

Small Scale Wind and Photovoltaics Feasibility

Appropriate Technologies and
Systems in Response to Climate
Change

CEHI 2010 Conference

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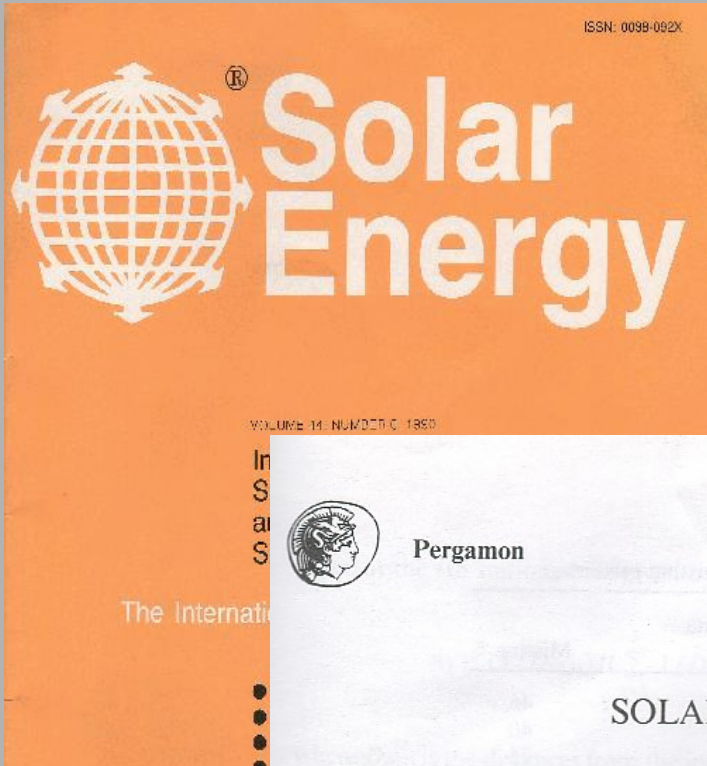
Anthony Hill, Convenor, Reflexion
Group

Background

- Oil Crisis of the 70's
- Reprieve in the 80's
- Crises of 2007-2008
- Transition to new green energy paradigm



