Symbiotic Systems for The Future of Energy, Water, and Food:
Advanced Thinking & Manufacturing are key!

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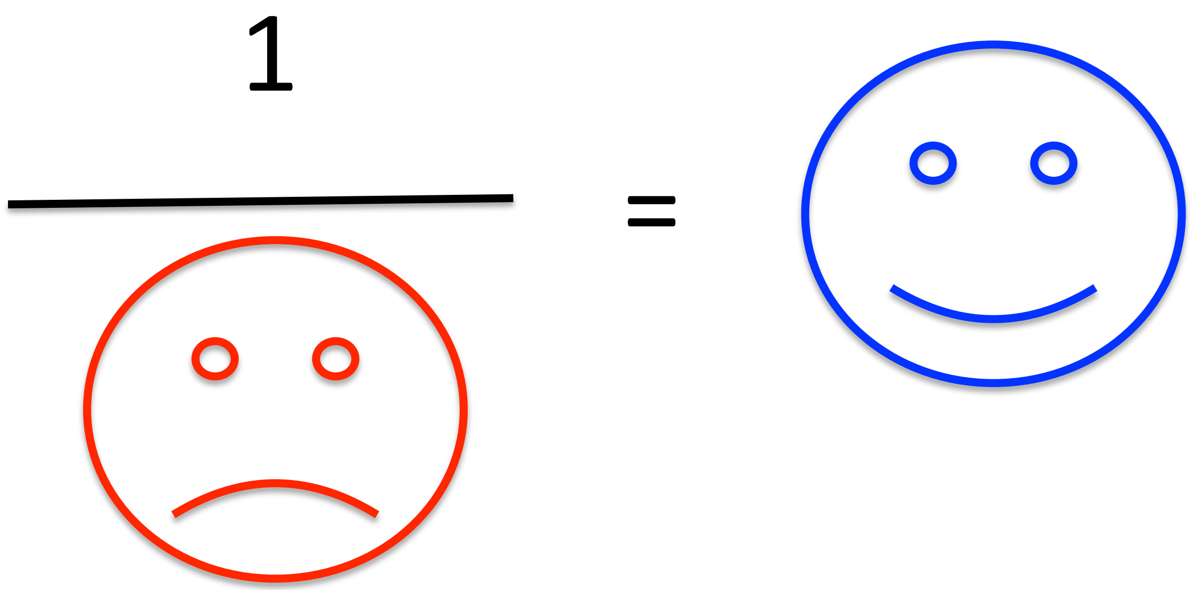
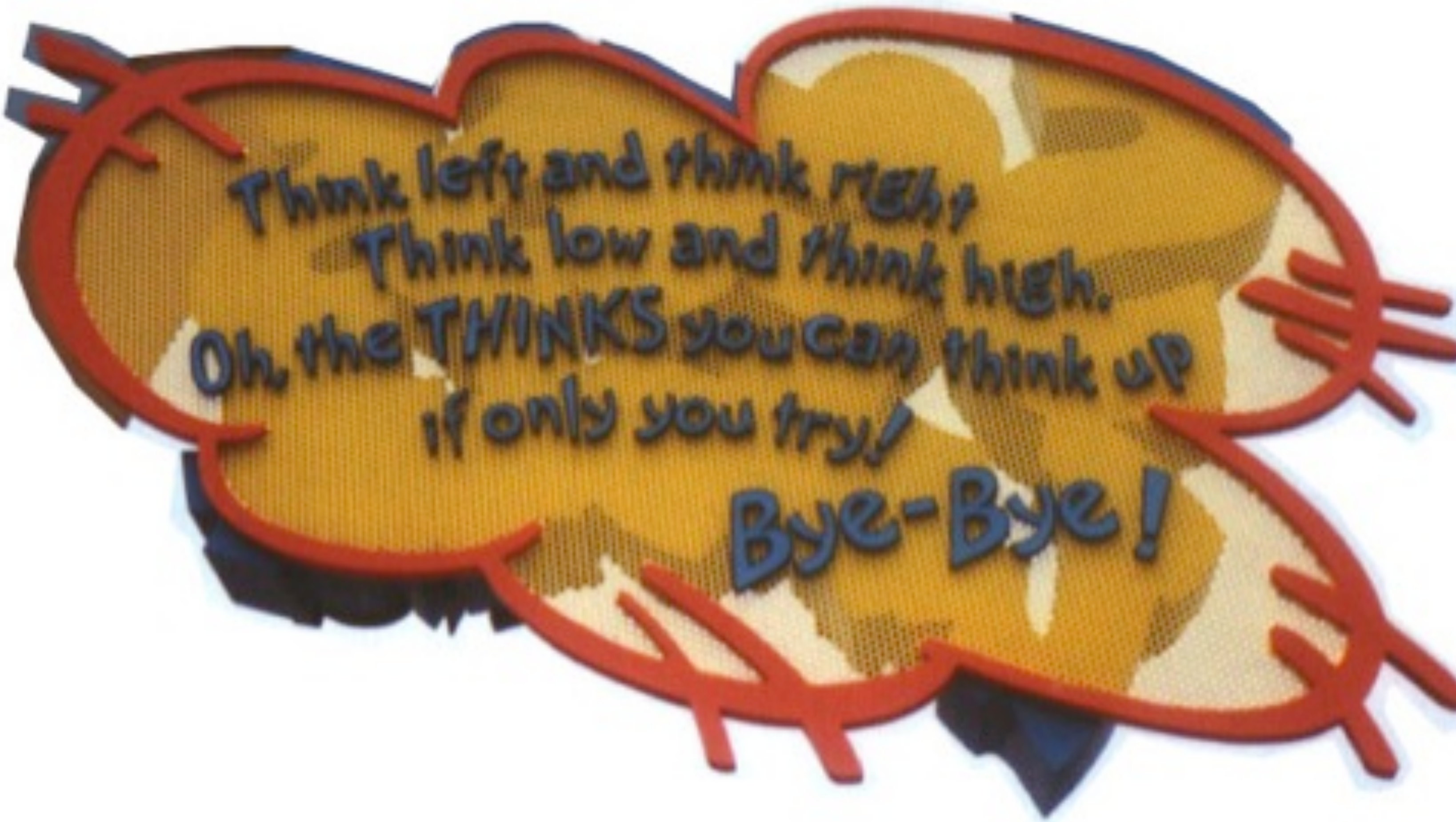


Dr. Seuss
An inspiration for all ages for all the ages



What Future Have We?

For the money spent on wars in the last decade we could have had >500 GW of CO_2-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" !

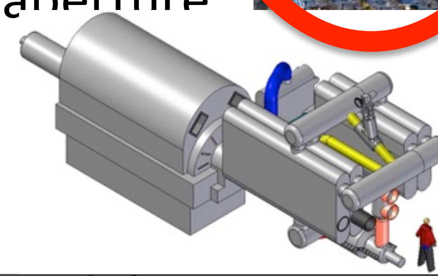
Energy is ***KEY*** to EVERYTHING

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 CO_2 cycle



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

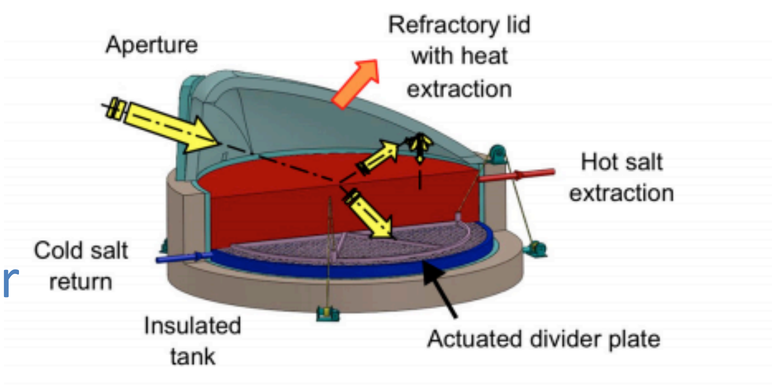
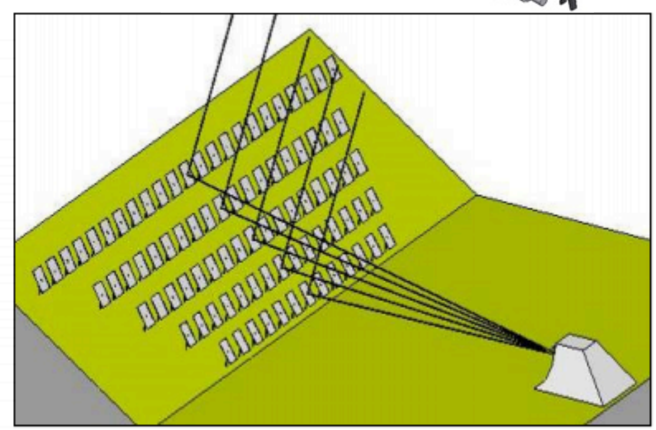


Fig. 1: Section view of CSPonD receiver

Light Collected Inside Insulated Building With Open Window

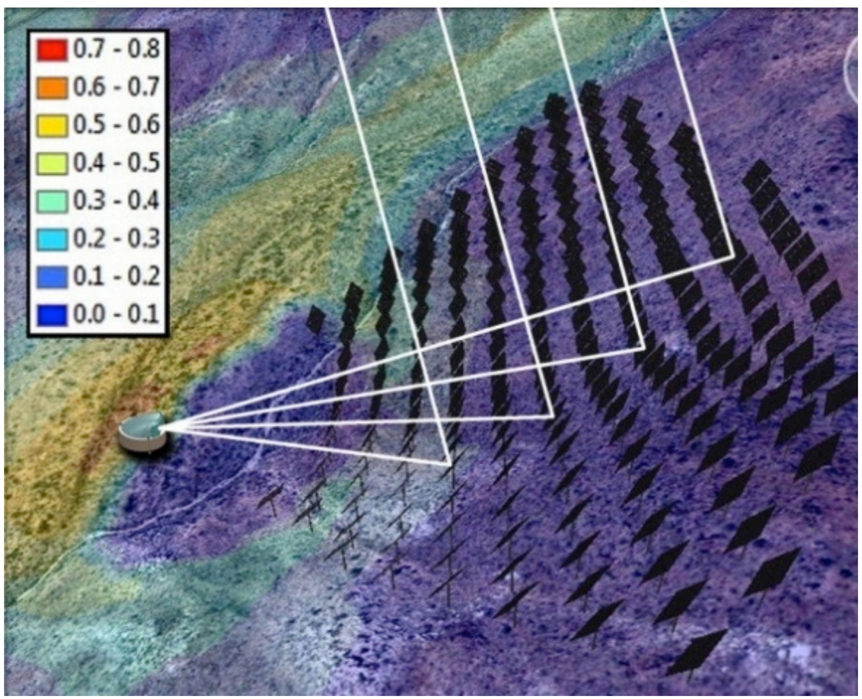


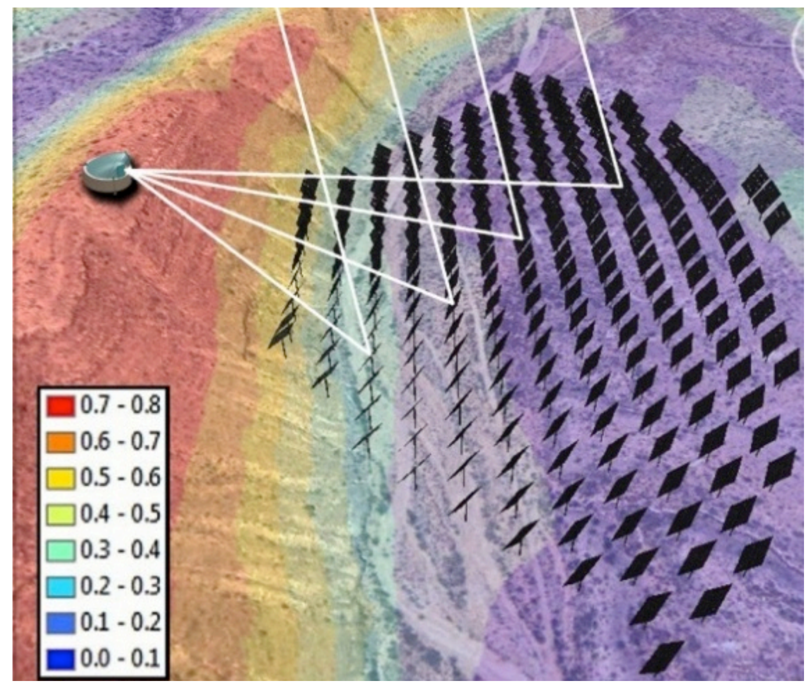
(Not to scale!)

