Options for Solar Power

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Introduction

In the first lecture of the climate-energy nexus series we explored the imperative of limiting CO2 emissions to 350 ppm to avoid the dangerous consequences of global warming. In reality we are presently at 396 ppm and rising. At the last UNFCCC Conference of Parties in Durban in December 2011, an agreement was worked out committing governments to agree a new global deal to mitigate GHG by 2015 and have it in force by 2020, with every country included. The actual agreement seems to give small island states some flexibility in committing but the wording is vague. Already doubts are being cast on the reality of a 2015 commitment, and as suggested in the first lecture, commitment will probable only come when evidence of dangerous consequences, such as accelerated sea level rise, increased extra-tropical storms or increased heat waves, begin to mount, perhaps in 10 to 20 years' time. When that time comes, all countries including Jamaica will be forced to commit, especially since the carbon footprint of the Caribbean compares to some European countries. (Also by that time Jamaica expects to become a first world country and so it will not be allowed leeway given to less developed countries.) So in looking at our vision 2030, we should see renewable energy as much more than 20% of our energy mix. I am glad to see that just last week, the PM announced that the new target will be 30%.

We should also be thinking of using more renewable energy as a step towards making the island more energy secure. The cost of RE is sloping downward. The levelized cost of wind is approximately US$0.12/kWh. Solar panel prices have fallen dramatically in the last 2 years. The cost of solar thermal energy is trending downward. We can expect large cost reductions through technical advances, manufacturing improvements and large scale production. These sources will make Jamaica more secure in energy since we have large resources of solar and wind, hydro and waste.

How much?

How much fossil fuel can we replace with RE? Theoretically we could produce 100% of our electricity from RE. Take as an example, the daily electricity consumption, which is 13700 MegaWatt-hours. If you assume a daily amount provided by other RE as 3200 MegaWatt-hours, to be provided by wind and hyro, then the amount to be provided by solar is 10500 MegaWatt-hours. Based on the solar radiation map of Jamaica, Produced by the Physics Department in 1994, we receive about 0.005 MegaWatt-hour/sq.meter of solar radiation. If we assume that our solar device is only about 20% efficient, we can show by calculation that the radiation falling on $1/1000^{th}$ of land area of Jamaica is sufficient to provide the 10500 MegaWatt-hours needed. We have no shortage of RE resources.

Solar Photovoltaic Farm

Thus solar farms such as used in India, China, USA, Canada and Germany in conjunction with huge inverters can supply our energy needs. They would be ideally suited for distributive generation needs, talked about in the last lecture by Mr Aston Stephens.

The largest solar farm is the Gujarat Solar Park in India. When completed it will generated 605 MW of power.

http://cleantechnica.com/2012/04/20/worlds-largest-solar-pv-power-plant-added-to-indias-grid/

With solar PV prices so low, US$1000 or less per kWatt ex factory, we should now be investigating the feasibility of solar farms. For example if it costs US$3800 per kWatt to install, the cost of producing electricity over the lifetime of the system is approximately 10.5¢/kWh. However to service the loan in the initial stages, the investor would have to charge much more, but after serving the loan there will be little operating and maintenance cost so that the charges can be ratcheted down. A feed-in tariff incentive could be offered to investors.

Feed-in tariff is a policy mechanism to encourage investment in renewable energy. It offers upfront higher tariffs to RE producers, higher than those given to fossil fuel producers. However the tariffs can be fixed and the contracts are long term. So that there can be benefits to the country and to consumers if the cost of fossil fuel increases significantly, while the cost of RE remains fixed. On the other hand, feed-in tariffs can include "tariff degression", which is a mechanism according to which the price (or tariff) ratchets down over time. This is done in order to track and encourage technological cost reductions. Again the country and consumers can benefit if the cost of fossil fuel increases significantly.

Firm Energy Needed

Of course the problem of using RE as a large percentage of the energy mix is the need to address the nececesssity for firm energy when the RE resource fluctuates, such as on days of calm, or overcast days. We could probable go up to 30% RE without serious problems, since there will be enough spinning reserve from conventional plants. Germany, e.g., has already achieved 20% RE of total power generations with a target of 80%, and Japan is debating renewable energy targets of between 25% to 35%.

