Puerto Rico, Renewable Energy Self-Sufficiency Roadmap

White Paper Presentation

Puerto Rico Renewable Energy Self Sufficiency Committee
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Previous Work

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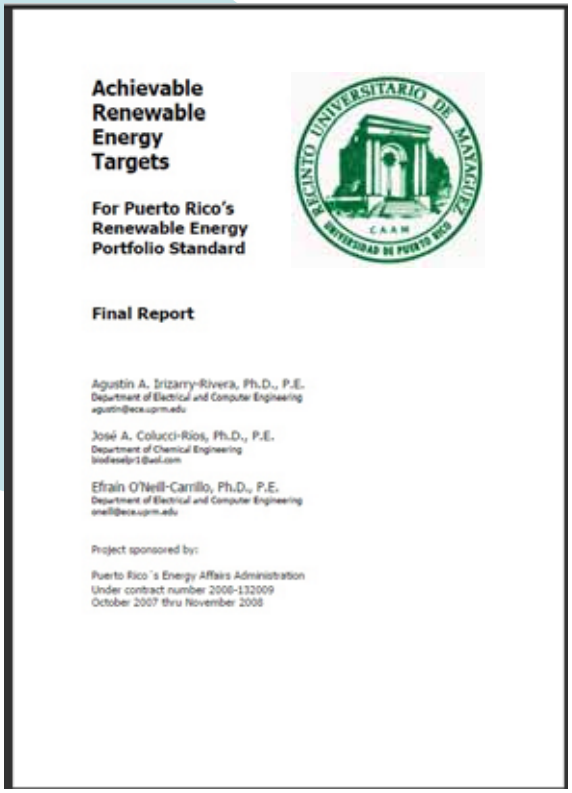
Project sponsored by:

Puerto Rico´s Energy Affairs Administration
Under contract number 2008-132009
October 2007 thru November 2008


Achievable
Renewable
Energy
Targets

For Puerto Rico's
Renewable Energy
Portfolio Standard

Final Report

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Puerto Rico Achievable Renewable Energy Targets
Available at http://aceer.uprm.edu/

Various studies has shown that Puerto Rico has the resources necessary for energy self sufficiency. One of the most significant studies is the Puerto Rico Achievable Renewable Energy Targets (ARET), by the College of Engineering of the University of Puerto Rico, Mayagüez Campus. ARET was sponsored by the Puerto Rico Energy Affairs Administration.

ARET

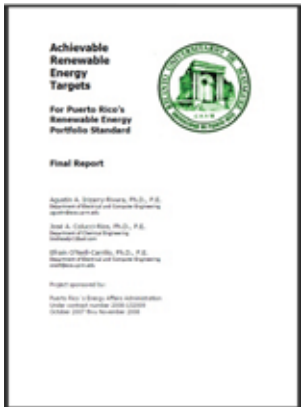
Available Renewable Resources in Puerto Rico and Surrounding Waters
ARET Year 2007-2009

ARET showed that, teoretically ,there are over 100% more renewable energy resources in Puerto Rico than those required to satisfy our present electrical energy needs. ARET included most of the potential renewable energy resources in Puerto Rico and surrounding waters. The study did not evaluate the energy efficiency and conservation impact on our total energy need, although it recognized its primary importance.

Purposes of this study

Build on ARET Study by adding:

- Location
- Area Requirements
- Compatibility with nature and society needs
- Grid integration



Add new elements

- Considers Energy Efficiency
- Evaluates Financial Aspects
- Proposes an Implementation Strategy
- Evaluates Impact to Puerto Rico economy
- Consider Sustainability Assurance

