Appropriate Technologies and Systems in Response to Climate Change

Small Scale Wind and Photovoltaics Feasibility

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Abstract

Alternative sources of non-hydrocarbon energy were first given serious consideration during the fuel crisis of the late 70's. However support for research in this area declined as soon as the cost of oil declined in the 80's. Renewed interest in alternative sources has been sparked by the fuel crisis of 2008 and sustained by the concerns of global warming. Alternative sources of energy are the major appropriate technologies and systems to respond to climate change. On the promises of these sources depends the much sought after global agreement to reduce GHG emissions to levels such that temperature rises would be limited to 1.5°C above pre-industrial levels. But these sources must compete economically with fossil fuel if the requisite investments are to be made in good time. The economic feasibility of two of the more readily available renewable energy sources, wind and photovoltaics, applied on a domestic scale to the situation in Jamaica will be explored. The methodology will involve the comparison of the present cost of producing energy using renewable energy sources compared with the cost of fossil fuel energy over the lifetime of the renewable energy source in terms of constant dollars. In areas of strong wind regimes, the use of wind is shown to be more economical than fossil fuel and photovoltaics. The prospects for photovoltaics are much improved when net metering is allowed.

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When the crises of the 1970's, precipitated by the oil embargo by the Oil Producing Exporting Countries (OPEC) and developing countries debt, governments and private companies, particularly in the industrialised countries, increased their research (pure and applied) on alternative energy sources and the related technologies.

The developing countries adjusted their economies but did little to reduce their heavy reliance on fossil fuel imports and their imported related technologies.

The primary response of the industrialised countries was to continue or attempt to reduce their reliance on fossil fuel imports, produced mainly in the OPEC in the southern hemisphere. Both political and economic security concerns dictated policy.

As oil prices dropped in the 1980's, both governments and private firms cut back their investments in the new technologies, though academia and research laboratories maintained their interest, but with less resources.

In Jamaica an initiative on wind and solar resource prospecting and in solar crop drying was started in the Physics Department, UWI, Mona. This resulted in the first published paper on wind energy in Jamaica (Chen, 1980) from a project funded by the Scientific Research Council.

The crises of the 2007-2008 brought renewed interest. There are two major structural differences this time. One, the problem is not one of supply management primarily for political ends, but physical supply constraints. Two, governments are now owning up to the huge costs to their environments from fossil fuel emissions. The warming effect on the planet poses great threats to sustainability of man's life support ecosystems.

The feed-through effects on food supplies, water stress, and geopolitical posturing is evident. The feedback loop is the equally pressing concern that tipping points will be reached, from which neither nature nor manmade systems can restore equilibrium.

The policy for sustainability and even survival, along with finding a new paradigm for jobs-led growth and development preoccupies the international communities of governments, business, academies of scientists and technologists, and other non-governmental bodies.

The policies and programmes of this new paradigm must reflect existing preferences of market efficiency and appropriate regulation that lead to optimum results.

The transition from the energy paradigm of almost exclusive reliance on fossil fuels to greater reliance on renewable (clean) energy sources and technologies is underway.

This transition must combine individual preferences, convenience and affordability within the wider societal framework and scale of community and nationwide infrastructure and networks. In these circumstances the comparative advantage of energy technology already being developed, easy to use and safe will ensure both a quick and less disruptive transition.

Advances made since the late 1980's in wind technology have now made that technology competitive with fossil fuel in areas of reliable wind speed where large-scale wind farms can be established.

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As indicated small scale wind technology for the home, enterprise and community will be important.

The promise of solar photovoltaic has largely not been kept, although PV cells are becoming cheaper and cheaper. With increased demand and more efficient production capacity, solar can be in as good a position as wind. Because of its portability and ease of siting compared to wind, solar photovoltaic technology has the advantage when deployed on the small scale for domestic use.

There is in Jamaica and the Caribbean the incremental expansion of renewable technologies, but it is neither on the scale and speed commensurate with the challenges. Governments must clearly fill the policy and regulatory spaces, though all must share responsibility.

