Wildcards – the Path to 2050

By John Benson

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1. Introduction

Two weeks ago I completed a five-volume series of posts that were summaries of the six section NREL Storage Future Study and report (SFS). Volume 5 of this series is described and linked below, and it has links to the other volumes.

Energy Storage Futures, Vol 5, Role and Impact in 2050: *The National Renewable Energy Laboratory (NREL) over the last year released a multi-section study titled "Storage Futures Study," hereafter SFS. The high level goal of this is to model energy storage systems' implementation out to 2050.*

SFS section 6 reports the final result of this study, and volume 5 is a summary of this section and my final summary volume.

https://energycentral.com/c/cp/energy-storage-futures-vol-5-role-and-impact-2050

SFS strongly suggests that we have at least one clear path to Net-Zero greenhouse gas (GHG) by 2050. Furthermore, SFS took a really conservative approach in that it largely used existing technologies, and safe estimates of price reductions by 2050. But there may be multiple alternative paths, and some of these will come from new technology.

This paper will demonstrate that (1) a revolutionary new technology can be developed in approximately 20 years and (2) such new technologies frequently have major spin-offs.

2. The Model – the Modern Electric Vehicle (EV)

The first question this section will answer is, what was the first modern electric vehicle with substantial sales in the U.S.? Answer: the Nissan Leaf, *a compact five-door hatchback battery electric vehicle (BEV) manufactured by Nissan. It was introduced in Japan and the United States in December 2010 and is currently in its second generation, introduced in October 2017… The United States Environmental Protection Agency (EPA) rated the 2010 model at a range of 73 miles.*[1]

The current version of the Leaf has an EPA range of up to 226 miles and the version with this range cost around $33,500 before tax, license and any state or federal incentives. Currently the U.S. has over 1 million EVs, 11-years after the Leaf was introduced. Although it will take many decades (from now) for virtually all of the internal-combustion-powered vehicles to leave the road, it is likely that by 2030 that sales of EVs will dominate the sales of light vehicles. Thus the future time of a new technology to go from introduction to dominance is judged to be around 20-years.

Furthermore, a second major new product (functionally unrelated to EVs) was hastened by EV-technology: battery-energy storage systems (BESS). Indeed, the co-emergence of EVs and BESS lowered the price and thus boosted the sales of each.

[1] Wikipedia Article on the Nissan Leaf, https://en.wikipedia.org/wiki/Nissan_Leaf

Thus it is likely that future energy-related technologies will emerge that are currently not on our radar, and is also likely that other applications will spin out of these during their market entry.

3. Potential Future Emerging Technologies

The list of technologies below are certainly not comprehensive, because I've limited them to existing technologies that could potentially be developed to the point that they can produce or store large amounts of very-low- GHG power.

3.1. Nuclear Power

This might come via several potential paths as described below. The initial implementations may be in a few years, and continue out to near mid-century.

The link below is to a directory of nuclear development and support organizations. This directory has a healthy assortment of these groups, which increases the probability that, at some point, a viable nuclear power industry will develop.

https://gain.inl.gov/SiteAssets/Advanced%20Nuclear%20Directory/GAINAdvancedNuclearDirectory-SeventhEdition_07.01.2021(1).pdf

3.1.1. Small Modular Fission Reactors

There are already several versions of these in production, See the post below for details. The calling card for SMR's is that their components (like cores) are small enough to be mass produced and transported over the road to the plant site. The post below is to "Nukes Part 5" which has instructions in the intro to get to other "Nukes…"

https://energycentral.com/c/pip/nukes-%E2%80%93-part-5

3.1.2. Advanced Reactors

I wrote a recent post on what appears to me to be the best of this type. Although I posted this a few weeks ago (as I'm writing this), this paper has not yet made it into my directory of papers, thus I'm providing a link below.

https://energycentral.com/c/gn/nukes-%E2%80%93-part-6

3.1.3. Fusion Reactors

These are under development world-wide, but will not be ready for prime-time until near mid-century. There is a link to a post reviewing the largest fusion projects below.

https://energycentral.com/c/cp/distant-nuclear-fusion

3.1.4. Spin-off Products

All of the above nuclear reactors are utility-scale power-producers. There are a class of reactors that are commonly called micro-reactors. These are generally used for either thermal (heat) generation or power generation for applications that are much too small for the above designs. The best site I've found for these is linked below.