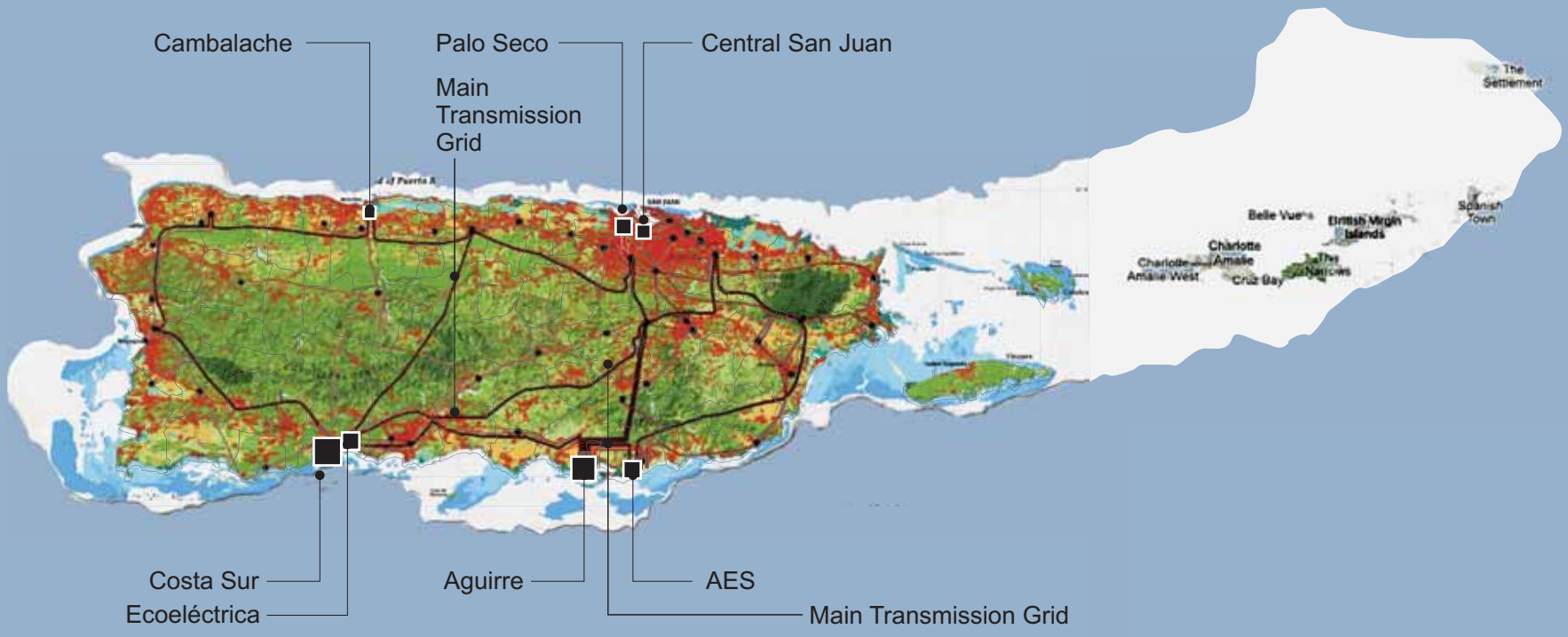
The purpose of this study is to continue the work started by ARET by considering other elements like: 1) the actual surface area required, 2)potential locations, 3) integration with natural resources, 4) the social impact, 5) integration with the present electrical grid. This study considers energy efficiency as part of the energy portfolio, as well as the financial and economic aspects of achieving renewable energy self-sufficiency in Puerto Rico in a sustainable fashion.

Basic Premise

As a society we have agreed in achieving, in 20 years:

- **The production of all our electricity with local renewable resources.,**
- **Maintain the price paid for electricity at the level of 2010 or lower.**
- **Dramatically improve the Puerto Rico economy**
- **Create thousands of new well-paid jobs.**

The basic premise of this work is that Puerto Rico has agreed, as a society, in achieving self sufficiency in the resources necessary to produce all our electricity needs, while keeping the price paid for electricity at 2010 levels or lower. This study also assumes that future political will and public policies will be aligned with the goal of energy self-sufficiency.



The location of the fossil fuel plants and the interconnection grid, was considered for sizing and placement of the renewable energy systems proposed. The energy storage and grid stabilization capabilities of the present fossil fuel burning facilities are assets in the implementation of large scale renewable energy systems.

