An Overview of Mark Mills'

THE "NEW ENERGY ECONOMY":

An Exercise In Magical Thinking

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CASF Presentation

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CO_2 another exercise in magical thinking

- Some climate scientists believe that all atmospheric CO_2 comes from human emissions
- Many sources in the past 30 years attribute about half of atmospheric CO_2 to human emissions
- Dr. Ed Berry using reservoir theory comes up with 25%
- There are a number of studies that suggest that CO_2 has almost no effect on global temperatures and so it doesn't matter how much there is in the atmosphere (human or natural)
- I propose that we can bound the possible influence of CO_2 by a simple back of the envelope calculation using the climate scientists accepted forcing values versus natural moderators

WSMR Solar Furnace

Eppley Normal Incidence Pyrheliometer (NIP) Specification

This instrument is a World Meteorological Organization (WMO) First Class Pyrheliometer designed for the measurement of solar radiation at normal incidence. The NIP incorporates a wire-wound thermopile at the base of a tube. The aperture subtends an angle of 5.725 degrees.

The sensitivity is approximately 8 micro volts/watts/m^2. The temperature dependence is +/-1% over an ambient temperature range of -20 to +40^o C. Linearity is +/-0.5% from 0 to 1400 W/m^2. Spectral Range 250-3000 nm.

What's CO_2 got to do with it?

- Assume that the climate community is right about 3.7 watts/m^2 CO_2 forcing (I could give them a 5 watts/m^2 value and not change the temperature dynamics very much)

- Is this level of forcing only when the sun shines on cloudless days? Or is it some sort of average of a rising level of CO_2?

- Discuss my findings on "forcing" of water vapor (up to 200 watts/$m^{2)}$, thin clouds (up to 400 watts/$m^{2)}$ and volcanic particulates (up to 100 watts/m^2) changes to values of surface readings

- Surface readings approach zero with thick clouds and will vary as shown above but will affect CO_2 forcing values accordingly

- Pick an instant of an average day at noon and with TOA values being equal 3.7/119 watts/m^2 = 3.1% (5/119 = 4.2%)

