Massachusetts Institute of Technology

MIT Energy Initiative

Symbiotic Energy Harvesting and Storage Systems

Presented at the 6th Atlantic Council Energy and Economic Summit
November 20-21, 2014
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Navier Stokes Equations!

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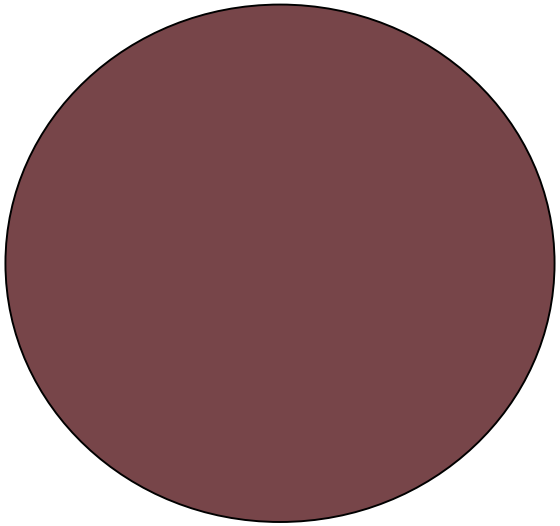
1/(Doom & Destruction)

- 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!

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, THE WORLD ECONOMY, AND OURSELVES

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

Symbiotic Thinking is the Key

Just utilizing idle capacity can make a HUGE difference!

Auto industry capacity (million autos per year)	**20**
Current auto production (million autos per year)	**16**
Idle capacity (million autos per year)	**4**
Weight automobile (tonnes)	**1.5**
Wind turbine system size (MW)	**5**
Weight wind turbine system (tonnes)	**750**
Automobiles per wind turbine	**500**
Capacity factor	**50%**
24/365 continuous power outout of a wind turbine (MW)	**2.5**
US electric power demand (GW)	**1000**
% power to be provided by wind	**50%**
Power by wind (GW)	**500**
Number of wind turbines required	**200000**
Millions of automobile equivalents	**100.0**
Percent of industry idle capacity refocused on Wind energy systems	**50%**
Millions of autos not built and effort directed to wind turbines	**2**
GW/year of wind turbines by repurposed auto manufacturing	**10**
Years of redirected auto production to achieve wind energy target	**50**

In the race to save the planet:
Let's get there by trimming the excess

Nothing feels as good as crossing the finish line ALIVE!

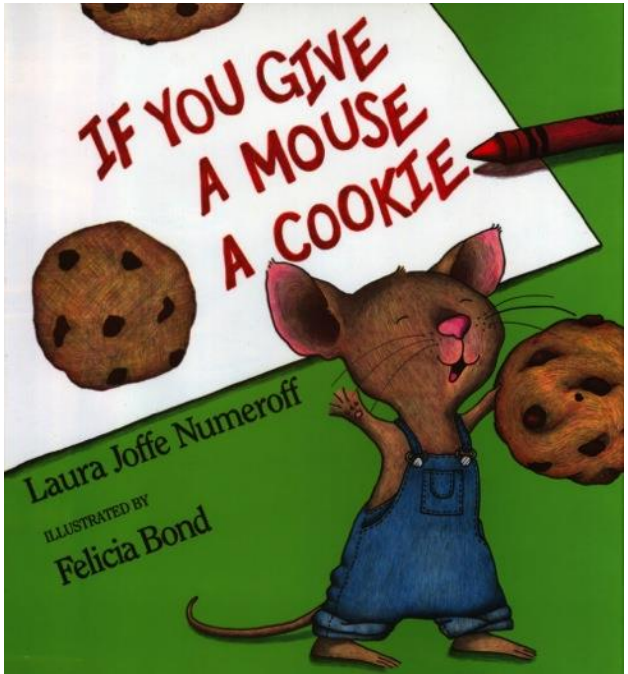
I used to have a mass >120kg and pack in the donuts and double cream triple sugar foofoo coffee like I packed my minvan with brush…

Then one day after my doc took off the veterinary glove and said "you are in bad shape…"

Number of super sugared foofoo coffees per day	**10,000,000**
Extra cost of foofoo coffee	**$5.00**
Money spent on fancy foofoo coffees per day	**$50,000,000**
Extra Calories per foofoo coffee	**500**
Total GCals energy value of all foofoo coffee consumed/day	**5.00**
Tonnes of body fat per day	**714**
18 wheelers of body fat per day	**24**
MWh of energy value of foofoo coffee per day	**5,814**
MWh/day of a 5 MW wind turbine at 40% capacity factor	**48**
Wind turbine equivelents of daily foofoo coffee purchaces	**121**
Wind turbine system size (MW)	**5**
Cost per turbine system	**$10,000,000**
US electric power demand (GW)	**1000**
% power to be provided by wind	**50%**
Desired power by wind (GW)	**500**
Number of wind turbines required	**250,000**
Wind turbines/year that could be bought with foofoo $	**1,825**
Years of foofoo coffee purchases to achieve wind energy goal	**137**
Statin sales per year ($)	**$30,000,000,000**
Do Cholesterol Drugs Do Any Good? - Businessweek	**not really**
Wind turbines per year that could be bought with Statins	**3000**
years of statin purchaces to achieve wind energy goal	**83**
Year to wind energy goal if no foofoo coffee and no statins	**52**

Catalysts are Key!

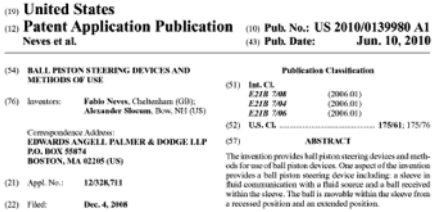
- IF <you give a mouse a cookie…>
- OR <a creative engineer a problem time…>
- THEN <we have a chance…>
- ELSE <we all goto hell we create on earth>

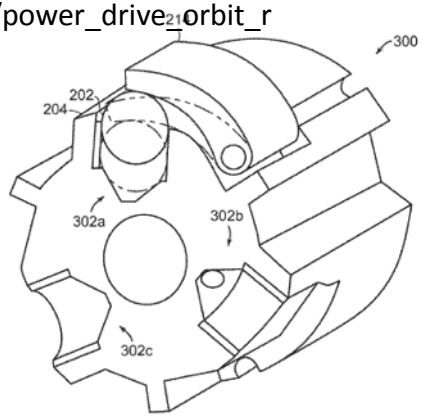


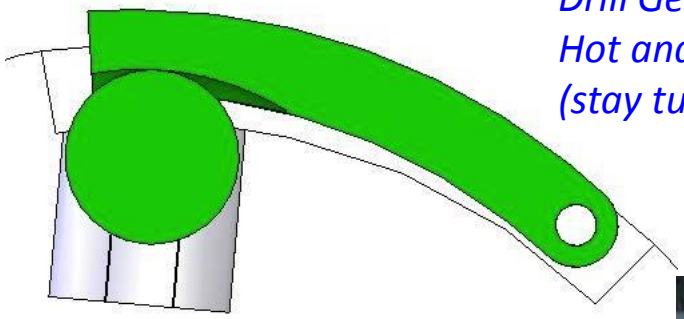
Seriously, EVERY engineer, manager and politician MUST read these books!!!