This paper takes up the feasibility of wind and solar power for domestic use. We will look at

- Medium scale wind system suitable for a factory or community
- Small scale wind system for domestic use.
- Stand Alone Solar PV system for domestic use
- Grid tied PV system for domestic use
- Ways to promote their usage

Renewable energy systems have high initial cost but very low maintenance and little fuel cost. On the other hand conventional fuel plants are relatively cheap to install per unit of power, but substantial cost must be added for fuel and maintenance.

The financial cost comparison is no longer sufficient when it excludes the externality of CO2 emissions and the social cost to the public health system, society and the shared responsibility to reduce the volume of greenhouse gases (GHGs). There are credible estimates that may be put to these 'externalised' costs, but which will be omitted on this occasion.

Based on the conventional analysis the comparison is made on the lifetime of the renewable energy system. In these analyses we compare the lifetime cost of producing energy by the renewable systems with the cost paid for the equivalent amount of energy produced by fossil fuel over the lifetime of the renewable technology.

In the initial comparison we assume a constant US dollars, which in present circumstances has drawbacks. Keep in mind that on this assumption the comparison gives fossil fuel technology an advantage since its costs in reality will likely increase over time, whereas the cost of the renewable technology is up front and will not increase. An attempt at a future time will be made to look at the future cost of money.

The comparison will use realistic assumptions for renewable energy sources including degradation of performance over time, particularly of PV systems.

Thus for the constant dollar comparison we will assume the cost of energy produced by fossil fuel is the present approximate cost in Jamaica of J$30 per kWh or US 34¢ per kWh. For small scale PV and wind systems the cost of energy (dollars per kWh) will be the ratio of the total cost of the system plus maintenance for the total energy produced over the lifetime of the system. It is further assumed that these systems will be self financed by the owner.

For the medium scale wind system where a loan would likely be necessary, the cost of energy (dollars per kWh) will be the ratio of the annual cost of capital and maintenance/annual energy produced.

Medium scale wind system

The analysis of a medium scale wind system (about 200 kW) is based on a study of the performance of a Vestas 225 kW rated system done in 1998/9 (Chen and Amarakoon, 1999). Since that time the cost of turbines have increased by about 50%, while the cost of energy sold by JPS has increased about 100% in terms of constant US dollars, so that the conclusion draw then are now much more in favour of wind energy.

Using constant US dollars we computed the cost of producing energy per kWh per annum as a function of repayment period on a loan to purchase the system. The cost of producing energy is the amount that has to be paid out annually to produce energy. This includes mainly the cost of servicing the loan and maintenance and operation costs.

The calculation parameters used were

Annual cost of capital and maintenance

- C = Initial capital cost of turbine
- R = annual charge rate (%) on capital, assuming money was borrowed for venture
- M = annual operation and maintenance cost as a fraction of the initial capital
- C(R+M) = annual cost of capital and maintenance

Annual energy produced

- W = rated power of wind turbine kW
- h = number of hours in year (8760)
- F = overall load factor
- hF = effective number of hours in a year during which turbine operates at rated power
- W(hF) = annual energy produced in kWh

Overall load factor F

- L, Capacity factor = expected power extracted from wind divided by rated power
- A, Availability factor = fraction of time of time turbine is operating
- a = efficiency of conversion of wind energy to electricity
- Overall load factor, F=LAa

Cost of producing electric per kWh G

- G = Annual cost of capital and maintenance divided by annual energy produced
  = C(R+M)/ W(hF)

Values used

- C, initial capital cost = US$300,000
- W, rated power = 195.3 kW
- M, operation and maintenance cost = 2% of C, including insurance

- h, hours in yr = 8760
- L, Capacity factor = 0.35
    - L depends on the wind speed, the average value of which was 7.4 m/s
- A, availability factor = 0.953
- a, efficiency = 0.83

G is calculated for various repayment periods n, and interest rates r, of 0, 8, 10 and 15%

The results are shown in Fig. 1 which is a graph of the cost of producing energy as a function of repayment period.