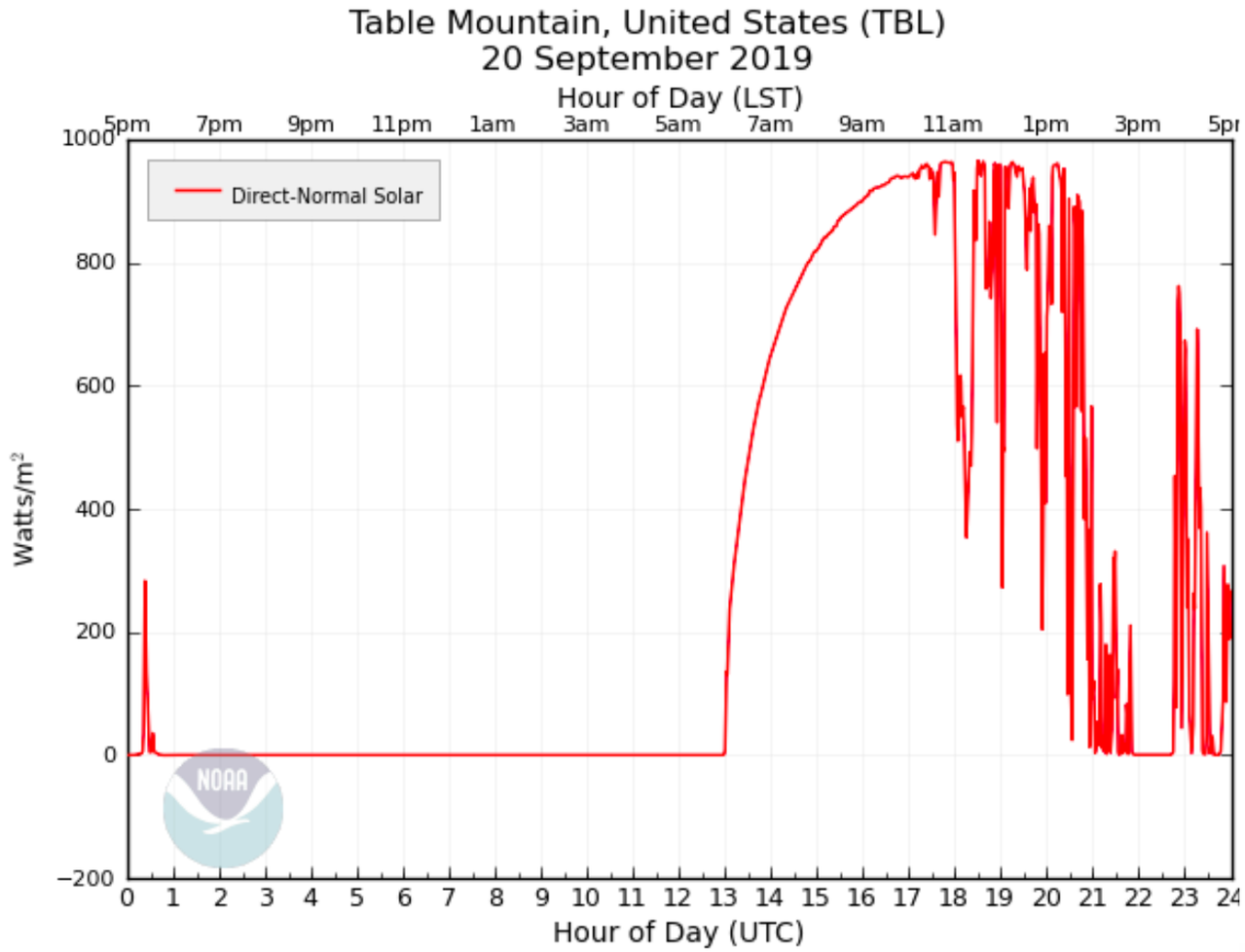
Table Mountain, United States (TBL)
20 September 2019
Hour of Day (LST)
5pm 7pm 9pm 11pm 1am 3am 5am 7am 9am 11am 1pm 3pm 5pm
Direct-Normal Solar
Watts/m²
1000
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Hour of Day (UTC)
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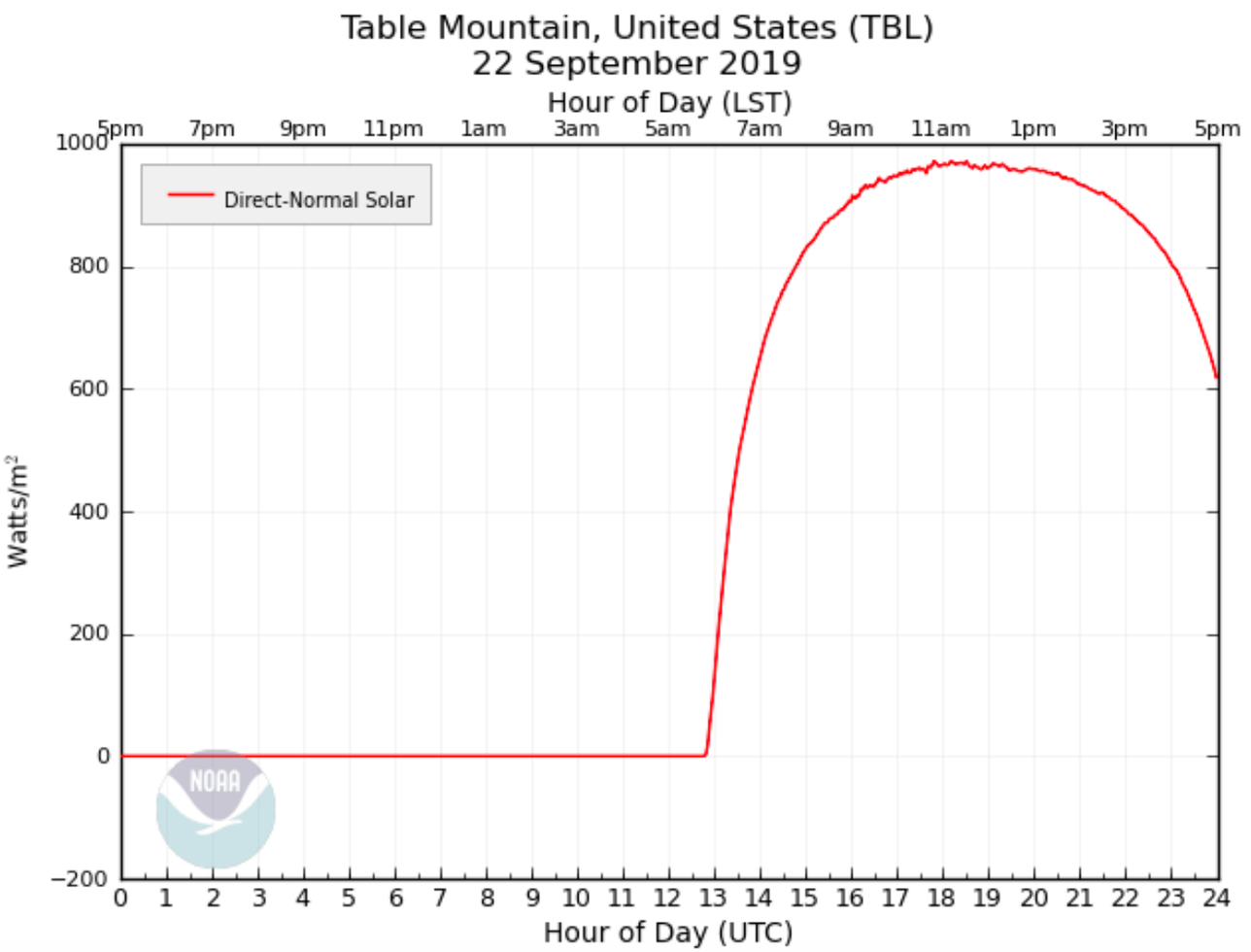
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22 September 2019
Hour of Day (LST)
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Direct-Normal Solar
Watts/m²
1000
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Hour of Day (UTC)
NOAA
Generated ESRL/GMD - 2019-September-29 20:54 p