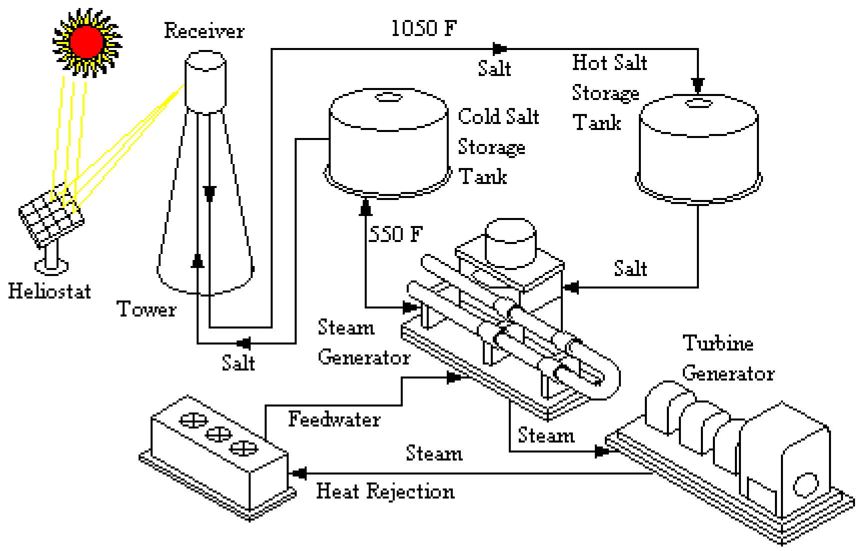
We can go higher than 30% if the problem of firming energy is addressed. This problem is being addressed in Portugal by the use of pumped storage, whereby water is pumped to an elevated storage reservoir in times of excess RE and recovered by gravity in RE down-time. Of course the drawback is the additional cost of building a reservoir, but this may be offset by using the reservoir to aid water management. It would be a complicated however, but not unmanageable especially with the ability to predict wind and solar radiation and demand.

Firming of energy can also be done by the use of combined cycle gas turbines which can be used for spinning reserve, because of their ability to run at low power (50%) and to be quickly brought up to full power. This method however would be inefficient with a lot of wasted energy when the RE plants are running at capacity. Again the ability to predict wind and solar radiation and demand would lead to a more efficient system.

Solar Thermal with Storage and OTEC are the solutions

Solar Towers and Parabolic Troughs

Solar Power Towers and Parabolic Troughs can store energy overnight and can be part of the solution for firm energy. In the solar towers system a tower resides in the centre of the field, while thousands of tracking mirrors (called heliostats) in roughly a two square mile field capture and focus the sun's thermal energy in concentrated form onto a receiver at the top of the tower. Within the receiver the concentrated sunlight heats molten salt to over 1,000 °F (538 °C). The heated molten salt then flows into a thermal storage tank where it is stored, maintaining 98% thermal efficiency, and eventually pumped to a steam generator. The steam drives a standard turbine which uses the Rankine cycle, similar to a standard fossil fuel power plant, to produce electricity.