Fossil Fuel Plants

Today

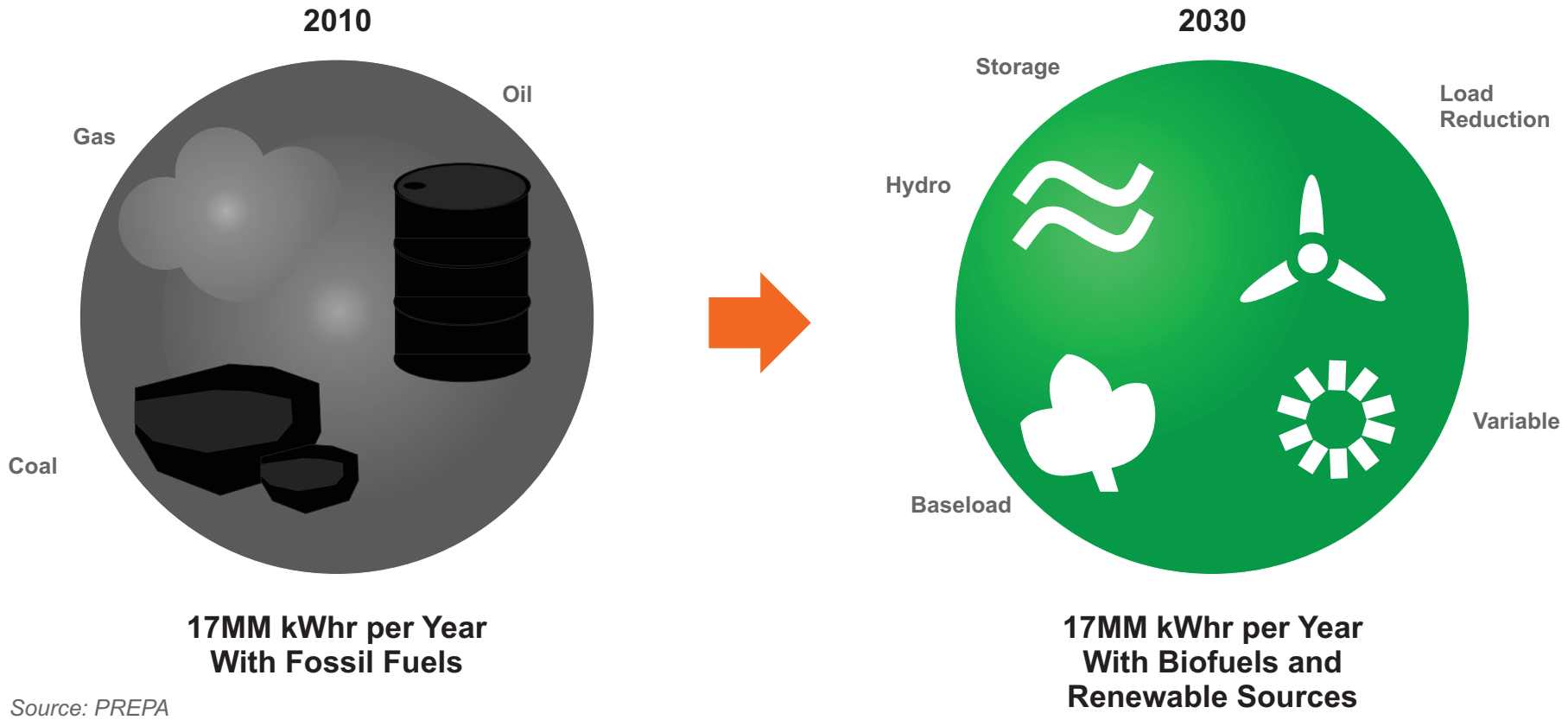
Oil **Diesel**

2030

Algae Oil **Seed Oil**

The present fossil fuel plants will be used as baseload power producers using diminishing amounts of fossil fuels as the efficiency and energy production systems are put in place. Longer term, the oil burning plants will be conditioned to burn 100% biofuels produced within the development area of Puerto Rico, Virgin Islands and the Dominican Republic.

Renewable Energy Transition



17MM kWhr per Year With Fossil Fuels

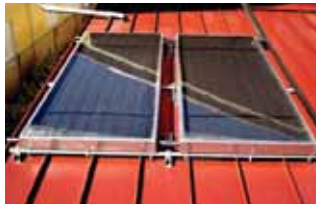
17MM kWhr per Year With Biofuels and Renewable Sources

Source: PREPA

The renewable energy production systems portfolio to replace the 100% of the present need of fossil fuels for the generation of electricity is a combinarion of: 1) Load Reduction systems, 2) Baseload Renewable Energy Production systems, 3) Variable Renewable Energy Production systems, 4) Hydro systems, and 5) Energy storage and frequency control systems, to provide the approximately 17 million kWhr per year of electricity proyected to be consumed in Puerto Rico, every year, during the next 20 years.

