KEYS TO ENERGY EFFICIENCY

Cost-reducing strategies to promote energy conservation

June 28 to July 13, 2011
Bluefields, Nicaragua

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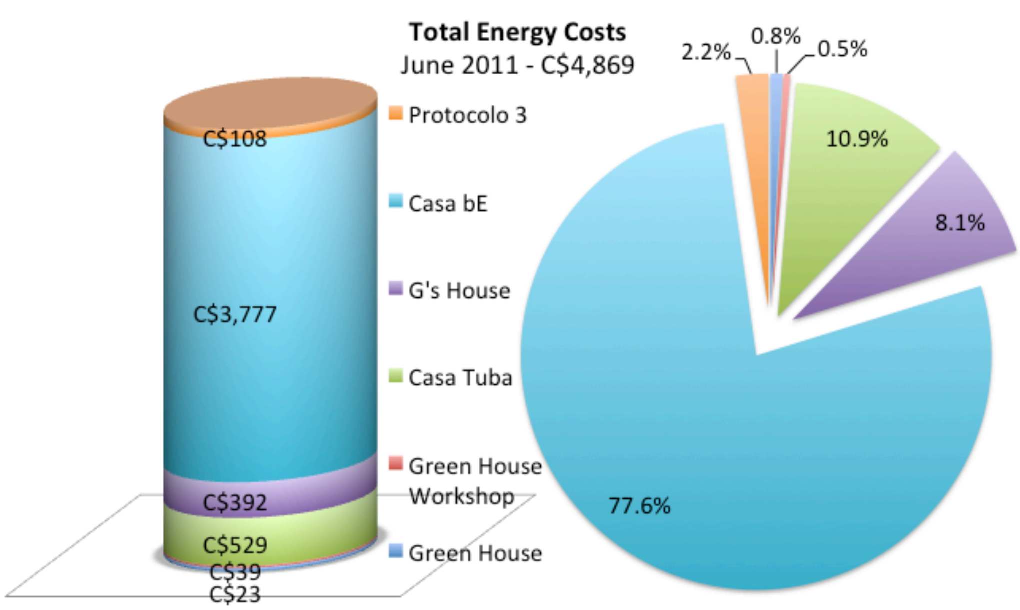
Abstract: *This study utilizes climate-specific energy audit techniques to trace and scrutinize energy expenditure patterns in order to identify, design, and report recommendations to reduce energy costs and promote conservation. A field audit was conducted at blueEnergy's Nicaragua location to accurately account for usage profiles and pricing structures that drive energy expenditures. Analytical tools were then employed to develop a two-phase energy strategy focused on reducing consumption and generating energy on-site. This report identifies energy-efficiency, renewable energy assets, zone management, and passive cooling as four routes that would directly reinforce conservation efforts and reduce energy expenditures without disrupting blueEnergy's operations.*