Light Reflected From Hillside heliostat rows To CSPonD system

Potential Conflict-Free Sites

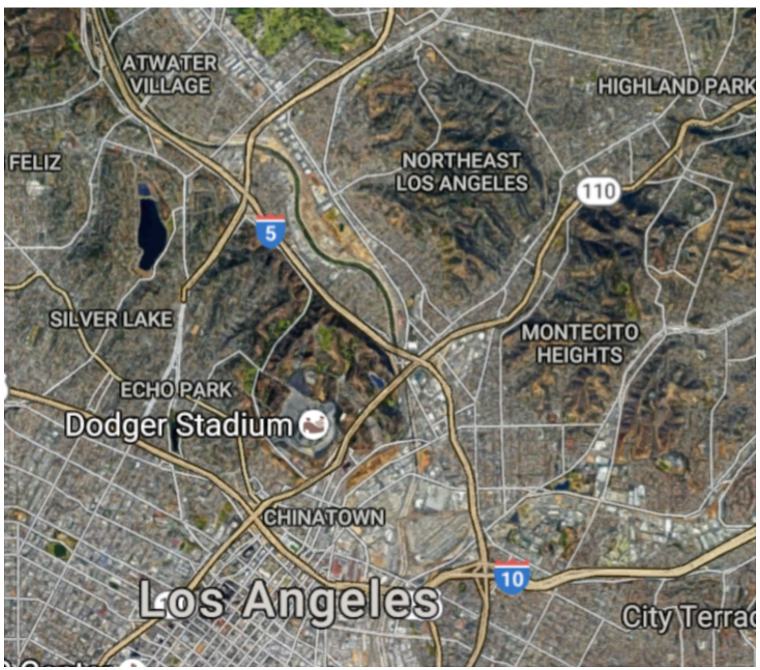
- Use unused portions of military basis which has no development, recreation or commercial potential
  - Assume 15% of land can be utilized, 30% is covered by heliostats, a solar-to-electric efficiency of 22%, and a 24/7 average solar insolation of 200 W/m^2:
    - White Sands site could provide 20 GW_e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



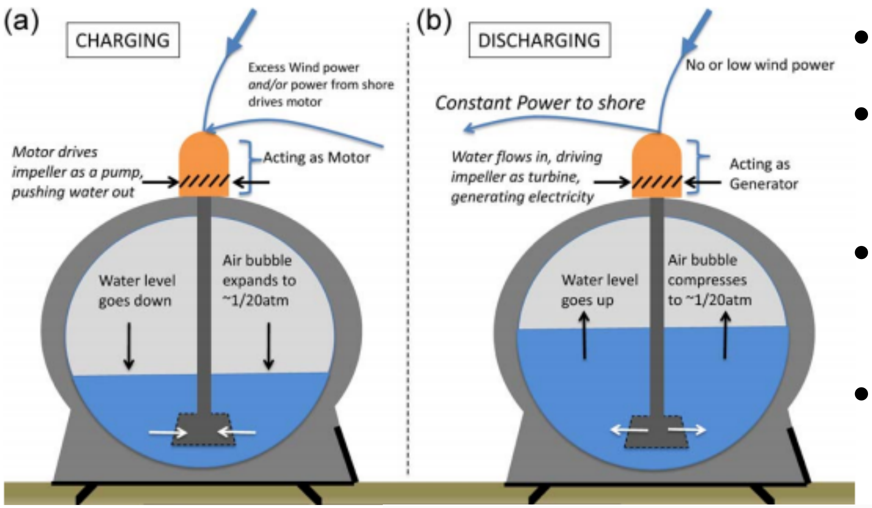


Hillsides also great for PV!

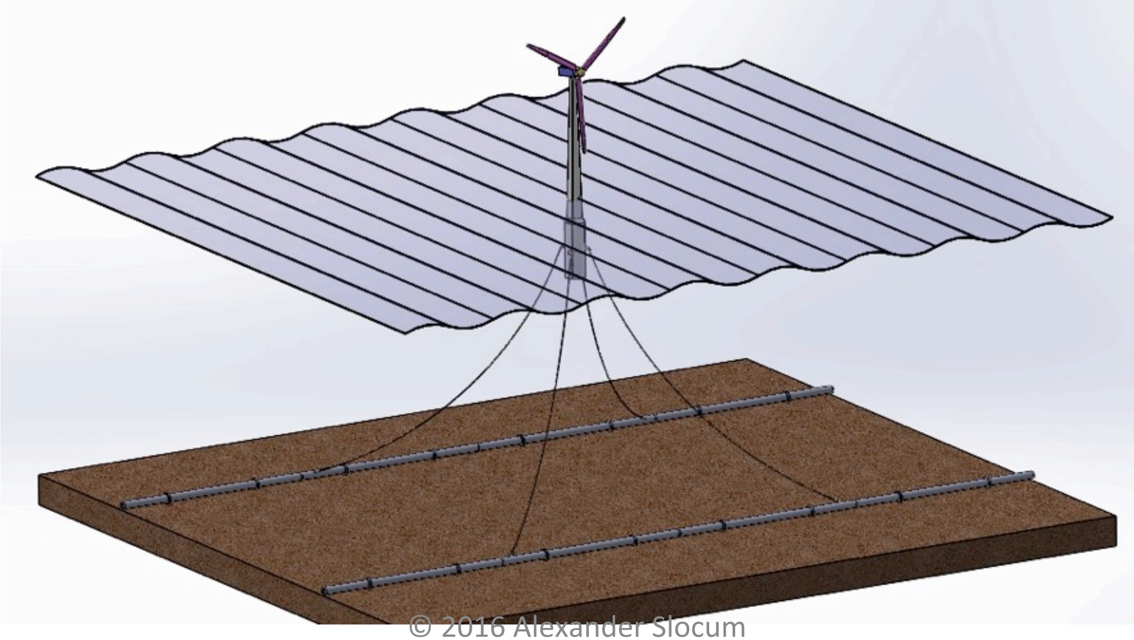
- Less shading means potential for closer spacing and lower cost mounts
  - There are a lot more unused steep hillsides facing south than flatlands



Offshore Wind *with* Pumped Hydro Storage

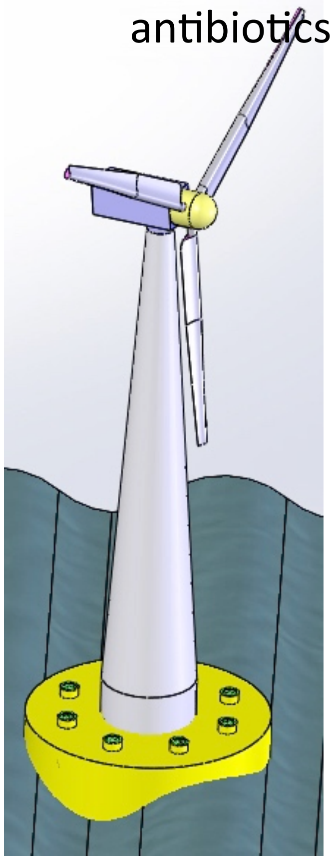


- Floating wind turbines with built-in storage
- Concrete spheres or pipes on seafloor anchor turbines and store energy
- Excess power used to pump seawater from hollow structures
- When power needed, water flow back into structure through turbine



Offshore Wind *with* Aquaculture

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



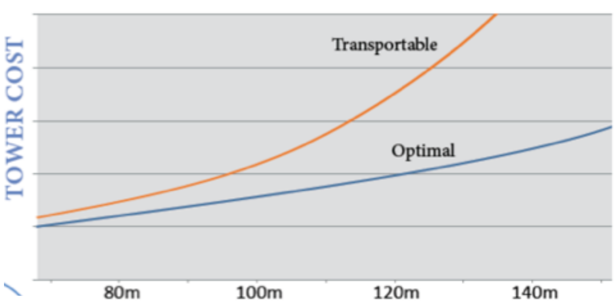
Symbiotic System Requirements		
population served	**10,000,000**	
kg of fish per person per day	**0.2**	
average electric power per person (includes industry needs) (kW)	**2**	
average net electric power per offshore wind turbine (MW)	**2**	
Percentage of population to be covered by grand challenge	**50%**	
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

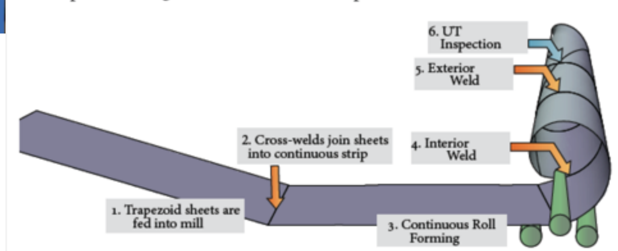
Meanwhile, in Colorado, an MIT spinoff is….