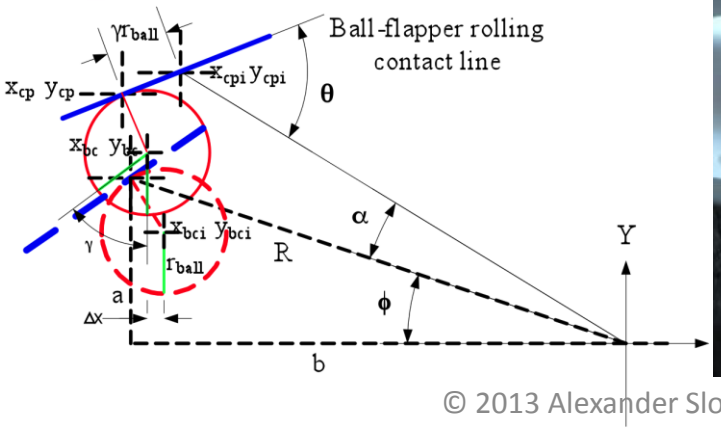
OIL: We still Need it (at least for a little while)

- No matter how deep and hot it hides, we can get it (drill baby drill!)
- Deep hot holes cause hydraulic seals to fail prematurely
- Fall 2007 Slocum developed concept for Schlumberger
  - 5 years of extensive develop and test by Schlumberger engineers led to:
- http://www.slb.com/services/drilling/drilling_services_systems/directional_drilling/powerdrive_family/power_drive_orbit_rotary_steerable.aspx

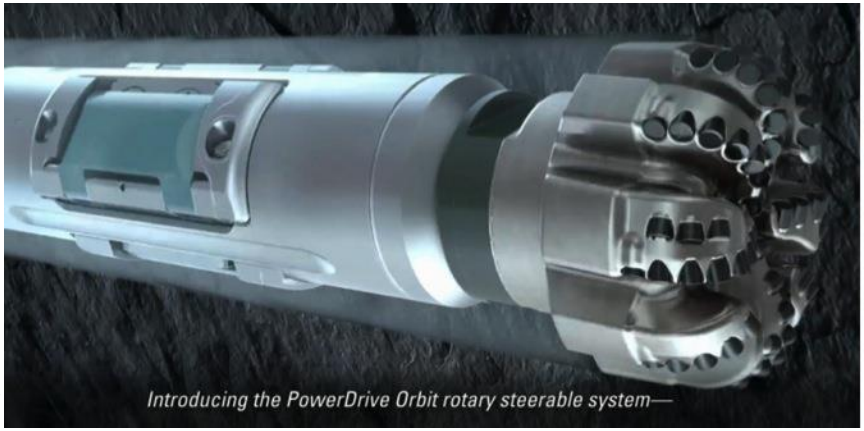

(19) United States
(12) Patent Application Publication
Neves et al.
(10) Pub. No.: US 2010/0139980 A1
(43) Pub. Date: Jun. 10, 2010
(54) BALL PISTON STEERING DEVICES AND METHODS OF USE
(76) Inventors: Fabio Neves, Cheltenham (GB); Alexander Slocum, Bow, NH (US)
Correspondence Address: EDWARDS ANGELL PALMER & DODGE LLP P.O. BOX 55874 BOSTON, MA 02205 (US)
(21) Appl. No.: 12/328,711
(22) Filed: Dec. 4, 2008
Publication Classification
(51) Int. Cl.
E21B 7/08 (2006.01)
E21B 7/04 (2006.01)
E21B 7/06 (2006.01)
(52) U.S. Cl. 175/61; 175/76
(57) ABSTRACT
The invention provides ball piston steering devices and methods for use of ball piston devices. One aspect of the invention provides a ball piston steering device including: a sleeve in fluid communication with a fluid source and a ball received within the sleeve. The ball is movable within the sleeve from a recessed position and an extended position.





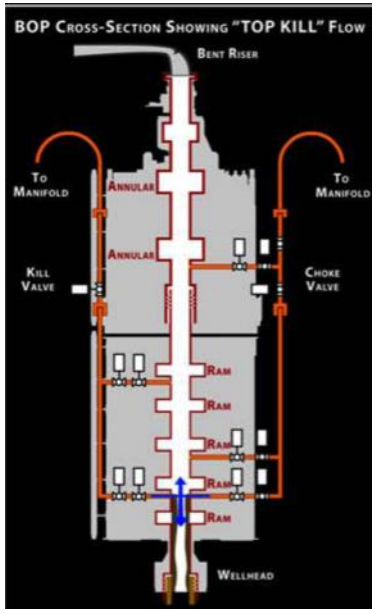


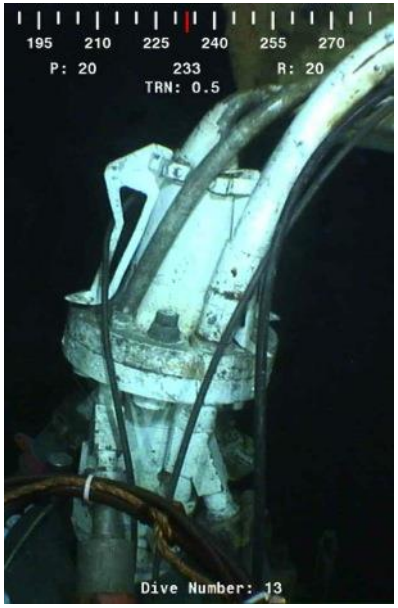
Drill Geeks Drill!
Hot and deep into the future
(stay tuned!)

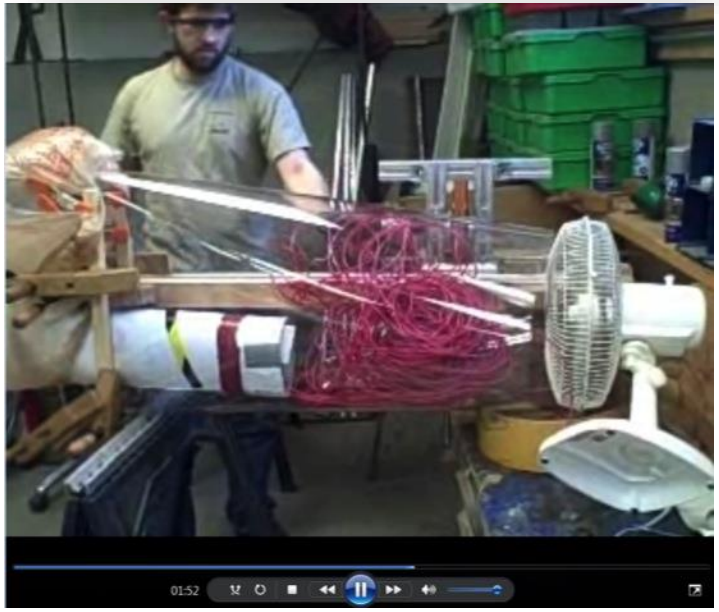


OOPs, They Did It Again (are they NOT that innocent ☺?)