I. ENERGY AUDIT

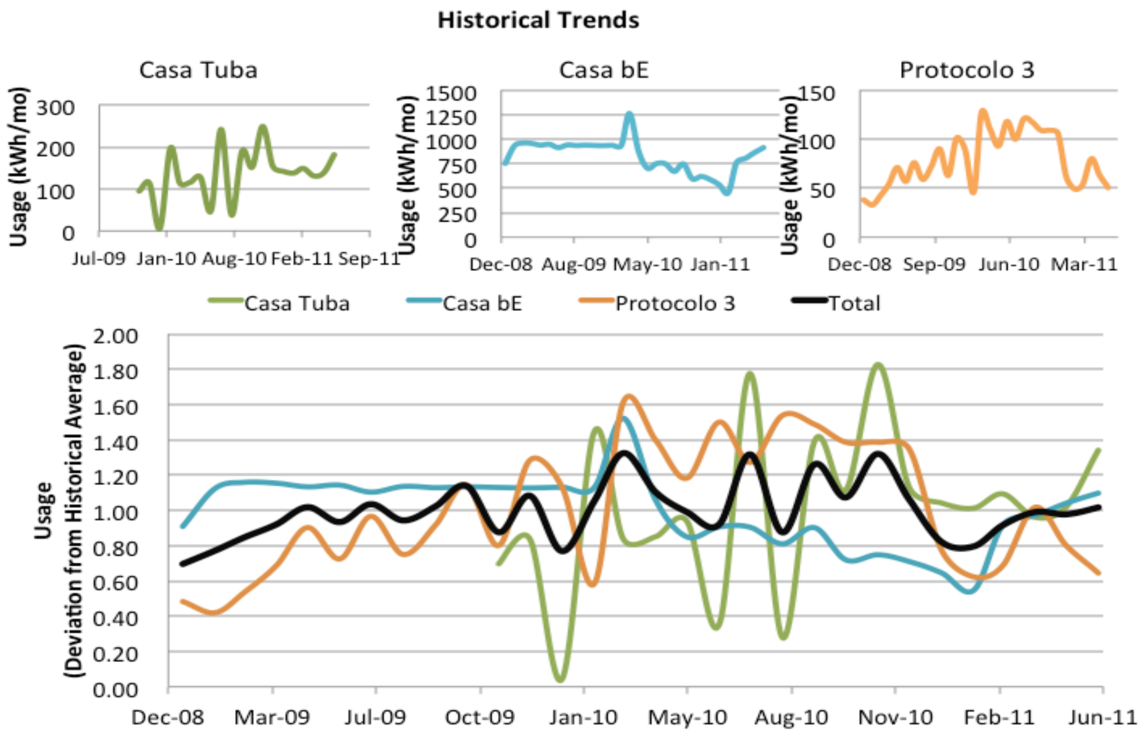
Electricity currently accounts for 1% of quarterly expenditures (C$ 4,869 in June 2011), drawing a baseline average of 1.65kW. Casa bE is by far the most energy-intensive property, accounting for ~78% of total electricity expenditures (C$ 3,777 in June 2011). Hence, an energy audit is required to determine the factors that drive this skewed snapshot. An analysis of historical usage patterns, pricing per kilowatt-hour (kWh), and equipment load identified the culprit.



HISTORICAL ELECTRICITY USAGE PATTERNS

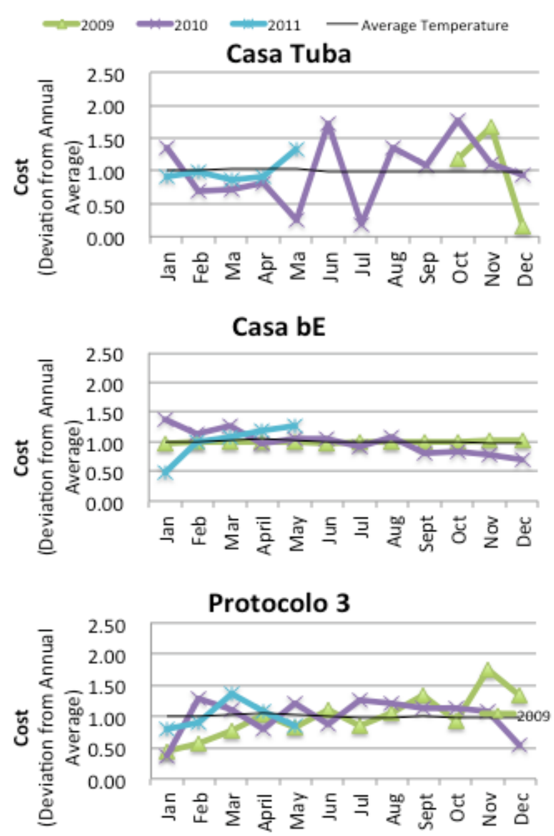
Electricity Usage Data

Electricity bills since January 2009 were analyzed to examine electricity usage patterns. A plot of past electricity usage from three properties (Casa Tuba, Casa bE, and Protocolo 3) displays significant monthly variation, indicating no apparent trend.