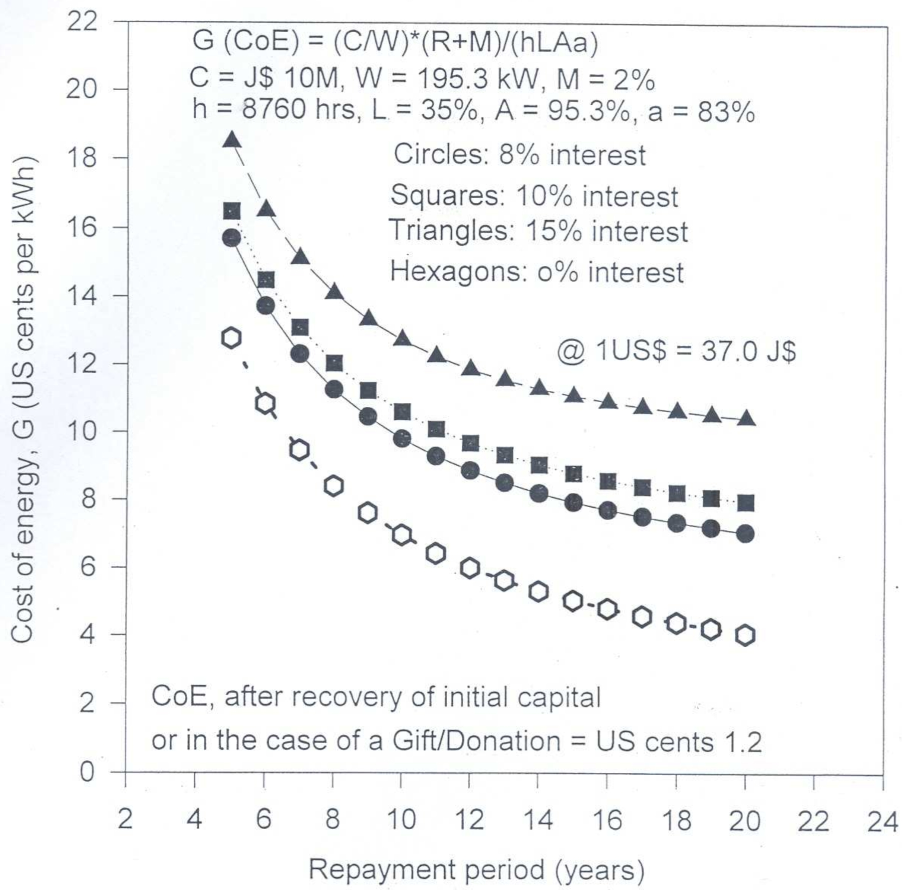
Analysis

In 1998 when the analysis was done the cost of electricity supplied by JPS was US 16¢/kWh. Assume that an institution borrowed funds at say 15% and used the amount saved by not paying JPS to pay for servicing the loan, i.e., the cost of energy is 16¢/kWh. From Fig. 1, it can be seen that the debt would be repaid in approximately six (6) years. Thereafter the cost of producing energy would only be for operation and maintenance for the rest of the lifetime of the turbine, i.e., for approximately 15 more years at approximately US 1.3¢/kWh. The savings by not paying JPS for those 15 years would be approximately US$ 333,000. Of course the results would be much better at lower interest rates.

It should be kept in mind that in 2010, while the cost of turbines have increased by about 50%, the cost of electricity from JPS has increased by about 100%. Whereas the turbine analyzed operated at a height of 30 m, newer turbines today operate at heights between 50 and 100 m so that their performance will increase substantially, since wind speed increases with height.

The wind turbine in this analysis produced 592,000 kWh for a year or 49333 kWh per month. Thus there is economic advantage for those institutions requiring this much energy to use wind turbine power provided that they are located in good wind speed areas. Further, that they consume the energy they produce and not sell to JPS or any third party.