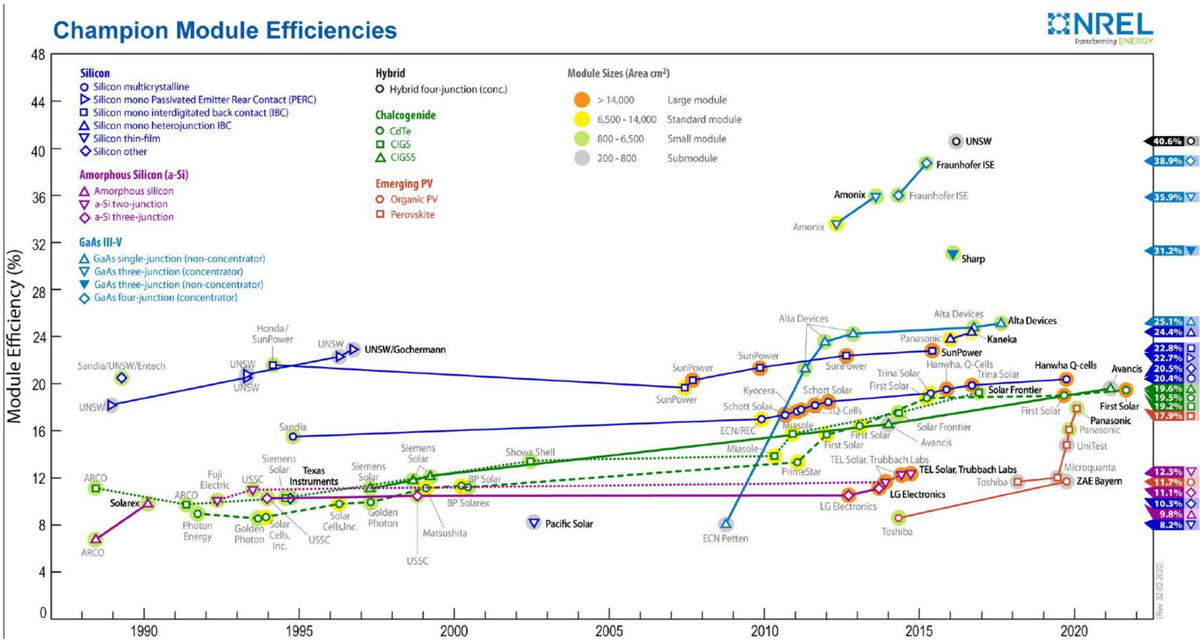
https://inl.gov/trending-topic/microreactors/

Another use for micro-reactors (and perhaps their big brothers) is for naval power generation. One of the SMRs (NuScale) is being converted by a third party to a ship-bourn reactor that will power on-shore loads. The U.S. Nuclear Navy has a long history of using this technology, but it probably needs to be made bullet-proof for civilian use.

3.2. Photovoltaic Power

Currently the most efficient Photovoltaic Modules (a.k.a. panels), that are commercially viable have an efficiency of around 27% (interdigitated back contact (IBC) with heterojunction passivating contacts). The IBC modules are just entering the market currently, and are expensive (but with their higher efficiency they are approaching competitive pricing and output levels vs. older technologies).

However, if you look at the chart below, you can see specialized modules (GaAs three- and four-junction modules) that are in the 40% efficiency range.



Although I don't believe that GaAs modules will be cost-effective anytime soon, I believe that in a decade or two the industry will develop modules that use the same architecture that they do (multi-layer cells with each layer absorbing a different solar-spectrum range), and I believe that they will rival the above top efficiencies.