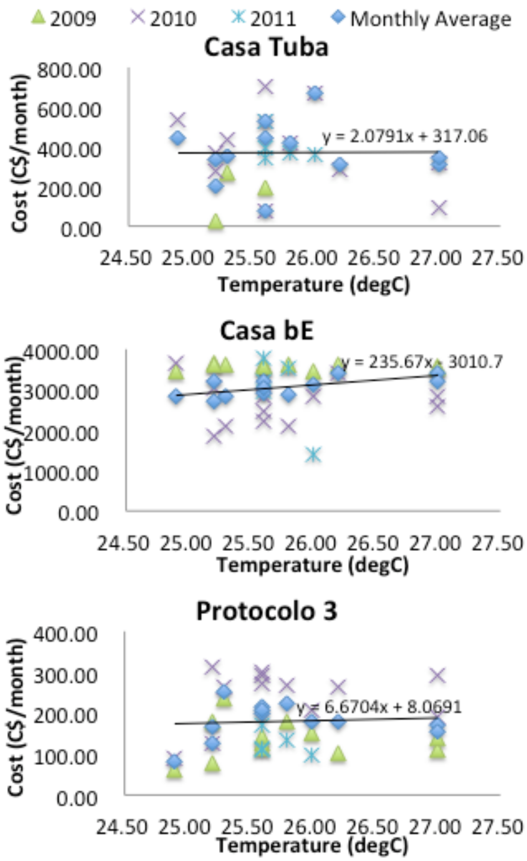


Key insights to be surmised from these plots:

- Deviations from the historical average among these three properties reaches +/-30%, varying wildly from month-to-month.
- The fluctuations for each property don't match one another; historical trends are uncorrelated.
- Casa bE & Protocolo 3 have the most consistent annual cost basis.
- Casa Tuba experiences wild monthly variation in electricity usage.



Climate-Related Usage



Next, weather-related electricity expenditures were analyzed. In many parts of the world, there is a strong correlation between ambient temperature/humidity and heating/cooling expenditures. This is usually attributed to user-comfort philosophies that, at times, necessitate complete isolation from environmental conditions.

However, analysis of blueEnergy's operations reflects a different philosophy; for each of the three properties, there is almost no correlation between temperature and electricity expenditure. Casa bE tends to use more per °F increase in ambient temperature than the other properties, however, the increase is nominal compared to overall usage. This indicates almost no reliance on electricity to create a climate-controlled environment. This is a commendable characteristic, and its success is proven by the comfortable conditions in blueEnergy's working areas.

Ramifications for Energy Conservation:

- Renewable energy assets can be implemented to offset the cost effect of usage fluctuations, however the designed capacity will have to assume an average level of electricity demand in order to mitigate costs. Designing for the highest possible electricity demand would be financially unwise; if the operations are intended to be off-the-grid in the future, monthly demand may need to be re-examined to ensure conformity with supply.
- Little financial savings can be realized through further weather-related energy conservation.

PRICING PER KWH

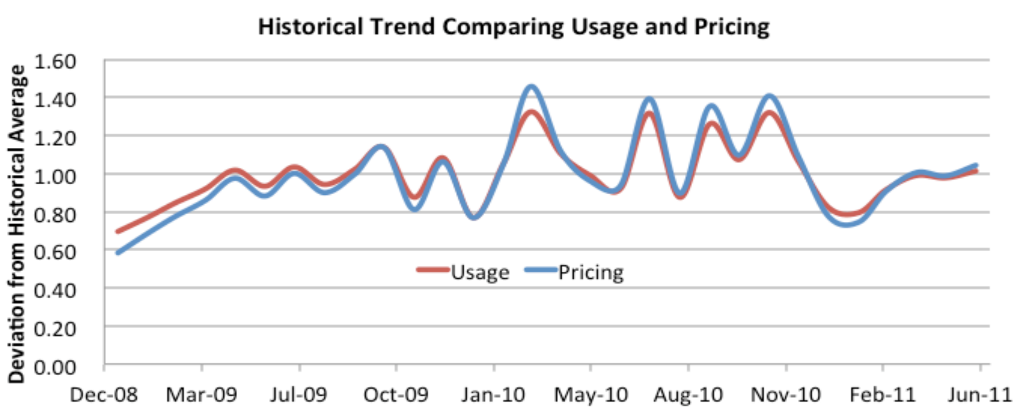
A compelling trait emerges from calculating the price charged per kWh for each property separately. Among all of the blueEnergy properties, charges range from C$ 1-3.6/kWh (USD 0.04-0.16/kWh), with an overall average of C$ 3.2/kWh (USD 0.14/kWh). Research into the pricing scheme imposed by La Empresa Nicaragüense de Electricidad (ENEL) yields an important explanation of the imbalance of costs: electricity pricing is both demand-dependent and set at the discretion of ENEL. For instance, the pricing schedule for June 2011 is as follows (each of the properties analyzed qualify as "T-0" tariff)[1]:

[1] Visit http://www.ine.gob.ni/DGE/pliegosTarifarios.htmlFor details on ENEL pricing during other months.

