STRUGGLING FOR SUSTAINABILITY IN A FOSSIL-FUEL DEPENDENT SOCIETY

By

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ABSTRACT

Puerto Rico is a Caribbean island with an area of about 3,500 square miles. The Island is 99% dependent on fossil fuels for transportation and electricity, but there are no fossil fuels in PR. The Island has an inefficient and irresponsible energy use, and the demand increased dramatically in the 90s. The social, environmental and economic costs of current energy sources and practices are too high.

There is an urgent need for a social and technological transition to a new culture of social and environmental justice, based on sustainable practices and technologies. Solutions being sought and implemented are mostly economic, and in many times short term in nature.

In 1980 the U.S. National Academy of Sciences concluded that "Puerto Rico, in dealing with its own energy problems, should grasp its opportunity to become an international energy laboratory, seeking and testing solutions especially appropriate to the oil-dependent tropical and sub-tropical regions of the world."

Puerto Rico did not become the international energy laboratory it could have been. And after the initial uproar created by high oil-prices and short-term strategies vanish, we fall again in the complacency of "acceptable" oil prices. We remain waiting, as if the answer to our oil dependency problem could be imported.

This paper will discuss the Puerto Rican context as an example of Un-Sustainable practices, and present the results of a recent study that establishes that the Island has enough renewable energy resources to supply most of its energy needs. The challenges for a sustainable energy future are not only technical, or created by resource availability, the challenges are also, and mainly, social and environmental in nature.

Keywords: Sustainable Energy, Renewable Energy Sources, Wind Energy, Ocean Energy, Biomass, Solar Energy Systems, Distributed Generation.

INTRODUCTION

The global dependence on non-renewable energy sources has brought about grave environmental and social consequences. The limited, fragmented views of energy production, distribution and consumption lead to negative impacts on society and environment. The solution to this dilemma should include an inter- and trans-disciplinary approach that integrates ethical considerations and scientific knowledge to face the social, environmental and economic dimensions of energy.

The ethical dimensions of the worldwide energy dilemma include the disparity between the energy consumption of developed nations, and the instabilities created in regions where energy sources are available. For example, Figures 1 and 2 show those countries with the largest proven oil reserves in the world as well as those who are the largest oil consumers. These graphs dramatize the long history of geopolitical problems related to oil (BP 2008).

Even more ethical questions are raised when one considers that approximately 20% of the world population does not have access to a reliable energy source (other than burning biomass). Current consumption levels in developed nations cannot be replicated in developing nations because there are not enough resources in planet Earth for all human beings to sustain those consumption

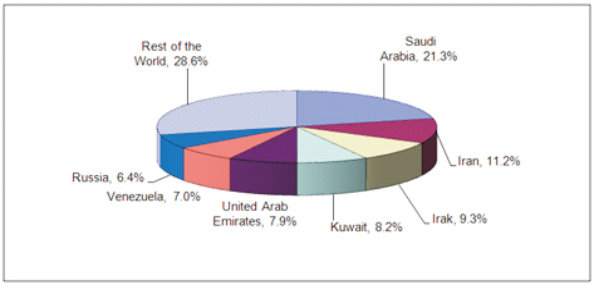

Figure 1. Proven World Oil Reserves

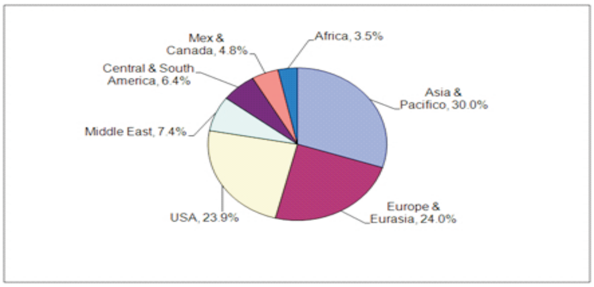

Figure 2. World Oil Consumption

patterns. Even if there were the resources, there are dire social and environmental consequences in providing reliable energy access to all 6.7 billions humans on Earth with current technologies and practices. This is further complicated by an increasing world population expected to reach 9 billion in less than 50 years. Current energy practices, focused mostly on economic and technological aspects, simply widen the gap between the ones that have much, and those that have almost nothing. Energy injustice characterizes the current situation where great inequities prevail in energy access and use. This creates the ethical mandate for a social and technological transition to a new culture of social responsibility and environmental justice.

1. Sustainability

The transition from the dominant energy model of developed countries to a more decentralized model should not be viewed as a mostly technological matter. Focusing only on technological fixes for our energy problems has historically proved to be a wrong strategy. Figure 3 illustrates the holistic approach discussed in the previous section. The sustainability concept evolved from ideas on human impact on the environment and the welfare of people, one of the first international forums on the subject was the Stockholm Conference on Human Environment in 1972 (Moffat 2001).