Renewable Energy Sources Considered

Load Reduction



- Conservation and energy efficiency
  - > Efficient Air Conditioners
  - > Efficient Lighting
  - > Efficient motors and appliances
- Solar water heating

Variable

- Solar
  - > Solar PV Residential
  - > Solar PV Commercial
- -Wind
  - > Offshore Wind
  - > Inshore Wind
- Waves
- Concentrated Solar

Baseload

- Biomass gasification
- Gasification of non-recyclable waste
- Energy from landfills
- Anaerobic digestion of cattle and poultry biomass
- Anaerobic digestion of sewage sludge
- Macro algae oil
- Micro algae oil
- Ocean-thermal

Storage and Frequency Control

- Network Attached Storage
- Pumped Water Storage

- Hydroelectric

Not Considered

- Source-Based Geothermal
- Gradient Geothermal
- Tide
- Large Scale Hydro

The total number of types of renewable energy sources considered is of 21 different types. Not considered were geothermal, tide and large scale hydro. The reason for this, was the lack of verifiable information in the actual amount of geothermal and tide resources, and space limitations associated with new large scale hydro facilities. Hydroelectric facilities were considered to be used mostly for frecuency control due to limitations in water availability.

Implementation Strategy

Resources available

+

Viable technologies

+

Integration to economic, social and environmental goals

+

Electrical energy needs

+

20 year implementation timeframe

=

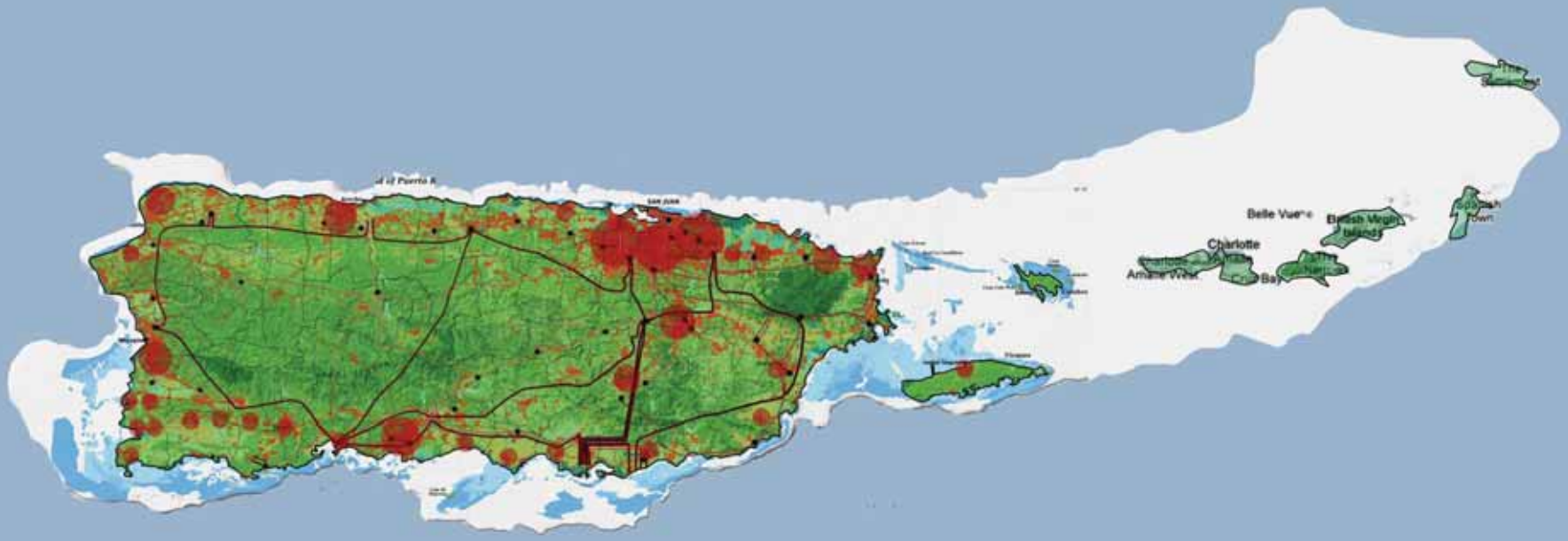
Economic Viability

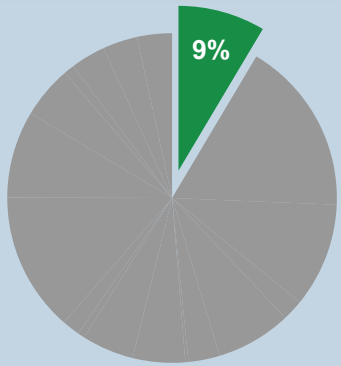
The renewable energy sources implementation strategy contemplated: 1) resources available, 2) the needs of the Puerto Rico economy, 3) social and environmental goals, 4) projected energy needs, in the 20 year implementation timeframe. The purpose of this strategy was to develop an credible estimation of the economic viability of the Puerto Rico renewable energy self sufficiency.