Response of the UWI Physics Department



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WIND POWER IN JAMAICA

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Pergamon

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SOLAR RADIATION IN JAMAICA



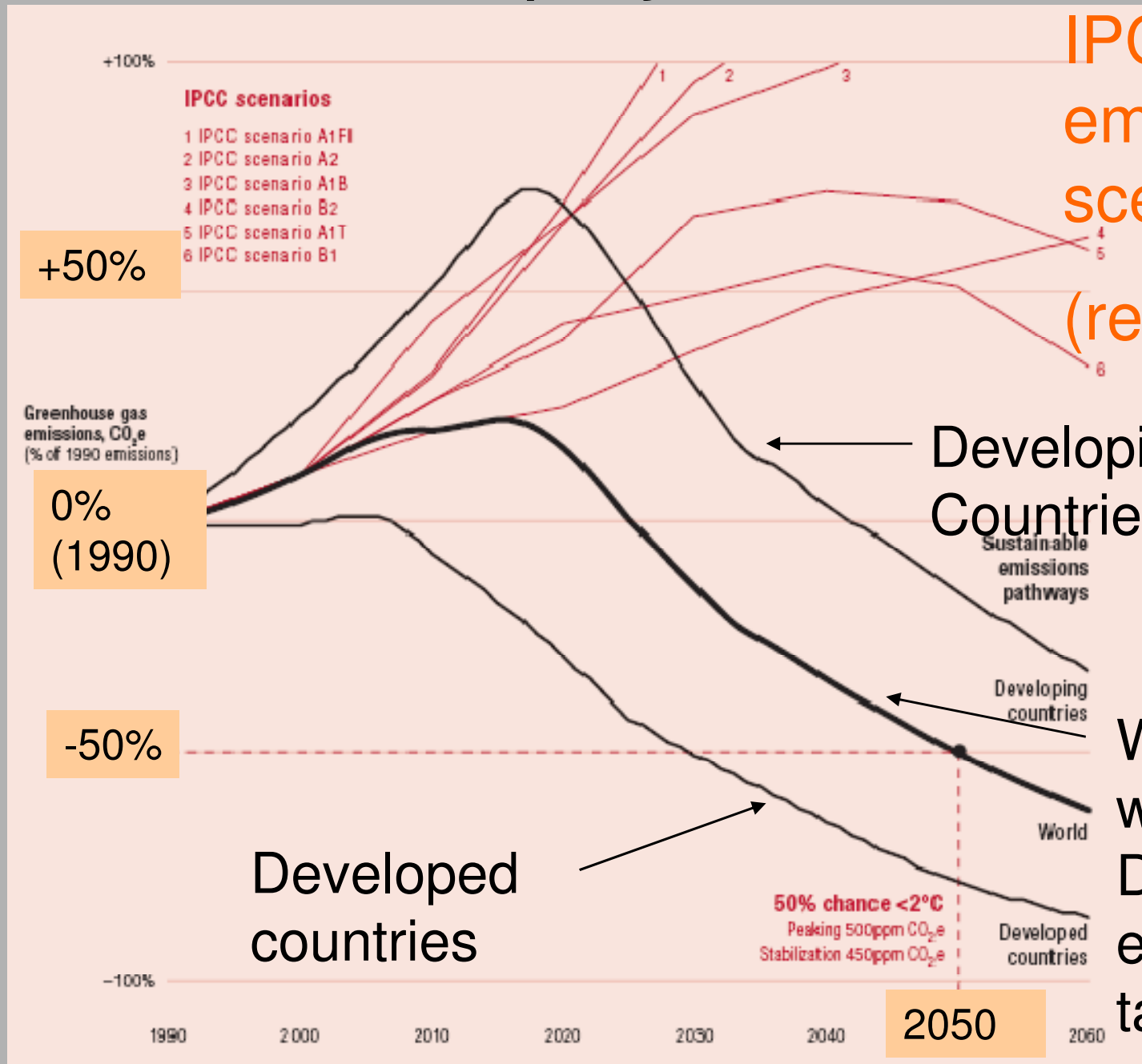
Resource studies: Measurements of wind speeds and calculation of wind power in Jamaica; Solar radiation measurements;

Applications: Solar Drying, PV, New technologies



Desired Mitigation Targets for emission vs IPCC projections

% Change in emission relative to 1990



Presentation

This paper takes up the feasibility of wind and solar power for domestic use.

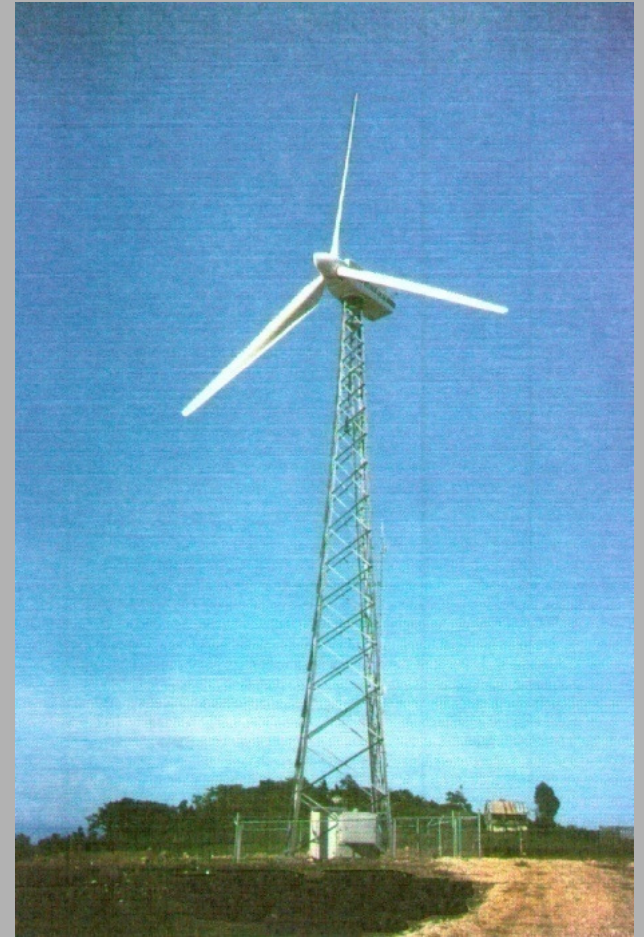
- Medium scale wind system suitable for a factory or community
- Small scale wind system for domestic use.
- Stand Alone Solar PV system for domestic use
- Grid tied PV system for domestic use
- Ways to promote their usage