There are many definitions of sustainability or sustainable development. In fact, there is literature comparing the various stances on sustainability, classifying definitions in terms of weak, strong or normative sustainability; for an example comparing Solow, Holling, Leopold, Pearce and Barbier see (Norton 2005). There are also various indicators of sustainability such as the ones from the World Bank, the European Union, and UN (Hake and Eich 2006). Perhaps one the best-known definitions of sustainable development is from Our Common Future and deals with how we use resources today in a way that does not compromise the ability of future generations to meet their needs (United Nations 1987). Wider exposure was given to sustainable development in the 1992 UN Earth Summit in Rio de Janeiro. Besides conflicting definitions, there are opposing views to sustainability, for example how can we determine the most important interests that future generations will have (Beckerman 2003). Regardless of particular positions on what is sustainability, a sustainable future will require sustainable energy sources and practices. Figure 3 illustrates the balance needed among different dimensions of energy, including ethics, in order to truly follow sustainable energy strategies (Moffat 2001).

Two common approaches used to integrate economic, environmental and social aspects in decision making are Life Cycle Analysis (LCA) and the Internalization of Externalities. LCA is a process to evaluate the environmental burdens associated with an activity by identifying and quantifying energy and material usage and environmental releases, to assess the impact of those energy and material uses and releases on the

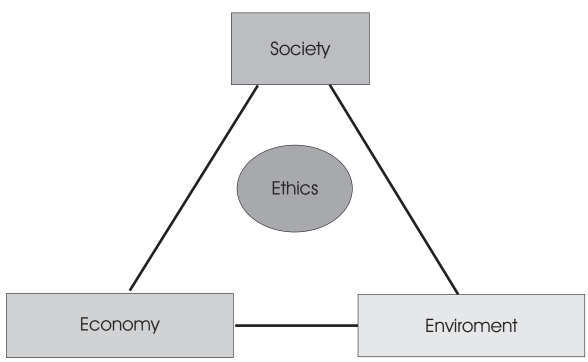

Figure 3. Sustainability Triangle and Ethics

environment, and to evaluate and implement opportunities to effect environmental improvements (Graedel and Allenby 2003). On the other hand external costs are defined as those actually incurred in relation to health and the environment and quantifiable but not built into the cost of a product or service to the consumer, but borne by society at large (Hohmeyer O. and Ottinger 1991), (Hohmeyer and Ottinger 1994), (Krewitt 2002). Example results of these methodologies are provided in Table 1. Notice that both LCA and external costs provide a better estimate of the impact of these technologies to society. These methods strive to correct market failures that ignore these environmental and social costs in traditional economic analysis. This is not a trivial process, but it is necessary to get a more leveled playing field when comparing alternatives on current energy practices and technologies.

2. The Puerto Rican Case

Puerto Rico is a Caribbean island with an area of about 3,500 square miles. It has been a territory of the United States (U.S.) since 1898. Its population is 3.8 million, it has 3,015,227 vehicles (among the largest in the world per capita), and Puerto Rican's Emissions per capita are 230% that of the average per capita of the Rest of the World, and 333% that of Latin America (Environmental Protection Agency 2008).

The Island is 99% dependent on fossil fuels for transportation and electricity, but there are no fossil fuels in PR. Figure 4 shows the fuel distribution for the electric power sector. The Puerto Rico Electric Power Authority (PREPA) is a self-regulated, public corporation that is the only utility in the Island. Puerto Rico has two co-generators under PURPA, EcoElectrica (uses Natural Gas), and AES (uses coal). The Island's has an inefficient and

Generation type	SO_2 (g/MWH)	NO_x (g/MWH)	Particulates (g/MWH)	CO_2 (g/MWH)
Nuclear	32	70	7	19,700
Coal	326	560	182	815,000
Gas	3	277	18	362,000
Oil	1,611	985	67	935,000
Wind	15	20	4.6	6,460
PV (Residential)	104	99	6.1	53,300

Table 1. LCA Emission Estimates for Electricity Generation (UIC 2004)

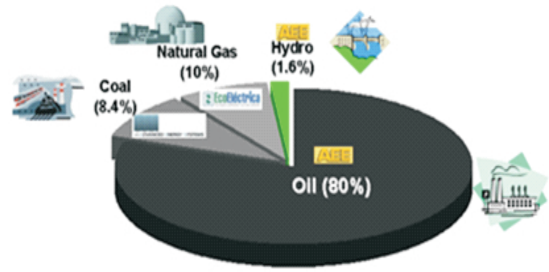

Figure 4. Fuel Distribution in the Power Generation Industry

irresponsible energy use, and the demand increased dramatically in the 90s. The social, environmental and economic costs of current energy sources and practices are too high. The Environmental Protection Agency has fined heavily our local electric utility for emissions. Industrial and commercial representatives have long voiced their concerns about high operating costs in the Island. Health problems related to pollution are commonplace, especially in vulnerable communities. Construction and urban development are pillars of the local economy, fostering urban planning disorder.