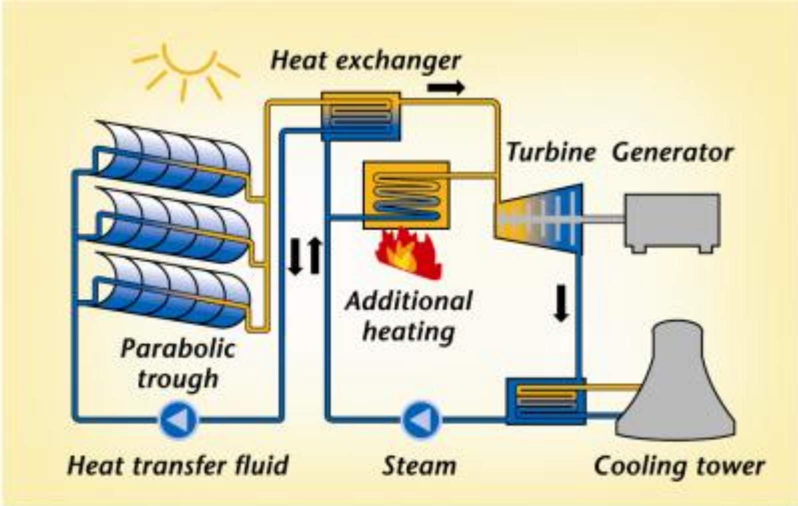
http://www.earthpm.com/tag/solar-tower/

There are many solar thermal plants worldwide, but mainly in Spain. Gemasolar, in Fuentes de Andalucía, Spain, bills itself as the world's first commercial-scale concentrated solar power plant (CSP) that uses molten salts receiver technology. The tower is 450 ft. high and there are 2,650 large mirrors in the field. Those energy-storing salts are a combination of 60% sodium nitrate and 40% potassium nitrate and are so hot that they are always in a liquid form. It can generate electricity for 15 hours in the absence of sunlight.

The usefulness of systems like these is that, since they use the Rankin cycle, it is possible to design them to use auxiliary fossil fuel heating when the solar storage is insufficient. Recall that in our scenario we are interested in using fossil only as a backup for RE.

Solar Parabolic Troughs

Parabolic trough systems also use concentrated solar power and can store energy. The system consists of oblong parabolic troughs which focus concentrated sunlight unto tubes carrying a heat transfer fluid, usually oil. The hot fluid at temperatures of about 400ºC transfers heat at a heat exchanger for storage in a salt solution or to produce high pressure steam used drive a conventional Rankine cycle steam power plant. Again there are many parabolic troughs worldwide, but mainly in Spain.



http://greenterrafirma.com/solar-thermal-for-electricity.html

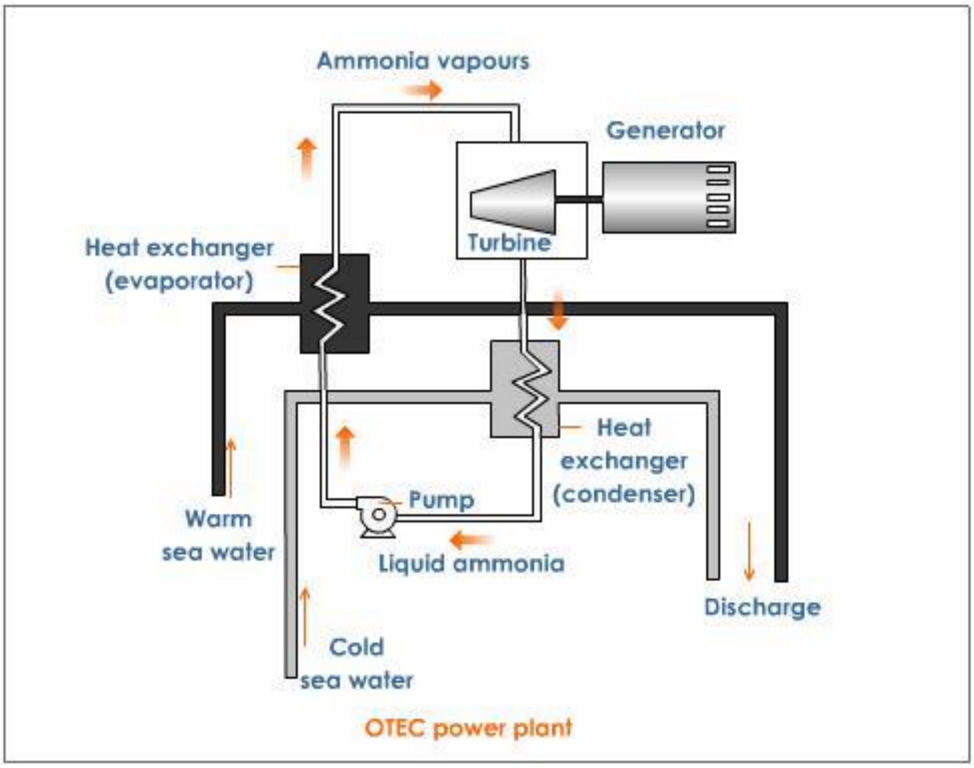
OTEC

The ideal solar energy plant for small island states is Ocean Thermal Energy Conversion (OTEC) since it can produce large amounts of electricity and energy storage is not a problem since the ocean has an enormous heat storage capacity. In addition possible by-products are desalinated water for domestic consumption and nutrients or fertilizer for agricultural use. I include OTEC under solar energy options since the ultimate source of the energy of the ocean is the sun's energy which it stores.

