Space Solar Power and Our Dying Electric Power Grid

Darel Preble, Space Solar Power Institute

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Space Solar Power Institute

5.8 GHz Space-Based Solar Power Energy Harvesting Using Flexible, Transparent Printed Circuits

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Space Solar Power Institute · The Propagation Group · UROP · Georgia Tech School of Electrical and Computer Engineering, College of Engineering · ORS

Purpose

This research aims to create a prototype "ground station" for Space-Based Solar Power: an efficient renewable energy source that could output 1.2 GWe [1], enough to provide power to 117,602 people annually [2]. In this project, the ground station is modeled by a rectifying antenna.

Objective

Three main goals for the 2016-17 academic year:

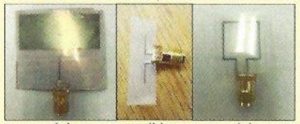
1) Replicate functionality of 2014-15 three stage rectifier
2) Use "peak" frequency of three stage rectifier to optimize loop antenna design
3) Refine prototyped loop antenna and test new model using vector network analyzer (VNA)

Background Overview

SBSP systems are comprised of two parts:

1) Satellites that transmit collected solar-power as RF signals to Earth
2) Ground stations that receive and convert the signals into DC power

Previously, this project developed a ground station prototype and designed antennas for 5.8 GHz energy harvesting.



(a) (b) (c)

Fig. 1: Previously developed (a) patch antenna, (b) dipole antenna, and (c) loop antenna

Methodology

Step 1: Model, simulate, and design

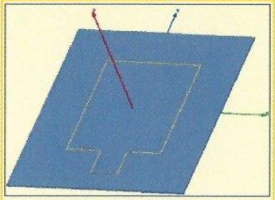
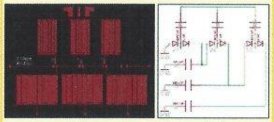


Fig. 2: HFSS model of loop antenna



(a) (b)

Fig. 3: 3-Stage Rectifier design
(a) EAGLE board layout
(b) schematic of loop antenna

Step 2: Print and assemble prototypes

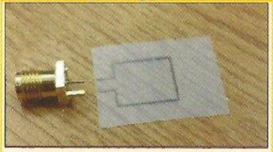


Fig. 4: Printed, unassembled loop antenna

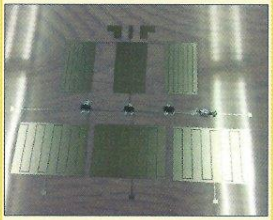


Fig. 5: In progress assembly of three stage rectifier

Step 3: Test designs and revise as needed

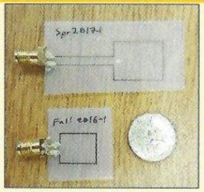


Fig. 6: Assembled loop antennas

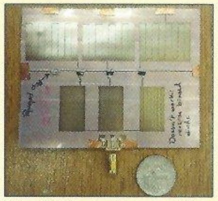


Fig. 7: Three stage rectifier, assembly complete

Models, Simulations, and Results

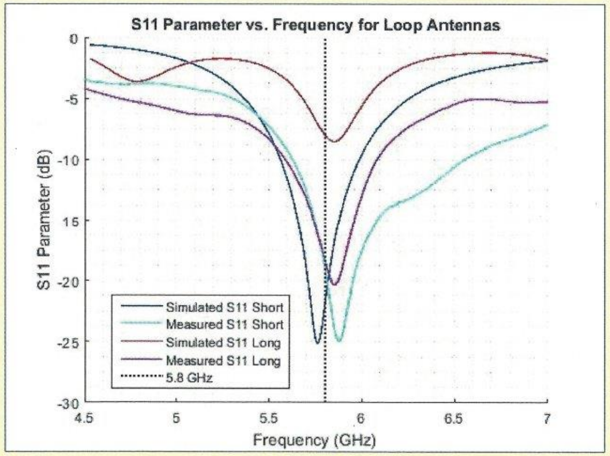


Fig. 8: Comparison of measured and simulated S11 parameter of short leg and long leg loop antenna

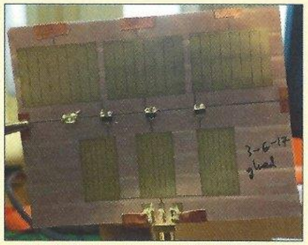


Fig. 9: Three stage rectifier, LED on

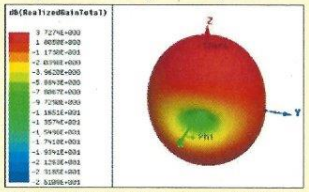


Fig. 10: Simulated 3D gain plot of short leg loop antenna

Observations

- Short-leg loop antenna is most optimal design
- Slightly longer loop antenna legs lead to lower optimal frequency
- Significantly longer loop antenna legs lead to lower realized gain (dB)
- PET has higher dielectric loss tangent compared to that of typical substrates such as Roger 5880 [3] or FR4 [4]

Future Work

- Print antenna and rectifier on single substrate sheet to create matching network
- Develop demo for wireless power transmission using magnetron
- Scale design up for larger loads

References

[1] R. Dickinson, "Magnetron directional amplifier space solar power beamer concept design," 35th Intersociety Energy Conversion Engineering Conference and Exhibit, 2000.

[2] 2014 GEORGIA ENERGY REPORT. Atlanta, GA: Georgia Environmental Finance Authority, 2014.

[3] "RT/duroid® 5870/5880 High Frequency Laminates." Chandler, AZ.

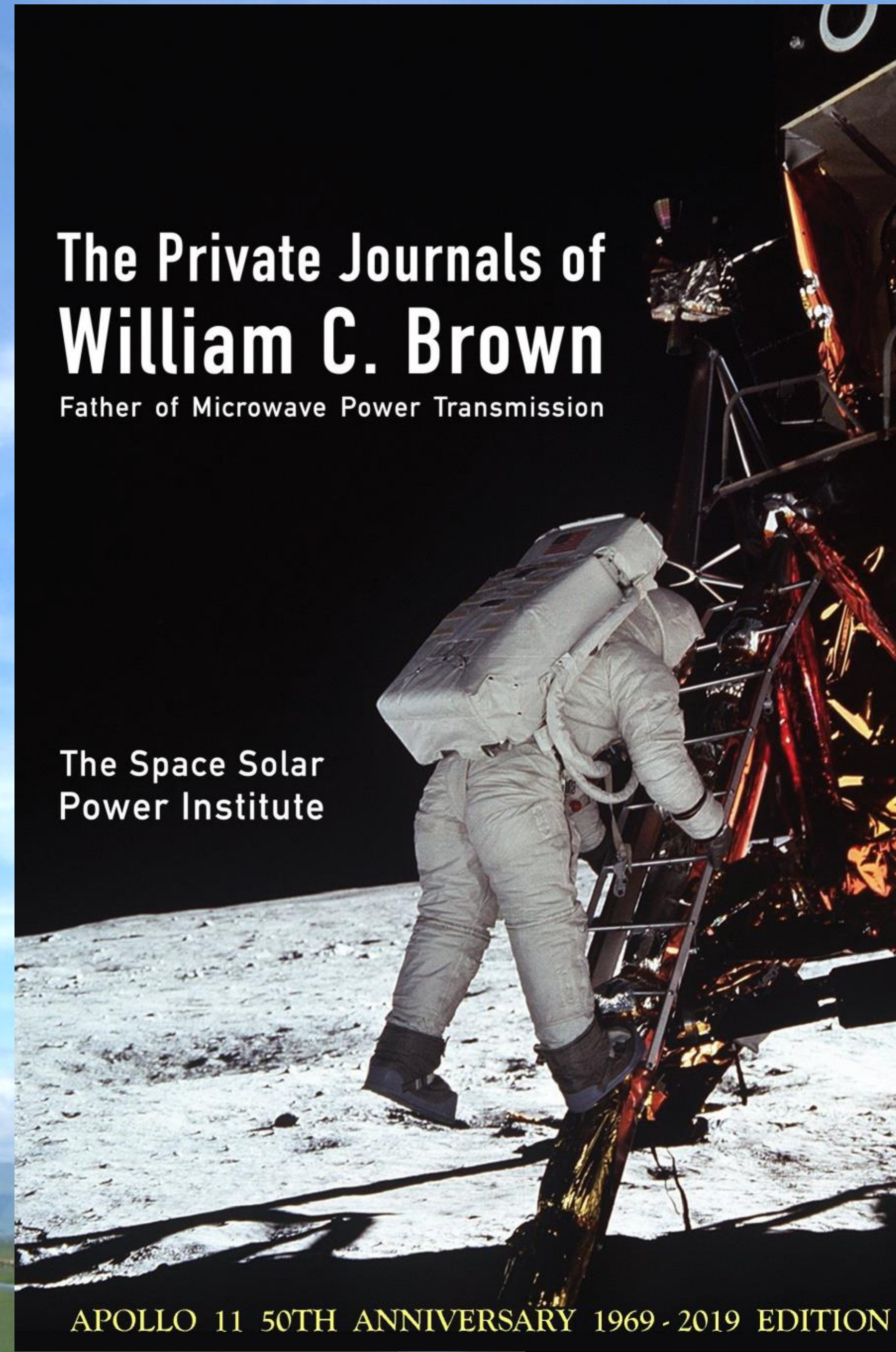
[4] E. Sayre, M. Baxter, and J. Chen, "Limits of FR-4 in High-Speed Designs," Successful Design of OC-48/2.5Gbps Interconnects.

They say there are three types of people in the world. …

Holder of over 50 patents such as the Amplitron, the first crossed field amplifier (CFA).

We are honored to announce that the Space Solar Power Institute is publishing the Private journals of William C. Brown on Microwave Power Transmission.

Now in print



Everyone wants clean, reliable, safe, economical, unlimited, all-the-time electric power

Closing Nuclear Power Plants
Closing Coal Plants
More Windmills, Terrestrial Solar or Virtual Hydro
Carbon taxes
Terrawatt/hr batteries are not affordable
Intermittent Power is bankrupting and strangling our grids
Eaton has crowned California the Blackout Queen, with the most blackouts for ten years straight!

Won't Fix Climate Change

PG&E is only the first Corporate Climate Change Casualty

Q: How do we Fix climate change?