Laws that encourage the conservation of natural resources are ineffective insofar the legal framework is disconnected from the reality with regard to energy and economic development strategies. For example: "The sustainable development strategy of Puerto Rico must recognize the need for a new vision that considers the environment and natural resources, in particular with regards to land and water use, transportation, energy production, waste management and coastal zone management. We must support our economic development but in a sustainable way, so that its cost does not involve an excessive degradation and destruction of the environment and natural resources or social injustice" this is part of Puerto Rico's Sustainable Development Law #267, September 10, 2004.

Under the scenario described above, there is an urgent need for a social and technological transition to a new culture of social and environmental justice, based on sustainable practices and technologies. Solutions being sought and implemented are mostly economic, and in many times short term in nature. For years the cost of electric energy has been identified as a major obstacle for doing business in the Island. Yet, long-term changes in the electricity cost have not occurred in Puerto Rico. The recent government effort towards supporting biosciences, and the investments of major biotechnology companies in Puerto Rico, stress the need to provide a business environment where the fixed operating costs are diminished as much as possible. Furthermore, other economies are also investing in attracting these same biosciences companies to their countries. Businesses will go wherever the investment environment is more opportune.

However, the electricity needed by Puerto Rico's businesses, citizens, and visitors comes at a premium cost (Colucci-Ríos et al. 2009). Puerto Rico's average electricity cost per kWh is the highest in the United States. In 2008, electricity reached $0.30/kWh for residential consumers during the summer. The increase in electricity price is directly related to our dependence in foreign oil to produce electricity. Contrary to the United States where only 3% of the electricity is generated from oil in Puerto Rico we depend on oil for around 80% of our electricity production. In the near future, especially in an island-environment like Puerto Rico's, the traditional view of equating energy use to economic development is not sustainable. A new perspective on energy use at all levels, and its relationship to economic development must be established. On the other hand, the fuel diversification strategy for the electric industry of equal division among coal, gas and oil perpetuates this dependence on external sources of energy. Alternatives that create local jobs and keep the money in Puerto Rico need to be sought. The electric utility announced in July of 2008 plans to reach up to 20% of renewable energy production, only to reduce that goal to 9% in early 2009.

There are substantial benefits from increased use of renewable energy resources. Among the benefits those cited most frequently in the literature are:

- Reduced cost of fuel for electricity;
- Reduced reliance on imported oil supplies and exposure to the volatile prices of the world oil market;
- Risk management by diversifying the portfolio of electricity generation options;
- Job creation and economic benefits; and
- Environmental benefits.

However, this call for reducing fossil-fuel dependence is not new. "A general broad consensus is needed in Puerto Rico so that plans and actions for oil substitution alternatives on a large scale may be implemented as soon as possible. Plans to implement alternative energy sources should be translated into action promptly. If not, in a few years our people will suffer from our present inaction. Oil is vanishing steadily and continues to be a very politically unstable energy source. Puerto Rico cannot afford to wait or relax until tomorrow. Prudence and economics dictate that we move toward energy self-sufficiency as rapidly as possible". These words seem to be taken from this week's newspaper but they are in fact from a 1983 conference (Bonnet 1983). A study from the National Academy of Sciences that concluded: "Puerto Rico, in dealing with its own energy problems, should grasp its opportunity to become an international energy laboratory, seeking and testing solutions especially appropriate to the oildependent tropical and sub-tropical regions of the world. The Island's geographical position and its established energy research and development facilities enhance this potential" (U.S. National Academy of Sciences 1980)" ".

Puerto Rico did not become the international energy laboratory it could have been. We still depend heavily on oil for electricity production to the point that every time the price of the barrel of oil increases $10, over $700 hundred millions of dollars leave Puerto Rico's economy. And after the initial uproar and short-term strategies vanished, we fall again in the complacency of "acceptable" oil prices, even though hundreds of millions of dollars are still leaving the Puerto Rican economy. We remain waiting, as if the answer to our oil dependency problem could be imported. To put in perspective our unfinished business with regard to the road towards energy sustainability, Hawaii has committed to 70% use of renewable energy by year 2030 (DOE 2008). Hawaii is a good benchmark for Puerto Rico because of the islanded nature of its electrical system, its high energy prices and its dependence on outside energy sources. In words of the Assistant Secretary of Energy Alexander Karsner: "Hawaii will be a living laboratory for integrated, renewable energy development". Meanwhile Puerto Rico remains stagnant, with an unfulfilled potential to become a showcase of renewable energy in the Caribbean. This must change.