INSTITUTO NICARAGÜENSE DE ENERGÍA
ENTE REGULADOR
PLIEGO TARIFARIO JUNIO 2011 CON DESLIZAMIENTO CAMBIARIO A JULIO 2011
AUTORIZADAS PARA LAS DISTRIBUIDORAS DISNORTE Y DISSUR

BAJA TENSION (120,240 y 480 V)					
TIPO DE TARIFA	APLICACIÓN	TARIFA		CARGO POR	
		CÓDIGO	DESCRIPCIÓN	ENERGÍA (C$/kWh)	POTENCIA (C$/kW-mes)
RESIDENCIAL	Exclusivo para uso de casas de habitación urbanas y rurales	T-0	Primeros 25 kWh	1.8036	
			Siguientes 25 kWh	3.8856	
			Siguientes 50 kWh	4.0696	
			Siguientes 50 kWh	5.3784	
			Siguientes 350 kWh	5.0164	
			Siguientes 500 kWh	7.9677	
			Adicionales a 1000 kWh	8.9308	

Such a demand-set pricing schedule dictates that as usage rises, cost per kWh is amplified; moreover, after 500kWh, the price increases dramatically. Thus, the highest pricing structure is applied to Casa bE, roughly translating to a multiple of 3.7 times the pricing structure for the Green House. If the amount of electricity used at Casa bE were priced at the same structure as Protocolo 3, the average monthly bill would fall by more than 50%, to approximately C$ 1,440. Furthermore, a measure of pricing freedom is exercised by ENEL; as demand increases, pricing seems to rise uncharacteristically. This suggests that the pricing schedule is partially dynamic depending on anticipated demand. The following graph depicts the extent of this effect:



Ramifications for Energy Conservation:

- Any reductions in energy usage will mean large cost reductions relative to energy usage reductions in the other properties.
- Energy usage reductions in Casa bE will be particularly beneficial; a reduction of 400kWh would reduce total electricity expenditures by approximately 38%**.**

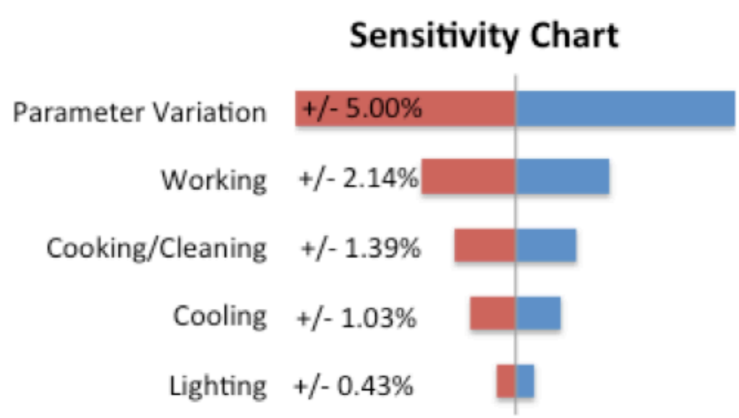
EQUIPMENT LOAD

A detailed inventory of appliances, personal computers, refrigerators, etc., clarifies the energy usage profile. The following analysis shows (a) the majority of high-draw appliances are used in Casa bE, and (b) all four activity categories (Cooking/Cleaning, Working, Cooling, Lighting) are generally housed in Casa bE.

The equipment inventory (provided with supplemental material) was calibrated to match the energy draw for each property by making educated assumptions regarding each appliance's wattage, kWh drawn per unit time, or usage profile. The chart below is provided to validate the low sensitivity of the resulting analysis to these assumptions. For example, a $^{+}/_{-}$ 5% variance in energy draw under the Working category corresponds to a maximum of $^{+}/_{-}$ 2.14% variance in total estimated cost. Thus, the analysis is relatively in-sensitive to the assumptions made.

Ramifications for Energy Conservation:

- Zone management wherever possible can offset the imbalance of energy usage.
- Any charges due to third-party tie-ins to bE power lines are unlikely given this analysis yields no clear irregularities.