A: Build Space Solar Power

WHY SPACE SOLAR POWER(SSP)?

1. LOW CO2 INTENSITY

2. ZERO FUEL COST

3. USES NO WATER

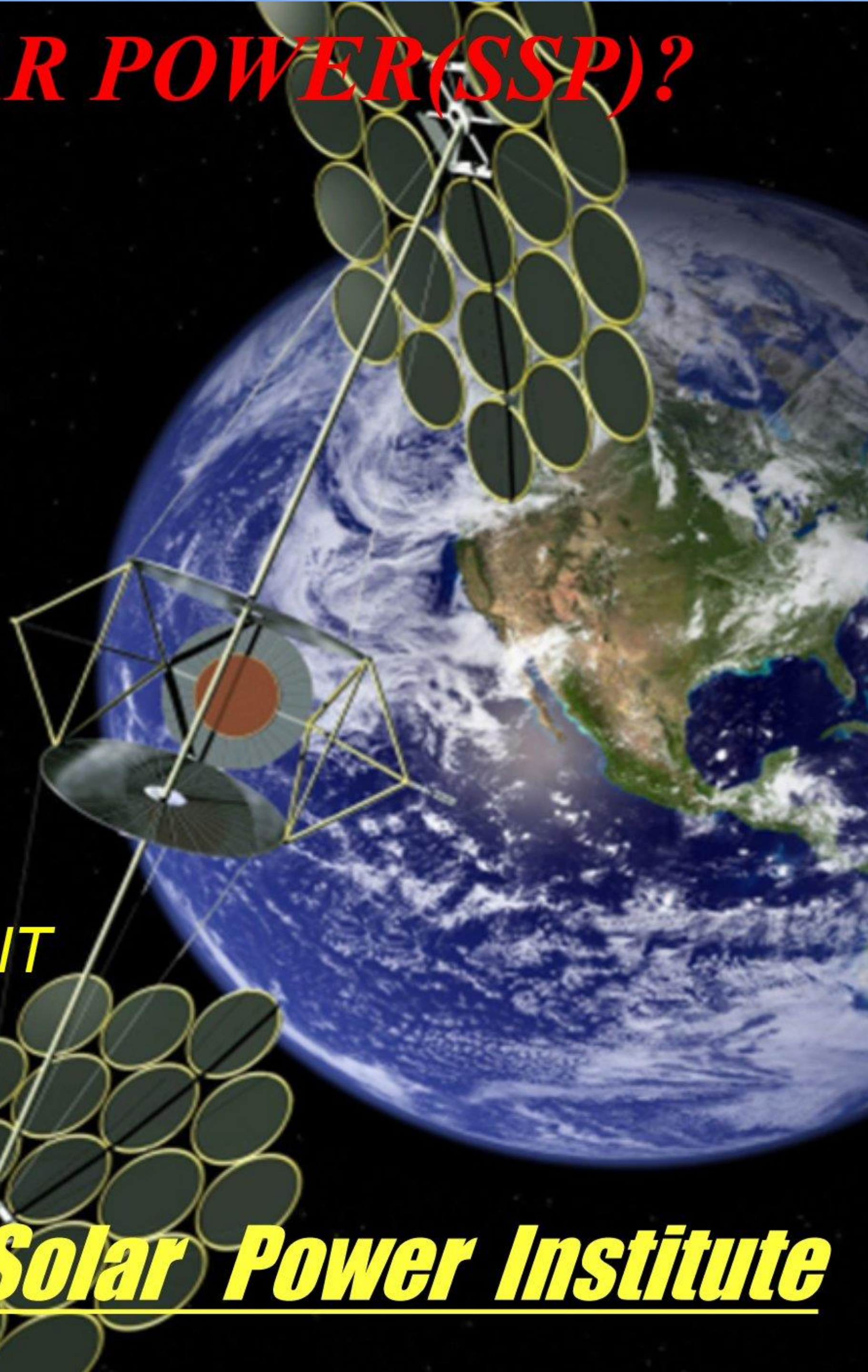
4. CLEAN, NO WASTE

5. SOLAR @ GEO COLLECTS
9.6 TIMES MORE ENERGY
THAN ROOF TOP SOLAR

6. RELIABLE: 24 / 7,
WEATHER INDEPENDENT

7. REDUCED LAND USE

8. UNLIMITED ENERGY



California, leading RPS state, also leads in Outages

California topped the list of states with the most power outages, 438 during 2017, for the ninth consecutive year.

Ominously, 31% were again of “Unknown origin” and 24% were due to “Faulty Equipment or Human Error”. 16?% of California’s 2017 In-State power generation came from windmills or solar. Texas, the highest national electric power producer had less than half as many outages.

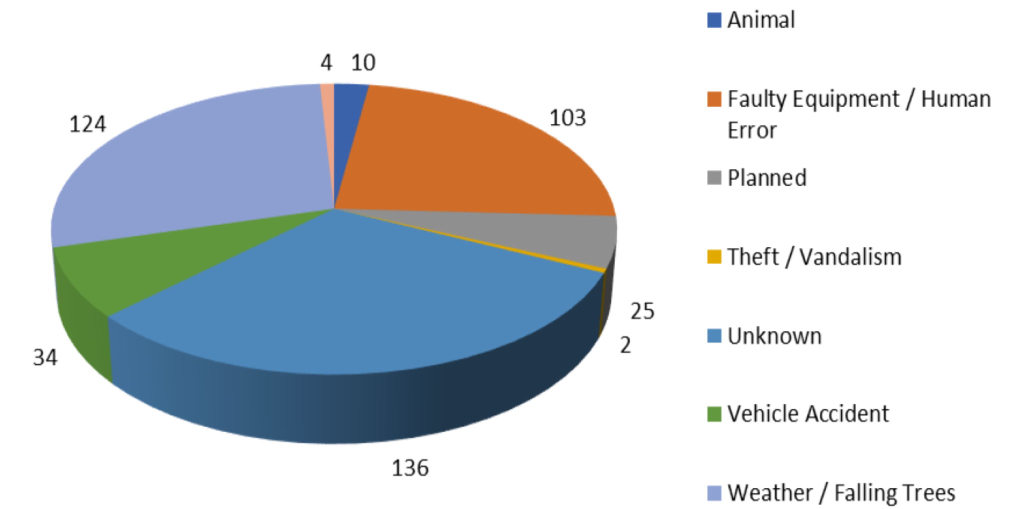
California

Outage summary

Total number of people affected by outages	2,709,740
Total duration of outages	25,868 minutes (nearly 18 days)
Total number of outages	438
State ranking (number of outages)	1
Average number of people affected per outage	6,187
Average duration of outage	59 minutes

Note: Total number of people affected (and average) based on 336 (77%) of the total reported outages. Total duration of outages (and average) based on 86 (20%) of the total reported outages.