However, which are the realistic goals for those energy alternatives and how to begin a transition to some of those alternatives represent a complex problem. A first step towards setting those goals will be presented next.

3. Renewable Energy Resources In Puerto Rico

We have performed a research study of each renewable energy resource, and related technologies, available in Puerto Rico for electricity production (Irizarry 2008). These are; biomass - including waste-to-energy, micro hydro, ocean – in the form of waves, tides, currents and ocean thermal, solar radiation (to be used thru photovoltaic technology) and solar thermal, wind – to be exploited at the utility level (wind parks) as well as small wind. The estimate also includes a preliminary assessment on the use of fuel cell technology. This estimate has been restricted using realistic constraints such as: estimated availability of the resource under consideration, estimated required surface area or "foot print", seasonal cycles, state of available technology (commercial and prototype) and estimated capital costs. This estimate provides the quantitative means to compare among renewable electricity production alternatives based on the amount of electricity that each resource may provide.

Also, a more realistic estimate for ocean, solar (photovoltaic) and wind resources has been done as requested by the Puerto Rico Energy Affairs Administration (PREAA). This estimate is based on the aforementioned criteria plus: weather effects, day/night cycles, state of available technology (commercial, prototype or laboratory available), costs such as capital investment (including retrofitting of existing facilities) and maintenance and operation, electric grid interconnection issues, and others as needed to realistically constrain the resource under investigation.

This estimate of renewable energy available in Puerto Rico for electricity production has been performed to provide guidance to those responsible of establishing an energy policy that ensures that a minimum amount of renewable energy is included in the portfolio of electricity resources serving Puerto Rico. Adequate targets, as a function of time, may be developed for example using a Renewable Energy Portfolio Standard (RPS). A RPS is designed to increase the use of renewable energy for electricity production by requiring that a specified percentage of the electricity for the state be generated from renewable sources. Such requirements exist in various countries and states of the United States and a first step in establishing a RPS is the study described in this report.

This study did not cover the potential benefits of energy conservation and energy efficiency, particularly the use of residential solar thermal water heaters as immediate and economic alternatives to displace electric generation. These merit further study, and should be the first strategy followed en route towards a sustainable energy future.

3.1 Summary of Results

The renewable energy resources we have studied have significant physical differences among themselves. For example biomass is measured in tons, with a great variety of heat content, while solar radiation is measured in Watts per square meter per year (W/m^2 per year). The variability, the change in availability with time, of these resources is also measured differently. Crops have different cycles (annual, semi-annual and such), the most obvious solar cycle is day to night while the wind changes randomly.

Due to the different nature of the resources the available technology for electricity production from them varies as well, including the fact that some of it is commercially available while other is at the prototype or laboratory level.

Thus these renewable energy resources and related technologies are intrinsically difficult to compare. In an attempt to compare them in this summary we have selected three parameters, namely; required surface area, or "footprint", capital costs and potential electric energy contribution from each resource. The remaining parameters studied in this work, the estimated availability and variability of each resource and the state of the technologies used to harvest their energy, are more justly discussed in the following sections of the report.

3.2 Ocean energy technologies

Ocean waves have extraordinary potential. With close to 17,000,000 MWh of potential annual production (if we only use 10% of the available ocean space in the North West coast) this resource represents the largest, naturally produced, untapped energy resource for Puerto Rico. Given the current development of these technologies we recommend to perform pilot plant studies in Puerto Rico that includes actual ocean wave measurements and technology validation.

Environmental, social and community concerns must be addressed in parallel with engineering developments for the sustainable use of ocean waves to produce electricity. Public policy, for licensing ocean space to harness its energy, must be developed.

Another important finding is that potential electric generation from ocean currents and tides, using currently available technology, is too small in comparison to wave energy and thus economically unfeasible. Although Puerto Rico is considered by many to possess excellent potential for OTEC, many unknowns regarding the technical, ecological, economical and social viability of this technology are still to be addressed.

Groups currently proposing OTEC for Puerto Rico do not disclose their economic and financial estimates to maintain a commercial advantage over other proponents. It is not possible to make a reliable economic comparison with other technologies under this lack of available data.

OTEC is a potentially disrupting technology to the environment given the massive flows of sea water necessary to achieve megawatt levels of power generation. This includes piping (20–40 ft diameter), pumps, etc. Maintenance costs considering corrosion and bio-fouling must be estimated carefully and conservatively.

The social and community site specific impacts such as fishing, ocean recreational sports, and coastal tourism developments must also be discussed in detail. Given these uncertainties and advanced level of development of other technologies, OTEC falls under a second tier type category. Note, however, that OTEC is considered a "baseload" alternative versus other renewable resources that are more variable in nature.