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

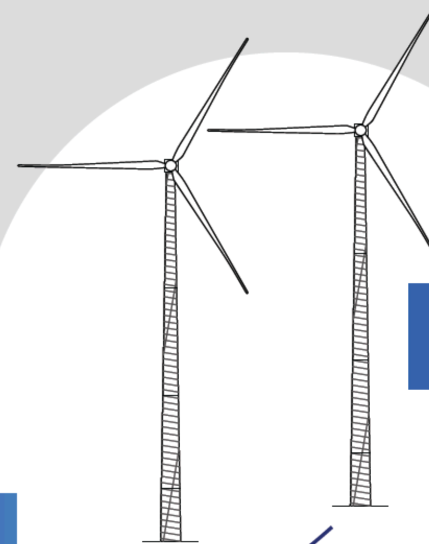


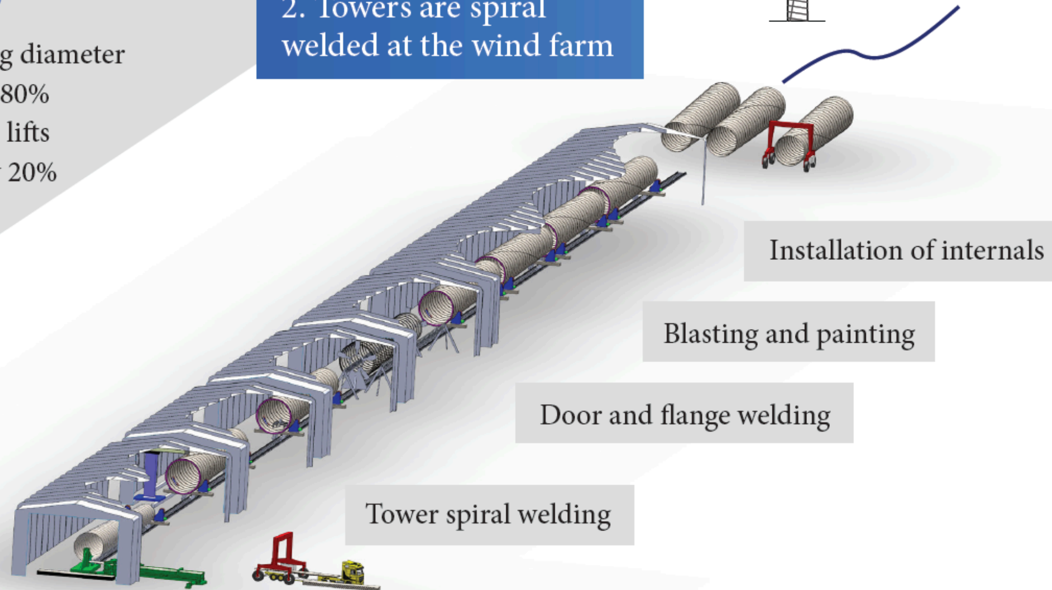
ON SITE SPIRAL WELDING

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

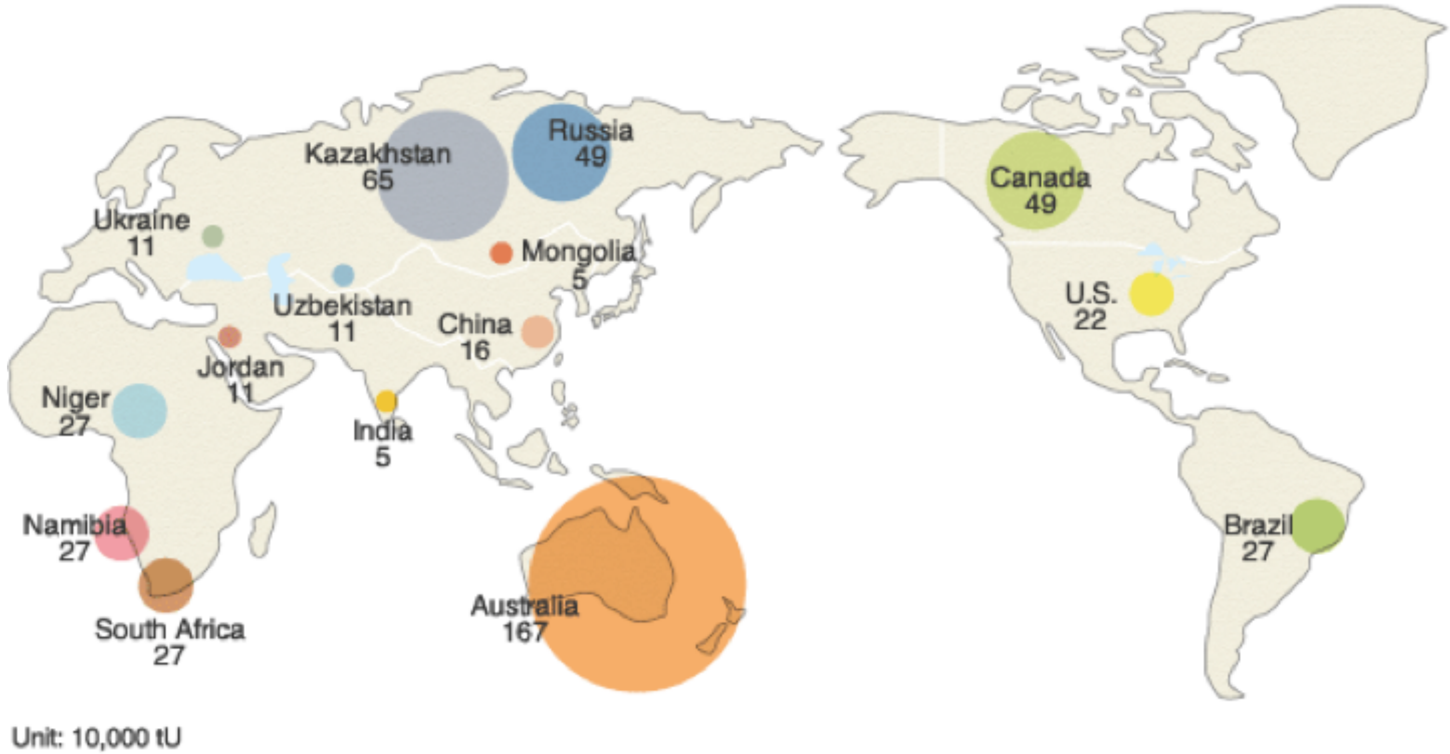




ON-SITE SPIRAL WELDING BY THE NUMBERS

- 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

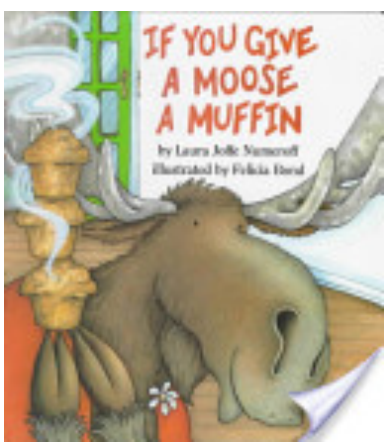
Problem (opportunity!)



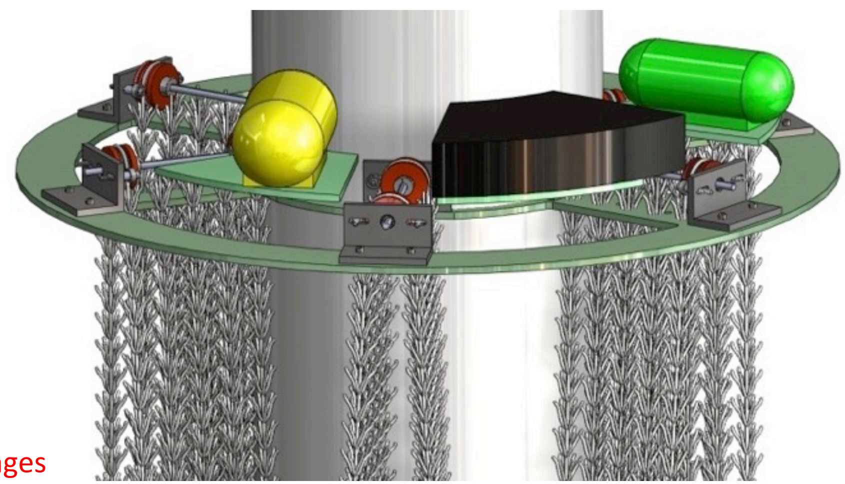
- Global conventional reserves of uranium = 7.6 M tonnes, could be depleted in ~100 years [OECD, 2014]
- Uranium present in the ocean at 3-3.3µg/L [Oguma et al., 2011] = 4.5 B tonnes and ~1,000 X that on land

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!

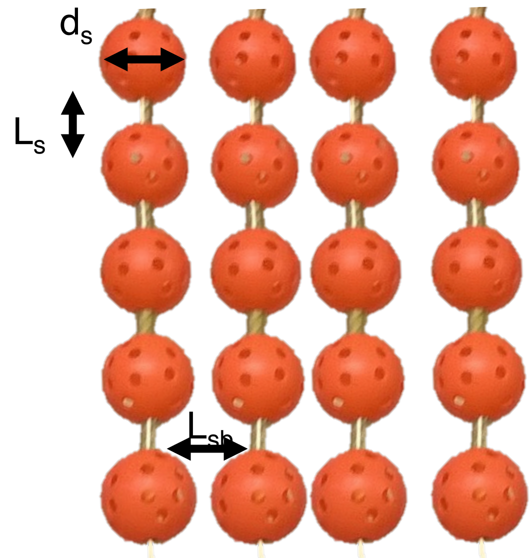


OK, did you get it? Dogs and cats living together (nicely)
=> oil, wind, nuclear all from the oceans....it CAN be done

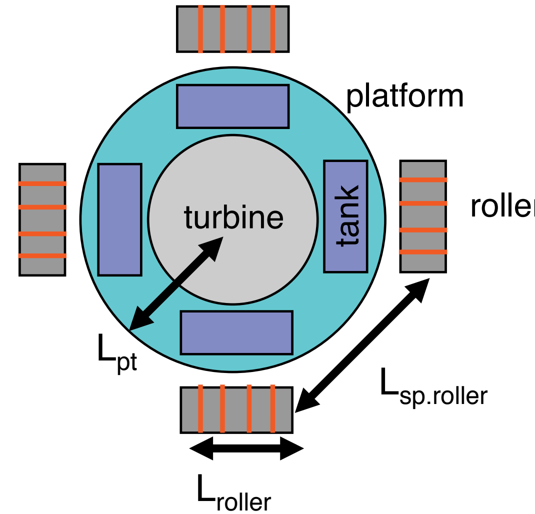
Full Scale Design

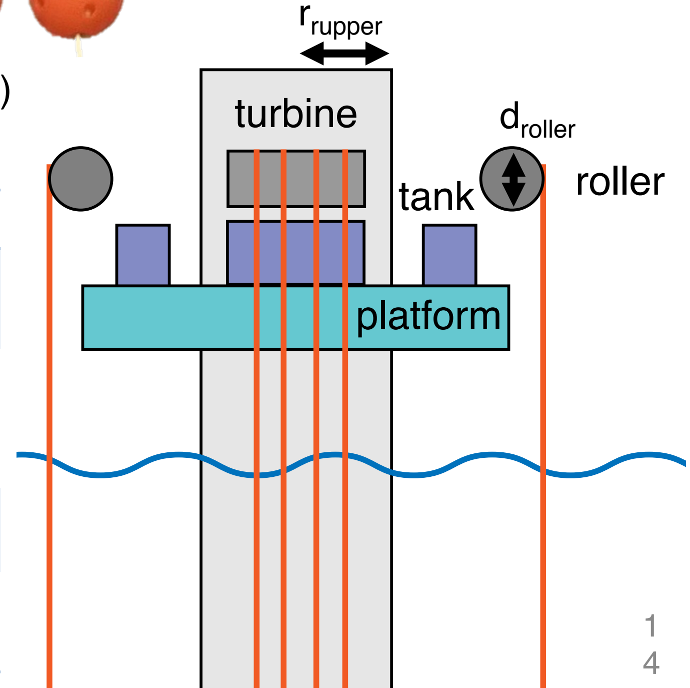
Parameter	Value
Shell diameter, d_s	0.25 m
Spacing between shells, L_s	0.05 m
Spacing between ball-chain lengths on a roller, L_{sb}	0.05 m
Number of rollers, N_{roller}	4
Number of ball-chain lengths per roller, N_b	10
Number of shells changed by half the roller, $N_{s,roller}$	6
Rail diameter, d_{rail}	0.15 m
Spacing between rollers, $L_{sp,roller}$	2 m
Upper radius of turbine, r_{upper}	3.2 m

Parameter	Equation	Value
Roller diameter, d_{roller}	$d_{roller} = \frac{\sqrt{d_s^2 + L_s^2 - 2 d_s L_s \cos(\alpha)}}{2 \sin\left(\frac{\pi}{2N_{roller}}\right)}$	1.15 m
Geometry angle, α	$\alpha = \pi\left(1 - \frac{1}{2N_{s,roller}}\right)$	2.88 rad
Roller length, L_{roller}	$L_{roller} = N_b(d_s + L_{sb}) + L_{sb} + 2d_{rail}$	3.35 m
Platform length, L_{pt}	$L_{pt} = \frac{N_{roller}\left(L_{roller} + L_{sp,roller}\right)}{2\pi} - r_{upper}$	0.2 m