Furthermore there is a pathway to get there. Just as existing high-volume panels (for utility-scale projects) have slowly climbed from 20% to 27% in the last decade, I believe this trend will continue. As efficiencies increase, older PV projects will be upgraded to new panels (and trackers, and inverters) with greater efficiencies and better pricing.

There are already spinoffs from utility PV technology like rooftop PV and PV on various types of vehicles. As efficiencies increase, these will proliferate.

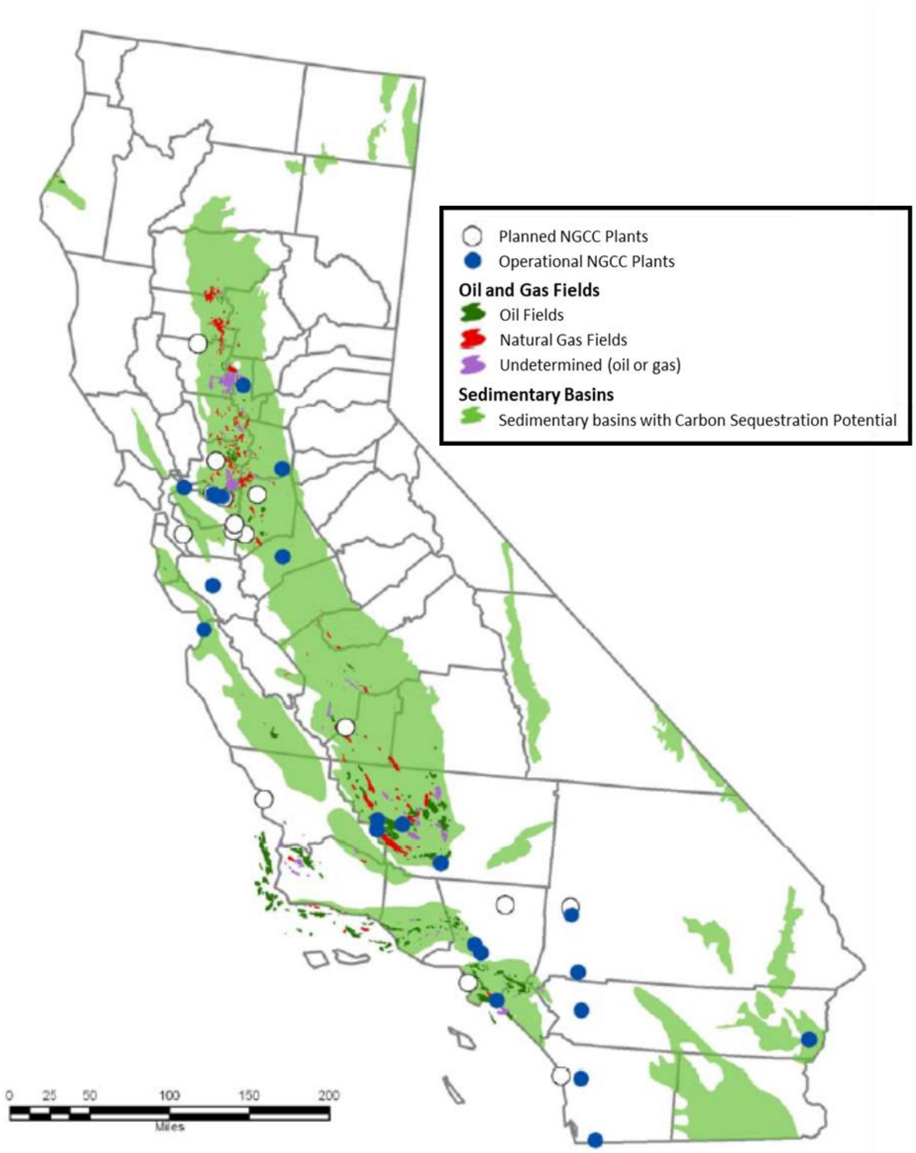
3.3. Biomethane + Net

Existing combined-cycle generating plants can already operate on biomethane with no modifications. The technology exists to produce biomethane from either biomass (via anaerobic digestion) or woody biomass (via pyrolysis and methanation).[2] The only piece that is not widely used is geological sequestration. The increasing price of carbon offsets in California will provide a strong incentive for owners of combined cycle plants to start