The operating principle is quite simple. It is similar to that of a steam turbine, which uses water as the working fluid, in the sense that water is made to drive the turbine by changing phases from liquid to vapour. Thus the steam turbine requires a heat source at the evaporator to produce steam which drives the turbine and a cold source at the condenser to liquefy the steam exiting from the turbine so that the cycle can be repeated. In the steam turbine, burning of oil provides the heat source and cold water provides the cold source.

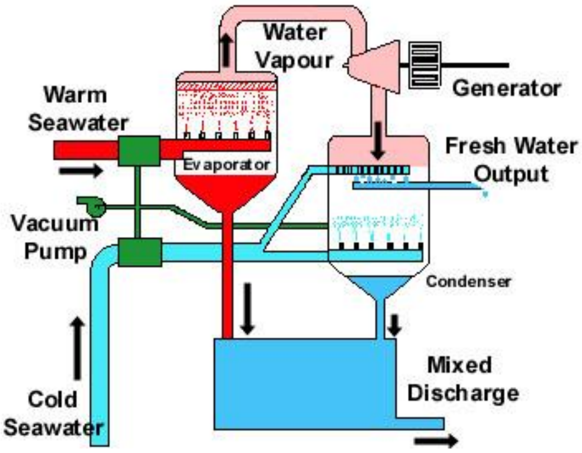
Since the temperature at the surface of the ocean is hotter than in the depths of the ocean, the surface and the deep ocean can be used as the hot and cold source respectively in OTEC. The working fluid which drives the turbine is one which evaporates at the temperature of the ocean surface and condenses at the temperature at the ocean depth. Ammonia is the most common working fluid in a closed cycle system, while sea water under partial vacuum is used as the working substance in an open cycle system.

Closed cycle:



http://www.tutorvista.com/content/science/science-ii/sources-energy/ocean-thermal-energy.php

Open cycle:



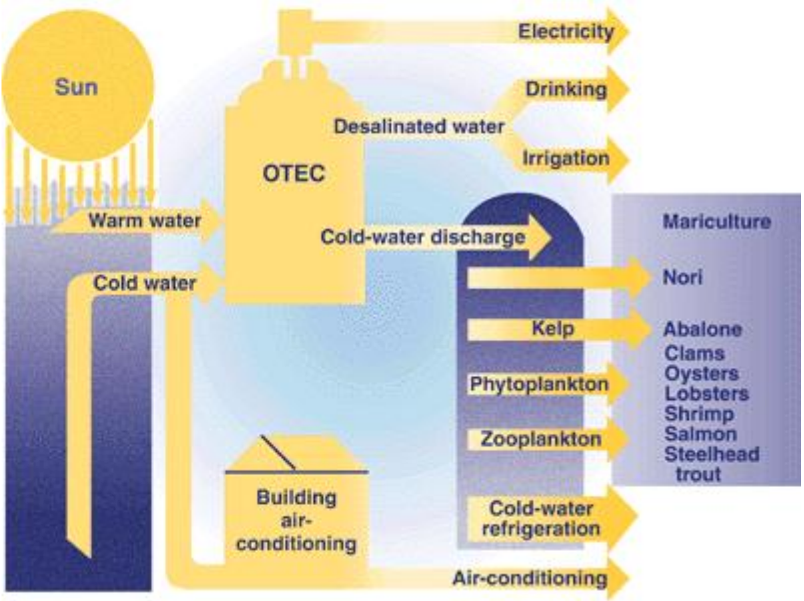
http://www.futurelab.net/blogs/marketing-strategy-innovation/2007/09/the_renewable_electron_economy_2.html

In the tropics there are many islands, including Jamaica, where the difference in temperatures between the surface of the ocean and a depth of 1000 m is between 20ºC and 22˚C. This temperature difference is sufficient to operate an OTEC power plant with about 3% efficiency. This efficiency is very small but since the ocean stores a great amount of energy it is possible to extract large amounts of energy from an OTEC plant.