- Oil Safety: Blow Out Preventers are amazing machines
  - Deepwater Horizon taught us they can fail..
  - It happened before and it will happen again
- Next time we will be ready!
  - Clog that well! Wire from a spool can be injected through existing ports to plug it up!
  - Plan for the accidents, preserve the future

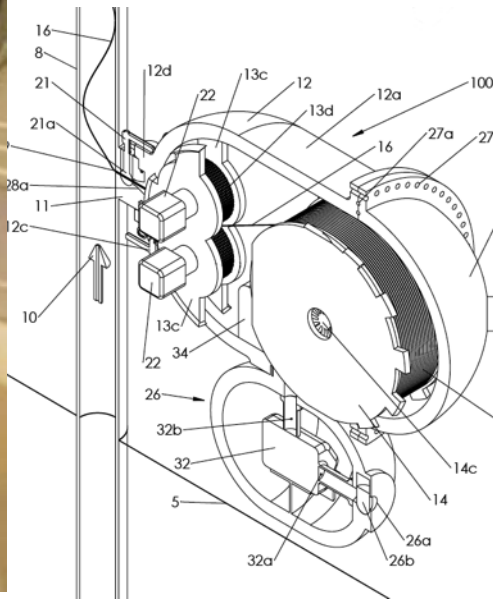


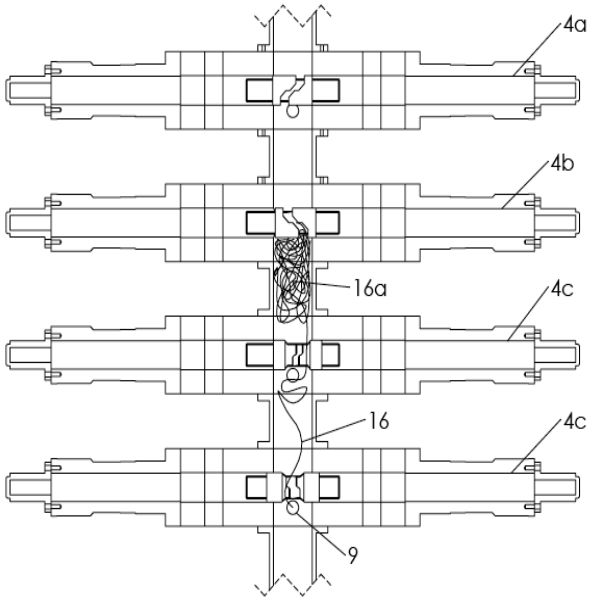


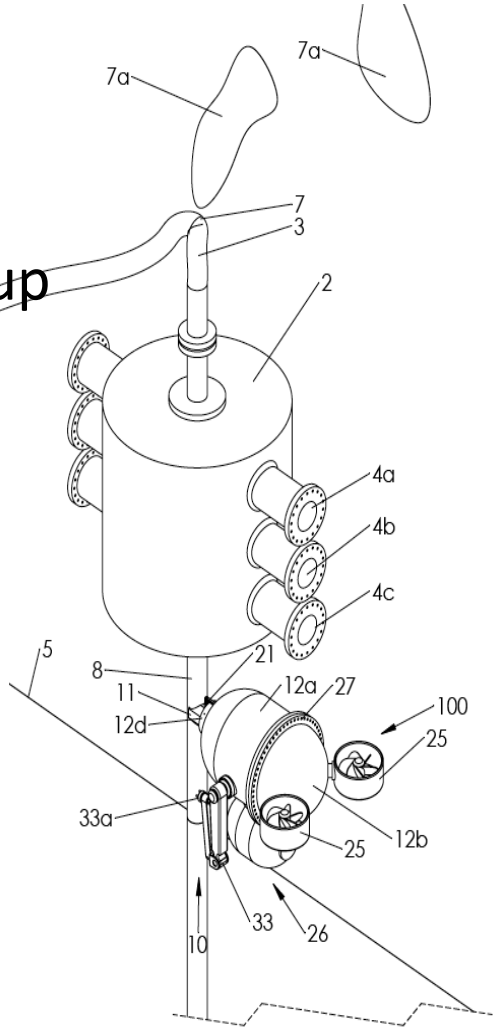


HAWK: The Angles Thing!

- A machine to inject wire through an existing port to create a tangled wire plug inside a failed BOP
  - Benchtop tests and theory developed (Folkers Rojas' doctoral thesis)
- Full scale machine design progressing as a startup company led by Dr. Rojas.