II. RECOMMENDATIONS

PHASE ONE (0-6 months)

Goal: To reduce electricity demand at Casa bE by an average of 400kWh/month

Savings: C$ 17,000/yr (USD 760/yr) *GHG emissions reduced by*: 1,950lbs/yr (0.975t/yr)

Given the ENEL pricing schedule, it follows logically to focus initial efforts on Casa bE. Based on an average electricity demand of 900kWh/mo, a reduction of >400kWh/mo would result in a lower price/kWh bracket (C$ 5.01 vs. C$ 7.97 in June 2011). By implementing the following demand-reducing strategies, blueEnergy can realize 38% savings in total electricity costs. However, if any of these measures are not incorporated, additional options in subsequent sections should be considered to achieve the full 400kWh reduction.

Energy efficiency

Managing energy usage is an effective route towards reducing costs. By focusing on efficient usage of electricity, a positive level of conservation of valuable resources can be maintained. The following recommendations are provided to realize efficient energy usage; furthermore, these can be applied to all blueEnergy properties. Where numbered, the recommendations are listed in order of increasing predicted difficulty of implementation.[2]

Cooking/Cleaning (ESTIMATED SAVINGS: up to 150kWh/mo, C$ 6,375/yr)

- *Fridges/freezers*: (1) Ensure that the temperature of refrigerators and freezers are not set colder than necessary. (2) Regularly clean the dust off the condenser coils, fins, evaporator pan, and motor (can be accessed in the back of refrigerators). (3) Remove the 2nd floor refrigerator; this is too underutilized to be considered vital. (4) Replace older refrigerators and freezers with ENERGY-STAR qualified models.
- *Toaster Oven*: Phase-in an upgraded model (better-insulated, more efficient heating elements, etc.).
- *Coffee Machine*: Phase-in an upgraded model (better-insulated, more efficient heating elements, etc.).

Working (ESTIMATED SAVINGS: up to 200kWh/mo, C$ 8,500/yr)

- *Computers*: (1) Phase-in laptops when upgrading; if necessary, these can be used with existing monitors or external keyboards. (2) Unplug power cords when not in use, as these still draw electricity.
- *Printers:* Unplug when not in use.
- *Wireless Routers*: Power-down/unplug one of the first floor routers at night. One is more than sufficient for personal computing.

Cooling (ESTIMATED SAVINGS: immaterial)

- (Almost no correlation between temperature and electricity expenditure. This indicates almost no reliance on cooling and little savings to be realized. See audit section on *Climate-Related Usage* for more information.)

[2] GLOSSARY *Phase-in*: When the unit fails or is being otherwise considered for replacement, the recommendation that follows should be considered. *Replace*: This unit should be considered for immediate replacement.

Lighting (ESTIMATED SAVINGS: up to 50kWh/mo, C$ 2,125/yr)

- Replace all incandescent lamps with compact fluorescents; these use 75% less energy and last up to 10 times longer (there are lamps available for use in the INATEC office).

Renewable Energy

An additional level of efficient energy usage can be realized through point-of-use generation. By installing electricity-generating assets in Casa bE, inefficiencies related to the ENEL grid can be avoided altogether. Due to generation, transmission, and distribution losses, approximately 25% of the available energy in oil consumed at centralized Nicaraguan power plants actually reaches the point of service as electricity.[3] ENEL electricity is predominantly generated from fossil fuels (75%, fuel oil and diesel). With about 1,700 kWh per barrel, every 425 kWh generated at the point of use can avoid the consumption of roughly one barrel of oil. With regard to greenhouse gases (GHG), every 1,000kWh generated from renewable sources reduces GHG emissions by 4,600 pounds (2.3 tons). As is, blueEnergy electricity usage can be attributed with ~5,500lbs per year of GHG emissions (or 2.75 tGHG).

Unfortunately, these advantages are not currently priced into the mix: (1) ENEL has no electricity buy-back plan for kWh supplied back to the grid and (2) no credit system exists for GHG reductions from decentralized generation. Meanwhile, electricity prices as low as C$ 1.00-3.6/kWh (USD 0.04-0.15/kWh) effectively counteract the economic feasibility of any grid alternatives in service areas; therefore the financial gain from renewable energy generation is fully offset.