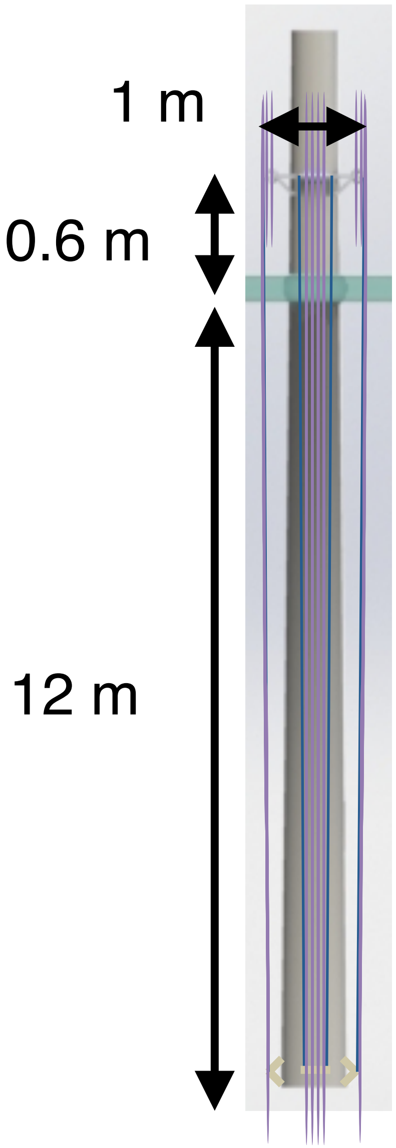


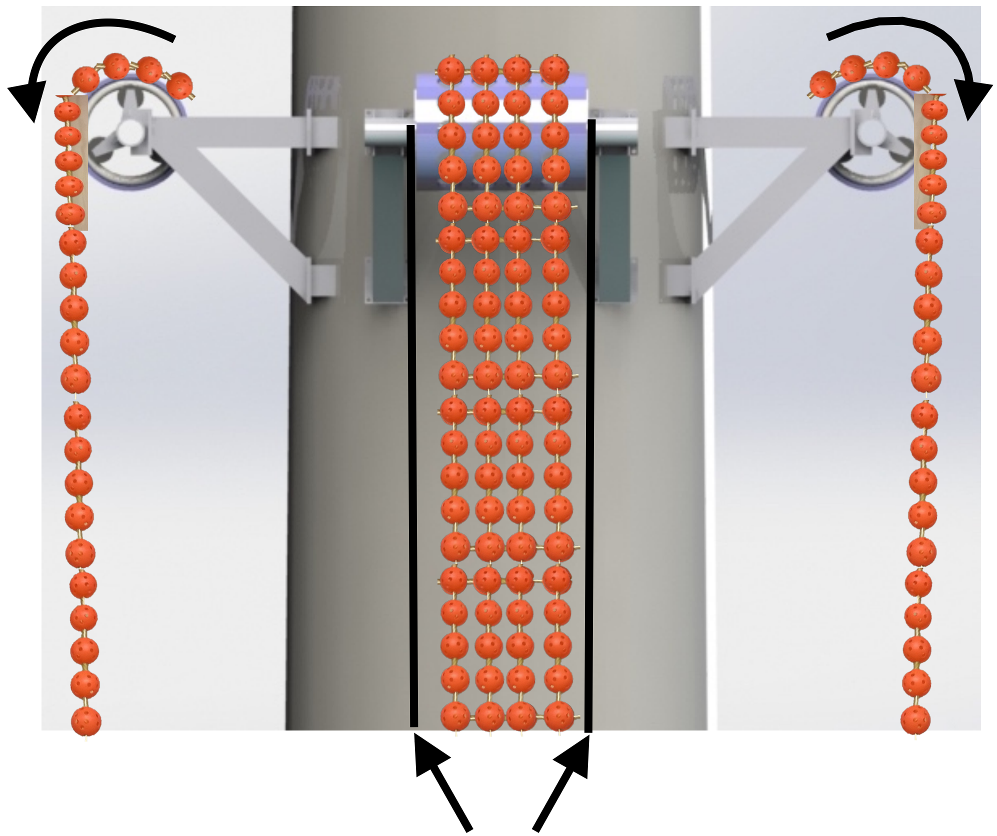
N_b (here = 4)





1/10th Scale Prototype

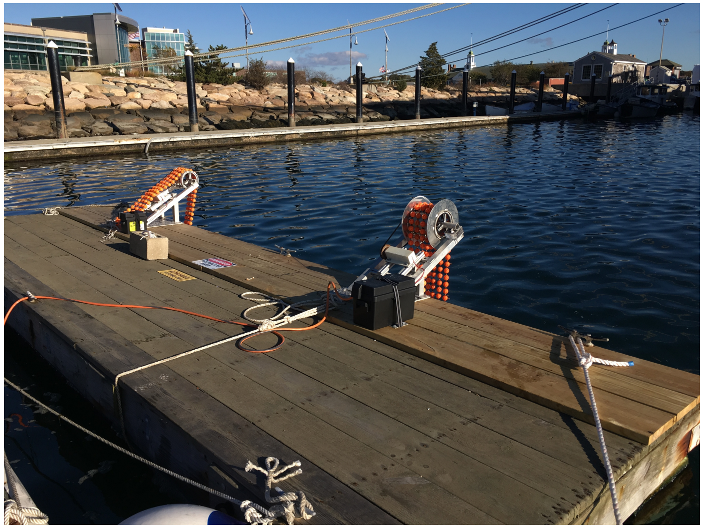




Motorized rollers move net up and down

Wire/rope guides on either side connected rigidly to bottom of turbine keep net from tangling

1/10th Scale Prototype – Adsorbent Deployment



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

Fish ~~Propellors~~

- **He** knew there would be a problem with the seals… ☺

(12) **United States Patent**
de Paula Neves et al.

(10) **Patent No.: US 8,157,024 B2**
(45) **Date of Patent: Apr. 17, 2012**

(54) **BALL PISTON STEERING DEVICES AND METHODS OF USE**

(75) Inventors: **Fabio de Paula Neves**, Brasilia (BR); **Alexander Slocum**, Bow, NH (US); **Ian David Thomas**, Sturminster Marshall (GB)

(73) Assignee: **Schlumberger Technology Corporation**, Sugar Land, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 212 days.

(21) Appl. No.: **12/328,711**

(22) Filed: **Dec. 4, 2008**

(65) **Prior Publication Data**

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(51) **Int. Cl.**
E21B 7/06 (2006.01)

(52) **U.S. Cl.** **175/73**; 175/61; 175/76; 166/329; 405/143

(58) **Field of Classification Search** 175/73, 175/61, 76, 99, 267, 408; 166/324, 328, 166/329; 137/513.5; 405/143
See application file for complete search history.

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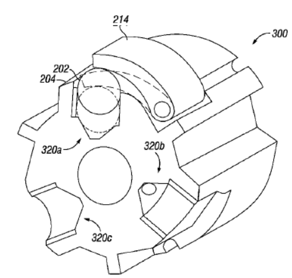
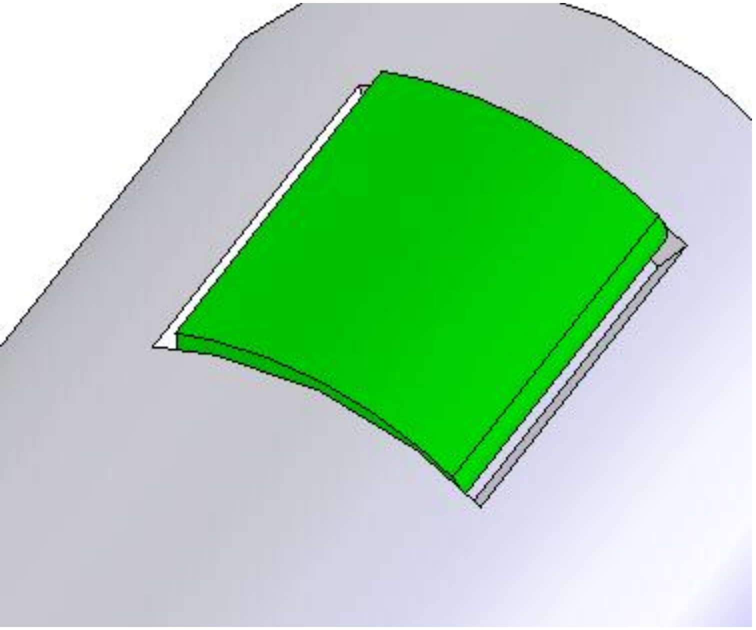
(57) **ABSTRACT**

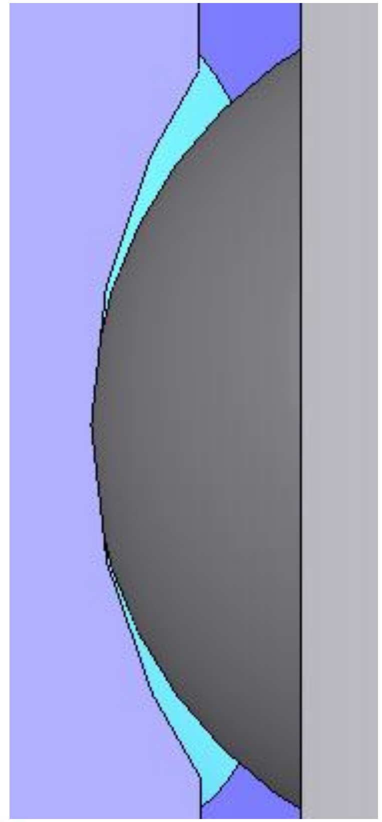
Embodiments include ball piston steering devices and methods for use of ball piston devices. In one aspect a ball piston steering device includes a sleeve in fluid communication with a fluid source and a ball received within the sleeve. The ball is movable within the sleeve between a recessed position and an extended position.