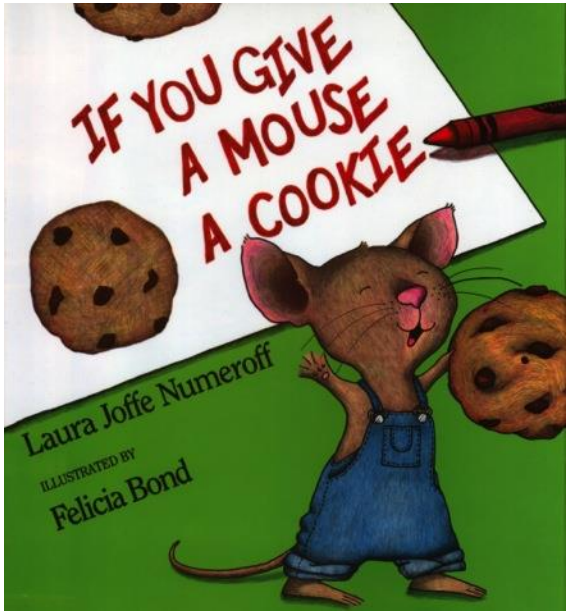






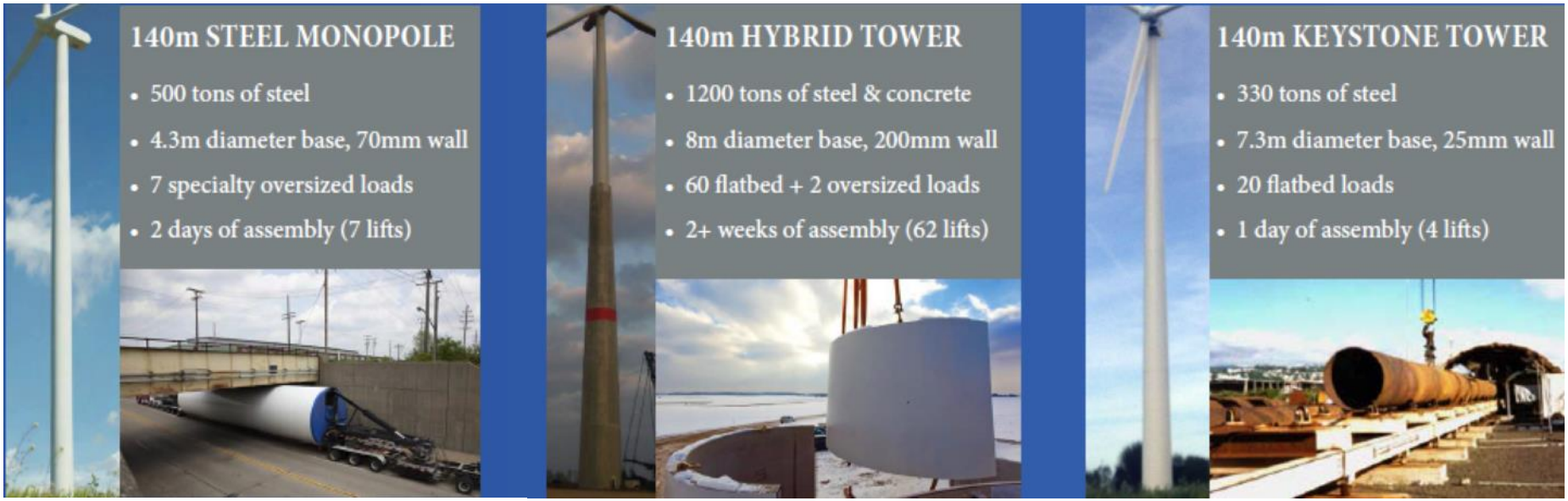
WIND

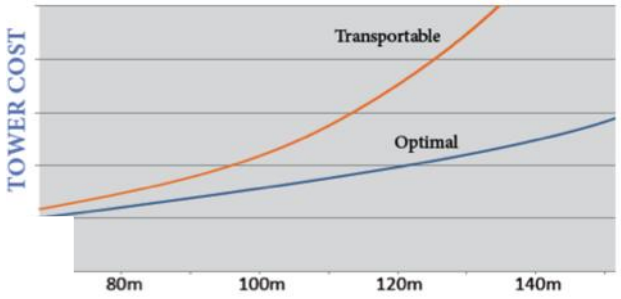
- *78% of US electricity is consumed by states bordering oceans/Great Lakes*
- Current Technologies
  - Offshore Wind
  - OTEC
  - Tidal
  - Wave
- All need storage
  - Undersea pumped hydro?
- Challenges and Opportunities (Oh My!)

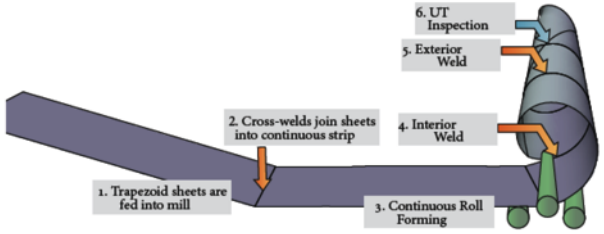


Lowering the Cost of Wind by 10%

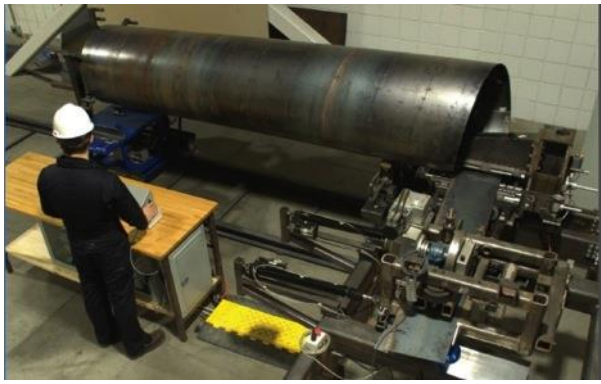
- Tall towers can greatly increase capacity factor and make class III @ 80 m sites into Class 4 sites @ 120-140m
  - E.g., Maine's 6 GW potential at 80m => 60 GW @ 140 m