Assumptions

- Not sure about how 3.7 watts/m^2 was obtained
- 119 watts/m^2 assumes maximum ground solar irradiance lies between 850 to 1050 watts/m^2 from the tropics to high mid latitudes
- Ground solar irradiance, time of day (sun angle) and atmospheric conditions should not matter to IR radiation calculations as compared to incoming short wave radiation values since the percent calculations are relative
- In the NM desert high water vapor content in the monsoons and low water vapor content in the fall change surface radiation values by about 200 watts/m^2
- Periodic equatorial volcanic activity may change surface radiation values by about 100 watts/m^2
- Jet contrails and thin clouds may change surface radiation values by about 400 watts/m^2
- NM dry (1050 watts/m^2) and high water vapor conditions occur about 35% of the time in each case. Volcanic activity may occur about 10% of the time. Contrails and thin clouds may occur about 5% of the time. Other variable atmospheric conditions that drops surface radiation conditions from 50 to 100 watts/m^2 to an average of 950 watts/m^2 make up the remaining 25%. These conditions - water vapor = 70 watts/m^2 - volcanoes = 10 watts/m^2 - thin cloud = 20 watts/m^2 - other = 19 watts/m^2 - Total 119

Details

- The climate community apparently is talking about on average radiative (IR) forcing by CO_2

- I am talking about moderation of incoming short wave radiation under certain conditions seasonal, temporal and event driven

- Certain daily and seasonal variations as well as TOA solar variations equally affect both of these phenomenon so cancel each other out (one could pick the instant at mid-morning instead of solar noon)

- Total of the water vapor and cyclical volcanic effects are averaged over time to be about 119 watts/m^2

- . . . so 3.7/119 = 3.1% which is the effect of all CO_2 in the atmosphere be it human or natural

Back to the Energy Overview

- If atmospheric CO_2 has such a tiny effect (and human emissions even smaller) why would we want to subject ourselves to the following catastrophe?

Not Possible in the foreseeable future:

- that scientists discover and entrepreneurs invent anything as remarkable as hydrocarbons in terms of low-cost, high energy density, safety and portability

- to see 10 fold gains in photovoltaic (PV) cells due to the Shockley-Queisser Limit

- to see 10 fold gains in wind power technology due to the Betz Limit

- to find ways for batteries to power the grid for more than a few hours and have power densities coming anywhere near hydrocarbons

We are running out of oil . . . alternate energy is a reliable, cheap and non-polluting way to solve the problem

- We now know we are not really running out of fossil fuels
- With respect to electricity generation, nuclear power produces no CO_2 if you happen to think that this is an issue (Bernie's 2 cents)
- This idea of a simple and cheap energy transition that occurred in past eras where for example, water and wood moved to coal fired steam engines begs the question are we on the cusp of another transition?
- Mills' short answer is no
- There are two flaws in this thesis that we are about to abandon hydrocarbons for something much better

The Two Flaws

- Realities of physics don’t allow energy systems to undergo revolutionary change seen in the digital domains

- No fundamentally new energy technology has been discovered or invented in nearly a century - nothing like the transistor or the internet