[End]



<u>Figure 1</u> Plots of the cost of energy G as a function of different repayment time in years for different interest rates using the V27-225

Stand Alone PV
For the stand alone PV system a starter system will be assumed, one that will only provide lighting for a house, but will not be able to power, say, a refrigerator or iron. The comparison for a scaled up system capable of more power would produce the same result. The system will consist of

- 2 x 100 W panels
- Inverter
- Battery
- Charge controller
- Transfer switch

- PV brackets
- Cables
- Miscellaneous

Except for the cost of replacement batteries, the cost of the above hardware and installtion gives the cost of the system For the energy produced by the system over its lifetime the following parameters are assumed:

- Wattage reduced by 13% due to use at 50ºC
- Annual average of 5 peak sun hours/day
    - average of 1000 W/m^2 for 5 hours/day)
- 95% Inverter efficiency
- 80% Battery efficiency
- Battery replacement 5 times over the lifetime of the system
- Panel lifetime of 30 years (25 guaranteed)
- Installation cost assumed
- Self purchased, not financed

These rough calculations show that the lifetime cost of producing electricity by a stand alone PV system is approximately US 37¢/kWh compared to US 34¢/kWh currently charged by JPS.

While this purely financial cost comparison shows approximately ten (10) percent cost disadvantage for the renewable (clean) PV-technology, several other important considerations if included would show a somewhat different result.

Firstly, if the PV system is viewed as a backup system in case of failure of the public grid, then it would favourably compare with a backup system consisting of a small gasoline or gas generator. The cost of producing electricity by a generator that costs approximately the same as the PV system is difficult to estimate but a guesstimate would be about US 60¢/kWh based on the generator cost, usage time and the cost of fuel. Of course a backup generator of about 5 kW would also power the heavy appliances which the small PV system would not be able to do.

On the other hand the PV system as a backup system is continually paying back for itself since it will be used nightly while the back up generator will be used only when there is a power cut. A compromise solution would be to have a small PV system for back up of lights and another small backup generator, perhaps 3 kW, for running household appliances.

Grid Tied PV system

Of course the PV system would definitely be cost effective, if 'net metering' were available. In a net metering configuration the electricity produced during the daytime would be fed into the public utility grid and available for sale to the general public. When non-PV electricity is needed, say during the nights, it would be purchased from the public utility.

The only accounting system required is the normal electric meter. When PV electricity is put on the grid, the meter reading is reversed. When electricity is taken from the public utility, the meter reading is advanced, so at the end of the month, the householder is charged the net amount the meter advances, assuming that more electricity is taken from the grid than put onto it.

This is the practice in Europe and North America. In a few cases a small access fee is charged by the utility company for PV electricity access to the public grid. Keep in mind that once the electricity goes on line, the public utility sells and collects the charges.

In Jamaica this is not presently allowed. According to OUR regulations JPS pays only US 8.88 cents for electricity put on their line plus a premium of 15% provided the energy source is renewable. At the same time JPS will charge the householder approximately US 34¢ per kWh for supplying electricity to the householder. This arrangement would require 2 meters, one to record the amount sold to JPS and the other to record the amount purchased from JPS. The arrangement is referred to as net billing. Even with this disadvantage, a householder (a PV system provider) cannot connect to the grid and put electricity on the JPS line without an agreement with JPS.

We do not know of anyone outside of the large independent power providers (IPPs) who have been allowed to enter such an agreement. Therefore in the following analysis it is assumed that net metering is allowed or that the householder consumes all electricity produced as it is produced.

For the 'grid tied' case a system generating 1.7 kW of power is assumed. This is a relatively small grid tied system, but sufficient to power a refrigerator and TV. Keep in mind however that the system will be used to feed electricity into the grid. Besides the PV cells, the other component of the system will be a grid tied or utility interactive inverter; no batteries are required.

The calculation parameters are

- 10 x 170 W Panel
- Output is 87% of 170W to account for 50ºC operating temperature
  - 170W at 25ºC
- 5 peak sun hours
- Life time of 30 years
- 3 KW GT inverter
  - 95% efficiency
- Disconnect switch
- Cables and miscellaneous
- local purchase

The calculations of the grid tied system show a marked improvement over the stand alone system largely because of the elimination of the need for batteries. On this basis, we estimate the lifetime cost at approximately US 22¢/kWh compared to US 34¢/kWh for electricity produced by JPS.