However, rolling blackouts, power outages, surges, and poor customer service are all issues that can be reduced with each increment of grid-independence. The following recommendations are made to realize a level of separation from ENEL demand-set pricing and are designed to take advantage of limited expenditure in implementation:

Investment in the lowest cost option towards localized energy generation has already commenced; one wind turbine is currently available in the workshop but remains idle, and a battery bank and inverter are installed in Casa bE. The remaining investment in a control panel and installation of a wind-solar hybrid system are approximated in the following table.

Component	Additional Cost	Prices USD	Purchased USD	TOTAL
Turbine		$984.20	$984.20	
Tower		$1,639.70		$1,639.70
Solar Array		$2,124.29		$2,124.29
Control Panel		$5,094.45	$3,840.00	$1,254.45
Toolbox		$175.00		$175.00
	10% overhead	$1,001.76		$1,001.76
		$11,019.40	**$4,824.20**	**$6,195.20**

[3] Electric power transmission and distribution losses in Nicaragua http://www.tradingeconomics.com

- *Solar Photovoltaic (PV) Panels*: 4 Kyocera Poly-Si 135W panels
    - Total capacity: 0.54kW
    - Efficiency: 13.5%
    - Capacity Factor: 14.7%

Local solar radiation data indicates that the available solar panels are capable of producing 693kWh annually at an optimal orientation for fixed installation at 8^o facing south. The following table summarizes local weather data and electricity generated from this array. USD 105/yr savings can be achieved.

Month	Daily solar radiation - horizontal	Daily solar radiation - tilted	Electricity Generated
	kWh/m²/d	kWh/m²/d	MWh
January	4.14	4.37	0.055
February	4.89	5.08	0.057
March	5.69	5.79	0.071
April	5.61	5.56	0.066
May	5.39	5.25	0.065
June	4.33	4.21	0.051
July	4.50	4.38	0.055
August	4.61	4.54	0.057
September	4.44	4.46	0.054
October	4.28	4.40	0.055
November	3.94	4.13	0.050
December	4.14	4.41	0.055
Annual	**4.66**	**4.71**	**0.693**

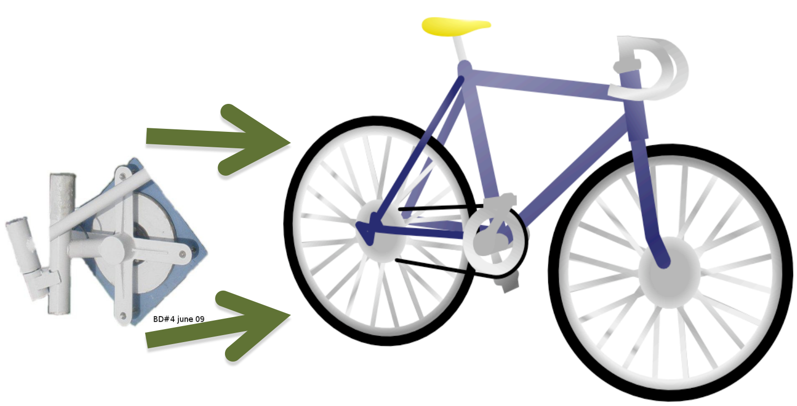
- *Wind Turbine*: blueDiamond4
    - Total capacity: 1kW
    - Capacity Factor: 10.2%

Local climate data coupled with the power curve below provides a good estimate for electricity generated from the blueDiamond4 (BD4) wind turbine. The BD4 can be expected to generate approximately 1MWh annually with a capacity factor of 10.2%. USD 133/yr savings can be achieved.

Wind Speed (m/s)	Power curve data (kW)	Energy Curve Data (MWh)
1-3	0.0	0.0
4	0.1	1.5
5	0.2	2.5
6	0.4	3.3
7	0.6	3.8
8	0.7	4.0
9	0.9	4.1
10	1.0	4.0
11	1.0	3.8
12	0.8	3.6
13	0.5	3.3
14	0.5	3.1
15	0.5	2.9

Month	Average Wind Speed
	m/s
January	4.4
February	4.0
March	4.0
April	4.0
May	3.4
June	3.3
July	3.7
August	3.4
September	2.8
October	3.0
November	3.7
December	4.3
Annual	3.7

- *Active Generation*: Stationary Bicycle Power
  - Another energy source worth pursuing is human exercise. An apparatus in which the rear wheel of a stationary bicycle is affixed to turn a turbine generating electricity allows for more control over supply. For instance, if the coil-magnet assembly from a deconstructed blueDiamond turbine is utilized with proper gearing, a user can be expected to generate approximately 1kWh per hour of pedaling; if pedaled for one hour per day, an estimated 30kWh per month can be offset (savings of C$ 1,300/yr, with nominal expenditure). Assembling such an apparatus is recommended for further testing; alternatively, commercial models are available.



