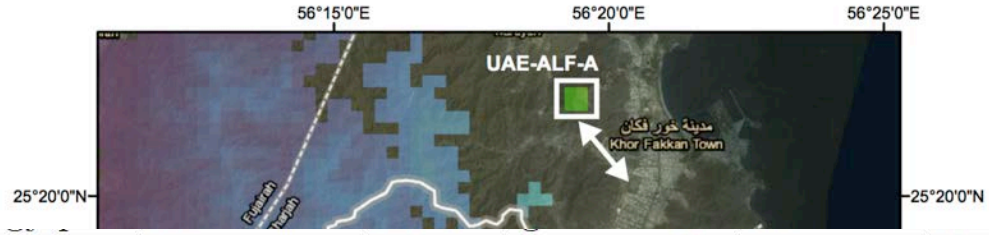
Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
MEX-ENS-A	886	3.5	15	0.059	Ensenada	9.2	119
MEX-ENS-B	636	2.7	9.6	0.066	Ensenada	7.6	101
MEX-TIJ-A	567	14.5	12.7	0.045	Tijuana	12.8	483
MEX-TIJ-B	542	10.7	8.2	0.066	Tijuana	18.8	388

Morocco

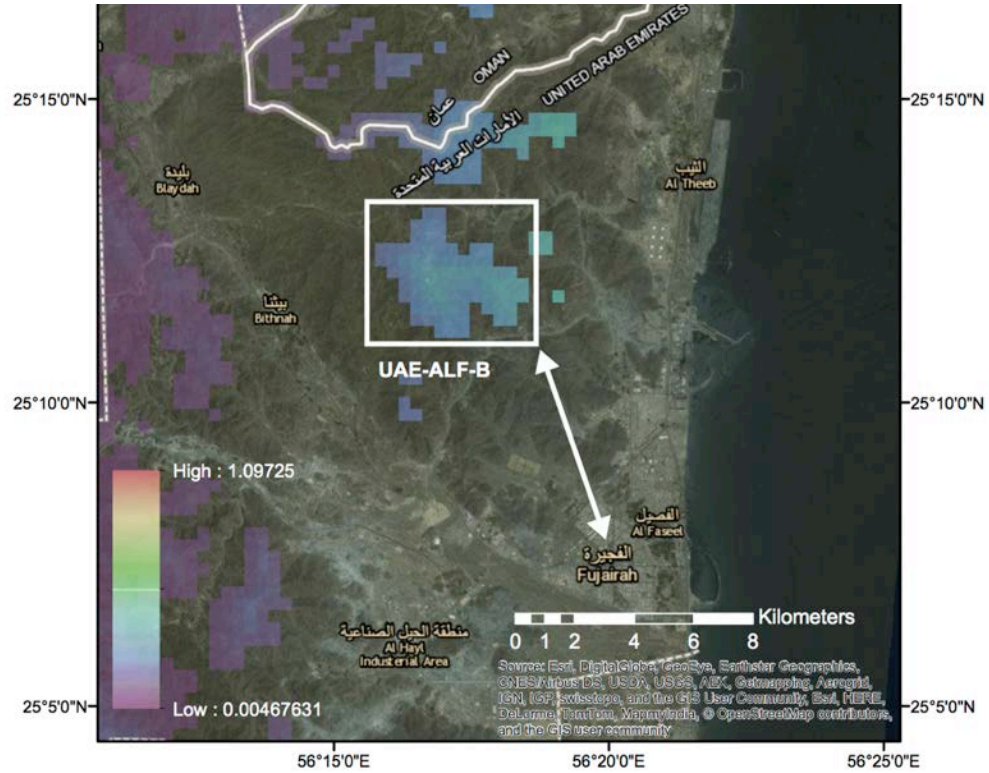


Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
MOR-AGA-A	687	292	13	0.053	Agadir	3.9	13503
MOR-GUO-A	582	112	13	0.044	Guolimim	27	4380