Cost comparison

- RE high initial cost, very low maintenance and little fuel cost.
- Fossil fuel plants cheap , add cost of fuel and maintenance.
- Comparison based on lifetime of renewable energy system.
 - Lifetime cost of producing energy by RE vs cost paid for the equivalent amount of energy by fossil fuel
- Assume a constant US dollars,
 - Cost of fossil fuel technology likely increase over time, the cost of the renewable technology is up front.
- Energy produced by fossil fuel approximate cost in Jamaica - J\$30 per kWh or US 34¢ per kWh.
- Medium scale wind system (loan is necessary), the cost of energy will be the ratio of the annual cost of capital and maintenance/annual energy produced
- PV and small wind systems, the cost of energy is total cost of the system plus maintenance divided by total energy produced over the lifetime of the system.
- NB Financial cost of CO₂ emissions, social cost to the public health system, etc omitted in this presentation.

Medium scale wind

- Based on study done at Munro in late 1990's
- Vestas V27-225KW turbine
- CSGM, Physics monitored the wind and turbine output



Simple calculation of life cycle cost for producing energy at Munro by wind turbine

G = cost of producing electric per KWh
= Annual cost of capital and
maintenance divided by annual energy
produced

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 (o & m) cost as a fraction of the initial capital
- $C(R+M)$ = annual cost of capital and maintenance

Calculation of 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

F, overall load factor

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

- G = cost of producing electric per KWH
= Annual cost of capital and maintenance
divided by annual energy produced