Reported power outages by cause



Source: Eaton's Blackout Tracker

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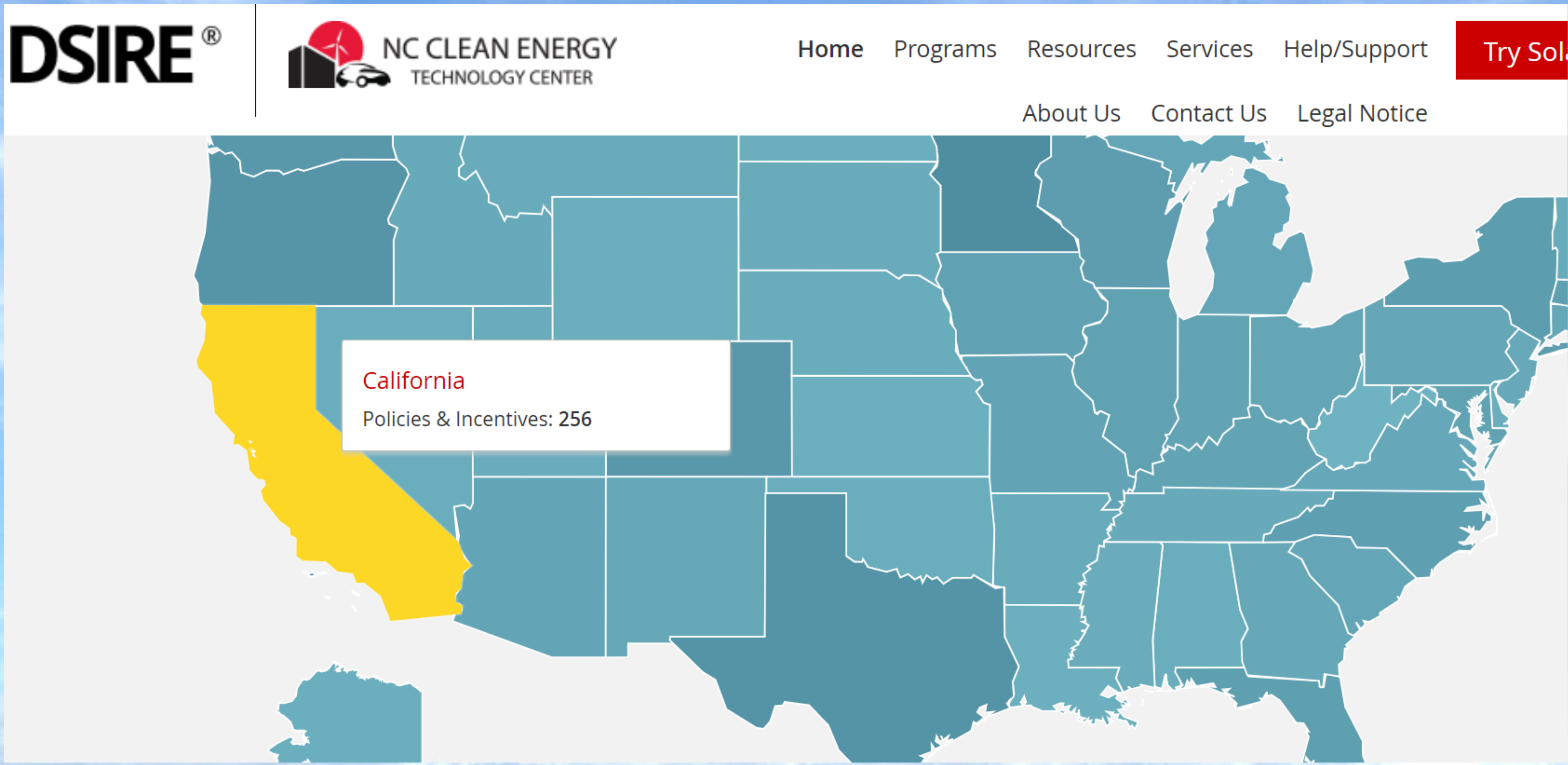
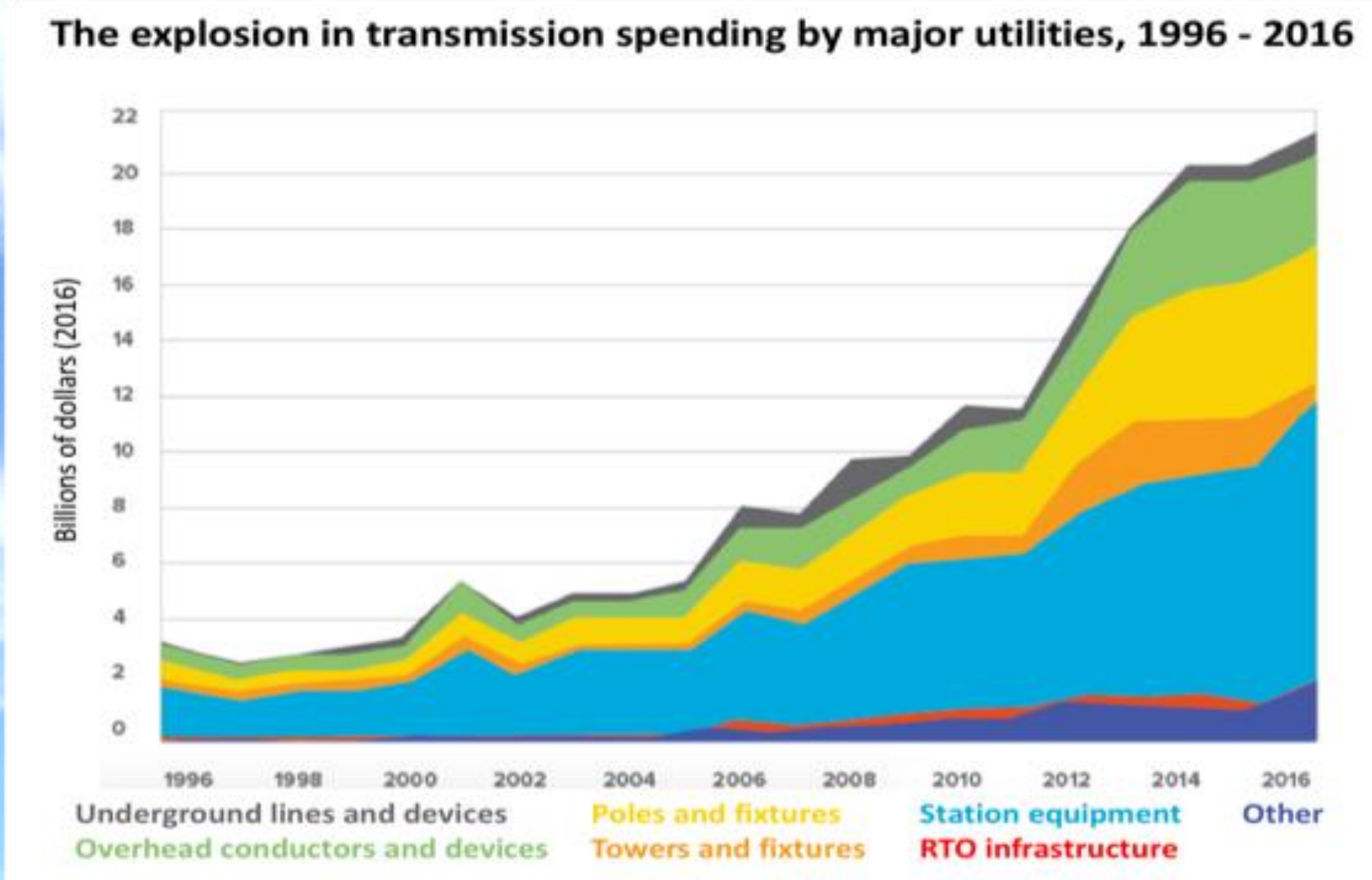
California, leading RPS state, also leads in Outages





Transmission costs are the fastest-growing part of electricity bills

Credit: Sunrun *https://www.utilitydive.com/news/how-to-protect-california-ratepayers-expand-clean-local-energy-and-avoid-b/554564/* *Published May 13, 2019 PG&E has racked up more than $30 billion in liabilities for wildfire-related damages caused by its transmission equipment.*

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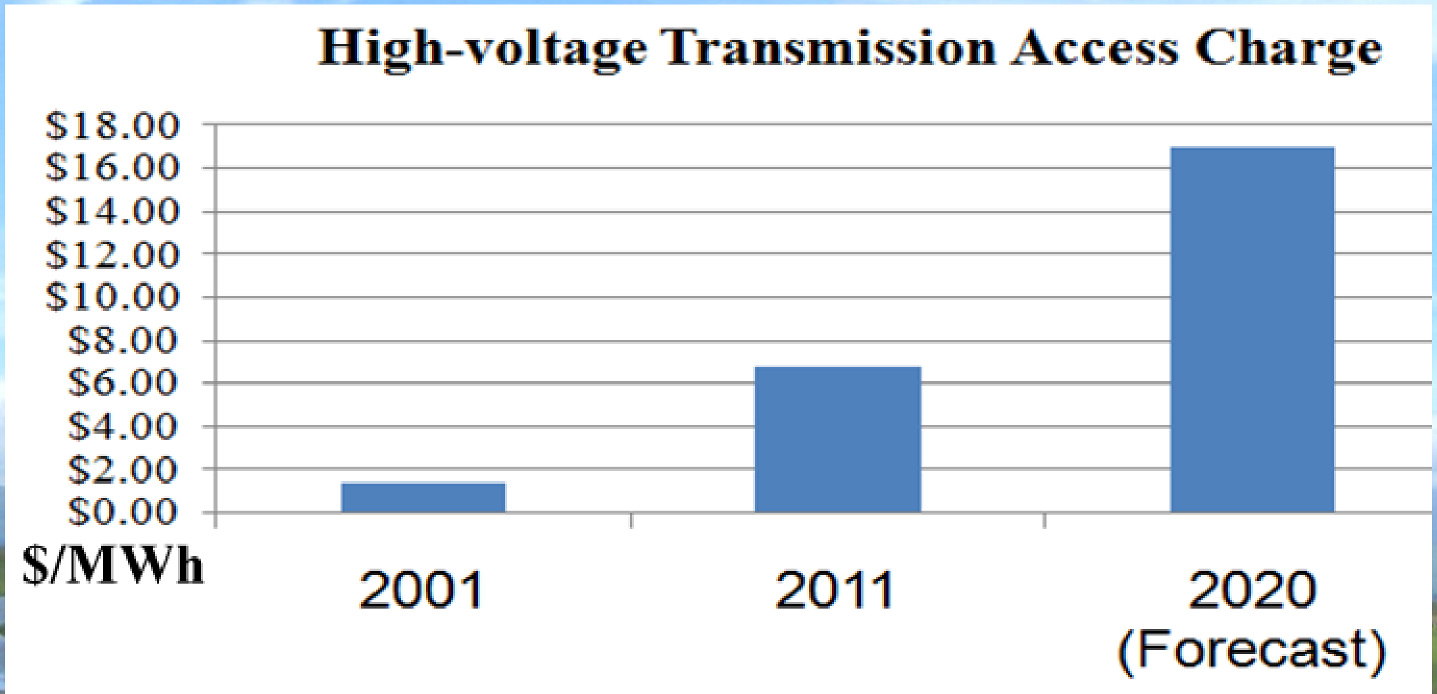
A New Alternative - Space Solar Power (SSP)

SSP - Not only lower cost *generation* but lower cost *access*.

A transmission grid based on the central generating station model is simpler, more reliable, and lower cost than rebuilding to a distributed generation model. To meet California's 33% RPS goal, ratepayer bills will rise drastically by 2020, not just from renewable energy's higher cost, but also from CA-ISO's <u>required</u> transmission upgrades:



"Effective control of rising CO2 is not financially feasible for even large electric power generation companies, using currently available technologies and RPS constraints. These companies and customers are *not* "capable of shouldering heavy substantive and procedural burdens. (EPA wording)" as their visceral connection to global economies prohibits deploying grossly non-economic and reliability-reducing power generation technologies. Space Solar Power is required to effectively address rising global CO2."

- Summary statement for Atlanta EPA Public Hearing November 19, 2015

Looking Back

"The world has made no progress over the past 20 years in reducing the carbon content of its energy supplies, despite over $2 trillion of investment into renewable-energy projects such as wind and solar power."

- " Scant Gains Made on CO2 Emissions, IEA Says, *WSJ*

Instead - Global CO_2 levels continue to increase more rapidly.