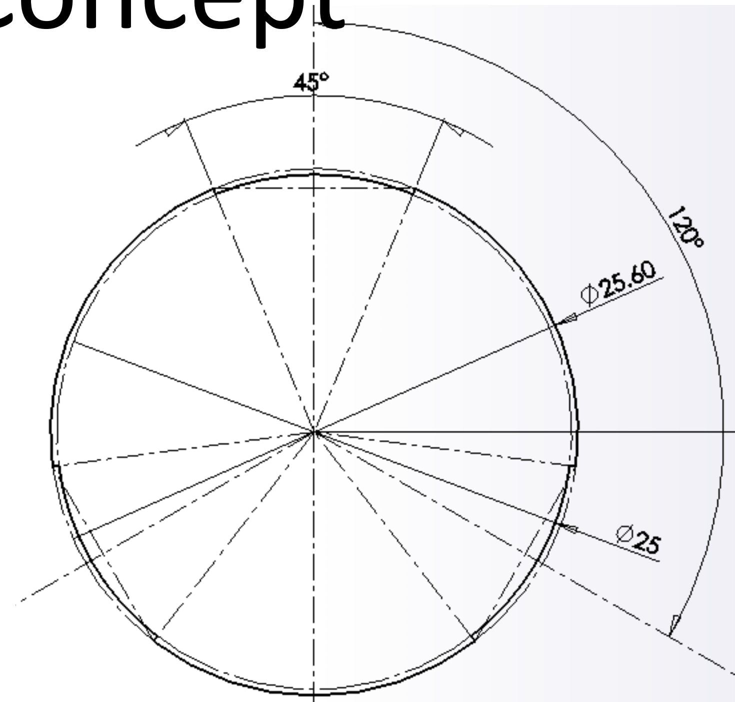
17 Claims, 6 Drawing Sheets

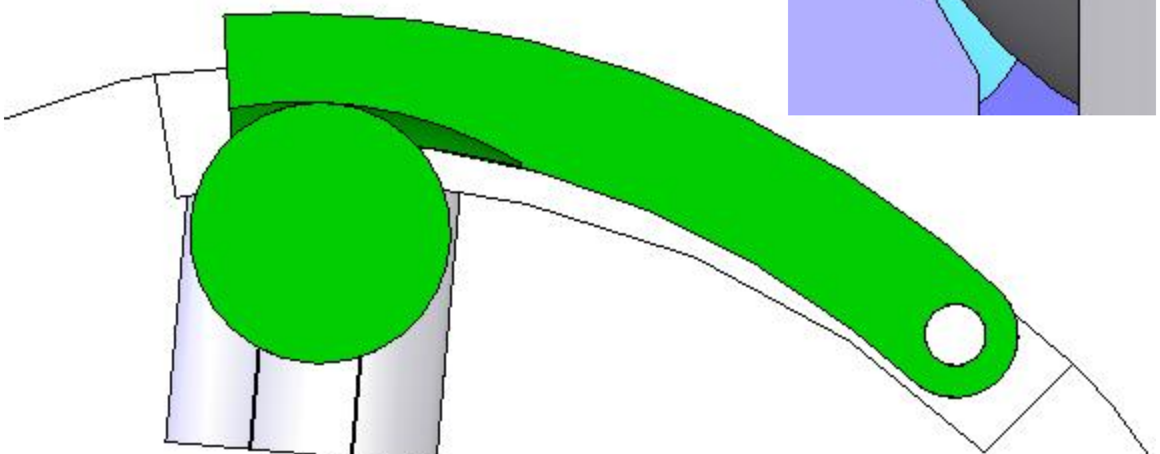


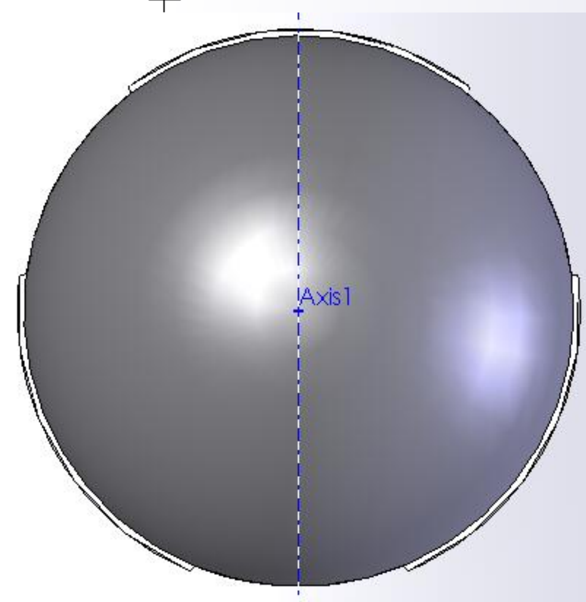
Solid Model of Concept











Design Calculations

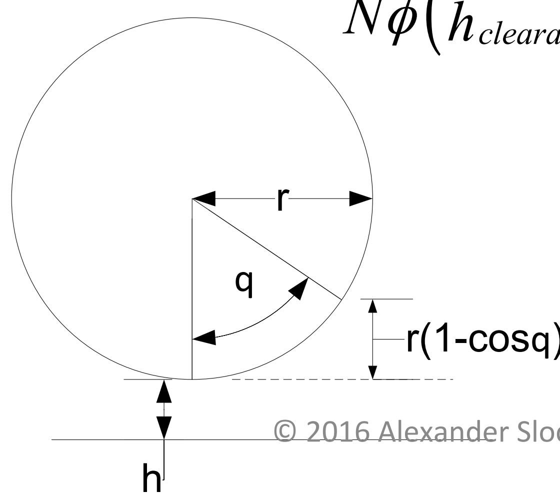
- Flow is not fully developed, but assume each axial differential slice *dx* through flow path of fluid through the current piston hole and around the ball are governed by laminar flow model
- The differential flow resistance through the hole and around the ball are thus:

$$dR_{hole} = \frac{8\mu dx}{\pi r_{hole}^4}$$

$$dR_{sphere} = \frac{\cos\theta d\theta}{\left(h_{clearance} + r_{sphere}(1-\cos\theta)\right)^3}$$

with fluid viscosity μ and N recesses each of angle ϕ:

$$dR_{sphere} = \frac{\mu\cos\theta d\theta}{N\phi\left(h_{clearance} + r_{sphere}(1-\cos\theta)\right)^3}$$



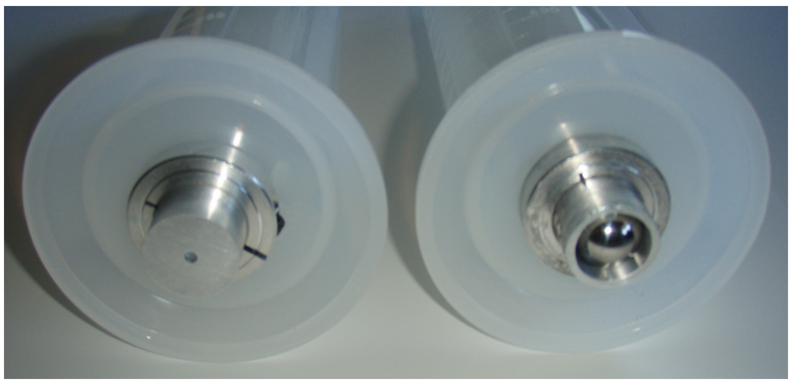
Design Calculations

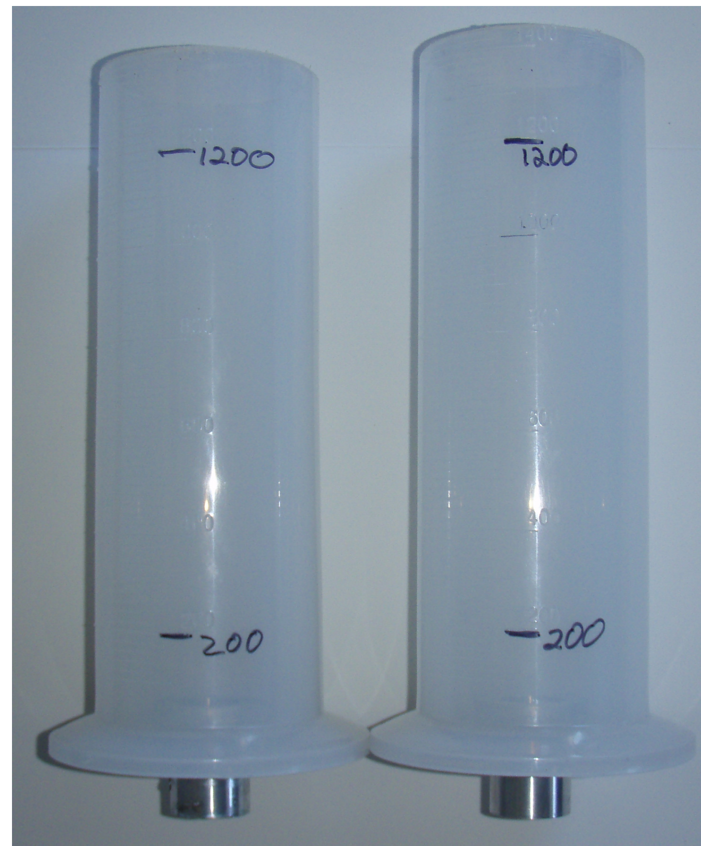
- The preliminary analysis indicates the design is feasible
  - Next step conduct bench level experiments
    - *Indicates the as-built design should be measured*
    - *The flow calculations appear to be way too high in absolute terms, CFD needed*

mu	0.015	viscosity (water = 0.001 newton second/m²)		
Baseline (current piston)				
dh	0.004	4	hole diameter (m, mm)	
Lh	0.0025	2.5	hole length (m, mm)	
Rhole	5968310		"capillary" resistance (assumes fully developed flow)	
Nball	3	number of ball pistons		
Rr	0.015	15	radius ball (m, mm)	
theta	1.0472	60	theta, angle (radians, degrees) over which integrate	
h	0.000285557	0.29	groove gap depth (m, mm)	
phi	1.3090	75	groove angle (radians, degrees)	
N	3	number of ball supporting lands		
philand		45	land angle (degrees)	
Rball	17904683			
Rballs	5968228			
Ratio resistance of N balls/piston hole resistance	1.00	make flow resistance past balls equal to flow resistance through piston center hole		
Areaball	0.000707	707	Ball cross section area (m^2, mm^2)	
Pressure	5000000	50	735	(Pa, atm, psi)
Fpball	3534	794	Force per ball piston (N, lbf)	
Fptotal	10603	2383	Total force from ball pistons (N, lbf)	
Flow	0.838	50266	m^3/sec, lpm	

Experimental Apparatus

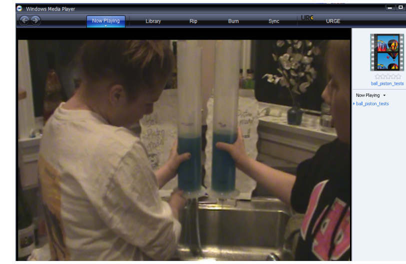
- The aluminum test parts were made and a standard steel ball was held in place with a setscrew
  - The aluminum test parts were glued into the bottom or Erlenmeyer flasks (tops cut off)





Experiments and Results

- The video ball_piston_tests.mpg (53MB) shows the tests where blue food-colored water was allowed to run from both test cylinders at the same time
  - The ball piston model was about 10% faster
  - Good results given the 1st order analysis



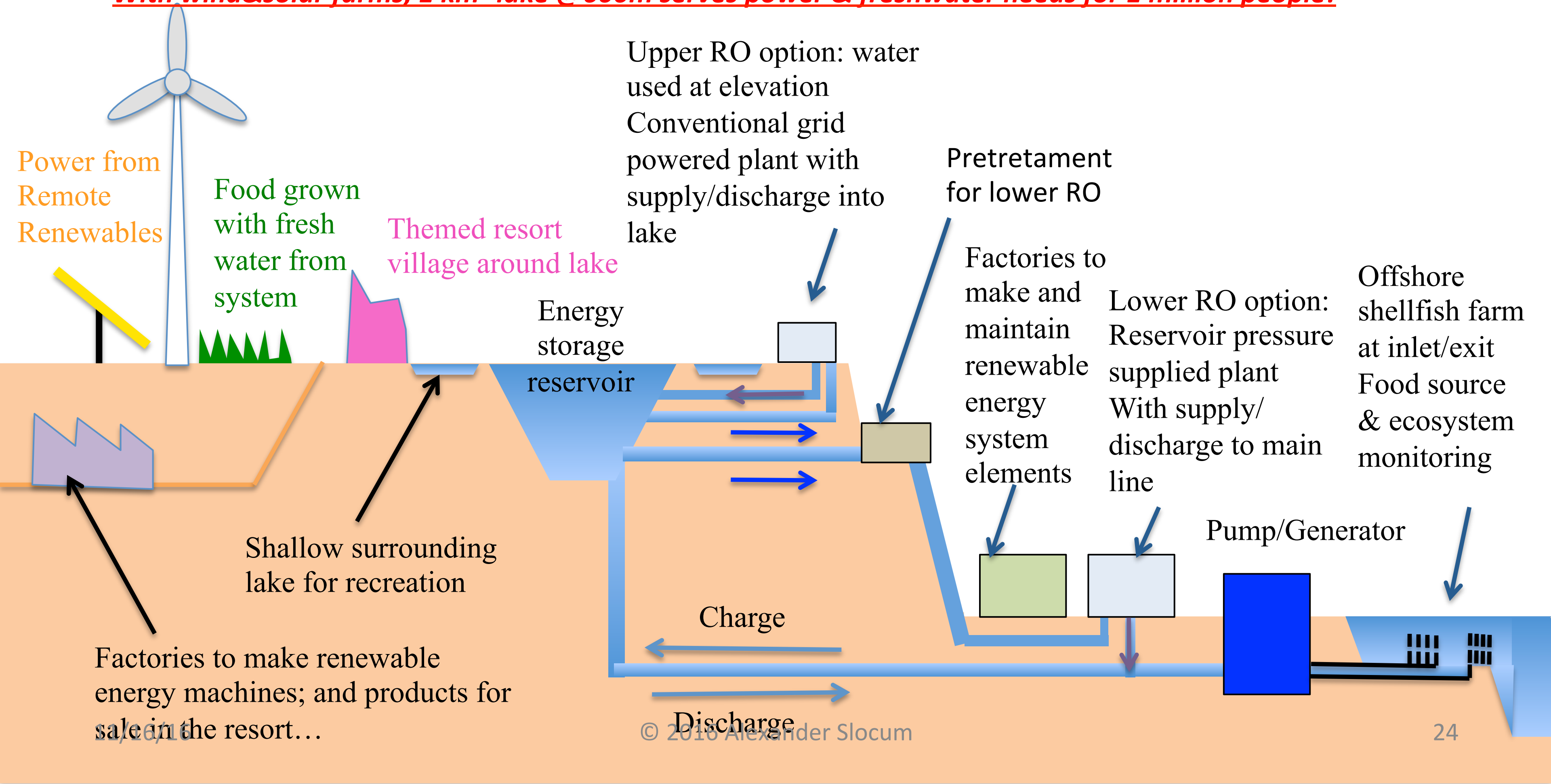
- Working with the Schlumberger team created to make this idea into a product… 6 years later a new product for reliability in drilling long hot deep horizontal bores became a reality…