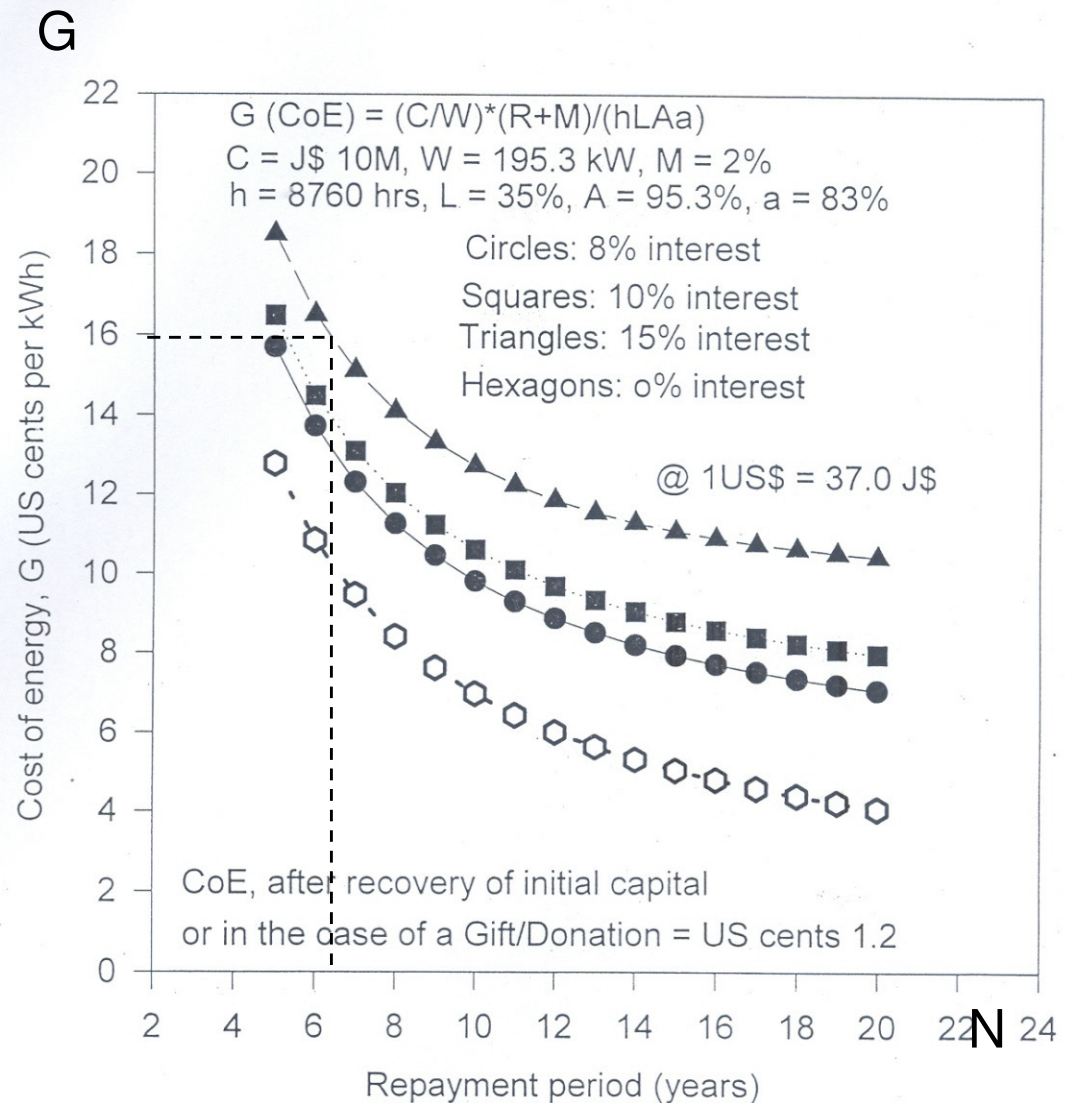
$$G = \frac{C(R + M)}{W(hF)}$$

Values used

- C, initial capital cost = US\$300,000
- W, rated power = 195.3 kW (corrected for density)
- M, o & m cost = 2% of C, including insurance
- h, hours in yr = 8760
- L, Capacity factor = 0.35 (operates at 35% capacity)
- A, availability factor = 0.953
- a, efficiency = 0.83
- G is calculated for various interest rates and repayment periods (See graph)

Plot of cost of energy G, as a function of different Repayment Years N for Different Interest Rates

Since Cost of JPS electricity is 16 cents/kWh
 Arrange for G=16 cents/kWh
 i.e. Savings by not paying JPS covers cost of servicing loan



Analysis

- When this analysis was done in 1998, if the turbine was purchased using a loan at 15% and the charge for electricity from JPS was US\$0.16/kWh, you would have paid back your loan in 6 years from the savings you would have earned by not having to pay JPS.
- Cost thereafter would only be for o & m for ~ next 14 years
 - 2% of initial cost or US\$0.013/KWH
 - savings by not paying JPS for these 14 years ~ US\$ 300,000
- Of course the results would be much better at lower interest rates.

If analysis extended to present day

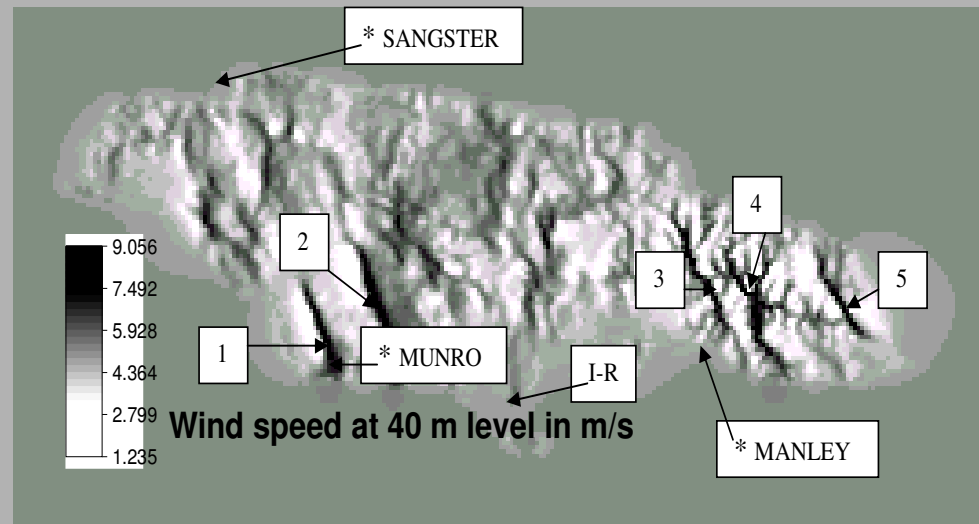
- Present cost of electricity is about J\$30/kWh or about US\$0.34/kWh
- Cost of electricity from JPS has increased by about 100%.
- In 2010, the cost of turbines have increased by about 50%
- Turbine analyzed operated at a height of 30 m, newer turbines today operate at heights between 50 and 100 m
 - their performance will increase substantially, since wind speed increases with height