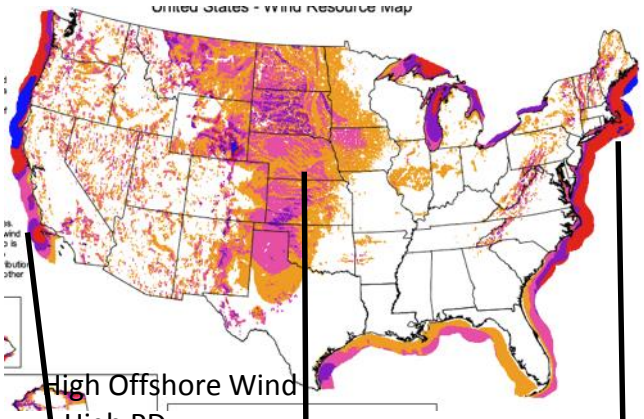


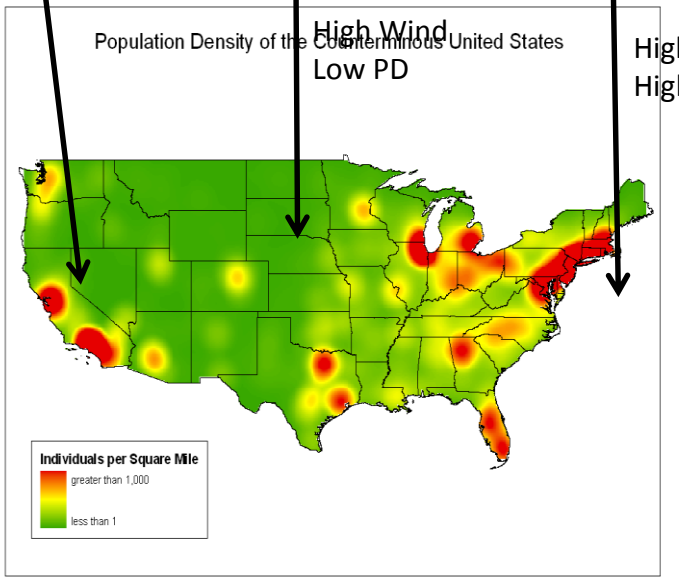


Keystone Tower Systems, Inc. in-situ tapered tower manufacturing

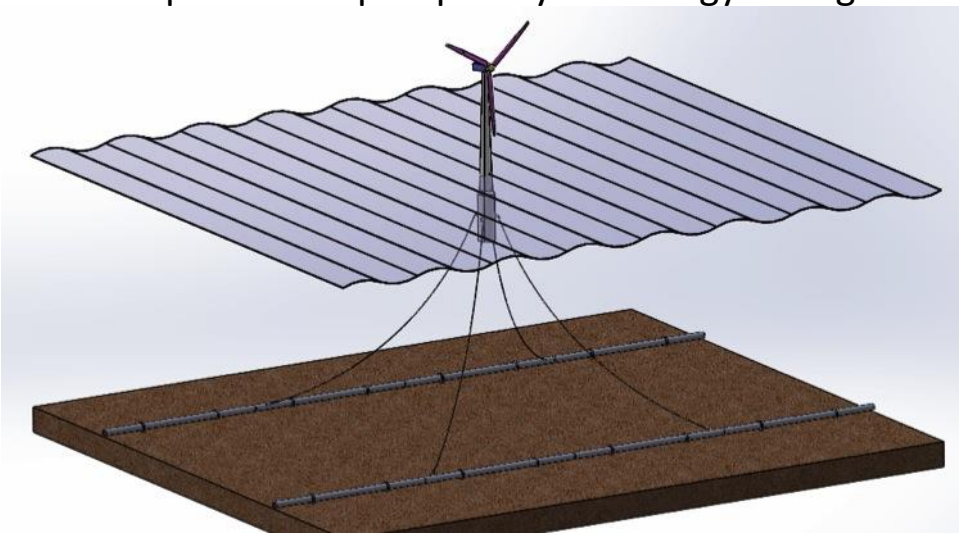


Offshore Wind with Energy Storage



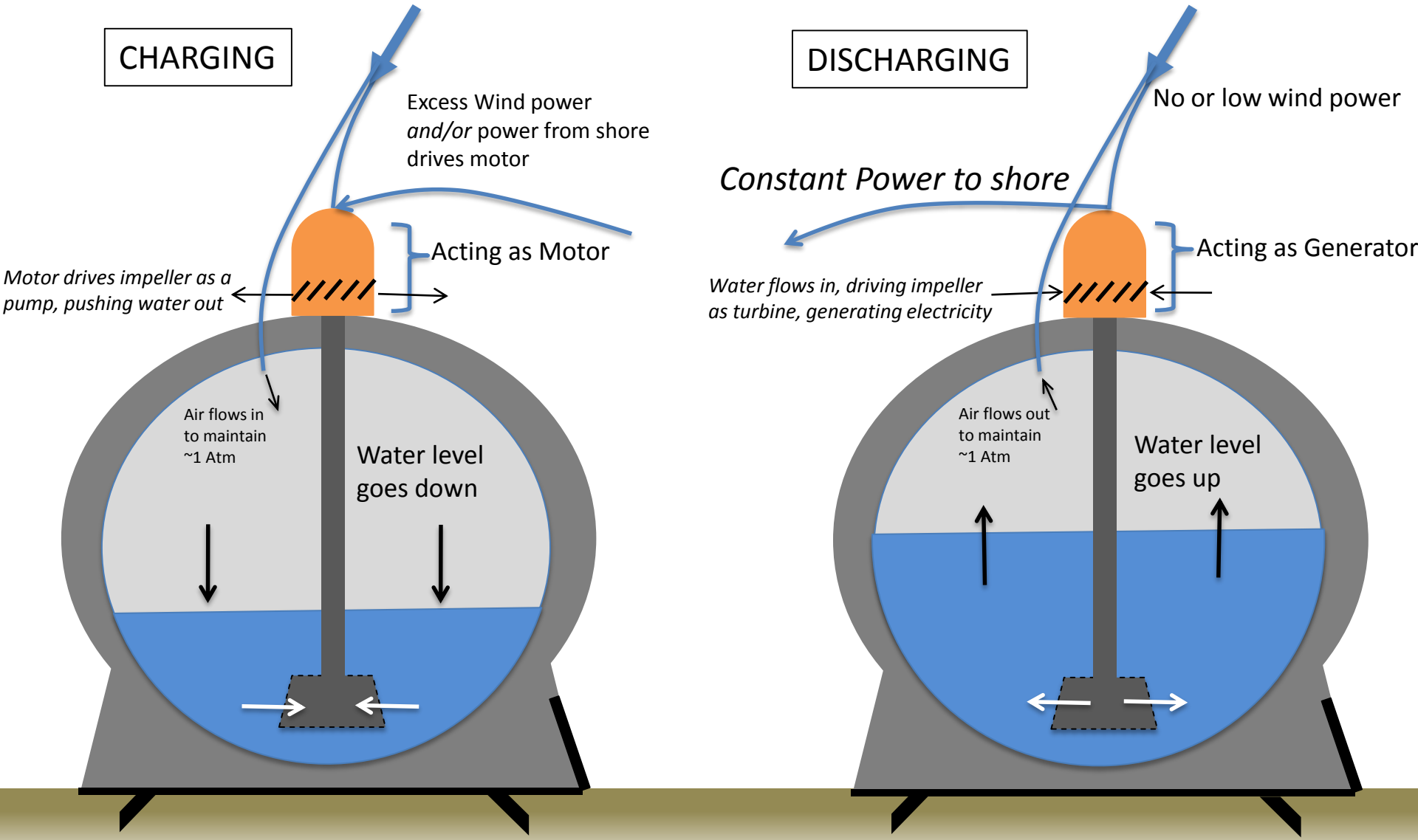


- Higher capacity factors
- Less visual impact
- Matches population distribution with wind resources
- Symbiotic design:
  - Wave energy harvesting
  - Energy storage
  - 3m diameter concrete tubes act as mooring points and pumped hydro energy storage units.



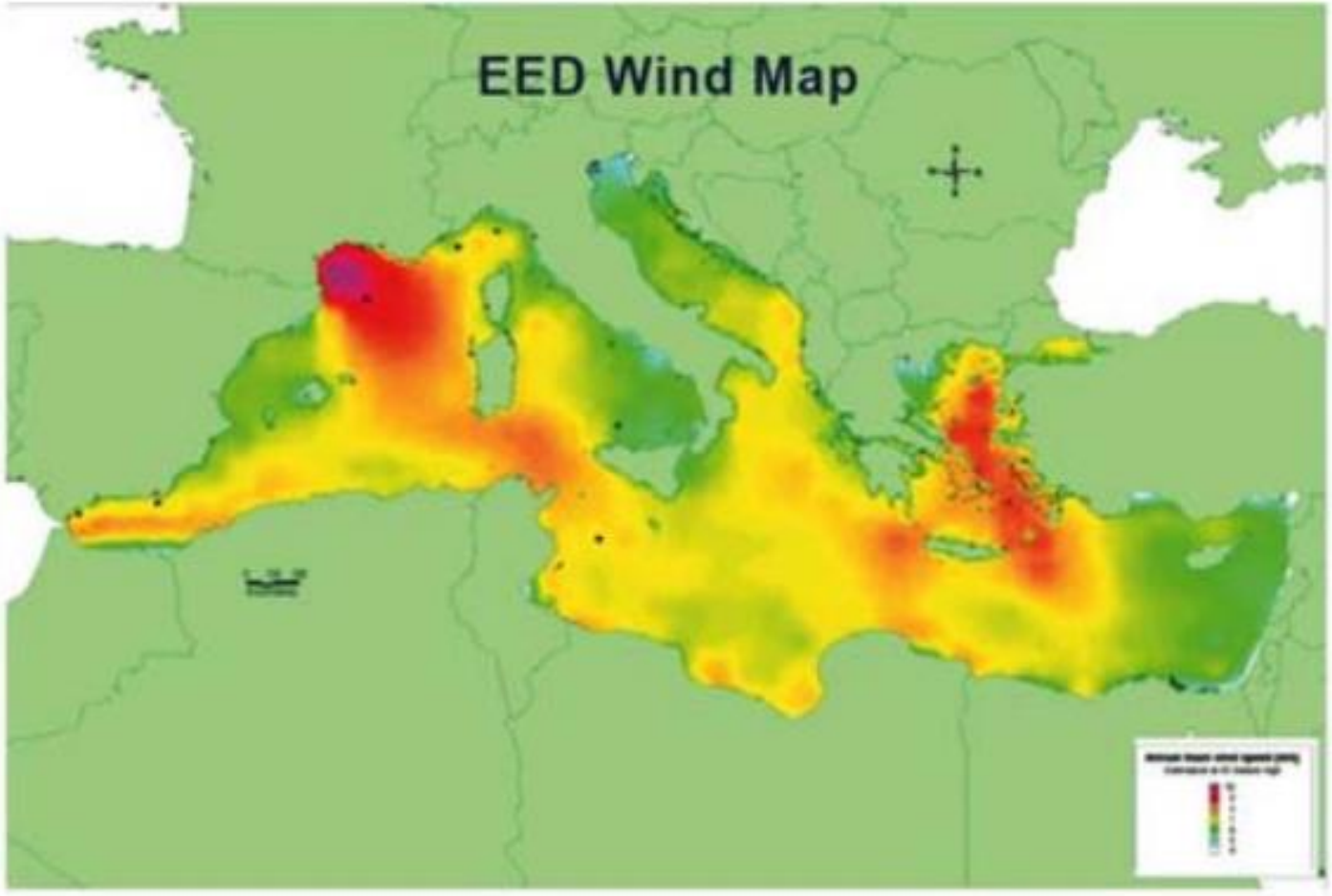
Sources: http://geology.com/articles/satellite-photo-earth-at-night.shtml; ISO-NE PAC33 Mtg, 5/20/2008; http://www.windpoweringamerica.gov/pdfs/wind_maps/poster_2010.pdf, http://www.windatlas.dk/Europe/oceanmap.html

