April 23, 2012

Japan has many energy problems and not a lot of options.

1. Imports almost all its energy
2. Has limited land for alternative energy use, small area, over 75% mountains, high population
3. Suffers from earthquakes, tsunamis and typhoons
4. Wants' to eliminate nuclear power
5. Is committed to greenhouse gas reduction(GHGR)

StratoSolar can help solve these problems.

1. Reduces imported energy and GHG while providing affordable electricity
2. Uses little land
3. Is impervious to earthquakes, tsunamis and typhoons
4. Could help replace nuclear in the short term, and with cost reduction over time could replace all energy sources with the addition of PV plants for fuel synthesis.
5. Solar PV on the ground or wind power are not realistic large scale options for Japan.
    a. Not enough land
    b. Severe weather raises costs
    c. Intermittent supply limits percentage of grid
    d. Are inherently expensive

Deployment scenarios for Japan

Electricity Generation (TWh)scenarios for Japan

	2008	**2008**	**2020+N**	**2020+N**	**2020-N**	**2020-N**
StratoSolar	0%	0	25%	250	40%	400
natural gas	26%	260	16%	156	21%	206
oil	9%	90	5%	54	7%	71
coal	28%	280	17%	168	22%	222
Fossil	63%	630	38%	378	50%	500
Nuclear	27%	270	27%	270	0%	-
Hydro	8%	80	8%	80	8%	80
renewable	2%	20	2%	20	2%	20
Total	100%	1,000	100%	998	100%	1,000

The table above shows electricity generation by source for 2008 (IEA data) and two possible 2020 scenarios that include StratoSolar, 2020+N that keeps nuclear and 2020-N that abandons nuclear. Both scenarios assume that annual generation demand stays constant at 1000TWh.

Given the lack of electricity storage the daylight demand for electricity sets the realistic StratoSolar capacity in both scenarios.

2020+N scenario

In the 2020+N scenario Nuclear power stays at 2008 levels (270TWh) and StratoSolar provides 25% of electricity (250TWh). The 2008 existing fossil fuel capacity running at a lower utilization is the companion generation. Fossil fuel drops from 63% in 2008 to 38% in 2020. We assume the distribution among fossil fuels would stay the same, but in reality it would probably shift, with gas generation being favored over oil and coal.

The 250TWh of StratoSolar generation would need about 100GWp of PV capacity with a PV panel area of about 540km^2. At an average cost of $1.50/Wp, The cost would be about $150B, or an average of $15B a year. There would be no additional costs for spinning backup, electricity storage or grid changes. The electricity generated would average a levelized cost of about $0.06/kWh.

2020-N scenario

The 2020-N scenario has no nuclear, StratoSolar provides 40% of electricity (400TWh) and fossil generation only falls from 63% to 50%.

The 400TWh of StratoSolar generation would need about 150GWp of PV capacity with a PV panel area of about 840km^2. At an average cost of $1.50/Wp, the cost would be about $225B, or an average of $22B a year. There would be no additional costs for spinning backup, electricity storage or grid changes. The PV electricity generated would average a levelized cost of about $0.06/kWh.

Total energy scenario

Japan's total primary energy demand is about 6500TWh (22quadrillion Btu) (EIA 2008). To gain a perspective on the practical limits to StratoSolar-PV deployment it is interesting to examine what this scale of generation would mean.

Allowing for the fact that some of the primary energy makes electricity, 4000TWh of StratoSolar-PV generation might satisfy all of Japan's energy needs. This would represent about a tenfold increase on the 2020-N scenario's 400TWh. Plausibly this would take many decades to deploy, and on a learning curve, capital costs could come down to below $0.50/Wp and increased PV efficiencies of about 30% would reduce the PV panel area required to about 6500km^2. If we use 17 plants, each plant would have a capacity of about 90GWp. For the hexagonal plants depicted, the radius would increase from about 4,300m for 2020-N plants to about 12,000m. This is big, but plausible over a fifty-year time horizon.

For comparison consider fossil free alternatives that provide 4000TWh of energy.

1. Nuclear: about 800 plants of the size of the current 54 operating plants.
2. Wind: about 300,000 5MW windmills and a reasonable electricity storage solution.
3. Ground Solar: about 15,000km^2 of PV panels, about 40,000km^2 of reasonably flat land and a reasonable electricity storage solution.

The table below shows land use for various energy alternatives. Exclusion is land area affected but still available for limited use. For nuclear the exclusion area is the international standard 30km radius evacuation zone. This is the area of possible permanent contamination in a major accident and rationally should not include any major urbanization. For wind the exclusion area is more restricted only allowing agriculture. Ground PV exclusion allows for no other use. StratoSolar exclusion use is similar to nuclear allowing anything but dense urban use. Occupied shows the land area actually occupied