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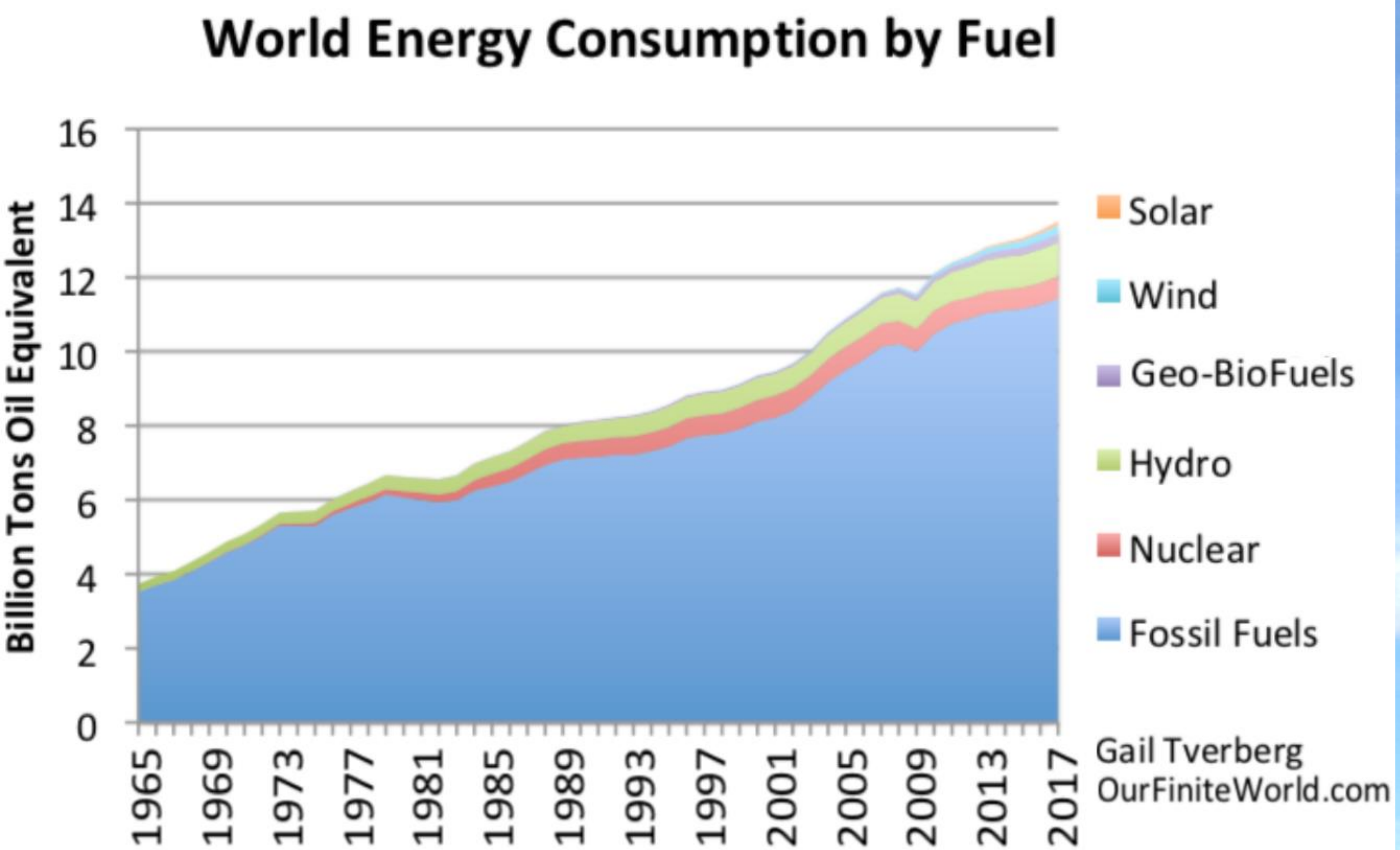
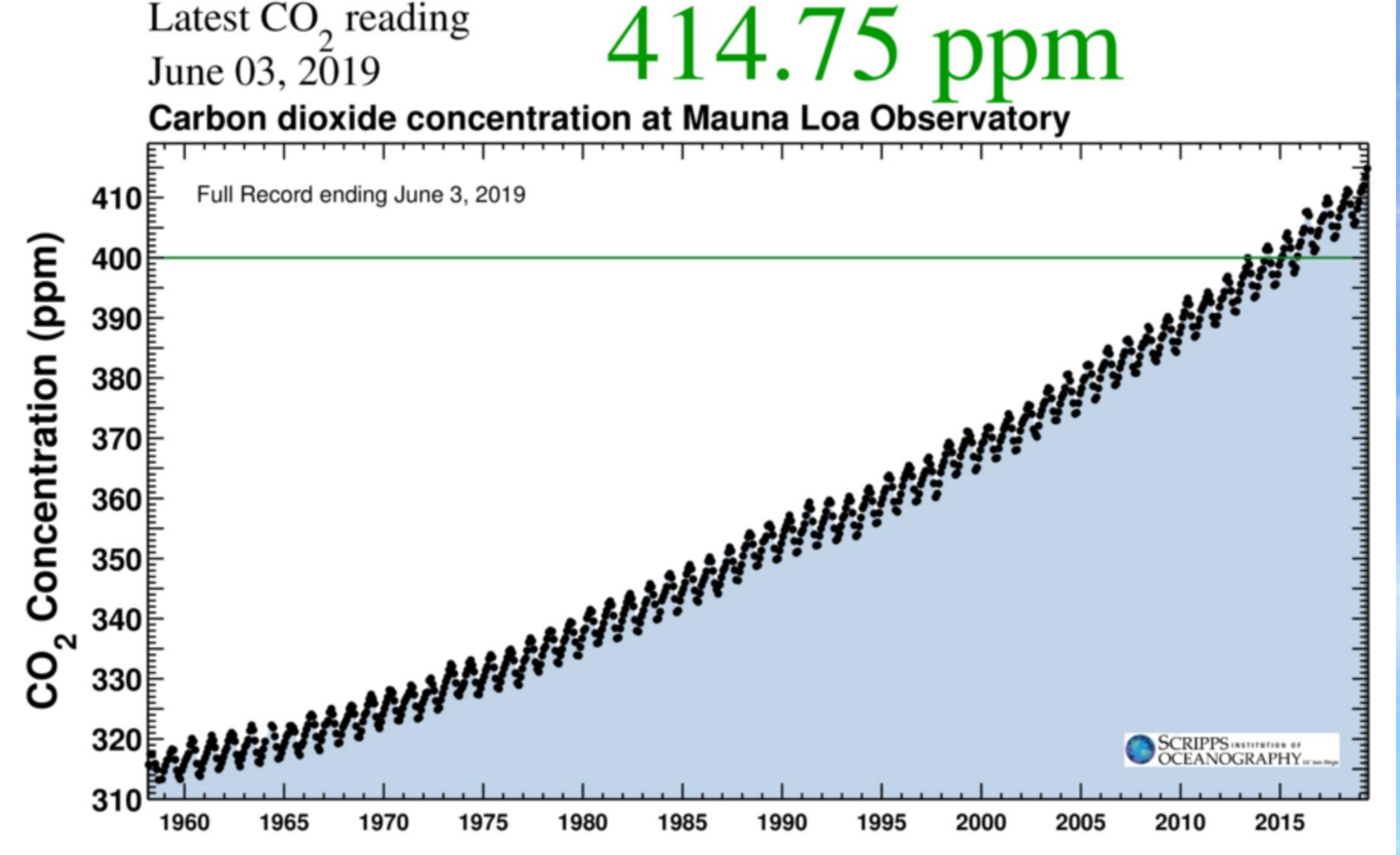


Data from BP World Energy 2018. Chart by Gail Tverberg, Director of Energy Economics, Space Solar Power Institute



Global CO_2 Levels rising and accelerating

https://scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-bluemoon/graphs/mlo_full_record.png

[*Making America Carbon Neutral Could Cost $1 Trillion a Year*](https://www.bloomberg.com/news/articles/2019-05-13/making-america-carbon-neutral-could-cost-1-trillion-a-year)

By Ari Natter – Bloomberg - May 13, 2019, 4:00 AM EDT Updated on May 13, 2019, 12:20 PM EDT
From https://www.bloomberg.com/news/articles/2019-05-13/making-america-carbon-neutral-could-cost-1-trillion-a-year

Experts Debunk Jacobson's 100% Renewables Decarbonization Plan

21 prominent energy and climate experts, writing in June 19, 2017 Proceedings of the National Academy of Sciences find that Stanford Professor Mark Jacobson's argument that the U.S. achieve 100% renewable energy using only wind, (terrestrial) solar, and hydro by 2050 uses invalid modeling tools, contains modeling errors, and made implausible and inadequately supported assumptions. Policy makers should treat with caution visions of a rapid, reliable, and low-cost transition to entire energy systems that relies almost exclusively on wind, solar, and hydroelectric power." Christopher Clack, of the National Oceanic and Atmospheric Administration, lead author of the PNAS study finds that Jacobson's work "has significant shortcomings in analysis."

Jacobson drops his ridiculous defamation lawsuit against his scientific critics

Attorneys for Jacobson's main target, environmentalist Christopher Clack, asserted that the reason for Jacobson's withdrawal is simpler: "No doubt Dr. Jacobson based his decision on the high probability that his lawsuit would be dismissed."
His action came after a hearing Feb. 20 in D.C., Superior Court, where Clack and the National Academy of Sciences, which published Jacobson's paper and Clack's critique, sought dismissal on anti-SLAPP grounds. SLAPP stands for "Strategic lawsuit against public participation," and applies to litigation brought to censor and intimidate participants in a public debate. - LA Times, Michael Hiltzik, Feb 23, 2018, http://www.latimes.com/business/hiltzik/la-fi-hiltzik-jacobson-lawsuit-20180223-story.html and http://www.sandiegouniontribune.com/business/energy-green/sd-sdfi-jacobson-withdraws-20180222-story.html

#4 Jacobson et. al claim
[Clack] claims wrongly that [*MZJ*] assumes a maximum hydropower output of 145.26 GW even though [*2*] Table S.2 shows 87.48 GW. [*Clack*] then claims incorrectly that the 1,300 GW drawn in [*MZJ*] Fig. 4(b) is wrong because it exceeds 87.48 GW, not recognizing 1,300 GW is instantaneous and 87.48 GW, a maximum possible annual average (Table S.2, Footnote 4 and the available LOADMATCH code).

#4 Response
As is clearly stated in Clack et. al, 145.26 GW was the most generous interpretation that could be made (summing pumped hydro storage and hydropower outputs), somewhat reducing the massive hydropower modelling error in Jacobson et. al. This statement confirms that the error is actually more severe than this.

In addition, there is no basis or supporting analysis for the assumption that 87.48 GW could be an annual average hydropower output, since this would correspond to almost 3 times the average annual hydropower production in the US over the last three decades (US EIA 2017).

#5 Jacobson et. al claim

1,300 GW is correct, because turbines were assumed added to existing reservoirs to increase their peak instantaneous discharge rate without increasing their annual energy consumption, a solution not previously considered. Increasing peak instantaneous discharge rate was not a "modeling mistake" but an assumption consistent with [2]'s Table S.2, Footnote 4 and LOADMATCH, and written to Clack Feb. 29, 2016.

#5 Response

Nowhere in the 28 pages of main and supplemental material of the Jacobson et al. paper is there any mention or analysis of an expansion of hydropower. As confirmed above, the installed capacity of the hydroelectric system is stated as 87.48 GW.