Conclusion 1

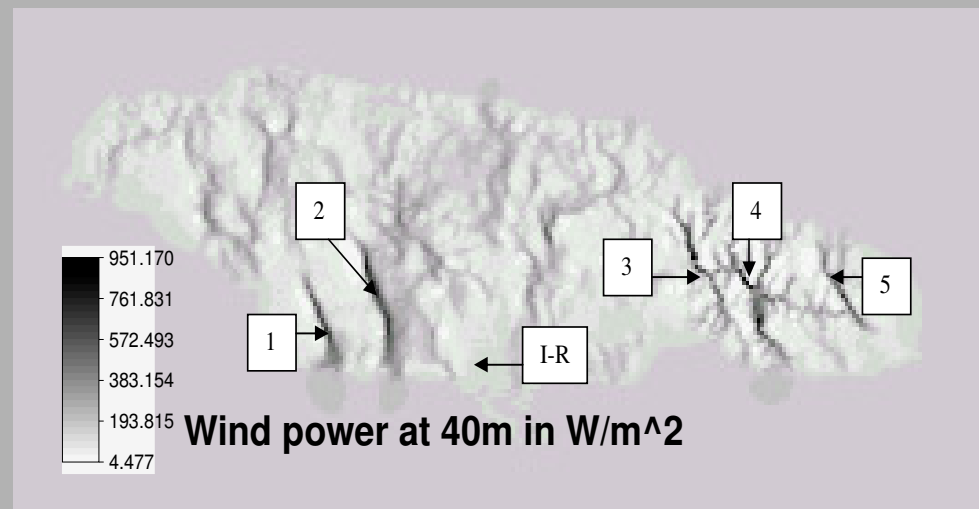
- Munro wind turbine produced 592,000 KWH for a year or 49333 KWH per month
- Economic advantage for Institutions that uses this much energy to use wind turbine Provided:
 - They are located in good wind areas (above)
 - they use the energy themselves and not sell to JPS
- Wind power in areas of wind speed of 7.4 m/s (avg. wind speed at Munro) or more makes good economic sense

Wind Energy in Jamaica

Amarakoon, A.M.D., and A.A.Chen, Modelling of Wind Speed and Power Across Jamaica, *Ja. J. Sci. and Tech.*, 12 & 13, 48-64, 2001 & 2002



(a)



(b)

Stand Alone Solar

(starter system for lighting)

- 2 x 100 W panels
- Inverter (1000W)
- Battery (12 V, 225 AH)
- Charge controller
- Transfer switch
- PV brackets
- Cables
- Miscellaneous

Calculation Parameters

- Wattage reduced by 13% due to use at 50°C
 - 200 W at 25°C 174 W at 50°C
- 90% power output over 25 or more years
- 95% Inverter efficiency
- 90% Battery efficiency
 - Least efficient component
- Battery lifetime 8 years
- Panel lifetime of 30 years
- Annual average of 5 peak sun hours/day
 - (average of 1000 W/m² for 5 hours/day)

Compare JPS with Stand Alone PV

JPS

- US 34¢/kWh

Stand alone

- US 61¢/kWh

❖ Stand alone does not offer economic advantage

❖ Assumes that JPS rates will not increase

❖ Very unlikely

❖ Advantages include

❖ Insurance against total blackout – enough for lighting

❖ No fuel cost

❖ Except for battery replacement, little maintenance required.