Load Reduction Systems

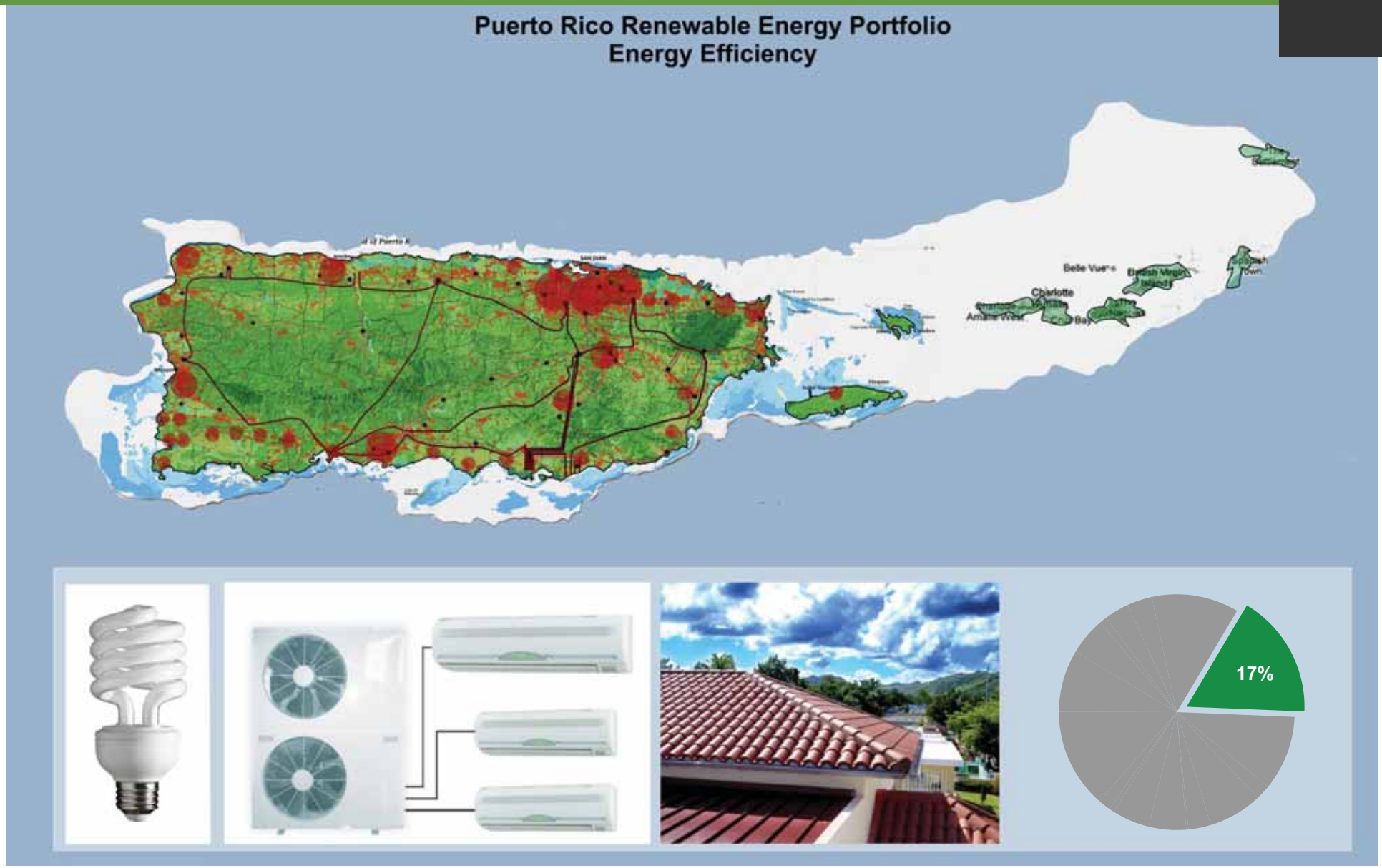
Load reduction mostly consists in the replacement of energy inneficient systems, and the implementation of practices that result in lower energy consumption for a given level of economic activity. Among these, the most important are the climatization of buildings, the replacement of lighting and air conditioning systems, and the improvement of motor efficiency. One important component in Puerto Rico is the replacement of electrical water heaters with solar water heaters in residences and institutions.