Table S2. CONUS installed WWS electric/thermal generator installed capacities in 2013 and proposed for 2050, along with capital costs of the generators and numbers of devices.[1]

	CONUS installed 2013 (GW)	Proposed existing plus new CONUS 2050 installed (GW)
Hydropower[4]	87.42	87.48

Table S2, of the supporting information document of Jacobson et. al (2015)

The scale of this error is staggering. The maximum instantaneous electricity generation capacity of *all* electricity sources in the United States today is 1170 GW (U.S. Energy Information Administration 2017). ***Jacobson et al. neglects to mention an assumed 1500% expansion in generation capacity of hydropower, leading to this system being capable of producing more power than all sources combined in the US today.***

One should note that the 1300 GW number is only what we have been able to infer from Figure 4 in the Jacobson et. al paper – it does not appear that any upper limit has been imposed at all on this value in the model. The capacity factor of wind power during the night of simulation day 1475 (in which 1300+ GW of hydropower is shown to be used) is around 24%. Since this is far above the likely minimum combined capacity factor of wind power seen during a night in a 5-year period[3], the actual installed hydroelectric capacity used in the model is actually far higher than 1300 GW. Perhaps even more alarmingly, had Jacobson et al. selected a time period for Figure 4 that did not happen to include high hydropower output, this error may never have come to light.

For the benefit of the reader, the footnote on the fourteenth page of the supporting information of the Jacobson et al. paper (Table S.2. Footnote 4) does nothing to change this error. It states, in full: "*Hydropower use varies during the year but is limited by its annual power supply. When hydropower storage increases beyond a limit due to non-use, hydropower is then used for peaking before other storage is used.*"

#6 Jacobson et. al claim

[*2*] only neglects the cost of additional turbines, generators, and transformers needed to increase the maximum discharge rate. Such estimated cost for a 1000-MW plant [*23*] plus wider penstocks is ~$385 (325-450)/kW, or ~14% of hydropower capital cost. When multiplied by the additional turbines and hydropower's fraction of total energy, the additional infrastructure costs ~3% of the entire WWS system and thus doesn't impact [*2*]'s conclusions. Increasing CSP's, instead of hydropower's, peak discharge rate also works.

[1] (Fig. 3) then claims mistakenly that [2]'s annual hydropower energy output is 402 TWh/yr and too high, when it is 372 TWh/yr because they missed transmission and distribution losses. This is less than half the possible U.S. hydropower output today, well within reason.

[*1*] next claims wrongly that [*2*] Table 1 loads are "maximum possible" loads even though the text clearly indicates they are annual-average loads. The word "maximum" is never used. They compound this misrepresentation to claim flexible loads in [*2*]'s time figures are twice "maximum possible" loads even though [*2*] P.15,061 clearly states that the annual loads are distributed in time.

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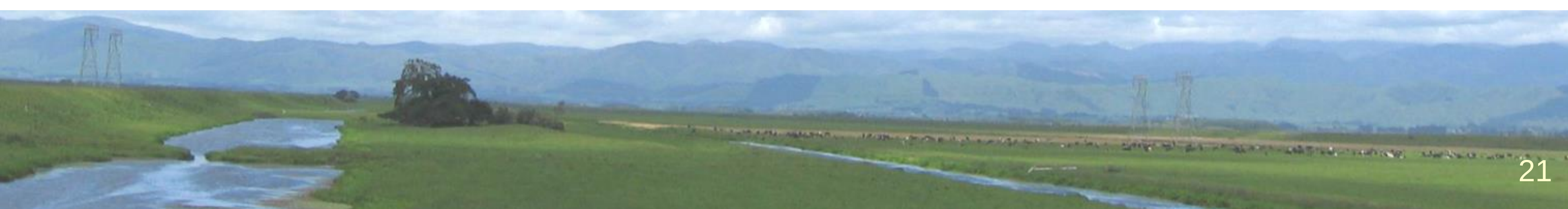
[3] For comparison, the minimum 1-hour combined capacity factor of all renewable energy sources in the EU (includi wind power data from 12 countries and solar PV data from 5 countries) was 3.39%, 2.64% and 2.75% in 2012, 20 and 2014 respectively.



#6 Response

In addition to not adding any costs at all to this, the Jacobson et al. study also neglects that additional turbines need extra water and therefore penstocks, tunnels, and space. Even disregarding all hydrological and legal constraints, one cannot simply assume that one can fit at least 15x more turbines in same space. A radically increased instantaneous flow rate would have a number of downstream impacts, such as: impact on other downstream (and upstream) hydro power plants, fisheries and ecosystem destruction, flooding of towns, illegal breach of water rights of downstream farmers and cities, loss of recreation and endangered species impacts.

For an output of 372 TWh/y, as stated above, the actual hydropower capacity factor of the WWS-system is at or below 3.26%. However, Jacobson et al. also states "*the annual average capacity factor of hydropower as used in LOADMATCH was given in Footnote d of Table 2 as 52.5% (before T&D losses)*". This is an assumed value based on a fictitious installed capacity of 87.48 GW and is therefore entirely nonsensical.

To illustrate one of the many problems that the omission of analysis regarding this capacity expansion entails, the Hoover Dam has been used as an example in Clack et. al supporting information section S.2.5.

Here are a couple more examples:

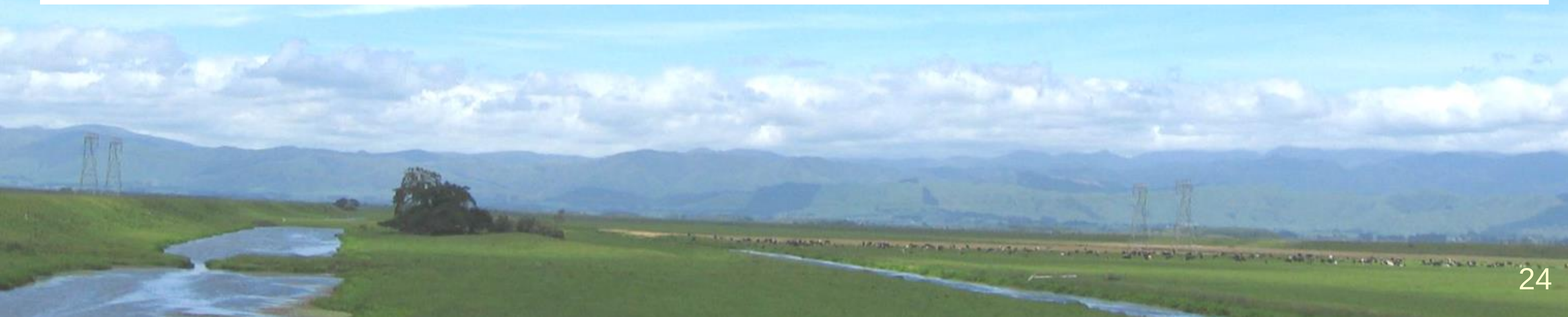
If the capacity at all major hydropower facilities are assumed to expand by the same relative amount, the Grand Coulee Dam would have a new peak power rating of 101 GW – more than all hydropower in the US combined today, and 4.5 times larger than the largest power plant of any kind ever constructed (the Three Gorges Dam). The required flow rate through the upgraded Grand Coulee Dam at full power would regularly need to be 5.5 times higher than the largest flow rate of its part of the river ever recorded in history, which occurred on June 12, 1948, during an historic Columbia River flood period (US Bureau of Reclamations 2017). This flow rate corresponds to 13 times the average discharge rate of the entire Columbia river system, 9 times higher than the peak discharge rate ever in January (when the Jacobson et. al. system assumes 1300 GW of total output), and 3.5 times the maximum spillway capacity of the Grand Coulee dam. One can only imagine the environmental impacts of the massive flooding of lands, towns and cities downstream of such reservoirs once water is released so rapidly.

The Robert Moses dam at the Niagara river (the 4th largest US hydro plant), once it is "upgraded", would then be relied upon to occasionally deliver up to 36.43 GW (by then also far larger than the world's largest-capacity power plant today). This would require a flow 6.3 times higher than the highest ever recorded flow rate of the entire Niagara river (recorded in May 1929), and about 18 times higher than its average total flow rate. To put it mildly, this project is hardly likely to be popular either with tourists, downstream and upstream residents or with the Canadians power plant operators drawing water from the same river.

The same type of examples as those above can be made for essentially all other major hydropower facilities in the US. As has been shown, the hydropower capacity error is one of many in the Jacobson et al. study, but it is so large (and so obvious) that it by itself invalidates the entire effort.

When the Academy refused plaintiff's demands for retraction of the Clack paper and for $10 million, plaintiff filed his Complaint, which states: "Dr. Jacobson has acknowledged that the Jacobson Article was not clear in the actual text . . . about the hydropower assumption and that there was an omission of the cost of the additional hydropower turbines," but avers that neither was material. Compl. ¶72.

Twelve days after filing the Complaint, and 21 months after the publication of his paper, plaintiff submitted to PNAS (and later posted on his website[11]) Errata, which acknowledge omissions about the assumptions he made in his 2015 paper, including two that relate to what he claims are the three allegedly most "egregious" defamatory statements in Clack's paper. Ex. C.



America's energy security and global environment are at risk.

The U.S. is doing NOTHING on the massive energy scale required.

Worse - we are failing to provide clean energy leadership.

#1 Reliability

Energy Return On Investment (**EROI**) = how many BTU's of energy are brought to market per BTU invested.

SSP has essentially zero fuel cost for power generation - a prime advantage for SSP. By tapping the sun directly, SSP is expected to be lower in cost (EROI), than anything else on the energy horizon. Next Figure shows EROI for various power generation plants.