It should also be noted that this calculation would apply to a user who consumes as much electricity as produced by the hypothetical grid tied system during the day, in which case it would not be necessary to put the electricity produced on the grid, but instead to use it. The calculation would be approximately the same for a scaled up system. Users such as supermarkets, small offices, clinics and the like could find it of value.

We conclude. There is economic advantage to a PV grid tied system for domestic consumption and, if net metering is allowed, for sale to the utility. On the national scale it would be beneficial - reducing the volume of CO_2 emissions (and particle pollutants) of the national target to which Jamaica will be required to commit as part of any international agreement of rights and obligations.

Small Scale Grid Tied Wind Turbine

The system investigated is Sky Stream 3.7 turbine which comes with a grid tied inverter. It produces approximately 550 kWh per month at a wind speed of 7 m/s. This speed can be achieved at many places in Jamaica at a height of 20 m. It has a warranty of 5 years and a life span of approximately 10 years. For comparison the cost of producing electricity is approximately US 21¢/kWh at an average wind speed of 7 m/s. This is 2/3 the cost of electricity produced by JPS.

It should be noted that since in areas of good reliable wind speed, the wind usually blows both day and night it may be possible to utilize wind power for a stand alone system without the use of batteries, in which case the above calculations still hold.

There are number of issues that should be followed up to inform policy and regulatory arrangements in the rapidly changing circumstances of climate change. Among them are, inter alia:

- Jamaica's peak load occurs at nights, due to the demise of the manufacturing sector, so that PV systems will not provide a back up to JPS during this period.
- PV could provide a backup for the secondary peak at mid-day when the demand for air conditioning systems is high.
- Reliable data on total solar and wind energy capacity in 'good' areas – wind and solar mapping
- Estimates of the potential capacity of grid tied solar systems.

Conclusions and Discussion

1. There is clearly the need for accelerating the research, experimentation with new energy technologies and a clear policy framework that builds climate change and energy efficiency into practical investment opportunities, supported by government incentives.

2. Even excluding full costing of the 'externalities' of fossil fuel energy production, the economic prospects for medium scale wind power are very good if constant wind speeds are over 7 m/s. These are achieved regularly at heights of 50 metres and above for areas of St. Elizabeth, Manchester, Portland and St. Tomas in Jamaica.

3. Small scale wind for domestic use offers advantage over total reliance on grid supplied electricity if net metering is allowed and also for stand alone systems where the wind, both at daytime and night-time, is fairly consistent.

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4. Photovoltaic systems become competitive with grid supplied electricity if net metering is allowed. Under a scenario of a stable price of electricity in terms of constant US dollars, stand alone PV just about breaks even. The situation will favour PV systems if the price of electricity increases, remembering that it increased by 100% form 1998 to 2010. A stand alone PV system can also be promoted as back up system and would compare favourable with a gasoline or gas generator.

5. In the face of uncertainty and risk, government should combine prudence and proactive policy responses. Full privatisation of the sole bundled generation and transmission/distribution utility should not be pursued until there is a much greater supply and balance in renewable technologies and the regulatory regime is completed and effective.

6. A more urgent and compelling case and national programme of action is required for renewable energy. These will include the adoption of a national target at which greenhouse gases in the atmosphere will be capped as Jamaica's contribution to a legally binding Climate Change Treaty. This requires political will to legislate energy efficiency and emission reduction targets, to provide funding for education and to provide incentives for promoting the use of renewable energy on the domestic market. Promoting conservation naturally will be a necessary part of this campaign.

Possible Promotion themes

The following are several promotional themes which could be used to promote renewable energy:

- $E=mc^2$ (Energy = Management of Carbon x Conservation)
- Conserving energy makes cents
- Avoid the dangerous consequences of global warming:

Alternative sources of energy will reduce Carbon emission and limit temperature rise to less than 2ºC, save coastlines for communities and tourism

- Alternatives (wind and solar) can be used as backups in power outages and as primary sources in time.
- Promote Alternative Energy and Conservation in the same way we promote Wellbeing: For good health use natural products/For good energy use natural unprocessed and renewable domestic resources
- Good for Jobs, economic growth and security. A sound energy balance is a sound bank balance.

References

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