Trends & Predictions 2024

By John Benson

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1. Introduction

This paper is a response to the Energy Central call for posts for "Trends & Predictions 2024" under the topic heading "Clean Energy Goals." I started composing this (in late December) by looking at my recent past posts and upcoming posts by the submission deadline. I post two papers a week so that gave me a good volume of posts to quickly review and parse into a particular topic. I ended up with four posts. Each of these involve a specific goal.

Below are four additional sections, and each of these draws from a specific post, and a specific goal that fit the above topic. I assume that "Clean Energy…" means greenhouse gas (GHG) reduction, because this will mitigate climate change, and dealing with climate change will be our (the world's societies and economies) biggest challenges over the next decades and centuries.

There is an old saying: "If you've dug yourself into a deep hole, stop digging." With respect to climate change, the equivalent action to excavation-cessation is to replace all of the activities that emit GHG with ones that don't. We are actually doing a reasonable job with this as I deal with in the first three sections below. However, that is only the first step. My final referenced post and section below explains what the other steps are, and why these are a really long road.

2. Really Big EVs, Type 1

The above section title is a drop-in for "electrically powered very big trucks." I'm skipping the lighter EVs because the auto-industry (especially Tesla) is doing a reasonable job of accelerating the production of these. A few states have emphasized this by legislating fairly short timelines (2035 for California)[1] for ceasing the sale of new gasoline- or diesel-fueled light vehicles.

Very big trucks will have a tougher-haul vs. lighter road vehicles due to a number of reasons:

1. Higher unit prices.
2. Lower volumes
3. Less frequent design changes
4. Much longer lifetimes

The early-stage fix is moving from IC-power to clean-fuel power. Early stage this will be a drop-in replacement for diesel fuel that has much lower net GHG emissions (like bio diesel). Mid to late stage this will probably need to be hydrogen. Although diesel engines can be modified to operate on hydrogen, it isn't easy. Also, fuel-cells that produce electricity plus batteries and electric motors will result in much higher efficiency. One problem is that hydrogen is hard to store onboard a big truck, especially with the current design. The paper below proposes a work-around for this issue.

[1] Victoria Albert, CBS News, "California to ban the sale of new gas-powered passenger vehicles starting in 2035, Sep 23, 2020, https://www.cbsnews.com/news/california-ban-gas-cars-gavin-newsom-mandates-that-all-new-vehicles-be-zero-emission-by-2035/

Efficient Hydrogen Storage for Big Rigs: *One class of likely mobile users of hydrogen are large road vehicles, ESPECIALLY if the space required for storage of the hydrogen could fit into current big rig tractor designs and provide a non-stop range comparable to existing diesel-fueled tractors. Although there are quite a few details to work out, this appears to be much closer to accomplishment.*

https://energycentral.com/c/ec/efficient-hydrogen-storage-big-rigs

Your author predicts: within the next year a few prototype-big-rigs based on current designs will appear with the hydrogen fuel-storage solution described in the above paper. At this point I would guess that these will use IC Engines modified to run on hydrogen.

3. Really Big EVs, Type 2:

In the prior section I listed four reasons why the conversion of very big trucks would be tough. Type 2 Really Big EVs share these reasons, except they are even a steeper climb. The above section-title is a drop-in for train locomotives. Replacing these will be a decade-long battle for the first mover states. As it has in anything having do with air-pollution (especially of the greenhouse gas (GHG) type), my home state is the first mover here:

The California Air Resources Board (CARB) fired a shot across the freight rail industry's bow to accelerate the drive to lower locomotive emissions to zero by 2035. In response, the Association of American Railroads (AAR) has filed suit against CARB. Regardless of the outcome, there is now heightened awareness of locomotive emissions. The issue isn't going away. Instead, the economic impact to implement tighter emission regulations will be in the billions for as far as the eye can see.[2]

Author's comment: Ha-ha. The California Government has more lawyers (and expert consultants) than just about any organization, and almost always wins. Apparently, the above suit is an attempted delaying tactic.

On April 27, 2023, CARB issued an "In-Use" Locomotive Regulation laying out a roadmap toward zero emission locomotives in California by 2035. Highlights of the regulation:

- *Establishment of a "spending account" that collects fees (taxes) commencing in 2024 on locomotives that operate in California. This will be calculated as a function of their operating use and emission levels. The funds will eventually be used to purchase new low/zero emission locomotives.*
- *Limit idle time to 30 minutes.*
- *Prohibit the use of locomotives over the age of 23 years by 2030. This is a very critical feature of the CARB regulation with far reaching impact.*
- *Mandating Zero Emission (ZE) locomotives to operate exclusively by 2035.*

The following recent post was a summary of the current technology for and deployments of zero-emission trains.