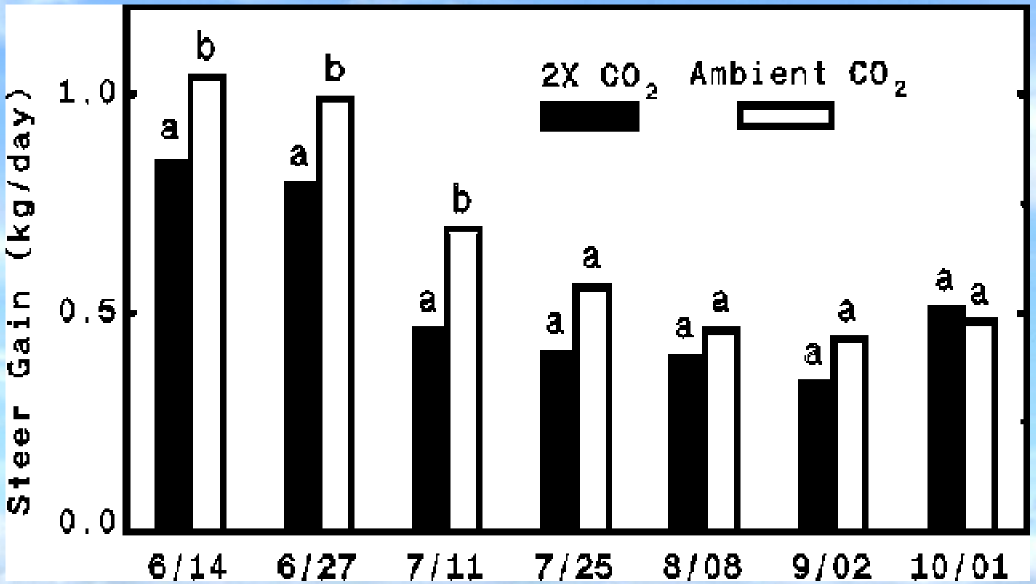
But what are our power alternatives?

	Clean?	Safe ?	Reliable?	Baseload?
Fossil Fuel	No	Yes	Imminent Peaks	Yes
Nuclear	No	Yes	Costs, Fuel, Politics	Yes
Wind Power	Yes	Yes	No, intermittent	No
Geothermal	Yes	Yes	No, Limited availability	Yes
Ground Solar	Yes	Yes	No, intermittent	No
Hydro	Yes	Yes	No; drought; complex scheduling	
Bio-fuels	Yes	Yes	Very limited quantities & competes with food production. Poor EROEI	
SSP	Yes	Yes	Yes	Yes

Climate Change - nutritional

Plant-available nitrogen decreases 40 to 50 % under doubled carbon dioxide levels expected around 2050 ... resulting in reduced nutrition from forage and grasses grown under doubled CO_2 .

Ruminants, including cattle, sheep, oxen, buffalo, deer, etc., the source of nearly all the milk and half the meat the world eats, will gain weight more slowly under doubled CO_2 »»



Kansas State University http://spuds.agron.ksu.edu/gainco2.gif

Climate Change - nutritional (2)

- Nutrition from wheat and rice decline:
- Wheat grown at doubled CO_2 declines in protein content by 9-13%. It produces poorer dough of lower extensibility and decreased loaf volume. The quality of flour for bread making degrades.
- The protein content of rice declines under doubled CO_2 corresponding temperature increase. Iron and zinc concentrations in rice, important for human nutrition, would be lower.

Climate Change - Summary (3)

As our atmospheric CO_2 level continues to increase, plant photorespiration decreases and nitrate assimilation in most plant species is severely inhibited. Declines in forest health and food quality that are associated with climate change derive in part from CO_2 inhibition of nitrate assimilation that diminishes plant organic N (Nitrogen, and therefore, protein concentration.) levels. This exacerbates damage from insects and other pests as they consume more plant material to meet their nutritional needs.

- "Elevated Carbon Dioxide", Arnold J. Bloom, Ph. D, Professor and chair, Dept. of Plant Sciences, Univ. of California, Davis. www.plantsciences.ucdavis.edu/Faculty/bloom/bloom.htm

Energy

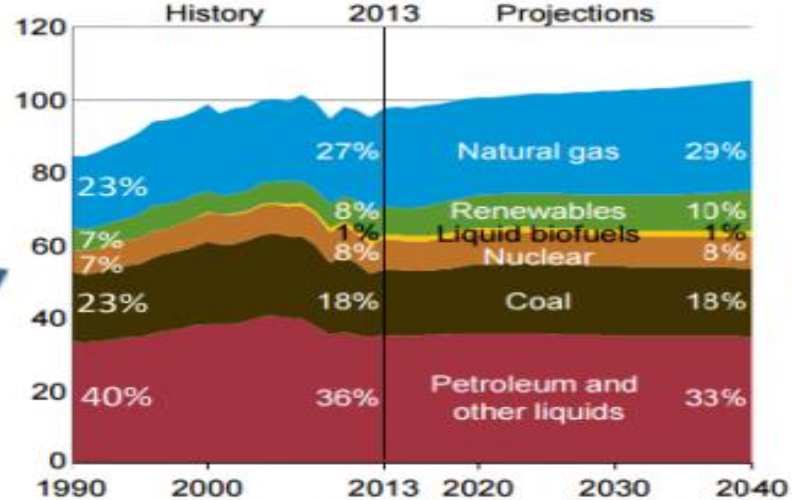
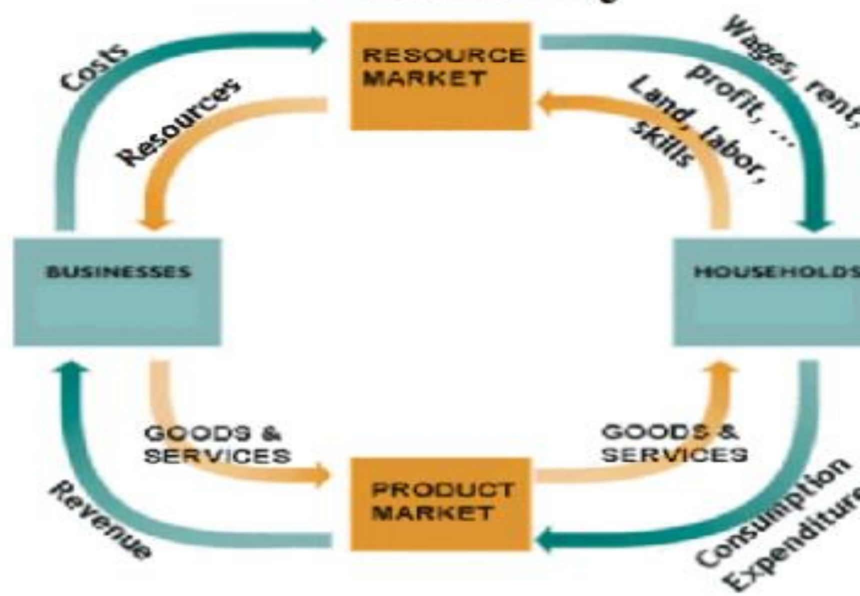


Figure 1. U.S. primary energy consumption by fuel, 1990-2040 (quadrillion Btus / year)
Source: EIA AEO2015 Reference case

Environment

Salt Marsh, the most productive agricultural land known, nursery for shrimp, crab, fish, etc.,.
Courtesy: University of Georgia

Economy



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Global Change Biology

Sound physiological knowledge and principles in modeling shrinking of fishes under climate change

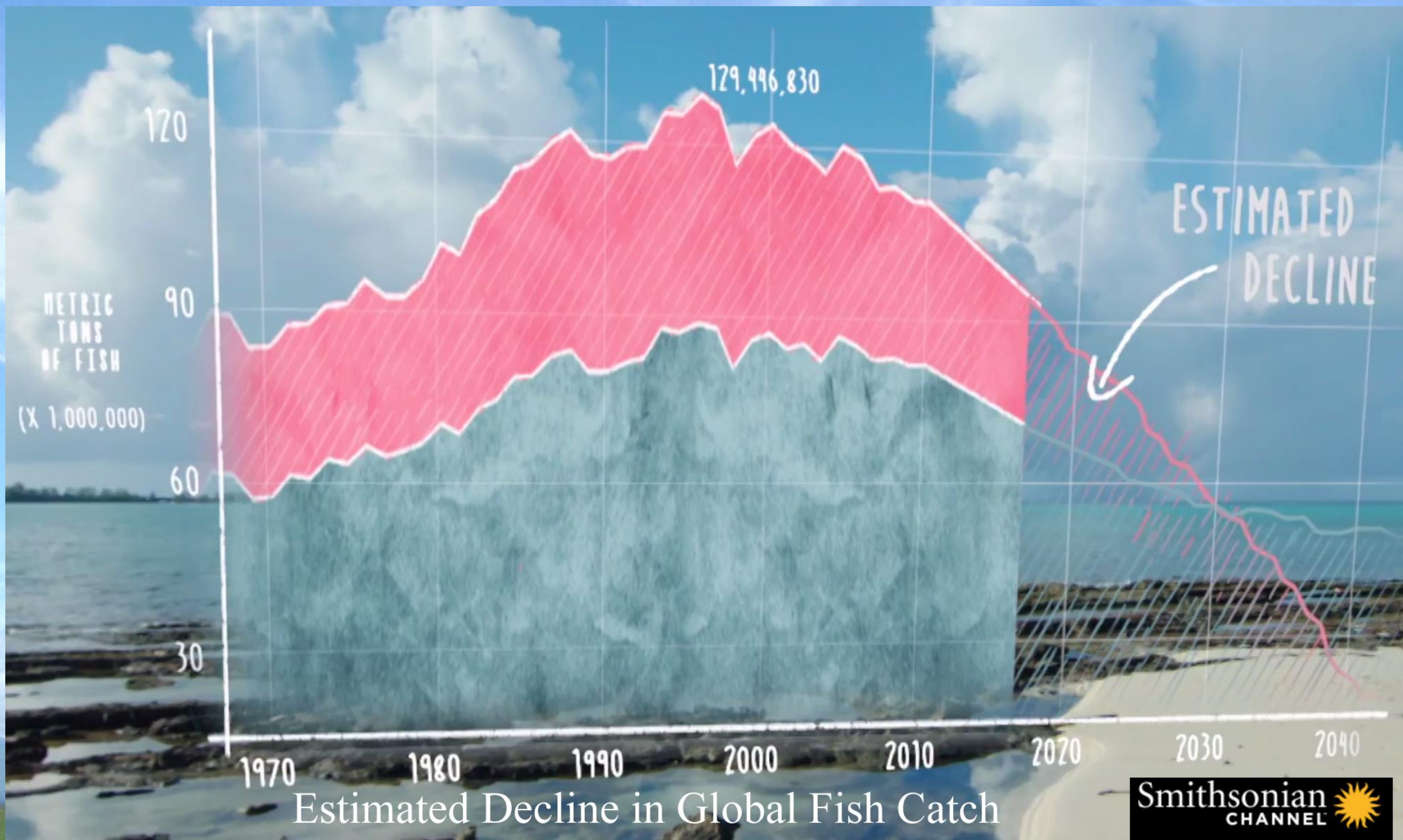
Authors: Daniel Pauly, William W. L. Cheung orcid.org/0000-0001-9998-0384 w.cheung@oceans.ubc.ca
Ecosystems Research Laboratory, Institute for Oceans and Fisheries, University of British Columbia, Vancouver, BC, Canada First published: 21 August 2017 DOI: 10.1111/gcb.13831 Last updated Oct 03 2017

Abstract - One of the main expected responses of marine fishes to ocean warming is decrease in body size, as supported by evidence from empirical data and theoretical modeling.