[2] See Section 3 of Tech Race: https://energycentral.com/c/cp/tech-race

using biomethane and sequestering the CO_2.[3] Also the CPUC has just started setting increasing biomethane procurement targets for gas pipelines.[4]

Although the above doesn't need any technology breakthroughs, it will change the need for renewables between now and 2050 if most of the California utility combined cycle generating plants (I counted over 30 of these in the map below) change to negative emissions technology. Also note from the map that most of the combined cycle power plants are over or near areas with sequestration potential.[5]



[3] Energy Central, "Carbon Offsets," Jan 2020, https://energycentral.com/c/cp/carbon-offsets
[4] California Public Utilities Commission (CPUC), "CPUC Sets Biomethane Targets for Utilities," Feb 24, 2022, https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-sets-biomethane-targets-for-utilities
[5] West Coast Regional Carbon Sequestration Partnership, "Assessment of Natural Gas Combined Cycle Plants for Carbon Dioxide Capture and Storage in Gas-Dominated Electricity Market," 2020, http://www.westcarb.org/pdfs/att20-prelimassessment.pdf

3.3.1. Spin-off Products

The primary spin-off product is obvious – a reliable, dispatchable source of electricity that isn't just renewable, but removes CO_2 from the environment and sequesters it for centuries to millennia. Another spin-off would be sequestration services for industrial sources of carbon dioxide.[6]

3.4. Energy Storage

Energy storage is the primary participant in the EV revolution, and may have the potential for a second act. Although various lithium-based chemistries are the state of the art today, there are many emerging chemistries and technologies that could boost the output and lower the cost of EVs and battery energy storage systems well beyond anything that SFS envisioned. The following are descriptions and references for a few future technologies.

The Perfect Rechargeable Battery? *From a chemical standpoint one battery chemistry, lithium-sulfur appears to be perfect, except for several major issues that made it totally non-viable in the past.*

Now a Company has designed a fix for all of these problems, by designing a completely new cathode material, and they will begin limited production of these batteries by the end of the this year.

This post is about this development, how it as the potential to be a game-changer for a number of industries, and how this development is different than every other "battery of the future."

https://energycentral.com/c/ec/perfect-rechargeable-battery

New Battery Technology: *In this post we will look at two more lithium-ion battery designs that include solid electrolytes and metallic lithium anodes and a third similar design that was reviewed earlier. All three of these designs have progressed enough to where they should be in EVs that are on the road by 2025.*

https://energycentral.com/c/ec/new-battery-technology

Future Long-Term Storage: *The hot technology now is Short-Term Storage (read: lithium-ion battery energy storage systems or BESS), and I write about these frequently.*

However there are really two or three types of energy storage systems from a duration (discharge time) standpoint. Li-ion BESS typically have a one to four-hour discharge period at full-output. Although it really hasn't found a strong market, a BESS based on flow-battery technology can economically provide a duration of up to eight hours.

And finally we have the subject of this post. Long-Term storage potentially provides a duration longer than could be economically provided by a Flow-BESS. In this post I will cover pumped storage, also I will cover a technology for long-term storage based on green-hydrogen, and finally a couple of emerging technologies that might provide long-term storage in the future.

https://energycentral.com/c/cp/future-long-term-storage

[6] Energy Central, "Verification of Geologic Greenhouse Gas Sequestration," Nov 2019, https://www.energycentral.com/c/cp/verification-geologic-greenhouse-gas-sequestration