Opinion

Japan Can Economically Decarbonize

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Experience abroad proves that variable renewables can be predicted, and along with efficiency improvements and flexibility measures, provide the most cost effective and reliable resource to achieve decarbonization and energy security at the same time.

1. Integrative design can improve energy productivity by three-fold more than previously assumed

As described in my previous study [1], much of the efficiency improvement is not in the technology itself, but in the way the technology is selected and combined －the design.

For example, integrative design for pipes and ducts can reduce friction, hence pump and fan power, by 80－90＋%, and that full potential could cut the entire world's coal-fired power in half.

Energy productivity has increased more than I predicted in 1975, and can could rise another three-fold by 2040 or five-fold by 2060.

2. 100% renewable is possible, because sun and wind are predictable, and much demand is flexible (experience abroad)

We are still told that only coal, gas, and nuclear stations can keep the lights on, because they are 24/7, while wind power and solar power are variable, thus supposedly unreliable. But variable does not mean unpredictable. **Fig. 1** shows how accurately the French grid operator in one stormy winter month forecast one day ahead the actual output of the country's wind farms. A decade later, Danish wind farms can reliably bid into the day-ahead hourly auctions just like fossil fuel capacity, because the forecasting is now so accurate.

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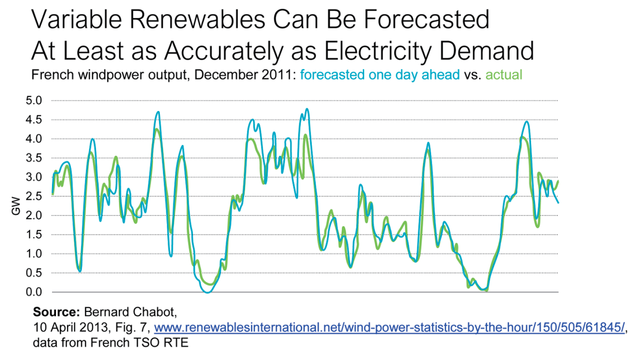

Fig. 1 A day-ahead wind power forecast and actual output

Without using fossil fuel to back up, there are about ten carbon-free ways, conceptually sketched in **Fig. 2**, to balance a renewably powered grid reliably across all time-scales. Big batteries typically are costliest and therefore come last, not first.

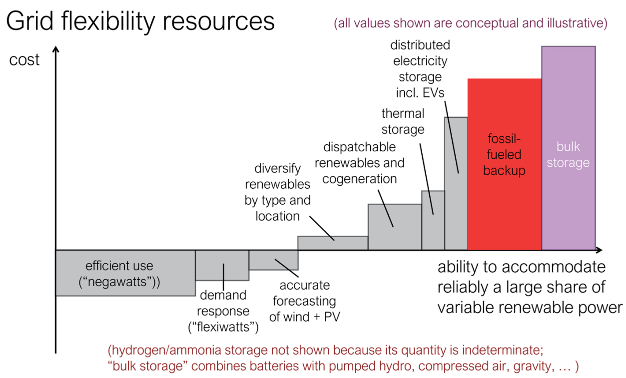

Fig. 2 Grid flexibility resources (conceptual figure)

For example, the electric vehicles now taking over the world auto market are starting to charge bi-directionally. They could profitably add at least several gigawatts or more of storage capacity each year in a country like Japan.

Two years ago, one European aggregator was earning an eighth of a million yen per auto battery per year by selling 13 of 21 kinds of valuable services back to the grid. Australia now gets more frequency stabilization from batteries' demand response and other inverter-driven resources than it does from coal plants, making

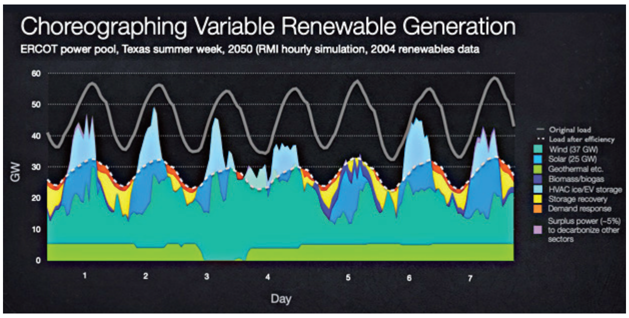

Fig. 3 Analysis for 100% renewable electricity supply in Texas, in summer 2050

that valuable service 39% cheaper in the past year. And electric cars are starting to join that supply.

Indeed, we built the grid because no generator is 24/7. They all break. Grids manage this intermittence by backing up failed plants with working plants. In exactly the same way, but at lower cost, grids can manage the forecastable variation of solar and wind power by backing up those variable renewables with a portfolio of other renewables – all forecasted, integrated, and diversified by type and by location.

Let me illustrate this with a difficult case that RMI analyzed 13 years ago. The state of Texas is nearly twice the size of Japan, hot, often humid. It has virtually no hydroelectricity, a mainly Kansai-like climate, and a nearly isolated grid. The varying loads that were then forecasted for a summer week in 2050 do become smaller and less peaky with profitably efficient use, but they still need more than 30 peak GW. The hourly simulation shown makes that electricity 86% from wind and PVs, 14% from dispatchable renewables, and a little bit from biogas and biomass, also dispatchable.

That leaves surplus power to charge ice-storage air conditioners and smart bidirectionally-charging electric automobiles. Then recovering that distributed storage (in yellow) when needed, and filling the last gaps with unobtrusively flexible demand (in orange), yields 100 % renewable electricity every hour of the year with no bulk storage, and with only 5 % left over to decarbonize other sectors, yielding great economics even at today's prices.