The theoretical underpinning for fish shrinking is that the oxygen supply to large fish size cannot be met by their gills, whose surface area cannot keep up with the oxygen demand by their three-dimensional bodies. However, Lefevre et al. (*Global Change Biology*, 2017, 23, 3449–3459) argue against such theory. Here, we re-assert, with the Gill-Oxygen Limitation Theory (GOLT), that gills, which must retain the properties of open surfaces because their growth, even while hyperallometric, cannot keep up with the demand of growing three-dimensional bodies. Also, we show that a wide range of biological features of fish and other water-breathing organisms can be understood when gill area limitation is used as an explanation. …

Climate Change (Micro – Nutritional)

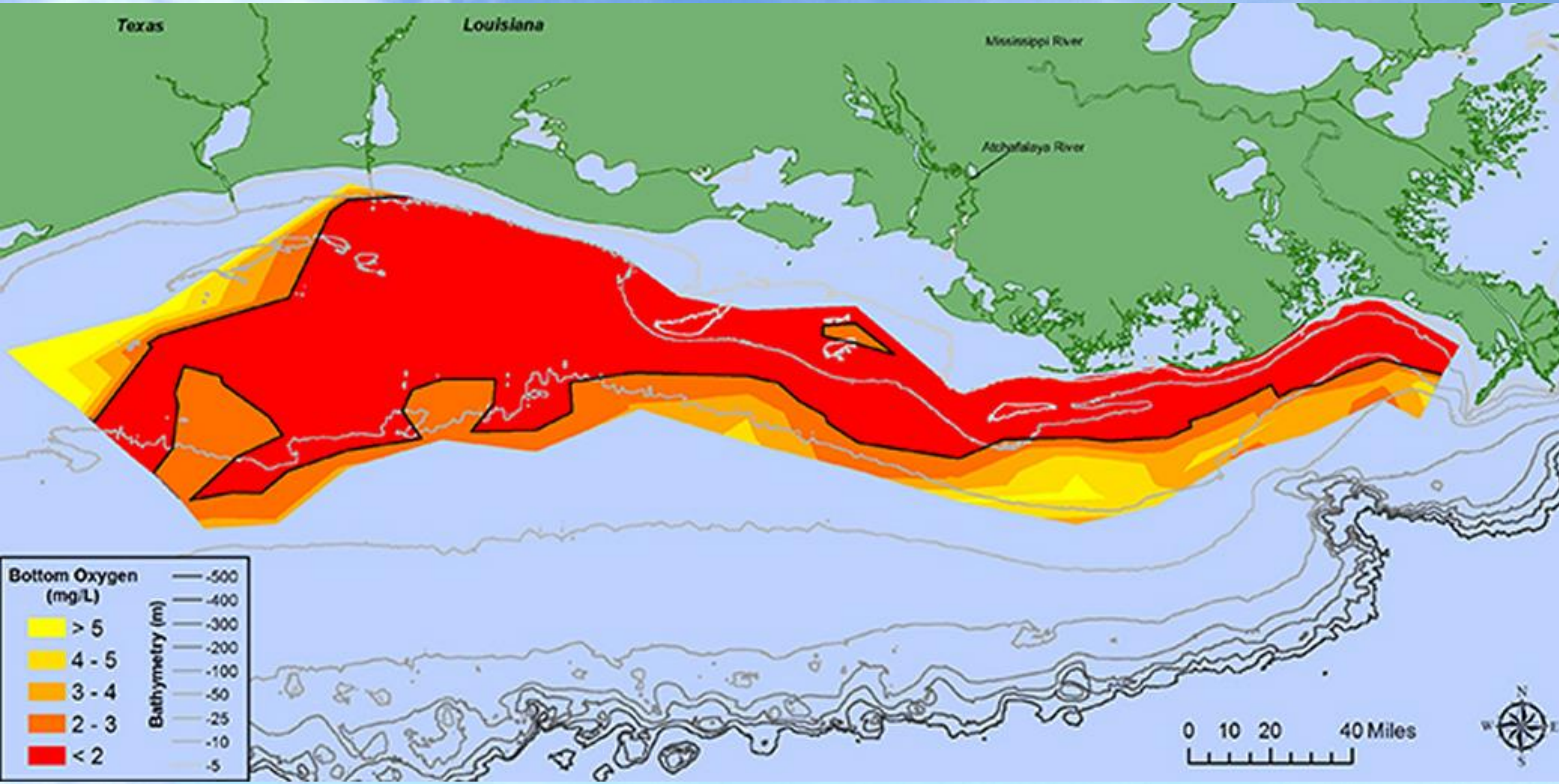
Laboratory duplication of the changes affecting the oceans in the years ahead is virtually impossible. Oxygen levels in the Pacific tropics has been declining since the 1970s. Measuring *today*'s ocean productivity shows that since 1996 global catch has been in decline.



Estimated Decline in Global Fish Catch

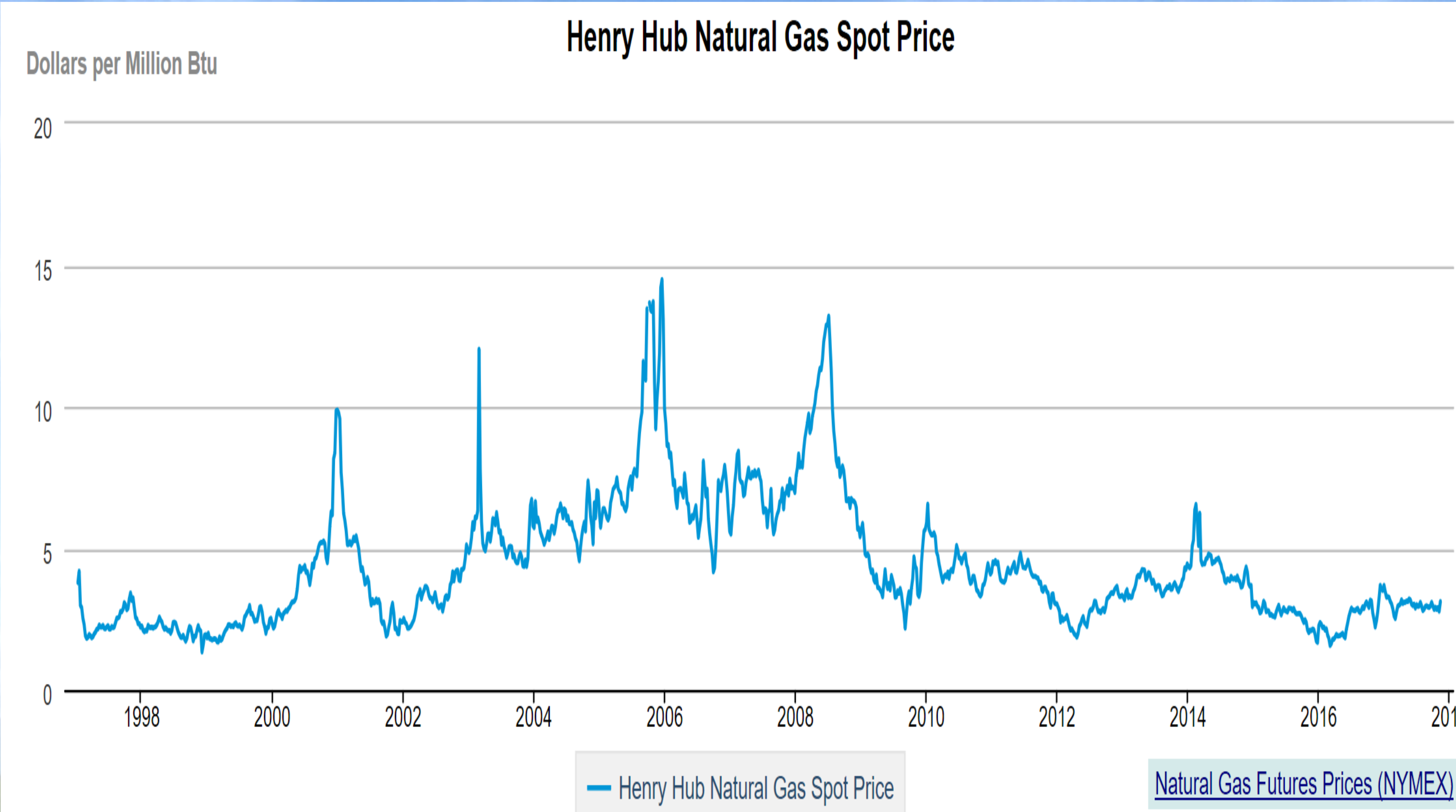
www.smithsonianchannel.com/shows/an-ocean-mystery-the-missing-catch/0/3437476

Gulf of Mexico ‘Dead Zone’ is Largest Ever Measured



(NOAA) - August 2, 2017 http://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured

Natural Gas Prices



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Natural Gas Prices

Between 1999 and 2004, the US electric power industry built **200,000 MW** (about "4 Californias" worth of generation capacity or almost 10% of all US generation) of natural gas fired generation. Natural gas was <u>cheap</u> - $2 to $3 per Million BTU. By winter 2005/2006 the price soared above $14 per Million BTU and US electric power companies & consumers were burned. The DOE then retracted their estimation that Mexican natural gas would remain cheap.

Natural gas has now, once again, entered that "cheap" range and natural gas-fired generation is again increasing rapidly.
How long will gas be cheap this time??