3.3 Biomass

Another alternative resource that was only assessed in the preliminary study is biomass which included both agricultural based and solid waste. The preliminary analysis show that agricultural biomass from microalgae has an impressive potential. Annual electric energy production, using only 10% of the potential harvest of microalgae, is estimated at 24,000,000 MWh, a figure that exceeds the 2006 electric energy demand of 20,600,000 Mwh.

This finding becomes even more important if we consider that biofuels are a source of power and energy not just energy. Wind, ocean waves and solar photovoltaic are subject to fluctuations in the source of energy making them energy producers that require either energy storage, not necessarily in the form of electricity, or careful and precise grid management to allow for continuous supply of electric power. This extraordinary potential cannot be tapped easily. Many hurdles lie in the path of using 10% of the potential harvest of microalgae in Puerto Rico. Among these are:

1. The "fuel vs. food" debate has not occurred in a sustainable, i.e. inclusive and participative, manner in Puerto Rico. The benefits of using agricultural land to harvest microalgae must be carefully weighed against its harms. The current philosophy, as stated in Puerto Rico´s Constitution, is that food comes first.
2. Puerto Rico´s Constitution explicitly forbids the use of government owned agricultural land to grow non-food crops. If the "fuel vs. food" debate is settled in a manner, or even a limited manner, that permits the use of agricultural land to produce "fuel crops" a Constitutional change is still needed to take advantage of the many acres of fallow government owned agricultural land. The political process to

produce such change has in itself many hurdles.

3. Even if the “fuel vs. food” debate is settled permitting the use of agricultural land to produce “fuel crops”, and the Constitution is changed to make it legal, the agricultural sector still needs major restructuring.

Puerto Rico´s agricultural sector has been declining for decades. The use of outdated technology, lack of interest and support from the Puerto Rico government to this sector, non-consensus among farmers on the right strategies to improve, lower profit margins versus high tech higher paying jobs and foreign competition are just a few of the reasons for the decline. In addition, many farmers cannot resist the high, immediate, financial gains of converting farm land into real state developments. The lack of a well articulated, well implemented, modern plan for the use of land exacerbates this situation.

In summary, an inclusive debate beyond the superficial “fuel vs. food”, changes to the Puerto Rico´s Constitution and a major overhaul to the agricultural sector are needed in order to tap the potential benefits of using microalgae to produce not just biofuels, thus electricity, but other Fs (Feed, Feedstock, Fibre and Fertilizer).

3.4 Photovoltaic electric generation

The least intrusive renewable energy resource technology considered in our study is solar photovoltaic. Contrary to other countries were photovoltaic farms are considered, in Puerto Rico photovoltaic roofs were the main focus of the study. We have selected this approach based on Puerto Rico's high population density and historic single family housing trends.

Approximately 65% of residential roofs can provide the total electrical energy, not power, that is generated in Puerto Rico, as shown in Figure 5. The highly distributed nature of this alternative, with hundreds of thousands of potential energy generators, also possesses interesting challenges regarding the integration and inter-connection of these systems. Nonetheless, the energy generation potential is so significant that even 10% of the households can provide close to 20% of the overall energy demand. Developments in energy storage technologies should provide an opportunity for even

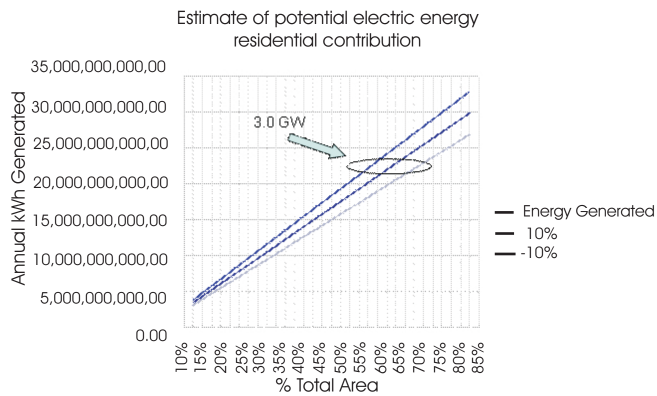

Figure 5. Estimate of solar Photovoltaic Electric Energy Contribution from Residential Applications

greater penetration of photovoltaic systems in Puerto Rico.

Photovoltaic generation is the least environmentally intrusive, and the one with minimum possibility of social and community conflicts during deployment, among the renewable energy resources and technologies considered in the study. Photovoltaic panels installed in roofs are virtually non-visible and the noise level of auxiliary equipment, such as the fan from DC/AC converter, is negligible. An important issue to consider is the “right to the sun”, an issue that will emerge as more PV systems are installed in rooftops.