Moonshot Policies and the Challenge of Scale

- The Universe is awash with energy
- Converting any kind of energy source into useful power always requires capital-intensive hardware
- Size matters in global population and the size of modern economies and so does inertia
- Turning or stopping a 747 versus a bumble bee is far more difficult to do and similarly to change the direction of a country is more difficult than it is a local community

Today's Reality

- Oil, natural gas and coal supply 84% of global energy while 2 decades ago these fossil fuels supplied 87%

- Over those 2 decades total world energy use rose by 50% (an amount equal to adding two entire US's worth of demand

- The 3% drop in fossil fuel use, required over $2 trillion in cumulative global spending on alternatives over that period

- Fossil fuels supply 93 billion barrel equivalent for the world and for the alternates to replace and supply growing energy needs requires alternates to increase 90 fold from today

The Fantasy of Gearing Up in the US

- It took 50 years for global oil and gas production to expand by 10 fold

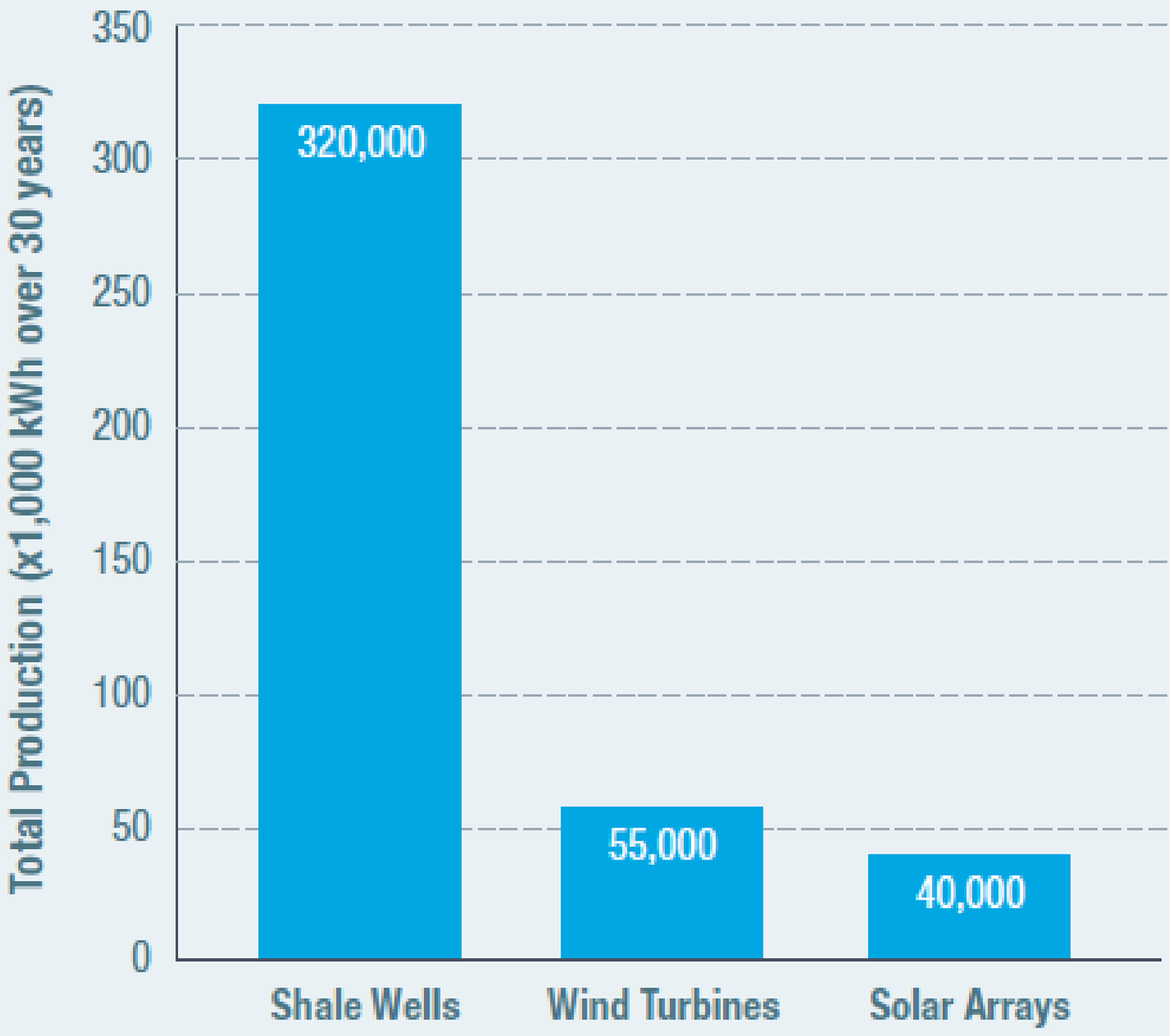
- Cost aside it is just a dream that a new form of energy infrastructure could now expand nine times in half that time (much less in the next ten years as some politicians propose)