❖ No GCT

How much are persons who purchase backup generators willing to pay for energy?

- Guesstimate:
- 6 KVA silent diesel with Automatic Transfer Switch
- Used for 1 month (24 hrs/day) every 5 years over 35 years
- 6 gals/24 hr day at US\$4/gal
- Actual capacity used on average ~ 50%
 - Not all energy generated is used
- Cost of energy ~ US60c/kWh

Conclusion 2

- Stand alone PV does not offer economic advantage
- Use comparison of stand alone with stand-by generators to sell PV as backup
 - Remember that stand alone powers lighting every night even when there is no blackout
- For Full Backup and to avoid high cost, purchase PV for lights and smaller generator (2.5 KVA) for appliances

Grid Tied PV System

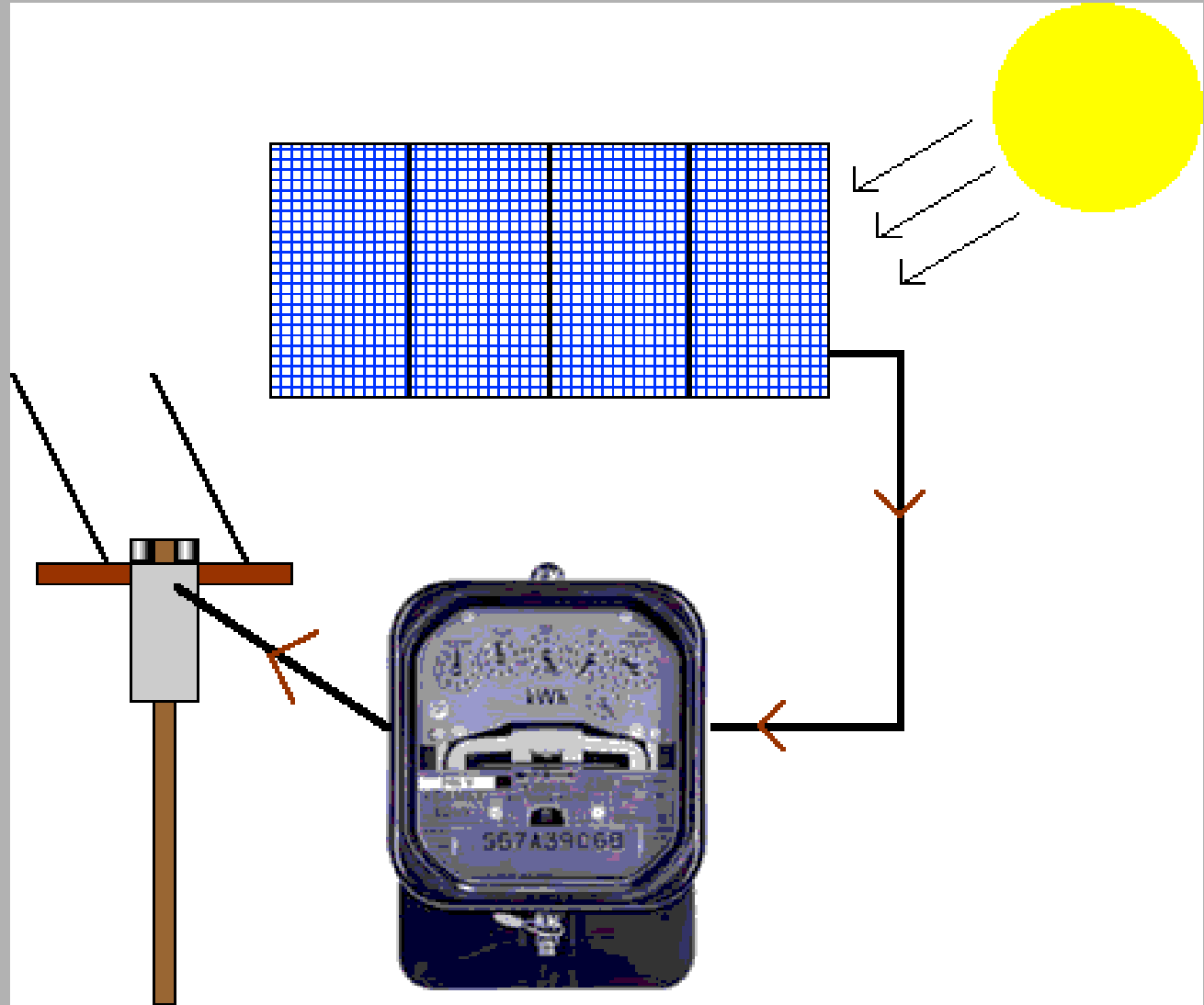
- All energy produced would be used
 - Unlike stand alone, unlike backup generator
- No backup battery needed
- PV Panels
- Utility Interactive Inverter
- Disconnect switch
- Cables
- Miscellaneous