UAE

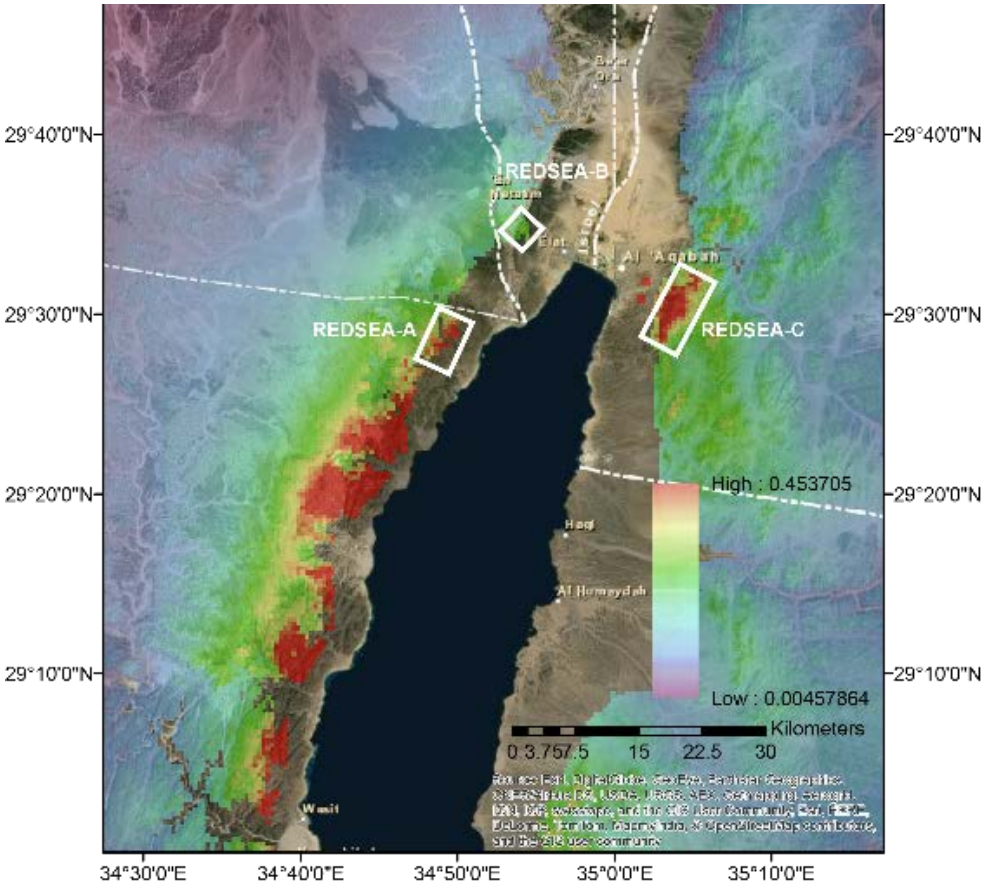


Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
UAE-ALF-A	529	0.64	2.8	0.186	Khor Fakkan	2.7	23
UAE-ALF-B	619	12.8	8.5	0.073	Fujairah	7.3	533