ORES Concept



Exterior water pressure at 40 Bar/580 psi @ 400m depth

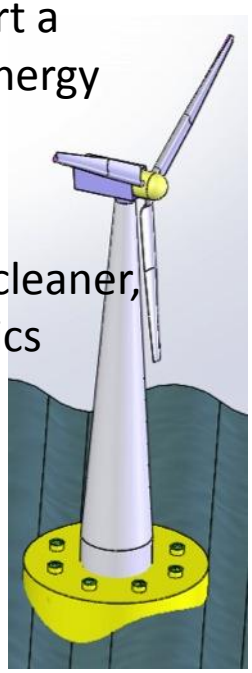
Mediterranean Wind Potential

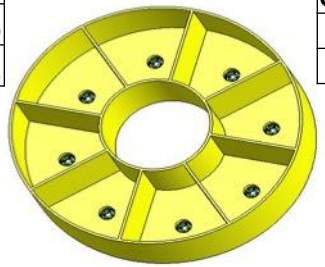


F. Cassola, M. Burlando, L. Villa, P. Latona and C.F. Ratto, '*Evaluation of the Offshore Wind Potential along the Italian Coasts*', Owemes, Citavecchia, Italy, *20-22 April, 2006.*

Symbiotic Design: One Tower to support them all!

- Wind and Waves often go hand in hand
  - The Tower can support a turbine *and* a wave energy harvester
- Fish Farming:
  - Far offshore water is cleaner, less need for antibiotics

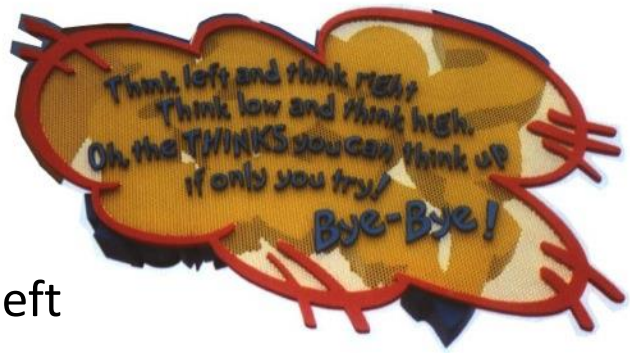




Circular generator	
ID (m)	15
OD (m)	30
annulus (m)	15
avg water height change (m)	2
Period (s)	9
efficiency	0.5
Power (MW)	6.2

Overall Symbiotic System Requirements		
population of Turkey	76,000,000	
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	38,000	
ocean area per turbine (km^2)	1	
rectangle ratio (length/width)	1.6	10
ocean rectangle width (km)	154	62
ocean rectangle length (km)	247	616
wind turbines installed per day	10	
years to full installation	11	
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	38	

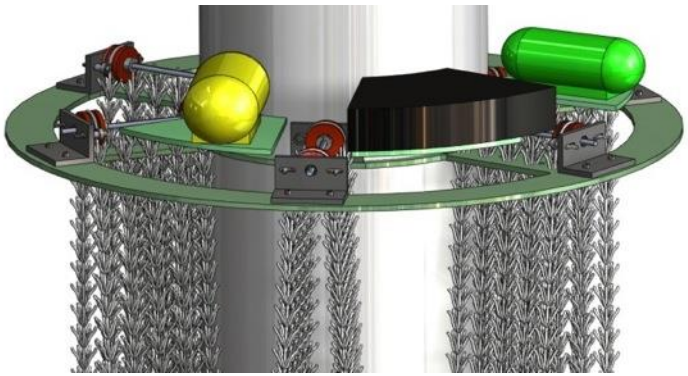
Nuclear



- Nuclear power is a critical part of clean energy future to provide baseload power
- BUT only 100 years of terrestrial uranium left
- Answer: Extract Uranium from ocean water!
- Uranium is present in ocean water in the form of uranyl ions at 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….

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

BIG challenges require a Moose-sized approach!



Nuclear

- Nuclear MUST be part of the low carbon future!
- BUT WE MUST address waste disposal!
  - Deep Borehole Disposal?
    - 5+ km hole near each reactor
    - Drop spent fuel in
    - Curved hole to slow it down…
    - New drilling and casing technology make it possible
  - The oil industry can be the savior of the planet!
    - Deep geographical formation mapping and deep drilling technology leaders