There were many technical problems to overcome including pumping water through pipes from 1000 m below the surface, biofouling of the pipes and the design of heat exchangers. Experimental plants, both on-shore and off-shore, have been built between 1930 and the present. The most advanced may be the 210 kW open cycle NEHLA Experimental Plant in Hawaii and the 100 kW Japanese closed cycle plant in the Republic Nauru. Earlier this year the Natural Energy Laboratory of Hawaii Authority (NELHA) Board of Directors authorized final lease negotiations with OTEC International LLC (OTI) to construct a one-megawatt full-cycle demonstration plant at the Hawaii Ocean Science and Technology (HOST) Park here.

And commercialization may not be far away. OTI is negotiating with Hawaiian Electric Company for a 100 MW plant off Oahu and with the Caribbean Utilities Company in Cayman for a 25 MW plant. Ocean Thermal Energy Corporation and Bahamas Electricity Corporation have signed a Memorandum of Understanding to develop two 5 – 10 MW OTEC plants in the Bahamas. The press release for the Bahamas agreement claims these will be the world’s first two commercially operational plants.

Besides reducing our dependence on oil, OTEC has other advantages. The open cycle OTEC produces desalinated water as a by-product and high nutrient deep water can be recovered to grow shell and other fishes



Bottom Line

Can we use solar thermal and OTEC to solve our energy needs? It depends on the bottom line, whether or not we can afford it. All the processes mentioned are technically feasible. The question is whether or not they are economically feasible. For the answer we must look at 2 modalities of economic feasibility.

One, are solar thermal and OTEC directly competitive with fossil fuel without incentives? The present answer is no. However with technical advances, through research and development, manufacturing improvements and large scale production, they will become competitive. I have cited as examples the downward trend in the price of wind and solar photovoltaic. The cost of solar thermal plants will surely fall. A market report, which is selling for US$3500 on the internet, contains information which shows that global solar thermal cumulative installed capacity has grown from 354 MW (Megawatts) in 2001 to 697 MW in 2009 at a compound annual growth rate (CAGR) of 9% per annum. However, the planned projects that are coming online from 2010 onwards are anticipated to accelerate the CAGR to 46% per annum during 2010 to 2020. In 2020, the solar thermal power capacity is expected to reach at 122,252 MW from 2,715 MW in 2010. With competition to install such large capacities, prices will surely fall.

Because OTEC systems have not yet been widely deployed, cost estimates are uncertain. Wikipedia states that one study estimates power generation costs as low as US $0.07 per kilowatt-hour, compared with $0.05 - $0.07 for subsidized wind systems. The original source could not be found and no dates were given. Xenesys Inc, a Japanese company incorporated in 1989, gives a comparison of OTEC with coal and LNG, stating that a 50MW commercial OTEC plant will be as competitive as the two. It is apparently based on a 2004 calculation. I assume that these forecasts are not as reliable as the market forecast for solar thermal above.

The other economic modality to consider is whether or not, it will make economic sense for the country as a whole to employ solar thermal if feed-in tariffs are allowed, despite the current high costs. This is an exercise that should be done by the Government.

In addition to these 2 modalities let us discuss if there are mechanisms which can make the cost of solar thermal and OTEC trend down faster than forecasted. R&D for solar thermal and OTEC are driven by private companies which aim at specific markets. For example, parabolic troughs are designed for sunny areas in temperate climate such as in California or Spain. Therefore they worry about freezing of the heat transfer fluid and use oil as the fluid of choice, instead of salt, since it will not freeze in the winter, whereas salt will. But salt can achieve much higher temperatures and lead to more efficient operations. If a solar parabolic trough system using a salt solution were designed for tropical countries, higher efficiencies could be achieved. Take also the case of R&D on OTEC. It is my opinion that only a few of these plants have been built because they are primarily of benefit to small island states.