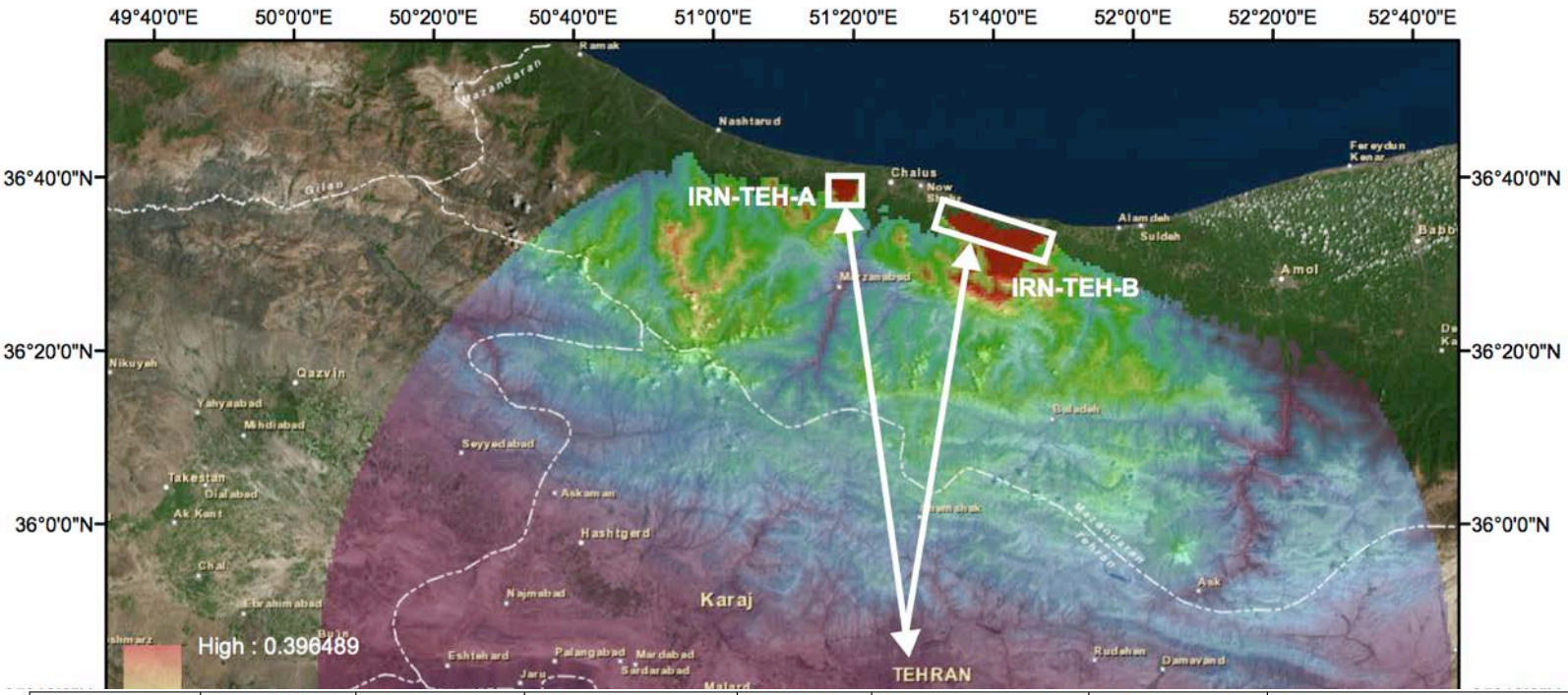


Northern Red Sea

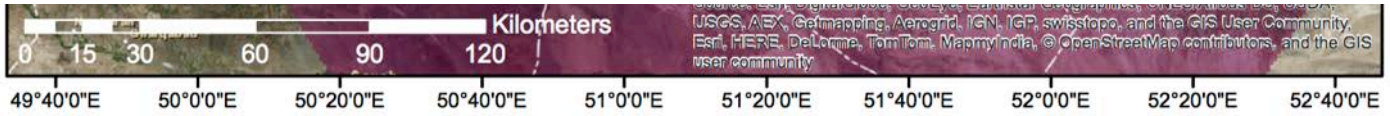
Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
REDSEA-A	573	12	5.5	0.105	Taba	6.67	13503
REDSEA-B	560	3.8	7.2	0.0.078	Eilat	3.62	4380
REDSEA-C	817	32	8	0.102	Aqaba	5.11	13503