Solar Energy Harvesting and Storage
CSPond:
Concentrated Solar Power on Demand

Inspiration from nature

USGS, Hawaiian Volcano Observatory website, March 2008

Massachusetts Institute of Technology

MITei MIT Energy Initiative

CSPonD Concept

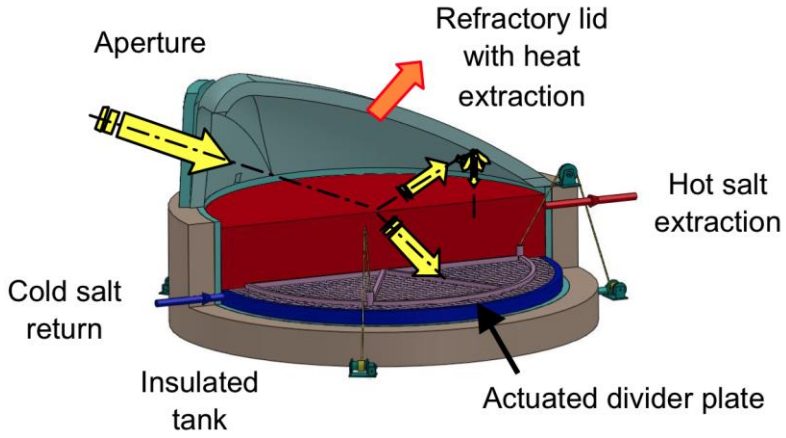
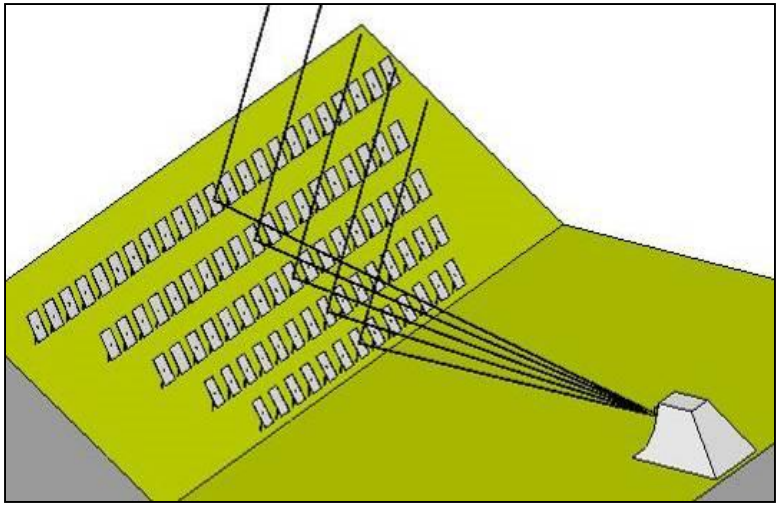


Fig. 1: Section view of CSPonD receiver



(Not to scale!)

Light Collected Inside Insulated Building With Open Window

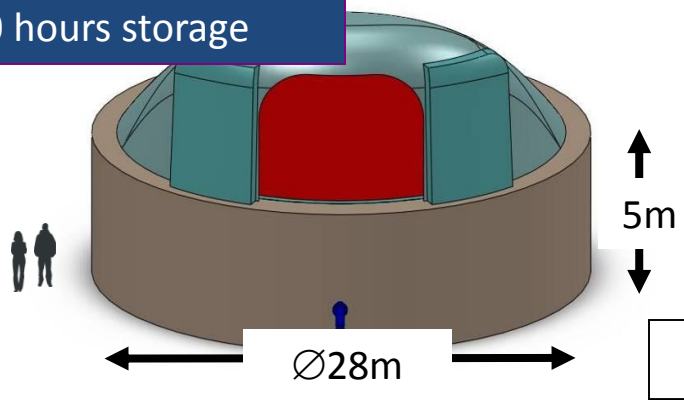
- Eliminate tower-based receiver: heavy equipment is on ground
- Avoid remote storage and high pressure pumps
- Lower land costs

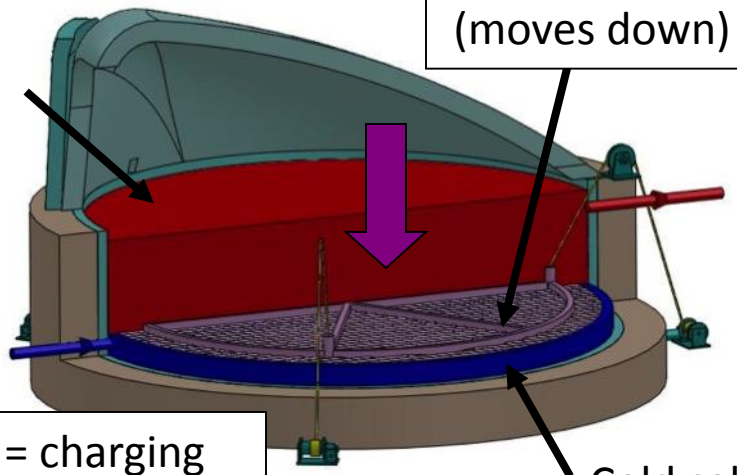
Light Reflected From Hillside heliostat rows To CSPonD system

Molten Chloride Salt Bath (1100°C)

Virtual Two-Tank System

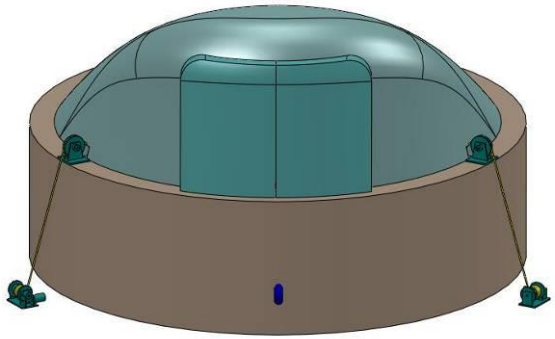
4 MW_e System Sizing:
2500 m^3 salt
40 hours storage



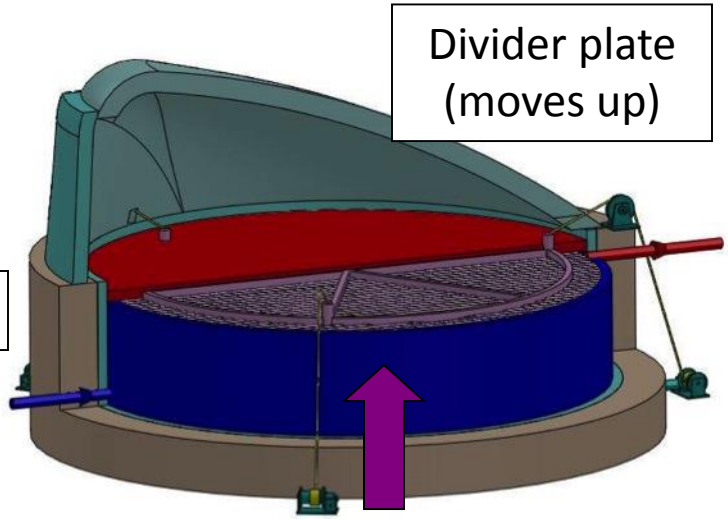


Daytime = charging

24/7 "hot salt" as the average temperature of the tank decreases when the sun is not shining