Again, perhaps the most important challenge, after is high capital cost per unit of power, is the adjustment needed in distribution systems, how they are designed and operated in Puerto Rico, so that these can accommodate as many distributed energy sources as it is economically, technically, socially and environmentally viable.

Economic affordability of low income families is a social issue that must be addressed in the economic incentives that are required for these systems. Notice also that these numbers indicate that photovoltaic farms that compete with other renewable resources such as wind and biomass should have a lower priority. However, areas such as state highways, parking lots, etc could also be considered.

Another important consideration with PV technology deals with the way we build new structures, for example access to the roof from the electric distribution panels and the layout and use of space in the roof. Piping and air conditioning equipment, dish antennas and any structure over the roof can cast a shadow that limits potential use of PV in a rooftop.

3.5 Eolic generation

Offshore and in-land wind farms offer a very high potential of electricity production in Puerto Rico. The Northern, Southern and Eastern coasts in Puerto Rico have enough in-land wind resource to provide power in the gigawatt level. The two identified areas for offshore wind power generation, in the east coast (1,920 km^2) and south coast (825 km^2), can result in a total installed wind capacity of 13,725 MW. Even 10% of that area will result in 1,375 MW which is still a considerable amount.

Similar to ocean based technologies, wind is undergoing strong scrutiny from environmental and community groups. Wind farms are not only highly visible but could affect species such as bats and birds. However wind generation is a mature technology, proven around the World, and the most cost effective of the renewable generation options.

3.6 Fuel Cell Technology

Fuel cell technology had definite disadvantages versus faster growing technologies in the short, 1 to 5 years, and medium term range, 6 to 15 years. The relatively high price of hydrogen and natural gas is a very difficult hurdle to overcome especially in Puerto Rico.

4. Challenges For Renewable Energy In Puerto Rico

This section briefly lists some of the issues that need to be addressed so that renewable energy can be a viable and important alternative in the energy source scenario of Puerto Rico (PR). First, the dominant energy model of central generation has existed for over 100 years. In Puerto Rico the dominant model has worked well, and the scale economies generated by the use of fossil fuels cannot be denied. Thus, any new energy alternative will face opposition from the industry establishment, and the burden is on proposers of the new practices to prove that their alternative is better, in some cases, much better, than current, well-known energy practices and sources.

Second, the regulatory structure in Puerto Rico presents a huge challenge. On one hand, the 1941 law that established the Puerto Rico Electric Power Authority (PREPA) gave it ample powers over all things related to electric power, including being mostly self-regulated. There are historic reasons for that decision, and the strategy definitely was vital in the economic development of Puerto Rico during the second part of the 20th century. However, such powers and structures should be evaluated in light of the new global and local conditions in the energy industry. Regulation of power however is not all in the realm of PREPA. There have been U.S. regulations that apply to Puerto Rico, regardless of the fact that our regulatory environment is different from the regulatory entities that exist in the 50 states. In PR, there would not be fuel diversification without the U.S. Public Utility Regulatory Policy Act (PURPA). Ecoelectrica – natural gas, and AES-coal, both entered the PR market through PURPA, a U.S. Energy policy from 1978.

The U.S. Energy Policy Acts (EPAct) of 1992 and 2005 also apply to PR. EPAct 92 encouraged states to open access of transmission lines for sales by private generators (known as wheeling). It also encouraged the use of distributed Generation (DG), generators operating at lower voltage levels closer to the points of use of electricity. EPAct 2005 reinforced federal programs on energy efficiency and renewable energy. It also stated that utilities and public service commission (or their equivalent public utility commissions, none of which exist in PR with regard to electricity) must consider important operating modes different from the dominant energy model: Interconnection of DG, and net metering (the sale of power by private producers at the same rate that utilities sale power to clients). It has been through EPAct 2005 that PREPA acted and approved interconnection of DG, and will also act on net metering by August 2008. The challenge is to obtain just and reasonable regulations and rules for both interconnection of DG and net metering that effectively encourage the use of renewable energy in PR. Another challenge is how Puerto Rico can be proactive in future energy alternatives instead of reactive to external energy measures. We must evaluate how to best comply with federal mandates in a way that is not a one-sided application of the federal laws or the development of state regulations with seemingly patronizing attitudes towards consumers in PR.