[2] Robert H. Cantwell, Railway Age, "Clean Track Ahead," Sep 6, 2023, https://www.railwayage.com/mechanical/locomotives/clean-track-ahead/

Zero-Carbon Trains: *In my writings I tend to classify electric vehicles and other vehicles that match the above title by their location in our transportation networks. That is:*

- *Road Vehicles*
- *Tracked Vehicles*
- *Aircraft*
- *Maritime Vehicles (a.k.a. ships and boats)*

World-wide, most tracked vehicles are already electrified. If a government agency is going to the trouble of laying a track system, it is not that much more expensive to put in an electric supply and equip the locomotives and/or train-cars to tap into that supply. Also, once this is done the operating cost is generally much lower than fossil-fueled trains.

The reason that diesel-electric (a generator driven by a diesel-engine driving electric traction motors) is dominant in the US (etc.) is that we have very long distances between metro-areas in many regions, and having just passive tracks in these stretches reduces the cost of installing and maintaining these tracks by a huge amount. Also, these sections are mostly used for freight, not passengers.

https://energycentral.com/c/ec/zero-carbon-trains

Your author predicts: Based on their past record, it is a pretty safe prediction that CARB will meet the above timeline, starting this year.

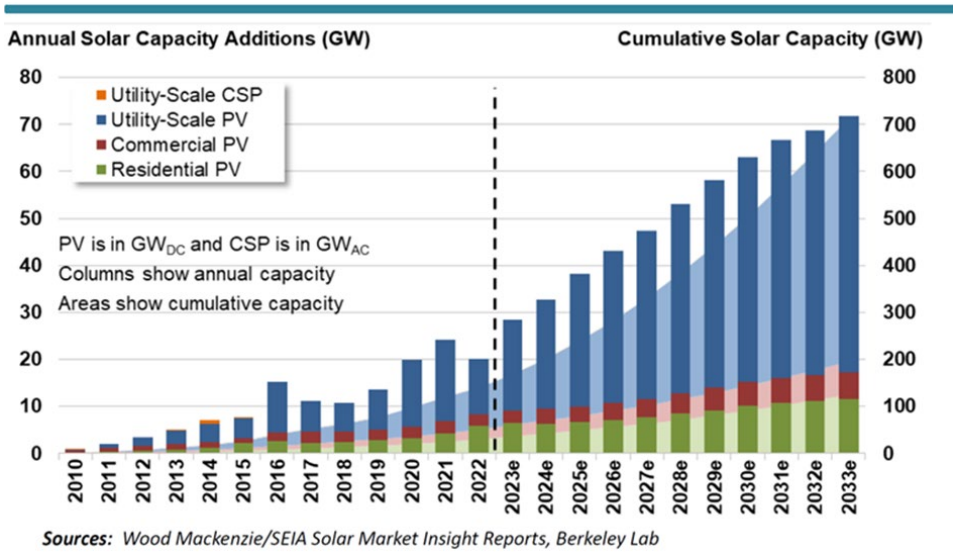
4. The Godzilla Renewable

In any collection of comparable groups, there is generally one that stands above the others. When it comes to movie-monsters, I believe Godzilla is well above his peers. When it comes to renewables, I also believe that photovoltaic (PV) arrays, especially when paired with storage is the king-monster. I cite my reasons below:

- Utility-scale sector added 12 GWDC of new solar capacity in 2022, and is projected to add more than 20 GWAC in 2023. [3] Windpower (the second most widely deployed renewable) only added 8.5 GW in 2022.[4]
- The U.S., solar deployments (almost exclusively PV) are accelerating and are likely to continue accelerating. See the chart below (next page).
- New PV Technologies are emerging that will increase efficiency and project yield (see my "PV & Storage…" post referenced below, subsection 2.2).
- Almost all new utility scale solar projects include co-located battery energy storage systems (see my post referenced below, subsection 3.1).