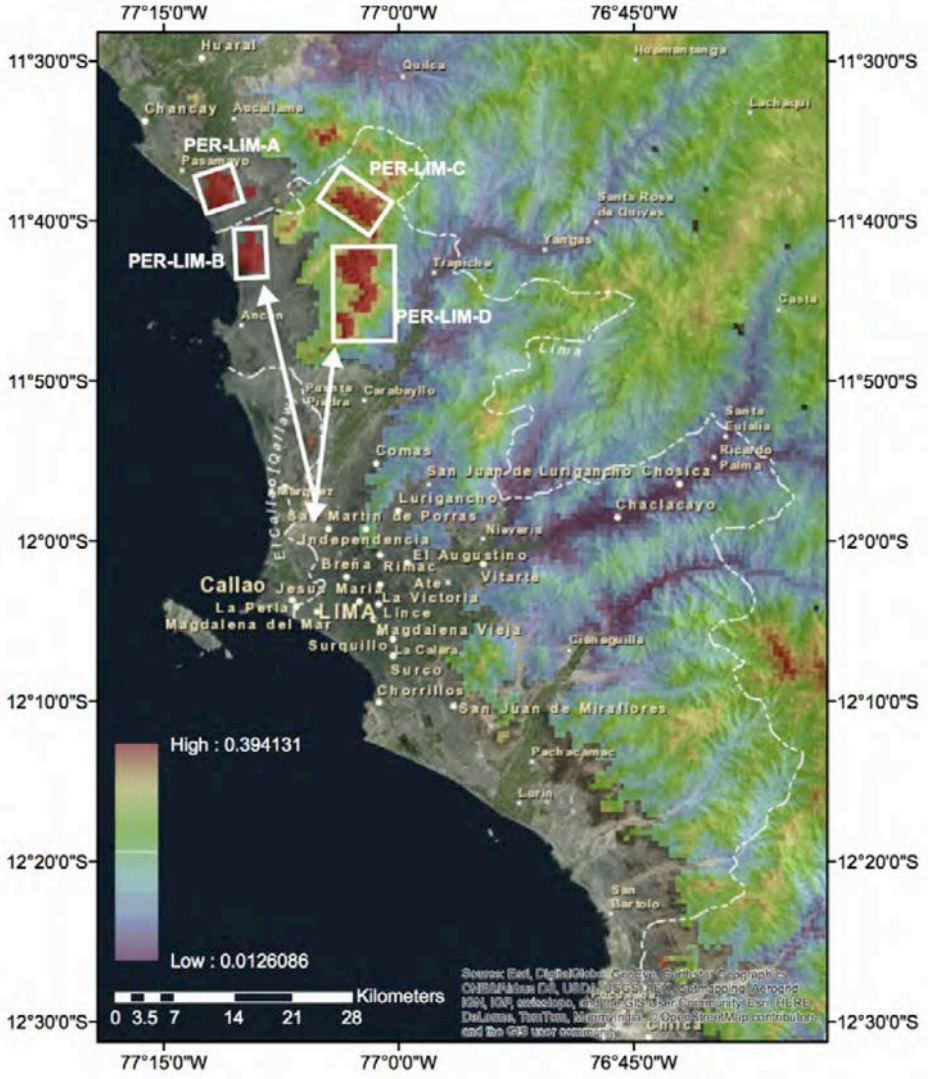
Iran



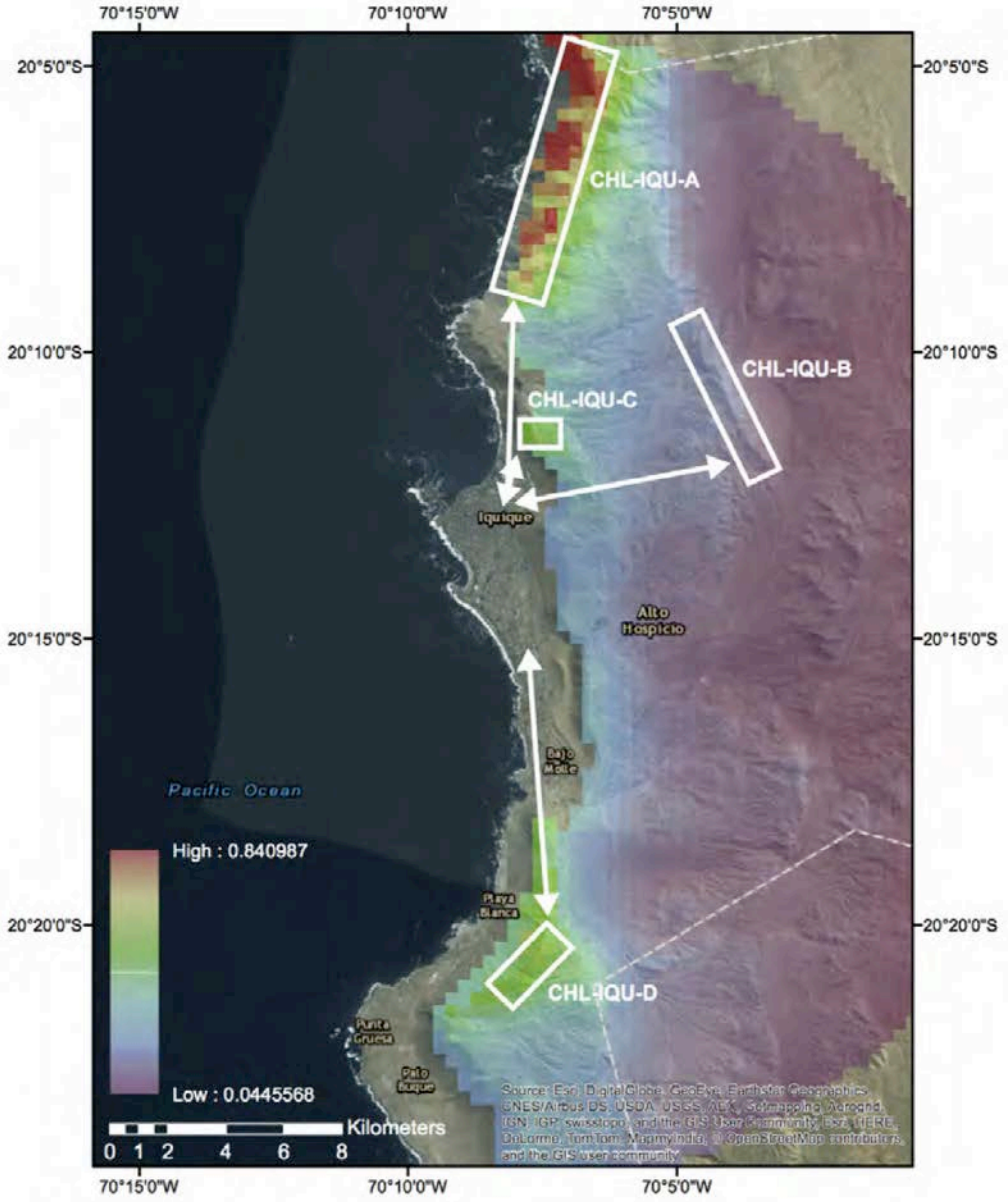
Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
IRN-TEH-A	778	32	6.4	0.122	Tehran	132	1672
IRN-TEH-B	888	93	4.2	0.211	Tehran	100	5547
IRN-SHI-A	565	245	8.4	0.067	Shiraz	200	9297
IRN-BAN-A	645	75	5.9	0.110	Bandar 'Abbas	128	3240
IRN-BAN-B	730	109	9.3	0.078	Bandar 'Abbas	72	5339



Peru



Chile


70°15'0"W
70°10'0"W
70°5'0"W
20°5'0"S
20°10'0"S
20°15'0"S
20°20'0"S
CHL-IQU-A
CHL-IQU-B
CHL-IQU-C
CHL-IQU-D
Iquique
Alto Hospicio
Pacific Ocean
High : 0.840987
Low : 0.0445568
Kilometers
0 1 2 4 6 8

The Future Is Ours!

- Engineering is a blend of science and statistics with which managers and politicians paint our future
- We are all responsible for the canvas of life
  - We CAN work together to create a beautiful future for the planet and all its lifeforms