Puerto Rico Renewable Energy Portfolio
Solar Thermal Roofs





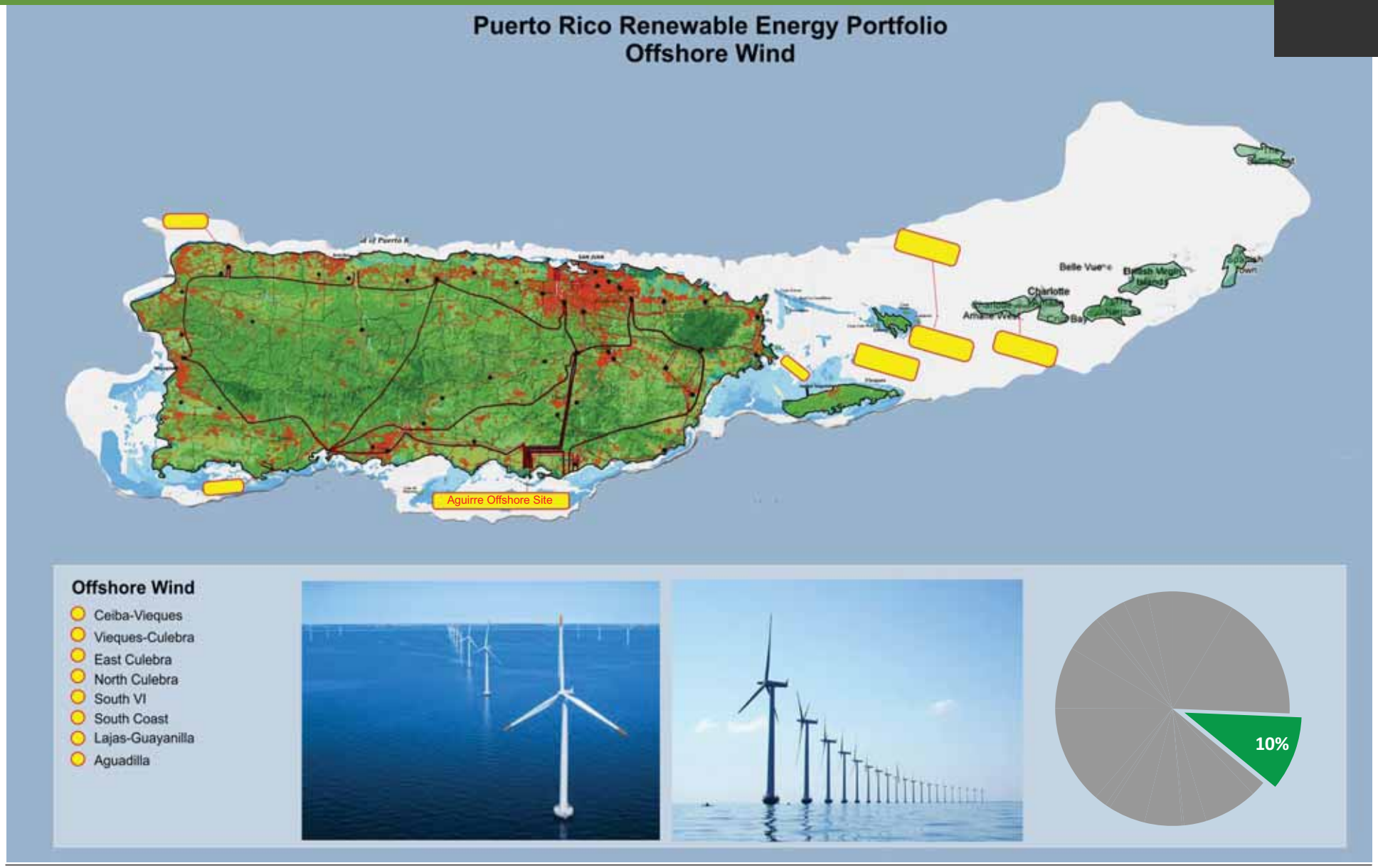
The solar water heaters are the most important systems in the recipe of reduction of electrical load in Puerto Rico. The study proposes the installation of 1,000,000 typical solar water heaters (of about 1.0kW of thermal energy production each). Using a 25% capacity factor typical for these systems, gives us an effective combined load reduction equivalent to 250MW, or 9% of our proyected energy requirements.