Internally or External

- Internal
 - Connected to an institutions grid and used internally, not sold to JPS
 - Design grid tie system so maximum energy is less than consumed by the institution
 - E.g., Physics department providing power to UWI
- External
 - Net metering required for maximizing cost effectiveness

Net metering will eliminate the need for backup storage (battery) and help to make use of PV less costly

- Excess electricity produced in the day is sold to the power company.
- Buy electricity from company at nights
- In practice this is done by a meter which can reverse directions. Pay for net usage.
- Eliminates cost of storage



Calculation Parameters for Grid Tied

- 10 x 215 W Panels
- Output is 87% of 170W to account for 50°C operating temperature
 - 170W at 25°C
- 5 peak sun hours
- Life time of 30 years
- 90% Power Output over 25 years
- 3 KW GT inverter (95% efficiency)

Compare JPS with Grid Tied PV

JPS

- US 34¢/KWH

Grid Tied

- US 17¢/KWH

If JPS rate inflated at 3% annually, then system would payback for itself in 12 years with approximately 18 years of free electricity

Conclusion 3

- Economic advantage to use PV Grid tied internally, or externally if net metering is allowed
- For internal application system maximum energy has to be less than that used by the institution
- Would be profitable for a domestic household if net metering allowed

Small Scale Wind

- Sky Stream 3.7 Turbine
 - Supplied by Alternative Power Sources
- Grid tied system
- 20m tower
- Lifetime of approx 20 years with maintenance

Calculation Parameters

- 20m tower
- Wind speed ~ 7.0 m/s at 20m
 - ~ 550 KWH/month output
- Maintenance $\sim 2\%$ of capital cost per annum
- Wind speed ~ 6.3 m/s at 10m
 - ~ 500 kWh/month output

Compare JPS with Small Scale Wind

JPS

- US 34¢/KWH

Small Wind

- US 13¢/KWH at 20m
- US 14¢/KWH at 10 m (over 20 years)

Payback time if 3% JPS inflation

- 7+ years (20 m)

- 9 years

Conclusion 4

- Small scale wind economical even at 10 m provided
 - Net metering is allowed (external use) or energy produced is used internally
 - They are located in good wind areas (above)

Problems to Overcome

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

- 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. Thomas in Ja.
- 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.

- Photovoltaic systems better grid supplied electricity if net metering is allowed. A stand alone PV system can also be promoted as back up system and would compare favourable with a gasoline or gas generator.
- A more urgent and compelling case and national programme of action is required for renewable energy
 - Net metering, Net metering, Net metering
 - National target at which greenhouse gases in the atmosphere will be capped as Jamaica's contribution to a legally binding Climate Change Treaty.
 - 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

Slogans and Promotion

- $E=mc^2$
 - Energy = Management of Carbon x Conservation
- Conserving energy makes cents
- Getting the message across
 - Avoid the dangerous consequences of global warming
 - Alternatives can be cheaper
 - Conservation saves energy
 - Alternatives (wind and solar) can be used as backups in blackouts
 - Promote Alternative Energy and Conservation in the same way we promote Wellbeing



Good Energy



**Natural Sources
Unprocessed**