Energy Storage Technologies Capital Cost Estimates (EPRI Estimate, February 2009)

Storage Type (See footnotes)	$/kW	$/kWh	Hours[4]	Total Capital, $/kW
Compressed Air Energy Storage				
Large (100-300 MW Underground storage))	590-730	1-2	10	600-750
Small (10 - 20 MW Above ground storage)	700-800	200-250	3	1300-1550
Pumped Hydro				
Conventional (1000 MW)	1300	80	10	2100
Battery (10 MW)				
Lead Acid, commercial	420-660	330-480	4	1740-2580
Sodium Sulfur (projected)	450-550	350-400	4	1850-2150
Flow Battery (projected)	425-1300	280-450	4	1545-3100
Lithium ion (small cell)	700 - 1250	450 - 650	4	2300 - 3650
Lithium ion (large cell, projected)	350 - 500	400 - 600	4	1950 - 2900
Flywheel (10 MW)	3360-3920	1340-1570	0.25	3695-4313
Superconducting Magnetic Storage commercial	200-250	650,000-860,000	1 sec	380-489
Supercapacitors (Projected)	250 - 350	20,000 - 30,000	10 sec	300 - 450

1. In this table, Total Capital Cost = $/kW + (Number of Hours x $/kWh)
2. All figures are rough order -of -magnitude estimates and are subject to changes
3. Total capital costs include power conditioning system and all equipment necessary to supply power to the grid. Not included are battery replacement costs, site permitting, interest during construction and substation costs.
4. These costs are for the hours shown ±25%
5. Cost may vary depending on the price of comodity materials and location of project

33% RPS by 2020 ?

How? CAES (Compressed Air Energy Storage) A natural gas plant “in disguise”, burning natural gas with the decompressed air stream.

1 MW CAES Plant	**1 MW Fossil Plant**
8,200,000 BTU (2403 kWh) plus 4,600,000 BTU (natural gas)	10,000,000 BTU
12,800,000 BTU	**10,000,000 BTU**
27% Efficient	34% Efficient

Can ground solar (or wind) run our grid?(cont.)

On average, it takes about 4 days of full sun to get 24 MWH. We need 14.8 of those days to store 24 MWh in order to power a sunless 24 hour day. That is to provide power for just one 24 hour day.

(***Note*** - CAES uses natural gas to make most efficient use of the cold compressed air to generate the power, but PV or wind cannot provide gas so it still depends on a fossil fuel.)

Approximately 50% of space solar's PV output will be provided to the grid, so the factor of 9.6 is reduced to 4.8 ;

Attempting to make terrestrial PV or wind "dispatchable" using the best available storage technology, we have shown by comparison that SSP provides **71 times** (= 14.8 x 4.8) **more dispatchable baseload energy.** (This assumes that we can perfectly predict the weather and the cost of CAES storage equipment is zero, since we don't know how long storage may be required.)

1. IF CAES were truly a cost effective method for time shifting energy generation, it would have been widely adopted in the US. It has not been. There is still just one CAES plant in the US.

2. True utility bulk power storage is not planned anywhere – peak shaving, frequency regulation, etc., but not bulk power storage. Bulk Storage technologies are fighting thermodynamics and see no way to win.

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Advantages of Space Solar Power

6. Drought & Competition for Water - Today's average coal or gas-fired power plant withdraws about 25,000 gallons of river water to provide an average household with 1,000 kilowatt-hours a month; 31,000 gallons if nuclear-fired.

   Output water must be carefully monitored, especially in summer, to avoid fish kills from dangerously higher water temperatures. Newer "closed loop" power systems that rely on cooling towers use less water, but "consume" much more - over 70 percent of the water withdrawn.

   - "Energy Risk – Sinking Water and Rising Tensions", December 7, 2007, by Ken Silverstein, EnergyBiz Insider, Editor-in-Chief, http://www.riskcenter.com/story.php?id=15710

So How do we build SSP?

No company(s) or agency(s), however, is prepared to assume the immense financial risk of initiating construction of an SSPS.

There are simply too many engineering, financial, regulatory and managerial risks for any US company or consortium we have been able to identify to undertake SSP today.

However, this road has been traveled by America before ...

How to proceed?

Comsat Corp, a public/private corporation chartered in 1962, opened space for communication satellites - when we knew *nothing* about space, rockets or space communications. Communication satellites are now a $330+/year Billion industry.

Similarly, a “Sunsat Act” public/private corporation would accomplish the task of creating a space solar power corporation and industry of far greater size. And it would also open the high frontier to commercial development.

Japan’s Prof. Shinohara, has initiated an application for ITU’s 2019 meeting for an SSP specific frequency assignment, which we all should support.

Current Research and Development of Wireless Power Transfer via Radio Waves and the Application [DML]

Apr. 7, 2017

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Ammonia Energy   AmmoniaEnergy.org

Fossil Energy Companies Making Ammonia

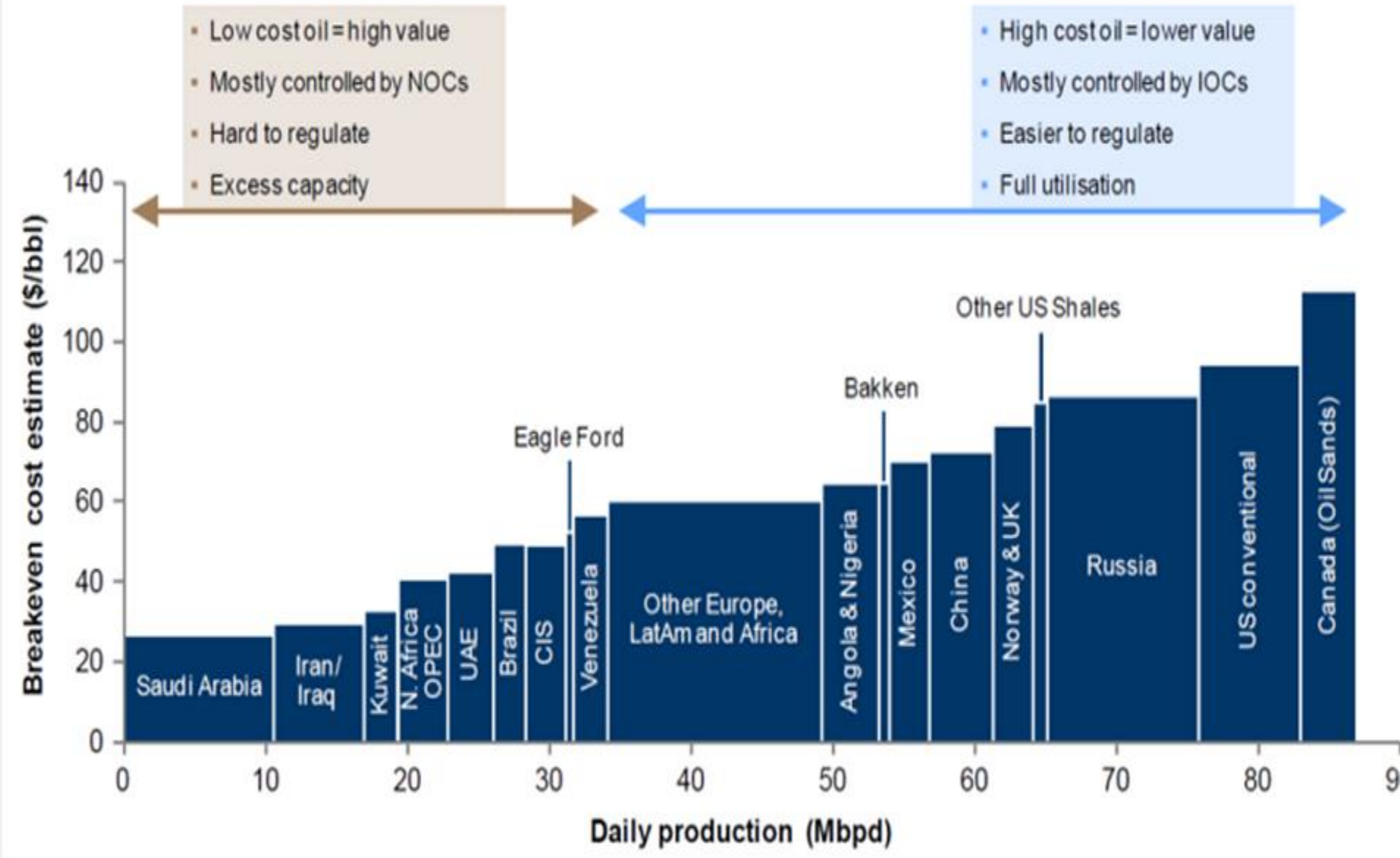
November 8, 2018 – 2017 - The world wants clean carbon-free ammonia. Equinor (Norwegian), Saudi Aramco, Woodside Petroleum, Shenhua Group, Shell, and Total are all now demonstrating or developing new technologies and or business cases for ammonia energy in a low-carbon economy.

One of the biggest global LNG exporters is investigating ammonia for the same market, as it considers Australia’s future as a renewable energy exporter.

Oil majors are assessing ammonia’s role in implementing an affordable hydrogen economy, looking toward fuel markets in California and Europe.

China’s biggest coal producer is funding the development of “the world’s first practical ammonia-powered vehicle.”

Global breakeven prices (considering only technical extraction costs) versus production



Source: Alliance Bernstein, Oct 2014; from "Why oil under $30 per barrel is a major problem"
https://OurFiniteWorld.com/2016/01/19/why-oil-under-30-per-barrel-is-a-major-problem/#more-40536

“For the first time in living memory, there is a realistic prospect of a superpower conflict.”

- John Sawers, British diplomat and former head of MI6 intelligence service

The U.S. confronts an aggrieved and newly assertive Russia and an aggressive rising power in China. Beyond the war in Syria are rising trade tensions with China. Chinese President Xi Jinping is intent on expanding Chinese economic influence across Asia and beyond, establishing a new military presence in the South China Sea and cementing his own personal and unquestioned power at home. - “Syria and Beyond, a Dangerous New Era Dawns”, **WSJ**, by Gerald F. Seib, April 16, 2018
https://www.wsj.com/articles/in-syria-and-beyond-a-dangerous-new-era-dawns-1523885521

The waves of Mid-East wars began with the "Arab Spring"(below), whose #1 cause was the rising price of food. These wars are basically over control of oil fields. China and Russia own or control major ports in Syria and Greece.