- For electricity alone and the grid to support it, would require an industrial effort greater than a World War II level of mobilization for the former and a grid construction 14 fold bigger than the grid build-out rate that has taken place during the past 50 years for the latter

The Physics-Driven Cost for Alternate Energy

- The technologies and hardware involve windmills, solar panels and batteries - with batteries being key due to the intermittent nature of the alternates
- Windmills and solar power are actually 50 year old technology with most of the innovations and increases in efficiencies in the past
- Lithium battery technology is also 50 years old
- It is still expected that these technologies will continue to get better within limits

Total 30-Year Electricity Production from $1 Million in Hardware: Wind Turbines, Solar Arrays, and Shale Wells



Source: Lazard, "Lazard's Levelized Cost of Energy Analysis," 2018; Gulfport Energy, Credit Suisse Energy Summit, 2019; Cabot Oil & Gas, Heikkinen Energy Conference, Aug. 15, 2018

A Poor ROI for Alternates vs Oil

- Shale wells constitute about 600% more electricity for the same capital spent on primary energy producing hardware

- Cost to drill a single shale well will build 2 each 500 foot high 2 MW wind turbines. The shale well produces 10 barrels of oil per hour and the turbines total energy equivalent production is 0.7 barrels of oil per hour.

- This disparity relates to energy density where the high energy density of hydrocarbons is unique and well understood

Density-Reliability(Availability)-Quantity

- The quantity of energy produced is determined by how much sunlight or wind is available over any period of time and the physics of the conversion efficiencies of photovoltaic cells or wind turbines

- For natural gas - a turbo-generator to convert fuel into grid electricity is required

- For wind/solar some form of storage to convert episodic electricity into utility grade 24/7 power is required

- Availability is the single most critical feature of any energy infrastructure followed by price and then by a continuing search for decreasing costs without affecting availability

High Cost of Ensuring Energy Availability

- Ninety percent of US electricity and 99% of energy used in transportation comes from sources that easily supply it at any time on demand

- In our data-centric increasingly electrified society, always available power is vital but there are physics constraints

- And costs for supplying availability

- Hydrocarbon based systems - availability is dominated by equipment to convert fuel to power continuously for at least 8000 hours a year for decades

- It is easy to store fuel to meet almost all contingencies that meet expected and unexpected surges, delivery failures and problems caused by weather or accidents

Low vs. High costs

- It costs less than $1 a barrel to store oil or a natural gas equivalent for a couple of months and coal is even cheaper

- US on average has about one to two months' worth of national demand in storage for each kind of fossil fuel at any given time

- With batteries it costs roughly $200 to store the energy equivalent to one barrel of oil which leads to the fact that only two hours of national electric demand is found (and not readily available) in grid scale batteries plus all the batteries in the 1 million US electric cars

Dispatch & Grid Issues

- Cheap and easy storage of hydrocarbons leads to a simple process of dispatching power and ramping up and down

- Wind turbines and solar arrays cannot be dispatched when there is no wind or sun

- Geophysics drives the production from wind and solar powered machines to an average annual value of about 25%-30%

- Conventional power plants have a very high availability in the range of 80%-95% and often higher

Wind/Solar Grid Sizes

- Alternate grids would need to be sized to meet peak demand and have enough extra capacity to store enough extra capacity in battery banks for when the wind does not blow and the sun does not shine

- This would require that a pure wind/solar system would have to have 3 times the capacity of a hydrocarbon grid

- Even this significant capacity would not be sufficient since meteorological and operating data indicate that output can drop as much as two fold during their respective “low” seasons

The Myth of Grid Parity
All Grids are not created equal

- The Alternate energy grid, especially if those energy supplies become 100% source of our power, will be a much more complicated system than our present grid

- The so-called “leveled cost of energy” (LCOE) calculations use wind values of 36% and solar array values of 46% which are more expensive than from natural gas turbines in order to “approach parity”

- The LCOE values for dispatch-able and non dispatch-able technologies are listed separately because as the EIA states comparing them “must be done carefully”