[3] Mark Bolinger, Joachim Seel, Julie Mulvaney Kemp, Cody Warner, Anjali Katta, & Dana Robson, Lawrence Berkeley National Labs, "Utility-Scale Solar, 2023 Edition," Oct 2023, https://eta-publications.lbl.gov/sites/default/files/utility_scale_solar_2023_edition_slides.pdf

[4] U.S. Department of Energy. Land-Based Wind Market Report: 2023 Edition, Executive Summary, https://www.energy.gov/sites/default/files/2023-08/land-based-wind-market-report-2023-edition-executive-summary.pdf



Sources: *Wood Mackenzie/SEIA Solar Market Insight Reports, Berkeley Lab*

PV & Storage Late-Fall 2023: *This paper contains:*

Technology:

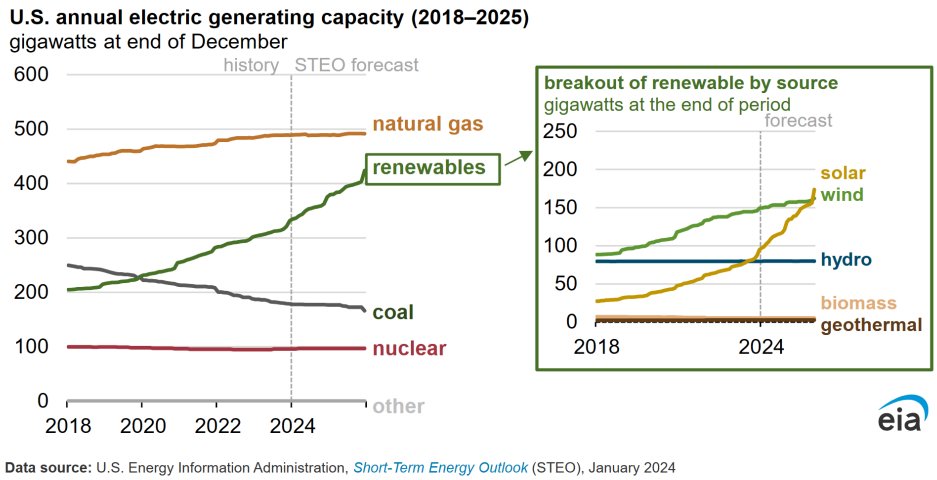
- *The Next Generation of Photovoltaic Modules*

Business:

- *New Rules, Incentives Shaping Solar-Plus-Storage Market*
- *U.S. Photovoltaic System and Energy Storage System Cost Benchmarks*
- *Solar Industry Update*
- *Projects*

https://energycentral.com/c/cp/pv-storage-late-fall-2023

Additional graphic information on how PV is driving renewables forward:[5]



Data source: U.S. Energy Information Administration, *Short-Term Energy Outlook* (STEO), January 2024

Note the Wood Mackenzie and EIA charts cover different markets for different periods.

[5] U.S. EIA: "Solar and wind to lead growth of U.S. power generation for the next two years," Jan 16, 2024, https://www.eia.gov/todayinenergy/detail.php?id=61242

Your author predicts: The trends in PV deployments predicted by the above charts, and the other trends described above will turn out to be accurate. Windpower deployments will continue to grow through the early 2030s, but PV (including PV+storage) will continue to outpace them.

5. No Sense of Urgency

I am on Dr. James Hansen's mailing list, and frequently reference his posts in my writings. In early December I received a post through Dr. Hansen's mailing list notifying me of a major paper originally published in Early November.[6]

The above referenced paper mostly focused on the reasons that the world's economies are slow to move on climate change, even as the world experiences increasing worsening side effects from this human-caused anomaly.

This paper was very long, and although somewhat easier-to-read than many scholarly publications on climate change, was still a tough read for me. Thus, I decided to post a paper that was shorter, with language more suited to my typical reader. This is referenced below.

In the Pipeline: *I'm writing these words in a paper that is a brief summary of a recent highly influential document from a team headed by Dr. James Hansen.*

Over the last one or two years I have come to believe that the effects of climate change would get much worse over future decades, before humankind could even begin mitigating it.

The last few days, I've been reading this paper, and now I still have the belief described in the above paragraph, but now know why, with many details. This paper will be a very brief summary, and I encourage readers to drill though this to the main document, linked in my paper.

https://energycentral.com/c/rm/pipeline

There are (at least) three reasons for the slow response:

First, it is not apparent that there is huge amount of warming that is in our climate's pipeline. That is, already committed by the long latencies inherent with any huge system like the world's climate, but specifically driven by the long-lived primary greenhouse gas (carbon dioxide) that continues to be pumped into and accumulate in our atmosphere. Thus, the amount of warming in the pipeline is growing over time.

Second, even though we are making reasonable progress, it will require many decades if not centuries to displace all of the greenhouse gas (GHG) generating energy production methods we are currently using with renewables.

Third, emerging economies are reluctant to convert from their current least-cost, GHG-generating energy production methods, when most of the GHG currently in the atmosphere were produced by mature economies.