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

IPHROS: Integrated Pumped Hydro Reverse Osmosis System

Supplying renewable energy, fresh water, and jobs for an entire region

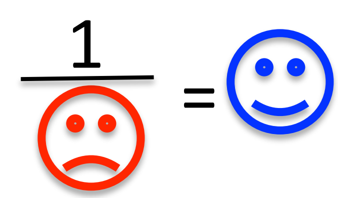
- Intelligent design ☺: Pumped Hydro Head = 500-700 m, = RO desal head
  - http://www.sciencedirect.com/science/article/pii/S2213138816300492
- Many drought stricken coastal regions have mountains near coast
- 20m^3 water => 2kWe, 1 m^3 => 500l freshwater
  - Brine out-flow from RO plant is readily diluted by the output from the turbine
- ***With wind&solar farms, 1 km^2 lake @600m serves power & freshwater needs for 1 million people!***



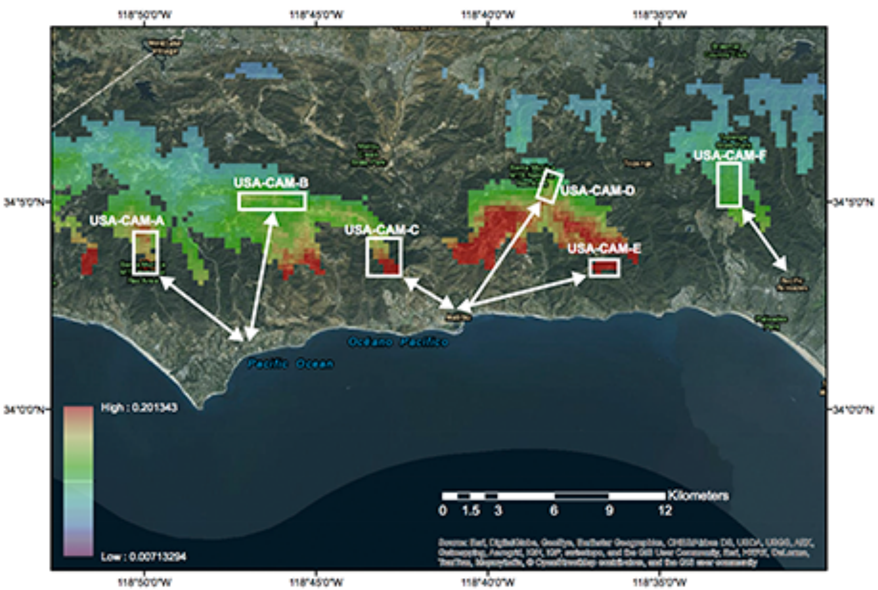
IPHROS: Key Parameters

Summary:

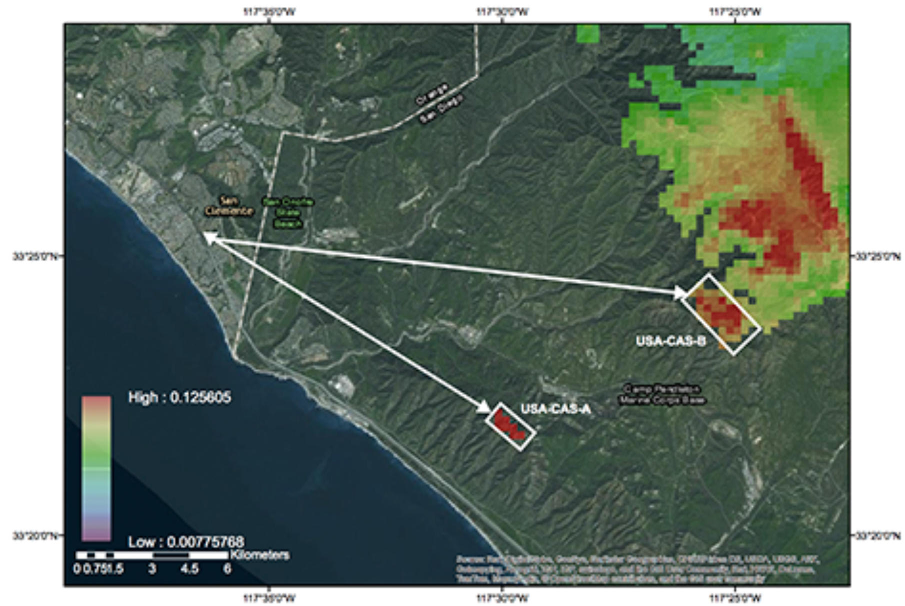
- One million people can be served by every 1 km^2 of pumped seawater lake at > 500m asl
- To provide the ideal daily power (2 kW) and freshwater (500l) needs of a person requires:
  - 20 m^3 seawater for storing energy from solar and wind farms
  - 1 m^3 of seawater for RO plant
    - Brine gets diluted 30:1 by seawater output from power turbine
- Energy system needed: Peak (6000 MW solar & wind + 3000 MW pumped storage) => 2000 MW 24/7
- New economy <=> good jobs!:
  - Solar and wind farms
    - Factories to make solar and wind energy machines, installation, maintenance
      - Jordan's Ma'an region has world's best silica for making solar cells!
  - PHROS system: Tunnels, earthworks, pumped hydro plant, grid
  - Resort & theme park: Construction, operation, supporting infrastructure
    - Hotels, restaurants, shops, manufacturing (souvenirs!), agriculture, transportation…
- Cost: $5 / Watt installed power for the renewable energy, storage, RO systems
  - 1 million people @ 2kW/person => $10 billion
    - Much of the tech equipment can be bought from hi tech economies that could finance the project
  - Amount Germany will spend on refugees in 2016-17: $50 billion
  - Amount US will spend on armaments in 2016-2017: > $100 billion
- ***Jordan: Working with the world to make the Middle East***