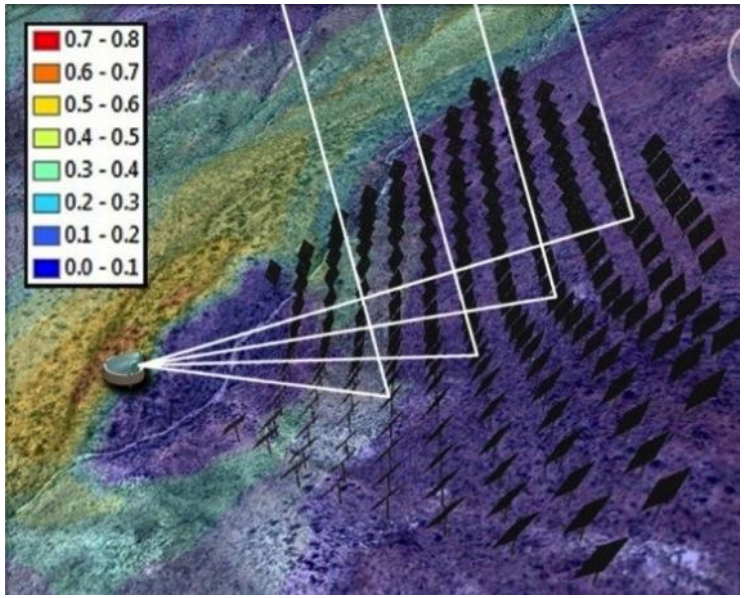


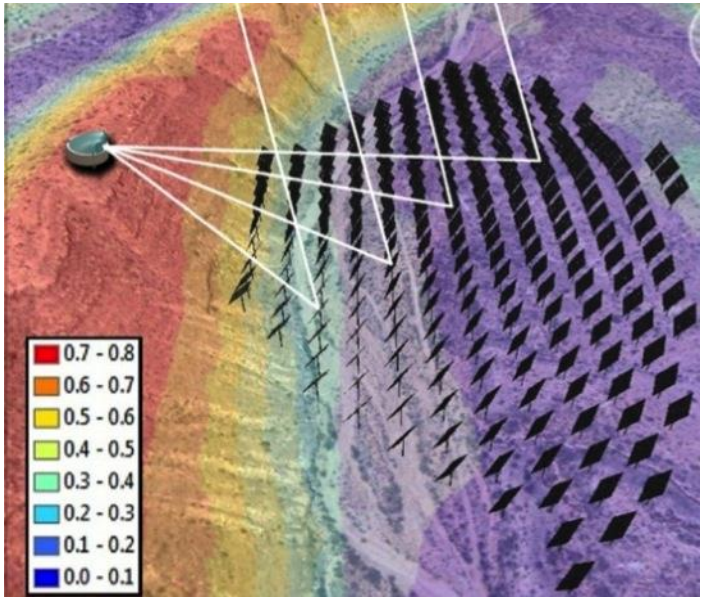
Nighttime



Potential Easy Sites

- In these sites, the heliostat fields are north (right) of the receiver
  - Field efficiency of the site with the secondary reflector is 77% and without is 70%
  - a difference of 7% despite the 10% loss associated with the grazing angle reflection off the inner surface of the lid.
- 15% of land utilized, 30% covered by heliostats, 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.



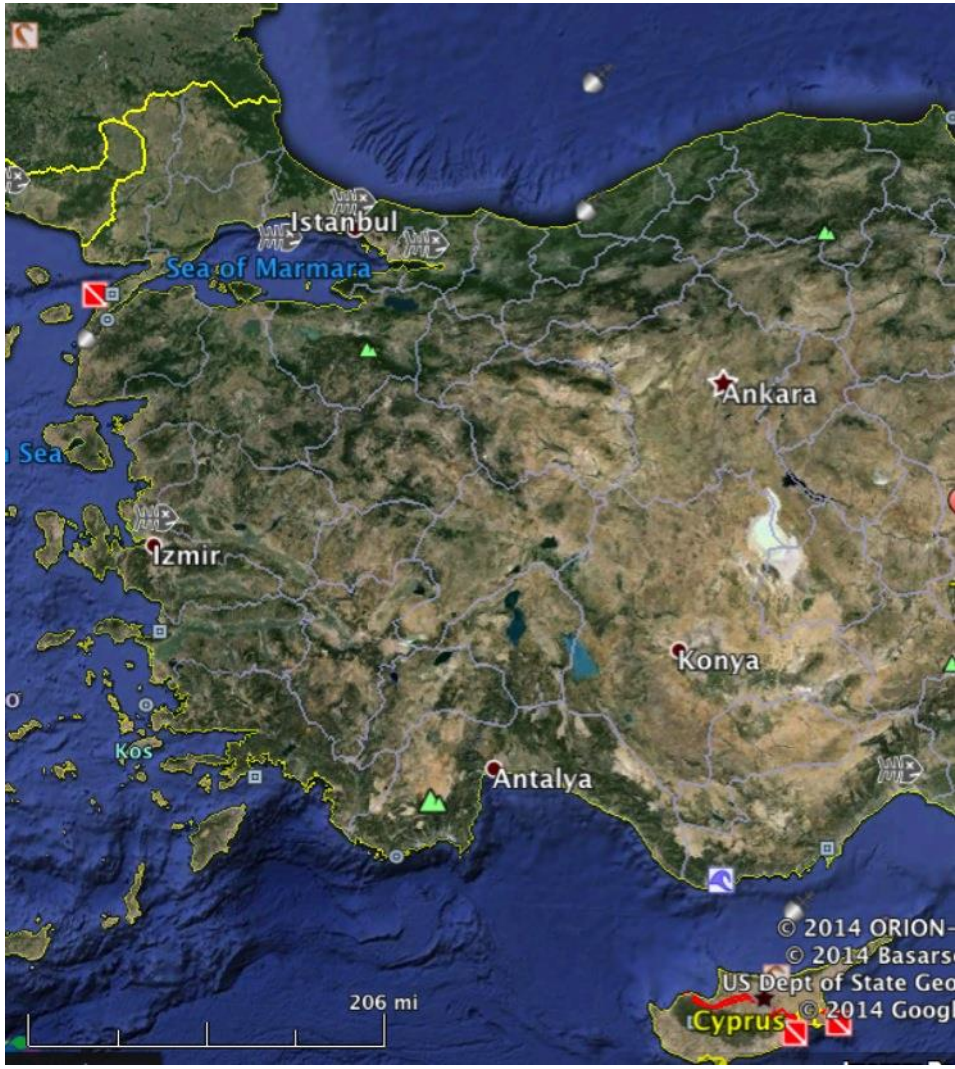


Lotsa Great Sunny Land Available! (all over the world!)

(Looking North from East-bound plane LA to Boston)

Turkey as the Region's Energy Leader!

- No oil!
- So be a solar, wind, energy storage symbiotic technology leader!
  - Design, produce, install!
- Supercharge manufacturing and civil engineering industries



Planetary Grand Challenge!

- Be the first in the world to feed your hungry population energy and protein from renewable sources!

Overall Symbiotic System Requirements		
population of Turkey	**76,000,000**	
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	**38,000**	
ocean area per turbine (km^2)	**1**	
rectangle ratio (length/width)	**1.6**	**10**
ocean rectangle width (km)	**154**	**62**
ocean rectangle length (km)	**247**	**616**
wind turbines installed per day	**10**	
years to full installation	**11**	
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	**38**	

Geeks:

We use Fizziks is our partner in creating technology to cut through problems!

The Future!

- 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