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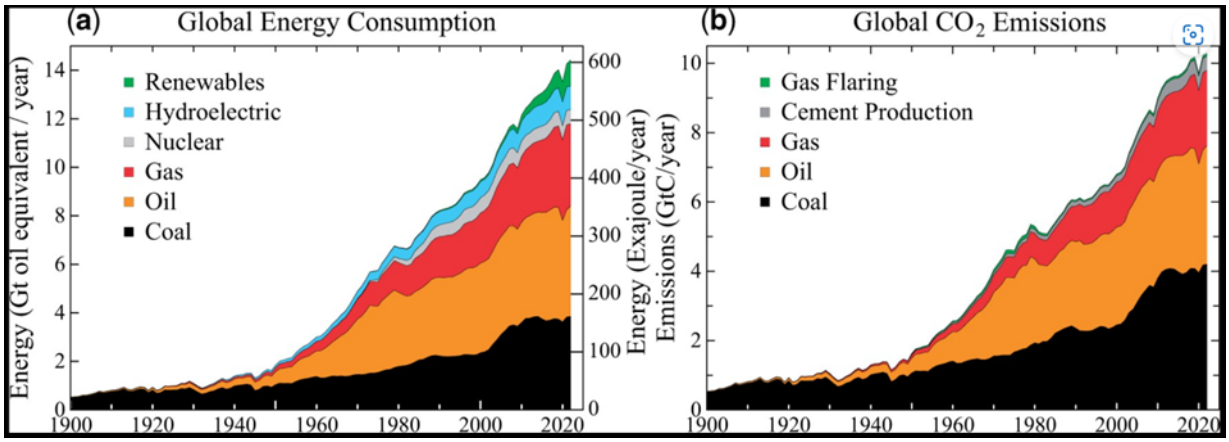
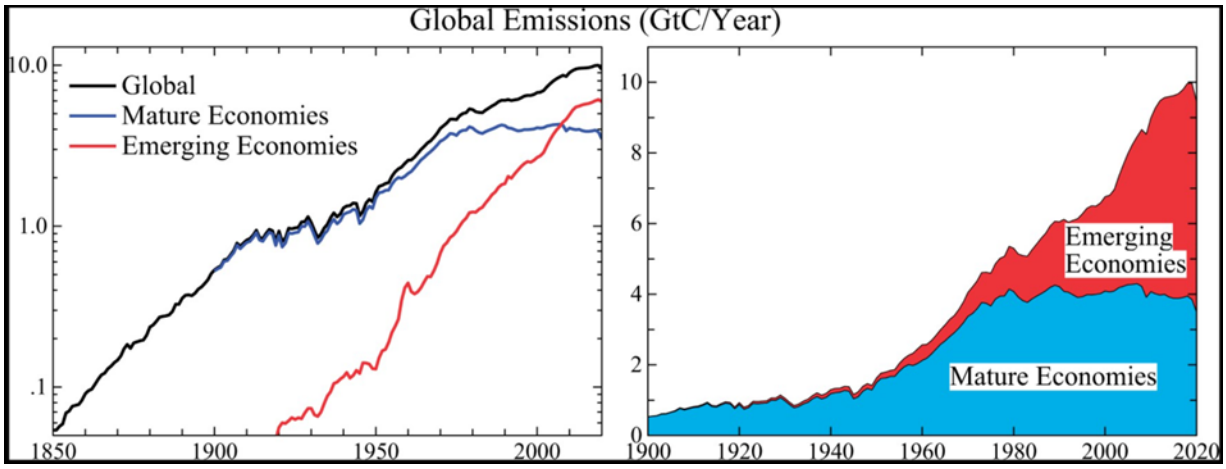
[6] James E Hansen, Makiko Sato, Leon Simons, Larissa S Nazarenko, Isabelle Sangha, Pushker Kharecha, James C Zachos, Karina von Schuckmann, Norman G Loeb, Matthew B Osman, Qinjian Jin, George Tselioudis, Eunbi Jeong, Andrew Lacis, Reto Ruedy, Gary Russell, Junji Cao, Jing Li, "Global warming in the pipeline, Oxford Open Climate Change, Volume 3, Issue 1, 2023, kgad008, Published Nov 2, 2023, https://doi.org/10.1093/oxfclm/kgad008

See the four figures below from reference 6.



Global energy consumption and CO_2 emissions.



Fossil fuel CO_2 emissions from mature and emerging economies. China is counted as an emerging economy. Note that the left chart has a logarithmic vertical scale, and the right chart is a stacked chart of mature and emerging economies.

Your author predicts: There will be no sudden acceleration of the world's economies' efforts to mitigate climate change, at least for the next decade. On the other hand, there will be continued slow, steady progress on many fronts (like in the prior sections). When humankind decides it has had enough (in future decades) we can accelerate our efforts and start to rapidly reduce the greenhouse gasses in our atmosphere.