Let’s Talk Grids & LCOE

- The LCOE calculations do not take into account the array of real, if hidden, costs needed to operate a reliable 24/7 and 365-day-per-year energy infrastructure, in particular a grid that uses only wind/solar

- LCOE calculations assumes costs of competing fuels like natural gas will rise significantly (Texas cancelled a very large wind system when the regulators found this increase buried in the proposal - thus protecting the ratepayers from major rate increases due to unlikely predictions)

- LCOE incorporates a low discount rate valuing todays money versus future money so that capitalization today looks favorable due to assumed future slow growth

More LCOE discussion

- Real assumptions must be made of multi-decade capacity factors, the share of time the equipment actually operates in reality and not the time that the wind blows and the sun shines

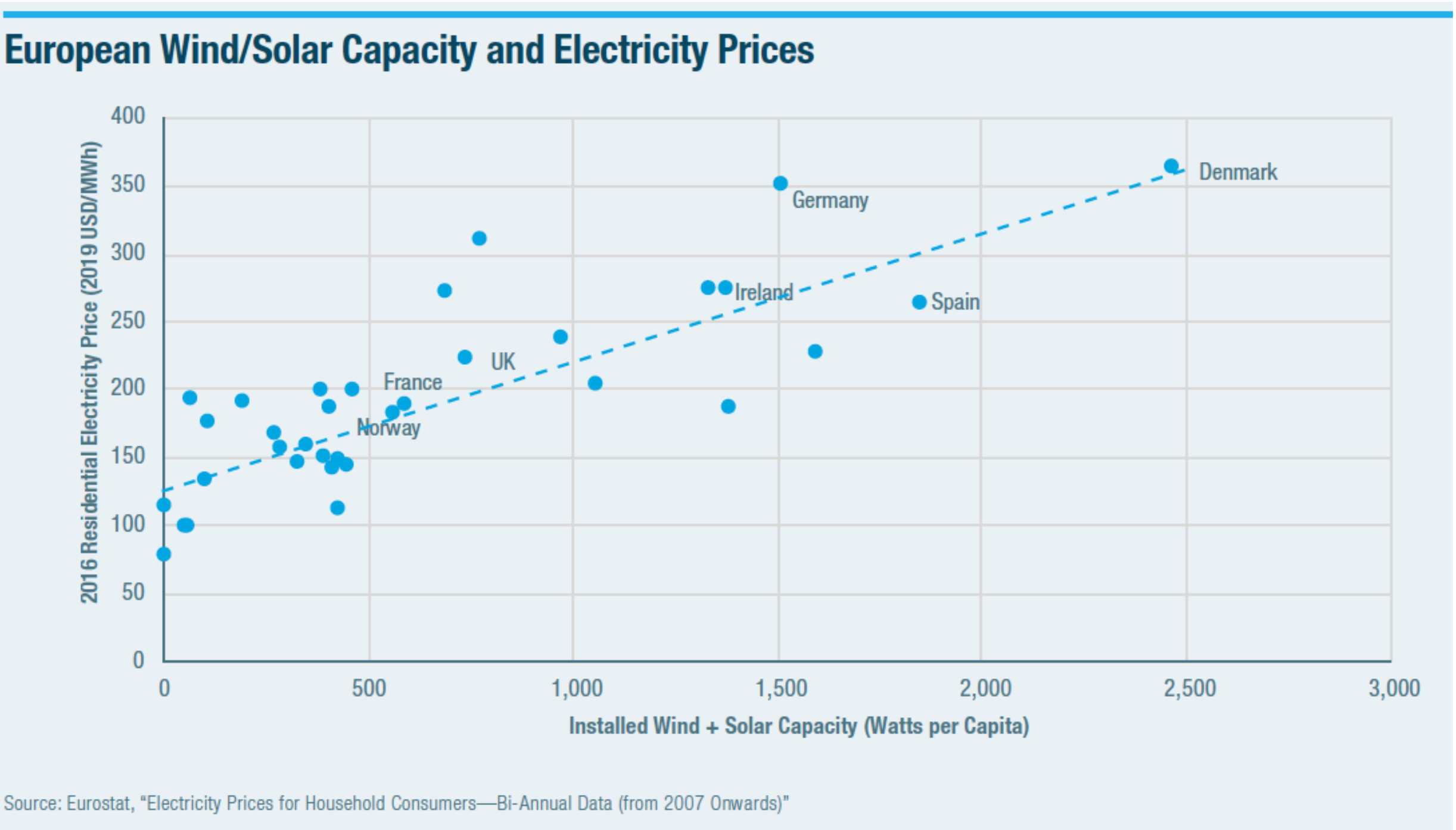
- EIA/LCOE assumes capacity factors of wind 41% and solar 29% when recent data collected indicate actual values of 33% and 22% respectively