How can the situation change?

I am proposing that it can be done through the mitigation funds which come as a result of the UNFCCC negotiations at the Conference of the Parties. At present, most of these funds go toward networking countries to effect consultation between developed and developing countries, and also toward development of RE in individual countries. All these funds, and more since the funds are supposed to be increased, could be pooled to finance an international R&D centre with a focus on Solar Thermal with storage and OTEC, with high quality engineers capable of accomplishing the task of designing RE for developing countries. It could take the form of a central body residing at e.g., AOSIS or SIDS, driving the process. If the task of reducing cost is achieved then developing countries themselves can invest in these technologies through World Bank loans and other sources of soft loans. I would argue that using the mitigation funds and even some of the adaptation funds that come from the UNFCC negotiations to establish an international R&D centre is a much more effective way of utilizing the funds. I would like our negotiators at UNFCC to seriously consider this proposal. Obviously fine tuning this proposal would require detailed ground work. The Climate and Energy Technology Group at Mona (Ambassador Hill, etc.) would be willing to assist in this task.

Small Scale Solar Energy Usage

I have not said anything about small scale utilization of solar energy. Usages include solar cooking, solar water heating, crop drying and generating electricity for domestic and small scale commercial purposes using photovoltaic cells. These are illustrated by the accompanying slides. Solar water heating is cost effective with a simple payback period of a few years depending on usage. A grid tied solar photovoltaic system can be shown to be cost effective, even when decreases in efficiency due to aging, use at high outdoor temperatures and use of inverters are taken into consideration, as long as the energy produced is used internally and not sold to JPS. Calculations show that at present installation costs, depending on whether or not capital is self-financed or based on a bank loan, the simple payback period for photovoltaic cells in Jamaica is about 8 to 10 years and the lifetime cost of producing electricity is about US 10¢ to 14¢ with 24 to 22 years of 'free' electricity after payback. In other words, even without net metering, there can be economic gain in using photovoltaic electricity if the system is properly planned. However this option will not work for Rate 40 and Rate 50 customers of JPS since they will be slapped with a demand charge based on the highest power consumption whenever they use JPS electricity, which is inevitable especially on overcast days. Stand-alone PV systems, as opposed to grid tied systems, are only marginally cost effective.

Summary

In summary we suggest that Jamaica's Renewable energy policy needs to be updated and even go beyond the 30% RE as suggested by the PM and Minister Paulwell. This should include the revision, on an expedited basis, of the country's "electricity policy" which was withdrawn and not recirculated for consultations. Use of RE for distributive generation, which I know has been considered by MEM, should be given more prominence. Besides electricity, our renewable energy policy should also consider more in depth look at energy efficiency in buildings, and private and public inland transportation.

For a sustainable development pathway we need to use our natural sources of energy to reduce our dependence on fossil fuel. In a future lecture we will discuss what the mix should be like to reduce the chances that dangerous consequences of climate change will occur. For RE more than 30% of the mix we must consider storage of energy to assure a firm supply of energy.

Storage can be achieved by the use of solar thermal and OTEC power plants. Capital cost of these plants has to be reduced and is anticipated to be reduced. Reduction can be accelerated by establishing an international R&D centre using fund from the climate change mitigation and adaptation funds. This centre would be focussed on development of solar thermal with storage and OTEC for small island states and LDCs. Feed-in tariffs should also be considered as a way of encouraging investment in RE as long as they benefit the country and consumers in the long run.

Solar energy can be employed on a smaller scale for cooking, water heating, crop drying and generating electricity for homes and small commercial establishment. For the latter the electric energy generated by photovoltaic cells must be used internally and not sold to JPS if significant economic advantages are to be gained. For Rate 40 and Rate 50 customers, the burden of demand charges will not make this option viable.

In closing let us recall the motto of the Jamaican flag: ‘Hardships there are, but the Land is green and the Sun shineth’.