Pictured unit available for purchase at Fenix International: http://fenixintl.com/

Zone Management

In light of the higher pricing realized at Casa bE due to unbalanced electricity demand, transferring equipment load to other properties will yield financial benefits. However, since any transferred appliances will still draw the same level of electricity, the entrained savings will be limited.

For instance, if total equipment load is distributed achieving equal electricity demand among *three* properties, a maximum of C$ 4,530/yr can be saved; if the equipment load is evenly distributed among *five* properties, C$ 11,730/yr can be saved. Significant cost reduction from tailoring the electric load are evident in these hypothetical situation. However, the logistical difficulty in equitably spreading each appliance and operational function among multiple properties makes this impractical for realizing energy savings.

However, limiting the use of certain equipment to outside Casa bE could be a more practical application of zone management; for example, *laptops* make good candidates given their portability and wireless connectivity. Other examples of appliances that can be considered for transferal to other properties are: *the upstairs refrigerator, freezer, wireless routers, and/or the washing machine*. As these units draw approximately 230kWh/mo collectively, the savings realized from simply stipulating the location of their use could be up to C$ 6,000/yr.

PHASE TWO (6+ months)

Goal: To eliminate all grid electricity demand, or by an average of 1,120kWh/month

Savings: C$ 48,300/yr (USD 2,160/yr) *GHG emissions reduced by*: 5,500 lbs/yr (2.75t/yr)

By incorporating renewable energy generation in phase one, blueEnergy's target properties will be well on the way toward grid independence, however, electrical generation capacity must increase if this goal is to be realized. Currently, blueEnergy has 4.75 kW of renewable capacity installed near Bluefields: 1,250 W in solar PV panels and 3,500 W in wind turbines. The following recommendations are provided to eliminate grid-borne electricity demand, with intent to leverage fully blueEnergy's energy resources.

Renewable Energy

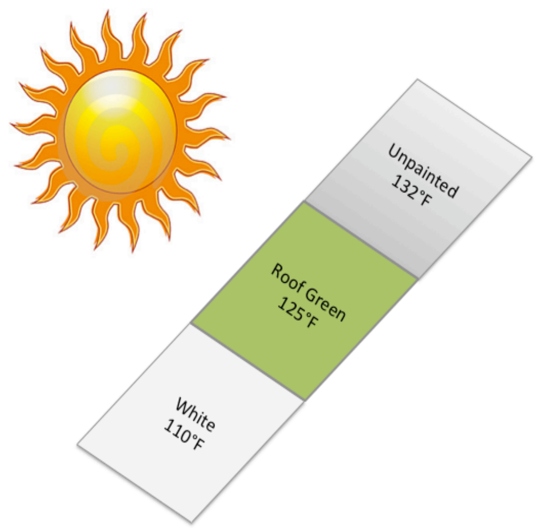
Grid-independence via renewable energy provides an excellent buffer from price shocks in global oil markets. Installing the remaining wind turbines in the workshop will increase available capacity up to 4kW, producing approximately 4MWh annually. Congruently, investing another $4,000 USD in solar panels will increase annual generation from solar radiation to over 2MWh. The resulting 6MWh annually provides approximately half of the electricity needed for all properties.

To attain the ultimate goal of grid-independence, it is advised to first exhaust energy efficiency efforts before local electric generation surpasses 50% of current demand. If energy consumption is reduced using phase one recommendations, additional electrical capacity may not be required.

Furthermore, at household levels of electricity consumption, the scope for available alternative energy can be widened significantly. By directing renewable energy technologies to specific tasks, energy can often be used more efficiently. One such specialized application considered for incorporation in blueEnergy's properties is as follows:

- *Biogas water heaters/cook stoves*
    - A particular on-site resource may have been overlooked for its capacity to generate energy: manure can be valuable when properly exploited. The methane produced through the biological breakdown of manure and other organic matter can be used for boiling water, cooking, and other processes involving a controlled flame. A simple system comprising of two tanks, a digester where microbes consume the biomass and another tank for storing the gas, can be readily incorporated into the properties. Potential designs can be provided upon request.