California: Malibu & San Clemente



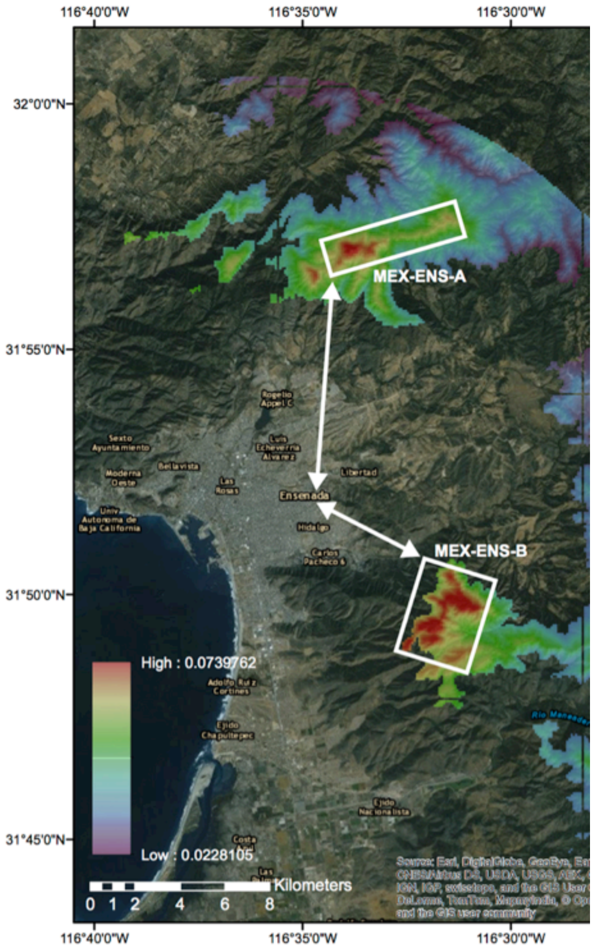
Malibu, CA, USA

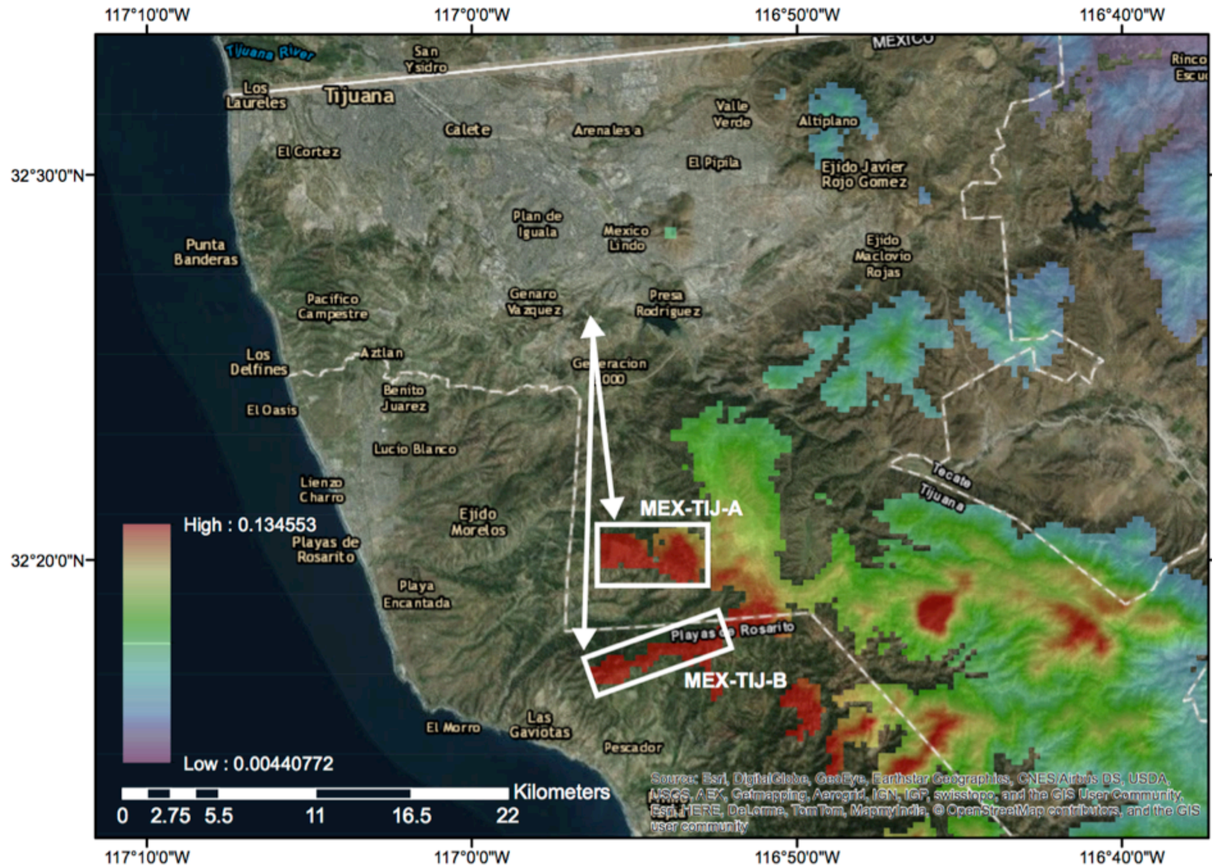


San Clamente, CA, USA

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

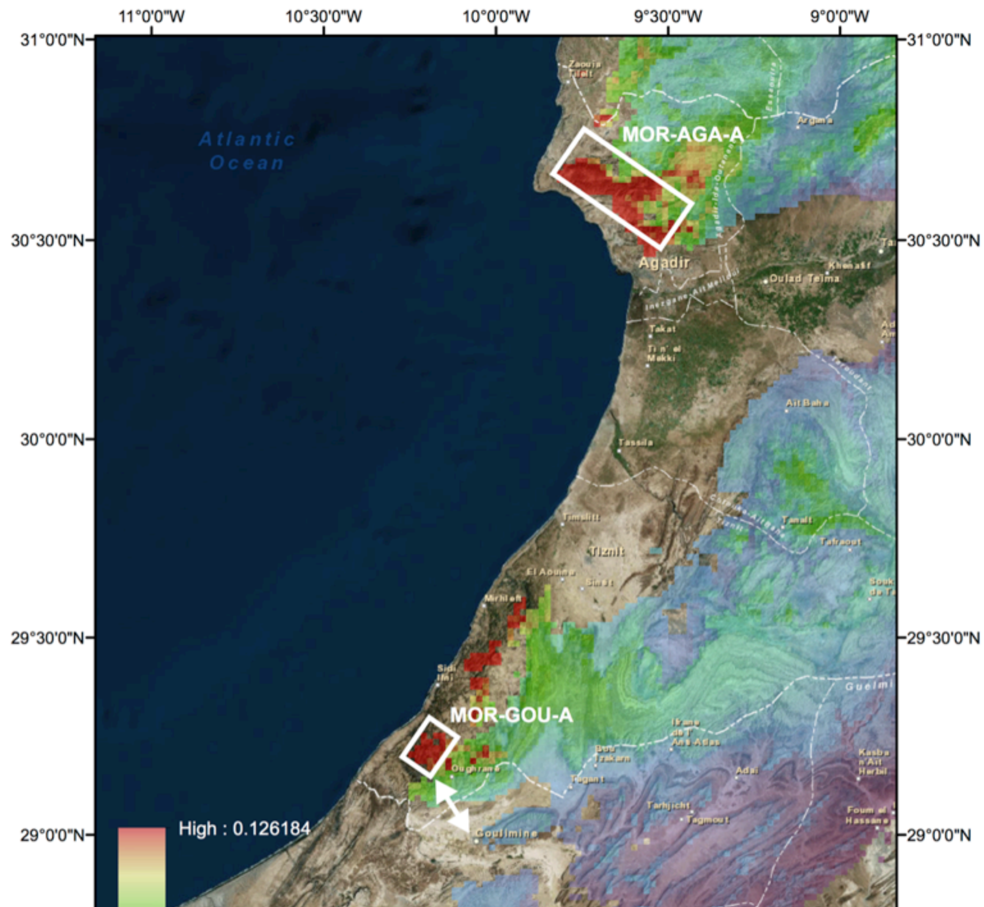
Mexico: Ensenada & Tijuana



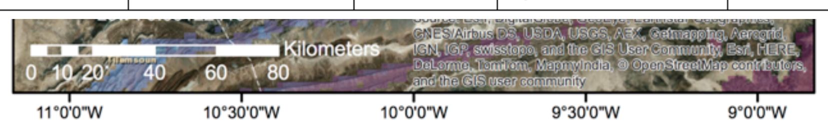


Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
MEX-ENS-A	886	3.5	15	0.059	Ensenada	9.2	119
MEX-ENS-B	636	2.7	9.6	0.066	Ensenada	7.6	101
MEX-TIJ-A	567	14.5	12.7	0.045	Tijuana	12.8	483
MEX-TIJ-B	542	10.7	8.2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

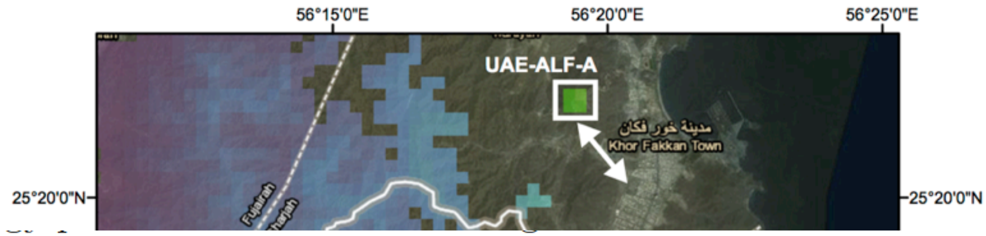
Morocco



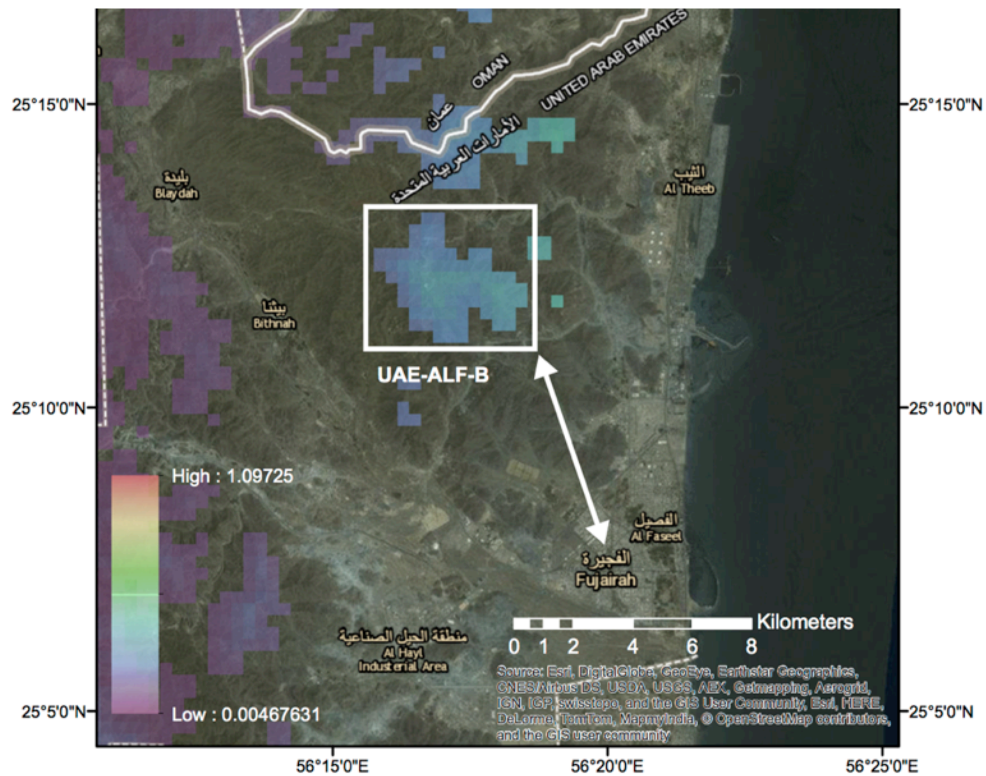
Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
MOR-AGA-A	687	292	13	0.053	Agadir	3.9	13503
MOR-GUO-A	582	112	13	0.044	Guolimim	27	4380



UAE

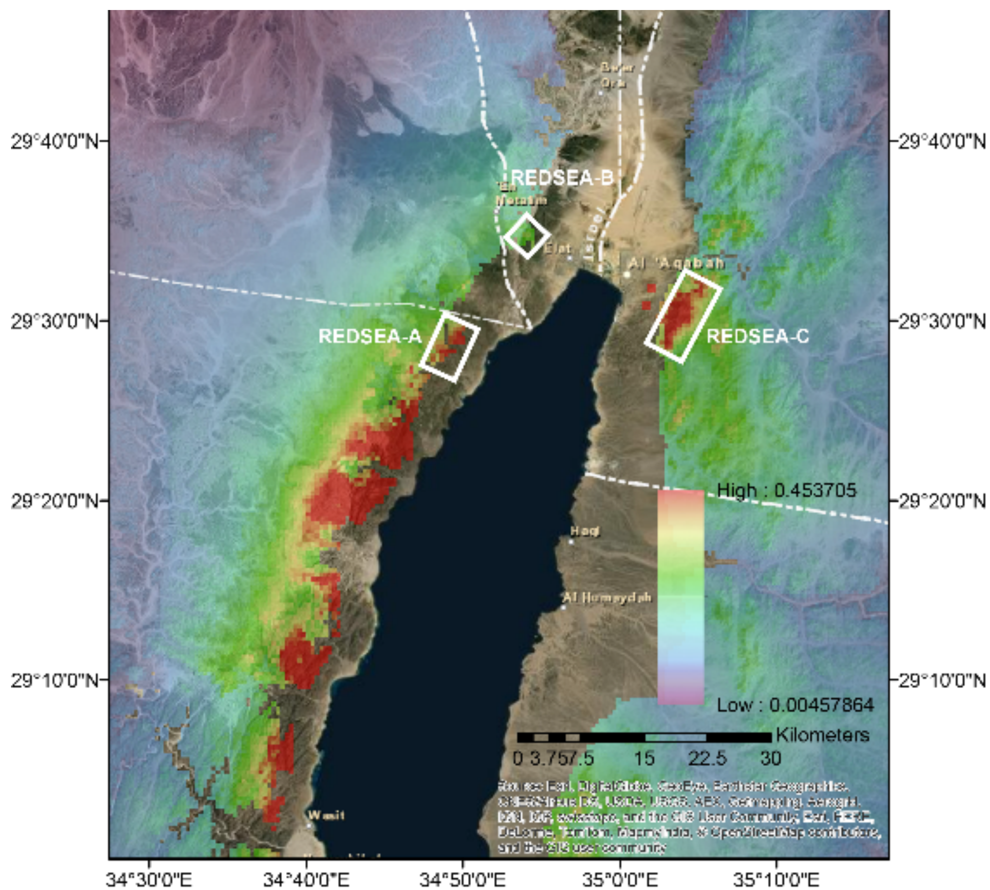


Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
UAE-ALF-A	529	0.64	2.8	0.186	Khor Fakkan	2.7	23
UAE-ALF-B	619	12.8	8.5	0.073	Fujairah	7.3	533