In line with the EPAct discussion, the Federal Energy Regulatory Commission (FERC) established Orders 888 & 889 to comply with EPAct. FERC regulates the inter-state sale of electric power in the USA. Thus, FERC does not have jurisdiction in PR (we have no inter-state sales of power), FERC has some jurisdiction through the use of natural gas. Nevertheless, the importance of orders 888 and 889 is the fact that they provide clear rules for how the EPAct mandates are to be implemented. What does this mean to Puerto Rico? Nothing, if one does not pay attention to alternative ways of operating PR's power system. However, how could a structure like this exist in Puerto Rico? Would it be beneficial to PR? Would this encourage broader use of renewable, decentralized energy sources? How can PREPA be a facilitator in this process? These are the challenges that need to be addressed if renewable alternatives are to have greater participation in Puerto Rico. However, another challenge is: where and how will these questions be discussed, evaluated and debated? Energy stakeholders have no formal forum to engage in this participatory exercise (O'Neill-Carrillo et al. 2008).

There is an urgent need to re-think Puerto Rico's electric system and energy consumption. Our electric infrastructure must be maintained and defended, and we need to deal with the stranded costs that exist due to the dominant energy model. PR needs to look beyond the limited cost-benefit, and think of alternatives that are good to all energy stakeholders. A challenge in this process is how to deal with the technical limitations imposed by the island nature of our electric system. In that line, there is a challenge in considering energy alternatives that include metrics and methods adjusted to PR's reality. For example, it is necessary to consider energy efficiency instead of “energy use” as an economic indicator. We must also examine current reliability standards in light of cost increase of fossil fuels and consider interruptible loads & rates to balance incentives given to DG.

Conservation, efficiency & renewable sources could halt new construction of fossil fuel plants, and must be included in the planning of our electric system (Colucci et al. 2007). Incentives for residential and small commercial customers must be aggressively pursued, and PREPA could become an enabler of DG so that it complements central generation, and considered in the planning and operation of our power system. However, there are no magic tricks or magic wands, including renewables. If there is no wind or sun, there is no energy. Renewables have environmental impact, e.g., the manufacturing of PV panels is energy intensive and has impact since they involve semiconductors. Also, manufacturing PV panels involves waste water, the use of batteries in renewable systems requires an effective battery-recycling program, there are sitting issues, and ethical issues related to renewable systems, especially the impact on vulnerable communities. Finally, what will happen to any program that strives to reduce fossil fuel dependence if such fuels remain in “acceptable” prices? Will society make a commitment to look beyond economics, and integrate social and environmental matters in decision- and policymaking processes? These are challenges not meant to discourage renewables, but to understand pros and cons of each alternative.

We must stipulate that a sustainable energy future and the decisions related to it are complex matters. We need to make long-term decisions under uncertainty. However, we need not predict the future, we should be enablers of our energy future, and at the very least, not become obstacles to new ideas and practices.

5. A Sustainable Energy Future

It should be emphasized that the challenges in the previous section cannot be an excuse to do nothing. Although those challenges are specific to Puerto Rico, they illustrate the kind of policy challenges that any alternative energy strategy will face. Again there is an urgent need for studies to understand what can be done, and how diversification of energy sources and systems can be achieved. When considering energy alternatives, we must include metrics and methods adjusted to reality of the location being studied. For example, we must begin to consider energy efficiency instead of “energy use” as an economic indicator. The internalization of externalities must be a priority. Conservation, efficiency & renewables should be an integral part of any effort, at all levels to use these alternatives to the maximum extent possible (technical, economical, social, environmental and ethical). There must be effective incentives for residential and small commercial customers to this end. Government needs to pay closer attention to one-sided application of federal laws or state regulations (that is, application should benefit all energy stakeholders, not some). We need to examine current reliability standards, and consider seriously interruptible loads & rates. Utilities should become enablers of DG, in a way that DG can effectively complement central generation, and be considered in the planning and operation of our power system.

It is vital to begin collaborations among government, industry, commerce and citizens. We need to go from an adversarial to a collaborative relationship, from mutual distrust, to a serious and lasting commitment for the public good, for the social, environmental and economic welfare of all stakeholders. National Dialogues that are inclusive and constructive are needed, so that we can have planning that go beyond any political cycle. And that process should yield actions: that are measurable and decisive so that we can hope to achieve a more sustainable future. Besides economical considerations, we need to integrate social and environmental justice. To re-think electric power systems and energy consumption we must talk about utility's stranded costs, and the minimum costs to keep our electric infrastructure in optimum shape. We need to go beyond the utilitarian view of cost-benefit analysis. Also, renewable is not the same as sustainable. We can have a great renewable project that fails in the environmental or social dimension, and thus the project is not sustainable. Finally, renewable sources do have environmental impact as discussed previously.

Nevertheless, in spite of obstacles, it is unacceptable that renewable energy sources are not being used to the maximum extent possible in the U.S. Participatory structures must be created that enables a national dialogue to reach the decisions needed to move forward with sustainable policies. All alternatives need to include social and environmental issues as equally important as the economic issues. The present consumption patterns are simply unsustainable; the Earth does have enough resources to sustain those patters for all human beings. The burden is too high, not only to the present generation, but to coming generations. It is time to quantify the benefit to future generations of sustainable practices, understanding that this strategy could imply sacrifices today. However, we already are passing future generations a huge economic debt, why not passing them a positive legacy with sustainability.