Passive Cooling



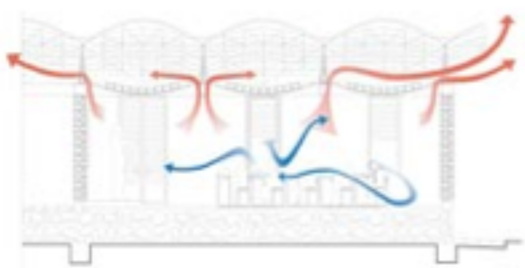
After a simple experiment involving a measure of corrugated iron painted different colors, the temperature variations related to material and color were apparent. When the material was exposed to full sunlight, the temperature underneath the green portion rose to 125°F, and the unpainted portion heated to 135°F. This compares with 110°F logged underneath the white portion of the material. These results suggest that the roofing above Casa bE, Casa Tuba, and Protocolo 3, all of which is painted a similar shade of green as in the experiment, is perpetrating a constant state of abnormally heated air above the ceiling; this, in turn, contributes to hotter living spaces.

While financial savings typically provide motivations for adopting cool roof designs, the interior spaces underneath these heated areas are generally unoccupied during daylight hours. Instead, most blueEnergy employees choose to work on the first floor of Casa bE, in the shaded areas of Casa Tuba, or in field sites altogether away from these buildings. As a result, not many personal or ceiling fans in these spaces are plugged in during the heat of day. Hence the ~C$ 700 (20% of total electricity expenditure) spent per month would not be significantly reduced by cooler roofs.

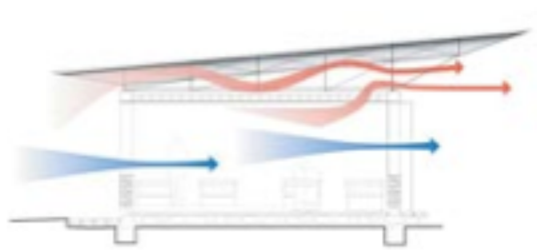
On the other hand, from a comfort standpoint, cooler living areas present benefits other than financial. These spaces are in fact occupied under various circumstances (sick or bedridden employees, while cooking, in-passing etc.…), and enhanced comfort would provide for marginally higher quality of life in these times. As such, here are a few comfort-enhancing recommendations.

- *Paint it White*
    - By simply painting the roofs white, the heating effect of the roofs would be dramatically reduced. A 15-degree difference in air trapped in a ceiling space is a noticeable difference that would translate to more comfortable conditions. With no apparent downside, cool white roofs are perhaps a compelling option for experimental purposes: the roof above one of the properties could be painted white and any differences in living conditions could be reported, with the decision to implement further pending positive test results.

- *Roof Design*
    - Recent trends in sustainable architecture have swayed to social considerations; in particular, designs that employ passive cooling have been the recipients of recent international awards and research funding. The focus has resulted in innovations that can be applied to climates similar to that of Nicaragua.
    - Key design characteristics of an example of cooling with natural ventilation are primarily (a) An overhanging roof raised by steel trusses both shades the façades and allows air to flow freely between the roof and the ceiling. (b) The ceiling is permeable, which allows the upper layers of warm air to escape. Thus, natural air flows in a prevailing pattern:



1. Cool, external air enters through the shaded windows
2. Gains heat from the interior environment
3. Rises through the permeable ceiling, and
4. Continues to flow out the roof



Images courtesy of: Francis Kere Architecture

Compared to the conventions in roof construction in the Nicaragua region, which are apparently limited to triangular roofs and enclosed ceiling-roof space, this is a more sustainable solution. Design characteristics like these are recommended for consideration in future construction or perhaps in modification of existing roofs.

III. APPENDIX

Scope

This is an analysis of the energy expenditures of blueEnergy's Bluefields, Nicaragua properties during the months of energy bills supplied. Direct observation and equipment inventory was conducted within five properties (Casa bE, Casa Tuba, the Green House, Protocolo 3, and G's House) during the field visit (June 28 - July 13). Aspects covered in this analysis include electricity consumption, electricity pricing structure, equipment utilization, zone management, and natural resources available for renewable energy generation ONLY. Any action taken outside of this SCOPE is the decision of blueEnergy.

Disclaimer

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