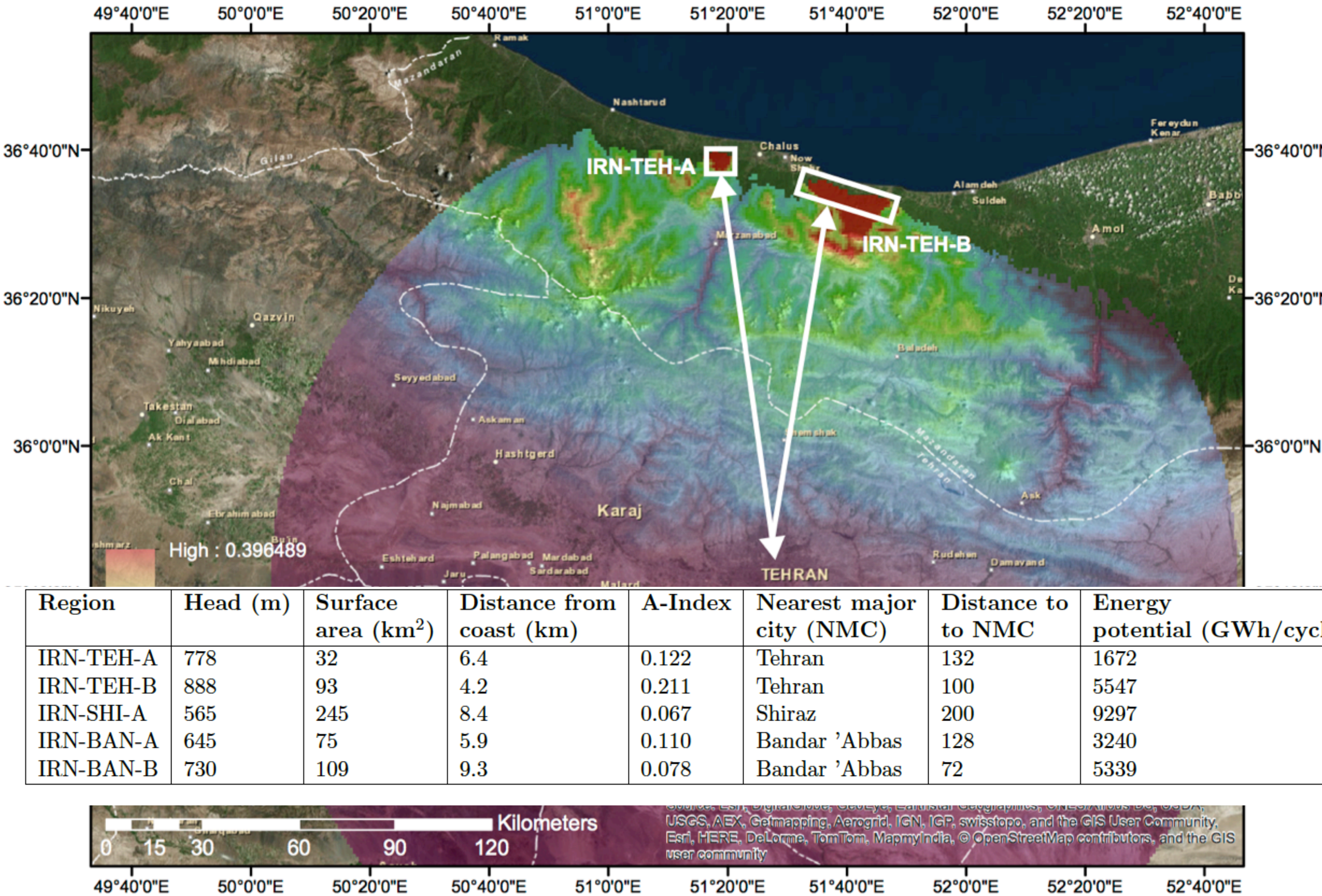


Northern Red Sea

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

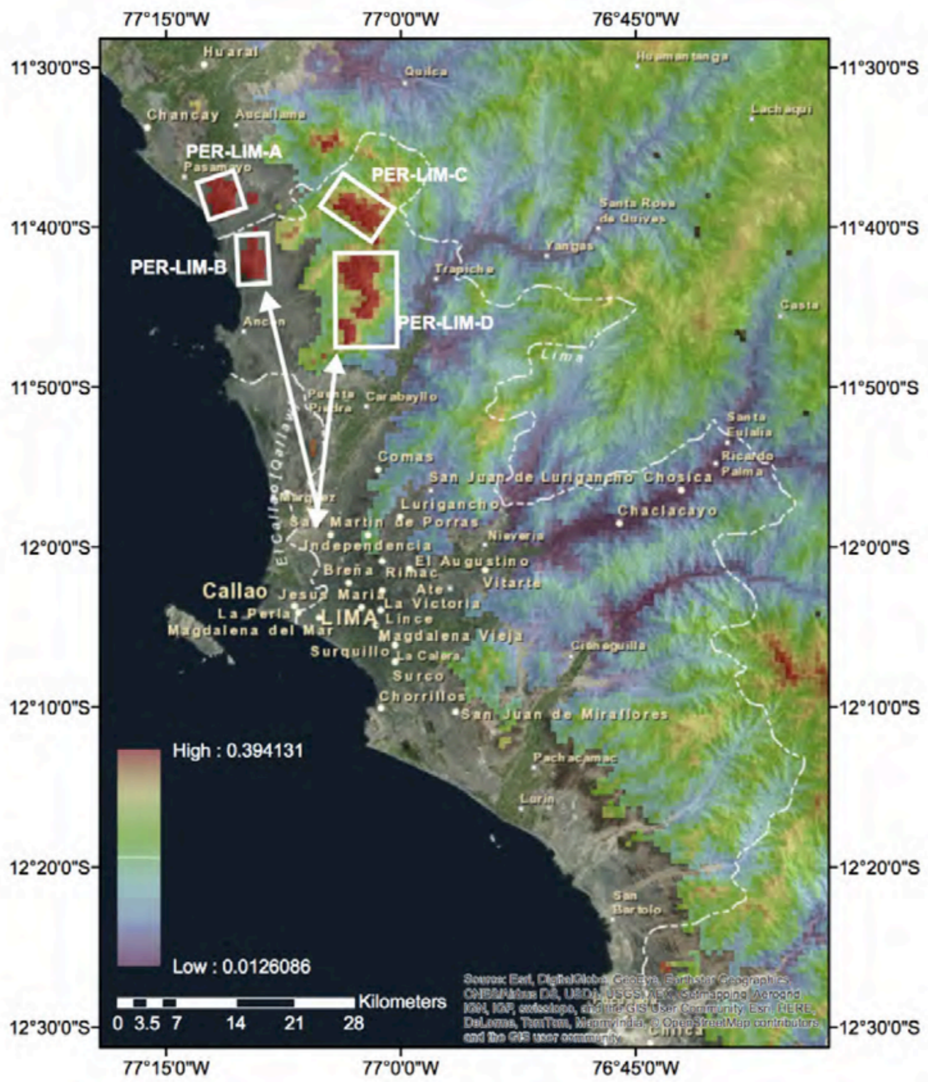


Iran



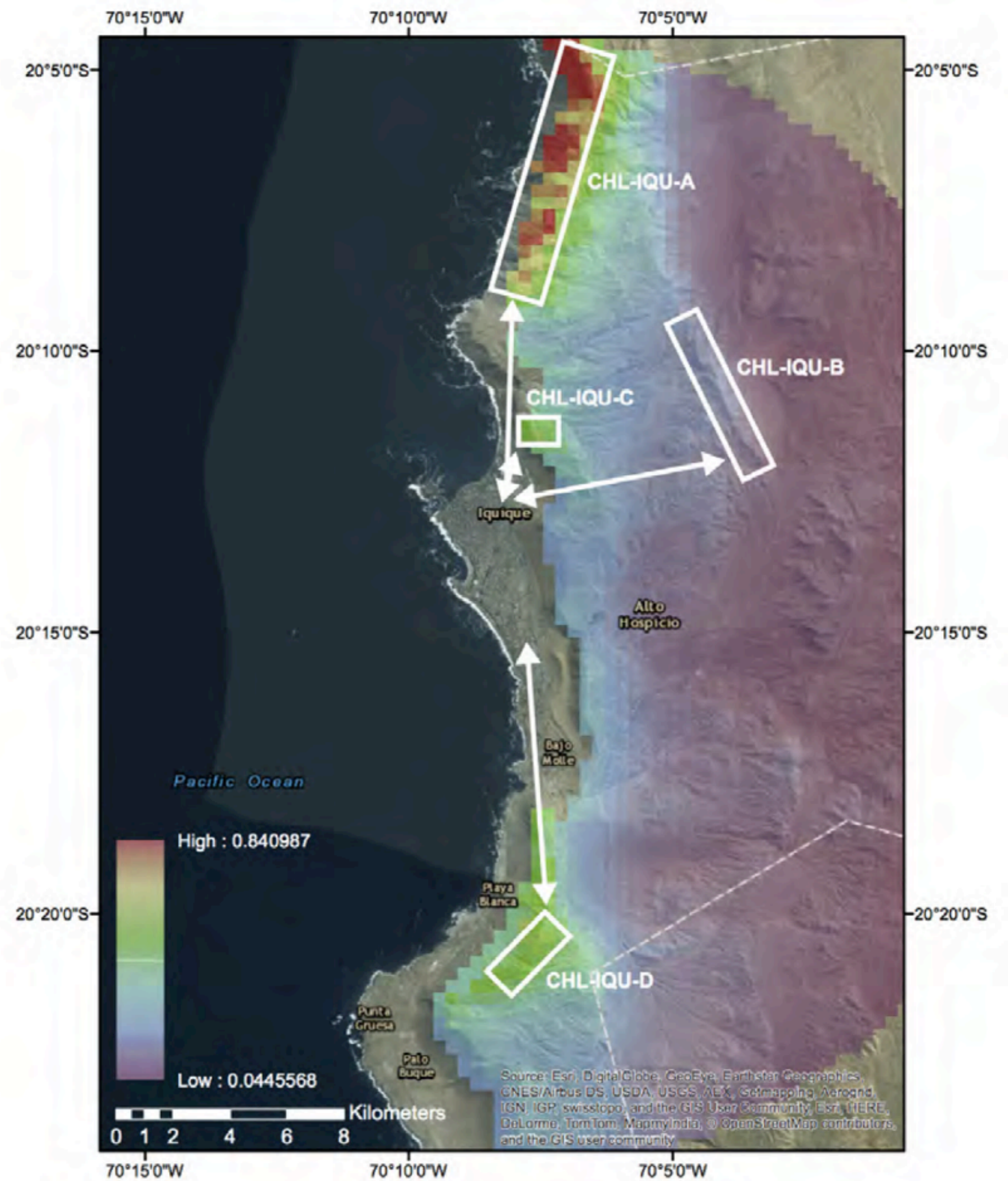
Region	Head (m)	Surface area (km^2)	Distance from coast (km)	A-Index	Nearest major city (NMC)	Distance to to NMC	Energy potential (GWh/cycle)
IRN-TEH-A	778	32	6.4	0.122	Tehran	132	1672
IRN-TEH-B	888	93	4.2	0.211	Tehran	100	5547
IRN-SHI-A	565	245	8.4	0.067	Shiraz	200	9297
IRN-BAN-A	645	75	5.9	0.110	Bandar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

Peru



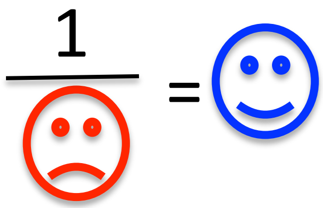
77°15'0"W
77°0'0"W
76°45'0"W
11°30'0"S
11°40'0"S
11°50'0"S
12°0'0"S
12°10'0"S
12°20'0"S
12°30'0"S
PER-LIM-A
PER-LIM-B
PER-LIM-C
PER-LIM-D
Huaral
Chancay
Callao
LIMA
San Martin de Porras
Independencia
Comas
Carabayllo
San Juan de Lurigancho
Chosica
Chaclacayo
Lurigancho
El Agustino
Vitarte
Ate
La Victoria
Lince
Magdalena Vieja
Magdalena del Mar
Surquillo
Surco
Chorrillos
San Juan de Miraflores
High : 0.394131
Low : 0.0126086
Kilometers
0 3.5 7 14 21 28

Chile

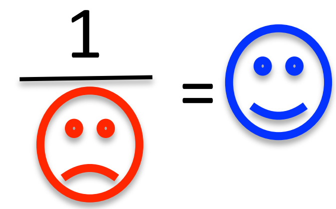

70°15'0"W
70°10'0"W
70°5'0"W
20°5'0"S
20°10'0"S
20°15'0"S
20°20'0"S
CHL-IQU-A
CHL-IQU-B
CHL-IQU-C
CHL-IQU-D
Iquique
Alto Hospicio
Bajo Molle
Playa Blanca
Punta Gruesa
Palo Buque
Pacific Ocean
High : 0.840987
Low : 0.0445568
Kilometers
0 1 2 4 6 8
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Its time We Put The World First

Marc Graham and Alex Slocum, http://www.marcgrahamphd.com/



The most important calculations are those that will save nations,
Like building wind plantations, instead of more gas stations,
And seeking new destinations in space, is complicated,
The Earth is worth saving from troubles that we created,
It's time to double efforts, in land, water and sky,
It's time to come together, it's time to solarize,
The answer is blowing in the wind and flowing in the water,
The polar caps are melting, sea levels are on a rise,
Surprised that super storms still haven't opened our eyes,
Some scientist theorize, and politicians decide,
That man is not at fault, so they gamble with our lives,
Let's get off the sidelines and show we're not psychotics,
Insane, awaiting change from the same planned periodic,
Debates with fate at stake, of our consequent generations,
Reversing the complications, requires more impatience,
No time to be wasted, this fight is not symbolic,
A catastrophic plight, or relationship symbiotic… Decide… It's Time…



Action, no longer passive, too massive to stagnate,
Reaction, we seize the moment, accelerate to create,
With force, remove mobs from desperate situations,
Renewed energy jobs, will lay the foundations,
Question, research, guess, test, analyze with a passion,
'Cause building what we create, is the prevalent high fashion,
Our fate's in our control, so let's stand hands united,
The only way we'll fold, is in a world divided
It's time we all put the World First

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

AND We Have the Shirt! ☺

(Aloha++ shirts now being sewn in Hawaii from Louisiana made fabric!)

1/☹ = ☺ pattern © 2016 by Slocum