The Puerto Rican case is presented as an example of UNSUSTAINABLE practices in energy. We are currently paying the consequences for bad assumptions, and inaction and bad decisions regarding energy diversification in the electric power sector. Puerto Rico is currently struggling for a transition to renewable energy systems, however, the fossil-fuel dependent systems is a terrible legacy, a heavy burden that must be dealt with. A word of caution to others in their own struggle for energy security, do not come this way, the way of heavy reliance on mostly one energy source or strategy, especially if such strategy is highly dependent on exogenous circumstances, such as oil production and distribution.

Conclusions

This paper presented the energy dilemma from the broader perspective of sustainability, striving to achieve a balance among the economic, environmental and social dimensions of energy. The dominant energy model needs to be complemented with an alternative scenario in which renewable energy sources, conservation and energy efficiency strategies and technologies are used to the maximum extent possible. Not internalizing the so-called externalities results in short-term economic gain at the expense of environmental degradation and long term economic loss. In spite of the difficulties in achieving sustainability, it presents a framework, not only of considering environmental and social "externalities" but to include them as integral parts in the energy decision making process. Such a framework can account for many of the interests involved in developing future energy directions and policies. A case study from Puerto Rico was presented, to illustrate the challenges of achieving sustainability in fossil-fuel dependent, energy-intensive, unsustainable societies.

Puerto Rico has enough renewable energy resources to wean out of our fossil-fuel dependency in over 50%. Photovoltaic systems can have a dramatic impact at the residential level in Puerto Rico. During the day, enough electrical energy can be generated to displace fossil-fuel based generation equivalent to the residential load using dispersed residential PV systems. Irradiance variations are not a big issue for dispersed PV systems since it is unlikely under typical weather conditions, to have the whole Island under cloud cover. Higher capital cost is its main disadvantage compared to the other technologies. Offshore and In-land wind farms offer a very high potential of electricity production in Puerto Rico and offer the advantage of no land use. Even with its higher capital cost off-shore wind remains attractive and competitive cost wise. Its main drawback is their high visibility and the potential to affect species such as bats and birds if sites are not carefully chosen. Ocean waves have extraordinary potential and represent the largest, naturally produced, untapped energy resource for Puerto Rico. Its footprint is small and current cost lie between photovoltaic and wind.

We recommend wind, solar photovoltaic and ocean waves as the renewable resources/technologies to be targeted via Renewable Portfolio Standards in the immediate future. A clearly achievable use of only 10% of these resources will provide an estimated 115% of the 2006 electric energy demand.

A common objection to the use of renewable energy resources is the electric grid interconnection issue. Electric grid integration and interconnection is a well studied area with a wealth of information and studies on how to deal with the technical challenges of taking advantage of renewable energy resources and an electric grid that was not originally designed for them. This is not to say that we can indiscriminately interconnect distributed or renewable energy resources to our power grid. Operational limits, dependent on the utility's particular operating region, must be defined to keep the grid operating with the renewable resources and within its safety and operational restrictions.

In Puerto Rico, with our abundant renewable energy resources, the question should be not how to best integrate renewable resources into the existing electric energy grid or other energy infrastructures, but how our existing infrastructures and practices should change or transition in order to allow maximum use of solar, wind, ocean and other renewable energy sources.

The renewable energy potential is available, the technological know-how is present, but we need the will as a People and the inclusive and open dialogue spaces to reach historic decisions. Environmental, social and community concerns must be addressed in parallel with engineering developments for the sustainable use of ocean waves to produce electricity. Public policy, for licensing ocean space to harness its energy, must be developed. We need to stop thinking within the bounds of our disciplinary or sector limits, start considering the bigger picture and identify the connections and implications of our decisions into other areas or sectors. It is up to us, all Puerto Ricans, to make a stand for the future, a true social pact in which we do not wait for problems to be solved from the outside but solve the problems ourselves. Participatory structures must be created that enable national dialogues to reach the decisions needed to move forward with sustainable policies. All alternatives need to include social and environmental issues as equally important as the economic issues. It is time to quantify the benefit to future generations of sustainable practices, understanding that this strategy could imply sacrifices today. However, we already are passing future generations a huge economic debt, why not passing them a positive legacy with energy sustainability. The Puerto Rican case is presented as an example of UNSUSTAINABLE practices in energy. This is a word of caution to others in their own struggle for energy security, do not come this way, the way of heavy reliance on mostly one energy source or strategy, especially if such strategy is highly dependent on exogenous circumstances, such as oil production and distribution.

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