- A 40% versus 30% difference in wind turbine capacity factor indicates that over a 20 year life of a 2 MW turbine $3 million of production won’t happen (consider the initial capital cost for the turbine is $3 million)

More Rosey News - not really

- Wind farm capacity factors have been getting better but at a rate of only 0.7% per year over the past 20 years
- This gain was obtained by reducing the number of turbines per acre that are trying to scavenge more moving air
- However, these changes increased land used per unit of wind energy by about 50%
- Maintenance cost assumptions over the long term are overly optimistic due to far faster degradation than planned

Some actual European rate costs compared to increased capacity



Source: Eurostat, "Electricity Prices for Household Consumers—Bi-Annual Data (from 2007 Onwards)"

Hidden Costs of “Green Grid”

- There are some hidden costs - subsidies, tax preferences and mandates - all of which finally show up for the rate payers

- US share of wind power is relatively low compared with Europe and Australia

- Nonetheless US residential electric costs have increased 20% over the past 15 years in spite of fuel costs going down

- Coal and natural gas supplied 70% of the electricity used over that period and the price of fuel accounts for 60-70% of the cost to produce electricity using hydrocarbons

More on US electricity Costs

- About half the average cost of US electricity depends on coal and gas prices and the price of those two fuels has gone down by over 50% in the past 15 years

- Utility costs specifically to purchase those fuels are down by 25% over the past decade reflecting costs savings from the shale-gas revolution which has insulated consumers from even higher rate increases

- Increase use of wind/solar in power generation imposes hidden physics-based costs that are rarely discussed

- One of the elements of dealing with an alternate energy grid is the rapid and dramatic cycle up and down of systems to balance the grid

Wear and Tear Costs

- OECD (Organization for Economic Co-operation and Development) analysts estimated that at least some of the “invisible” costs imposed on the grid add 20%-50% costs to grid kilowatt-hours

- Flipping primary sources to back-up sources leads to other real unallocated costs that come from the physical realities of this new system

- Increased maintenance costs and the reduced utilizations of these conventional assets means that capital costs are spread out over fewer kWh produced - increasing the cost of each of those kWh

Issues of increased scale of Alternate power production

- In South Australia, with 40% of their power produced by wind turbines, has had a couple of episodic events where the wind died unexpectedly with complete blackouts lasting for days in some areas

- After a total outage in South Australia in 2018 Tesla built the largest lithium battery “farm” on their grid that serves just 2.5 million people

- However to keep South Australia lit for 1/2 a day without any wind, requires 80 of these world’s biggest battery systems

Reliability in the Alternate Grid

- In a few words the answer to reliability problem is to use old-fashioned giant diesel-engine generators as backup (actually running on natural gas)

- These are the same engines used in modern cruise ships. In the US without much fanfare the utilities are installing these units at a furious pace (presently over $4 billion worth of generators enough to for about 100 ships)

- This hidden cost payed by electric rate payers is like US auto drivers paying for highway wear and tear by trucks while subsidizing the fuel costs of those trucks

- On a national scale Alternate power generation is impractical and not cost effective much like the helicopter, useful for special cases but not for flying the Atlantic

Batteries Cannot Save the Grid or the Planet

- At this point in the Alternate technology development curve, batteries are key to optimum functioning of the system

- Storage that is equivalent to oil in a barrel or even natural gas in a pipe or LNG form is, for now, very far over the horizon

- Batteries are a 200 fold more costly method of storage

- Equivalence of one barrel of oil (300 pounds) requires 20,000 pounds of batteries

- And yet, American and European policy makers continue to embrace programs and subsidies to expand battery use

Short List of more Battery Issues

- Tesla's $5 billion "Gigafactory" in Nevada is currently the world's biggest battery manufacturing facility
- It's total annual production could store 3 minutes worth of US electricity demand
- For two days of storage for the US would require 1000 years of Gigafactory production
- Wind/Solar advocates minimize battery usage by saying that there are always windy or sunny days somewhere
- The huge transmission line length and cost as well as as security challenges for parts of that line make this idea a huge challenge (transport by wire is 2X as expensive as by pipe)

Batteries and Mining

- Alternates are supposed to be environmentally friendly
- The truth is that 50-100 pounds of various materials are mined, moved and processed for one pound of battery
- Lots of minerals including lithium, copper, nickel, graphite, rare earths and cobalt must be extracted to build batteries for grids and cars
- That’s gigatons of material for batteries but also for many turbines and many acres of solar arrays
- This all alternate global power idea would expand mining of copper by 200% and 500% for lithium, graphite and rare earths and much more for cobalt

Where is this mining and manufacturing to occur?