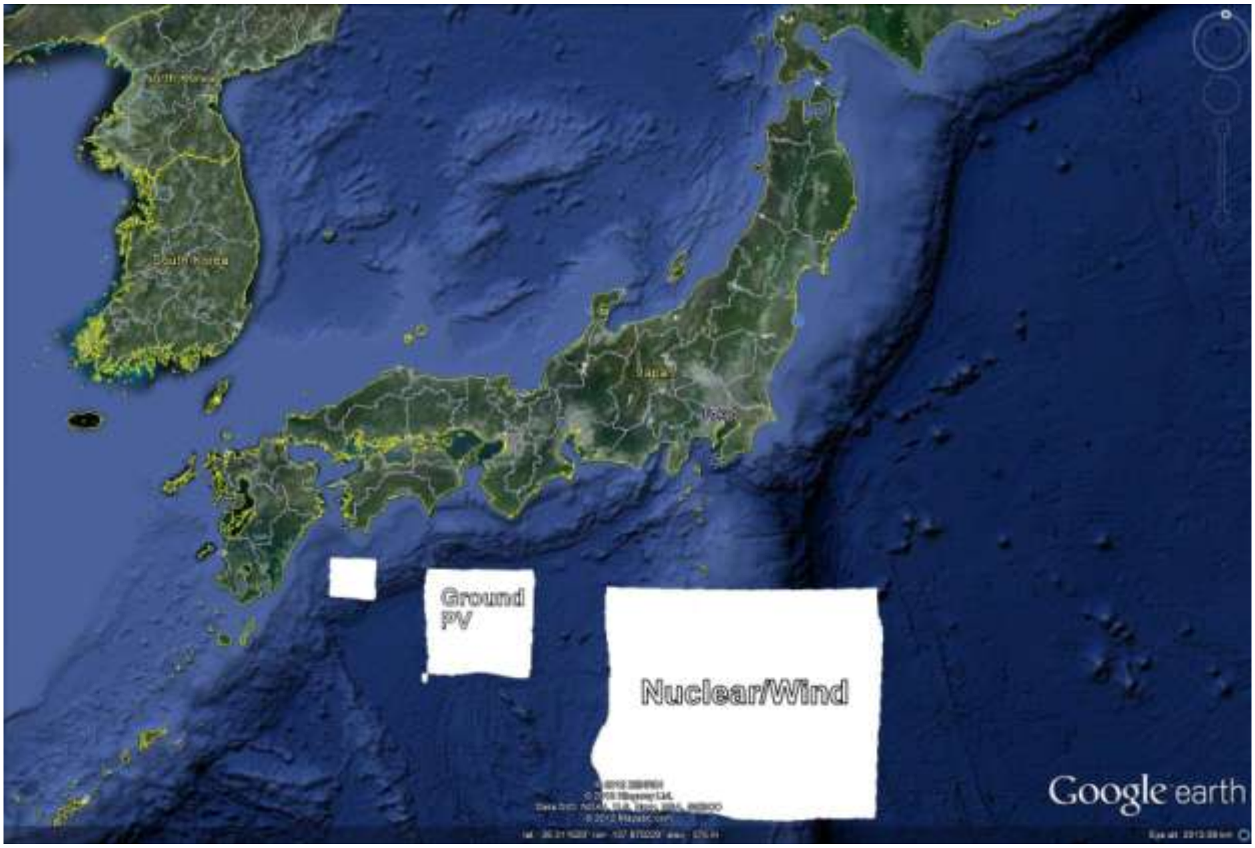
LAND USE	**(km^2/TWh/y)**			
	Nuclear	**Wind**	**Ground PV**	**StratoSolar**
exclusion	72	77	13	2.5
occupied	<1	2	13	<1

	TWh	**nuclear**	**wind**	**ground PV**	**StratoSolar**
Japan	4000	286,707	307,770	50,701	10,140

The table above shows the land area in km^2 affected by 4000TWh of generation for the various sources. Japan's total land area is 377,835 km^2, 73% of which is mountainous.

None of these options but StratoSolar seem plausible due to space constraints alone. In addition all are expensive and likely to get more expensive when we count storage and grid costs. Extreme weather is a big problem for wind and ground solar. Nuclear has public acceptance, safety, cost, and waste issues.

The PV electricity expansion beyond 2020 makes synthetic fuels, which can proceed without electricity storage. It does require the construction of synthetic fuel plants. A current gas to liquid (GTL) fuel plant synthesizes 100,000 barrels a day and costs about $10B. Based on this experience same sized electricity to liquid plants would cost around $15B. Japan would need 30 to 40 such plants to meet its fuel needs. The synthetic fuel plant investment would be less a fraction of the PV plant investment to power the fuel plants. The synthetic gasoline or diesel would cost less than $4.00/gal initially and reduce over time.



Location and size of StratoSolar plants

This picture shows 17 Japanese nuclear power plant sites with StratoSolar PV plants tethered overhead for the 400TWh of electricity scenario. Fukushima shows the larger plant size necessary for all energy and is the only easily visible plant. The smaller white area at the bottom left shows the area of ground PV to provide 400TWh of electricity. The larger area represents the area of land needed for ground PV to provide all 4000TWh of current energy. The largest area represents the area of land needed for wind or nuclear to provide all 4000TWh of current energy.

Because of the limited space available and the constraint of being a reasonable distance from population centers, where to site StratoSolar plants and how many plants to build pose an interesting problem. One possibility would be to tether StratoSolar plants at current nuclear plant sites. These are already away from population centers and already have the power lines connected to the grid. Japan's many space constraints would probably mean that a few large plants would be preferred to many small plants. The map above shows StratoSolar plants positioned at 17 current nuclear plant sites.

One plan would be to build plants at these 17 sites, and grow the plants over time rather than adding new plants. The modular approach for deployment and maintenance would make this possible. Many things improve with larger plants, but the scale of a potential plant loss increases. This would put a heavy emphasis on the design of safety systems to limit the possibility of catastrophic loss of a complete power plant.