As for demand response (timely use of electricity), the summary of 14 years of experiments with four kinds of time-dependent electricity pricing (plus information and technology) on three continents shows peak reductions above 30%, even above 50% [2].

3. Recommendation to Japan : No time and money to waste on legacy fossil assets

Renewables are the cheapest new source of bulk electricity, and can be reliably forecast with currently existing technologies, and combined with efficient end-use and with demand response.

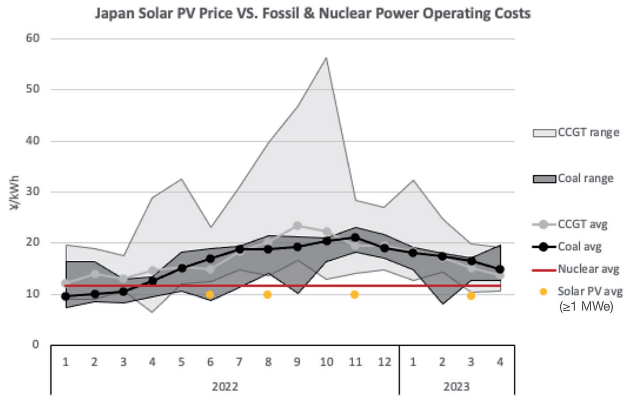

Fig. 4 Japan solar PV price vs. fossil & nuclear operating costs [a]

Today, Japan's new solar electricity costs less than 10 yen per kWh. That's about half the operating cost of fully amortized coal-fired or LNG plants. Bloomberg found that, now in Japan and for 82% of global power generation, unsubsidized renewables are now the least-cost source of new bulk electricity, in an analysis based on 31,000 actual projects worldwide [3].

New solar also beats restarted nuclear plants as shown in **Fig. 4**, and therefore should be dispatched first, before inflexible nuclear plants, to unburden customers and boost Japan's competitiveness. However, national and utility policies still shield legacy assets from competition by doing the opposite of economic dispatch. Curtailment that is idling existing renewable plants in order to run costly nuclear and fossil plants has now spread to every region of Japan except Tokyo.

The claim that nuclear expansion would enhance energy security is contradicted by France's continuing nuclear shortfalls, which caused a deeper gas shortage in Europe than Putin's War did.

Using hydrogen or ammonia is the most expensive way to supply bulk electricity. It should be limited to supplying long-term storage for extreme conditions. Even for that use, hydrogen is not always the best option. U.S. NREL conservatively studied the optimal supply mix for achieving a 100% renewable grid, and found that displacing long-duration hydrogen storage with retrofitting conventional building efficiency plus extra renewables can cut investments by about a factor 10[4].

There are more than 700 peer-reviewed analyses of 100% renewable electricity or energy systems now published worldwide. But these are just about choices of what details will be for the last 10 or 20% of supply around 2050. We don't need to know those details now. We only need to know that we'll have ample and attractive options to choose from at mid-century. As climatologist Prof. Ken Caldeira wrote, controversies about how to handle the end game should not overly influence our opening moves.

Japan's renewable electricity fraction in 2022 was just over 20%, while Germany, England, and Ireland were at almost 50%, Denmark at 84% (2022), Scotland at 99% (2020), Spain at 46% (2020), and Portugal at 66% (2018). All of these countries are able to operate without large storage batteries while also ensuring reliability. In Germany, the renewable share of electricity quadrupled in 2006-2021, while grid reliability improved (i.e., outage times decreased). The grid is run the way a conductor leads the Tokyo Philharmonic Orchestra : no instrument plays all the time, but the ensemble continuously makes beautiful music.

Is it because German engineers are so good? Perhaps so, but Japanese engineers are also very good. With integrative design, renewable energy, and wide use of flexibility resources, decarbonization can be achieved in Japan economically at an early date.

References

1) Amory B. Lovins : How big is the energy efficiency resource?, Environ. Res. Lett. 13 090401, 2018, https://doi.org/10.1088/1748-9326/aad965
2) Regulatory Assistance Project and the Brattle Group : Time-varying and Dynamic Rate Design (2012).
3) Bloomberg New Energy Finance, https://www.bnef.com/insights/31487 (Accessed on October 26, 2023).
4) S. Hussainey & W. Livingood, “Optimal strategies for a cost-effective and reliable 100% renewable electric grid,” J. Ren. Sust. En. 13, 066301 (2021), https://doi.org/10.1063/5.0064570, 2 Nov 2021.

Note

a) For existing coal and CCGT power plants : the operating cost is essentially the fuel cost observed (i.e., imported steam coal and LNG) . Operation & maintenance cost is ¥3/kWh for coal and ¥1/kWh for CCGT. Electrical conversion efficiency is 40% for coal and 55% for CCGT. Capacity factor is 75% for both coal and CCGT. No carbon cost is included (because it is currently negligible in Japan) . Initial investment is assumed fully amortized. For nuclear power plants : based on restarted reactors. Operating cost includes restart cost (i.e., safety upgrades) , fuel cost, and operation & maintenance cost. Capacity factor is 70%. Initial investment is assumed fully amortized. Lifetime extensions included when granted. For solar PV : based on auctions for projects ≥ 1 MW. Price includes total cost and profit. After auctions, solar PV power plants should typically start operation within 3 years. Steam coal and LNG from Japan MoF, nuclear from Professor K. Oshima (Ryukoku University) , and solar PV from OCCTO. Courtesy of Dr Romain Zissler, Renewable Energy Institute, Tōkyō, 18 June 2023. Consistent with https://www.bnef.com/flagships/lcoe, 11 June 2023.