- Any sort of mining in the US is faced with regulatory hostility
- China and African nations will probably handle large amounts of this mining
- Seventy percent of China’s grid is fueled by coal and will still be 40% by 2040
- Labor issues of this mining and manufacturing effort could play into world trade unintended consequences

Moore’s Law of energy?

- From the 1970s the integrated circuit annually shrinks in size and power requirements and increases in capacity at phenomenal rates

- So far all imaginable energy systems are made up of physically large machines and physics does not allow Moore’s Law to work through the eye of that needle

- Renewable improvements since most of the technology is at or approaching a 50 year age where major improvements and cost reductions are reaching diminishing returns (asymptotic results)

Physics and efficiency limits

- For combustion engines, Carnot Efficiency Limit is anchored in the temperature of combustion and the energy available in the fuel

- Even with today's high-temperature materials the best we can do in engine efficiency is 50%-60% of the theoretical limit of 80%

- For wind the boundary is the Betz Limit which dictates how much of the kinetic energy in air that the blade can capture which is about 60%

- Modern turbines already exceed a 45% conversion

Photovoltaics

- For PV cells, the boundary is called the Shockley-Queisser Limit where a maximum of about 33% of incoming photons are converted into electrons

- Latest state of the art commercial PVs are presently achieving just over 26% of conversion efficiency

- None of these efficiency limits, with modern systems getting very much closer to those limits every decade, allows any 10 fold possibility of improvement that is required of a truly breakthrough new energy technology

Aircraft efficiencies and Wright's Law

- Economies of scale can sometimes make for breakthroughs but there are also definitely physics limits there
- Manufacturing processes can see continual improvements which makes Wright's law a powerful tool in bringing technology costs down
- The experience curve (Wright's Law) was documented in 1936 involved manufacturing aircraft at costs that markets could tolerate
- Aviation "took off" and created a big worldwide transportation industry but it did not eliminate automobiles or the need for ships
- Shale oil technology is a very new idea where tenfold gains may still be possible as indicated by the fact that it has added 2000% more to US energy production over the past decade than wind and solar combined

Future Trends in Energy

- Will new software solve the electricity usage problem?

- Using driverless electric vehicles EV probably won’t solve the peak and valley issues and delays at the plug station

- Increasing population and increasing the world middle class will have a strong influence on power consumption

- As energy sources attain better efficiencies and prices drop, usage will increase so the only way to slow electrical demand is to increase the price in some way

Energy Revolutions are still beyond the Horizon

- Most of the present energy systems will get us into the future in a fairly graceful way

- And in a way if “it ain’t broken” why are we trying so hard to fix it?

- There might be new ways to deal with consumption and usage patterns that will spread the benefits of electricity and autos without running the cost up or harm people or the environment

- This should come from basic research not developmental research which is what most of energy research is these days

Google’s RE<C

- Bob discussed this idea of Renewable Energy < Coal recently
- About 10 years ago Google engineers worked on this until about 2014 when it was canceled
- The lead engineers on the project wrote: “Incremental improvements to existing [energy] technologies aren’t enough; we need something truly disruptive. . . .We don’t have the answers”.
- Mills’ comment: “Those engineers rediscovered the kinds of physics and scale realities highlighted in this paper”.
- That’s a pretty good conclusion. No need for anything further

Subsidies (Bob's 2 cents)

Subsidies have given us the insanity of ethanol and proliferation of wind and solar
when the construction nuclear would have solved the non-problem of CO2

This is insanity.
1 there is not a CO2 problem
2. If there was a CO2 problem nuclear would have solved it.
We have painted ourselves into a corner:
We produce too much ethanol. Car gas mileage is going up so much that
we don't need all the ethanol that is produced. So now compounding the felony
by trying 15% ethanol, which is parasitic of fossil fuels.
Subsidies got us there.
Another corner: wind and solar incompatible with dispatchable energy, vs nuclear.
Subsidies on Wind and solar got us there , too.