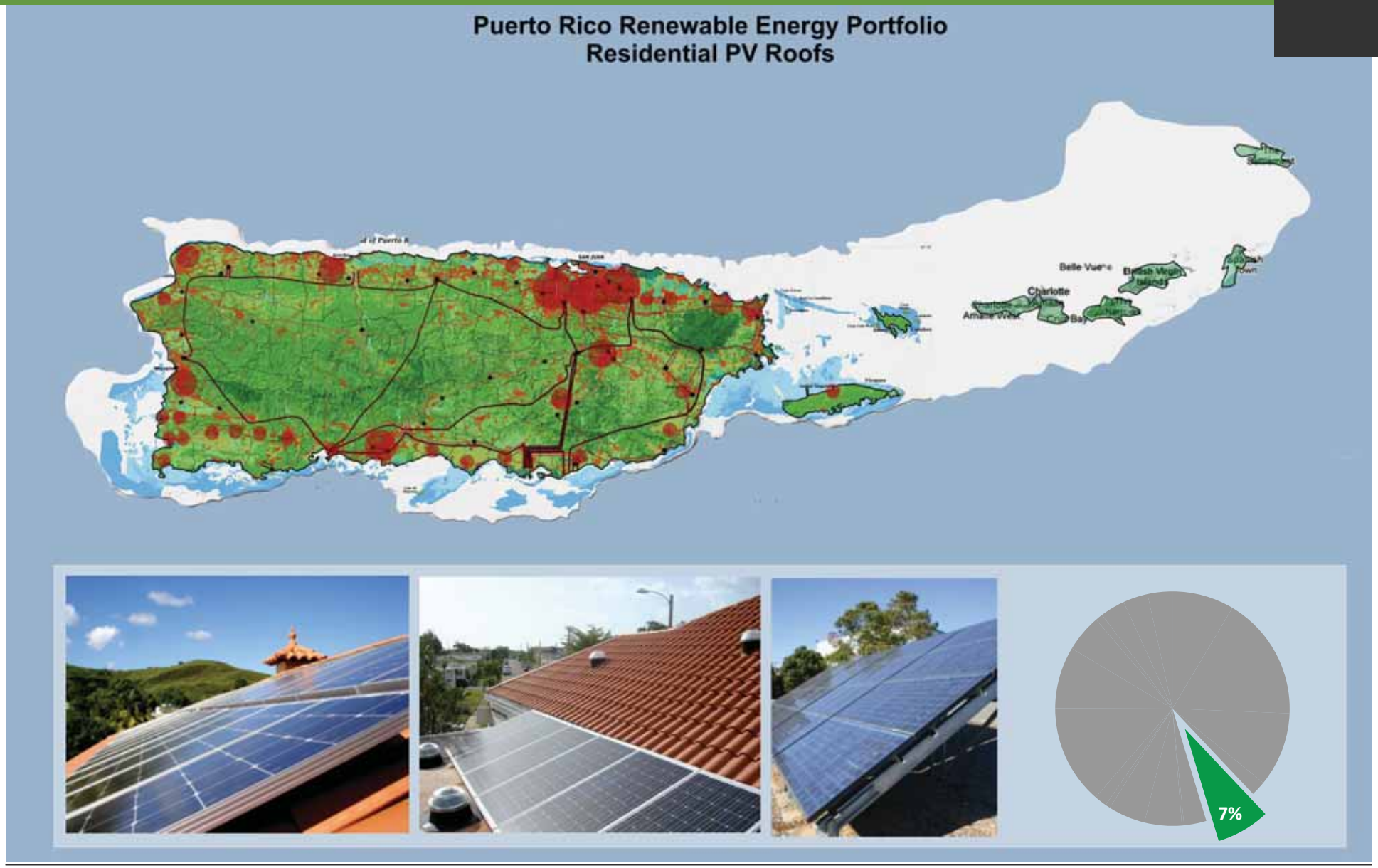
A net 17% reduction in energy load requirements was projected as technically and economically feasible given the experience with commercial, residential and industrial settings where energy efficiency improvements of over 25% have been easily achieved. Energy efficiency replaces baseload energy production through lighting replacement, air conditioning systems replacement and climatization of buildings and residences. An average energy efficiency improvement of 17% is equivalent to the electricity that produces a 500MW facility.

Variable Renewable Energy Production

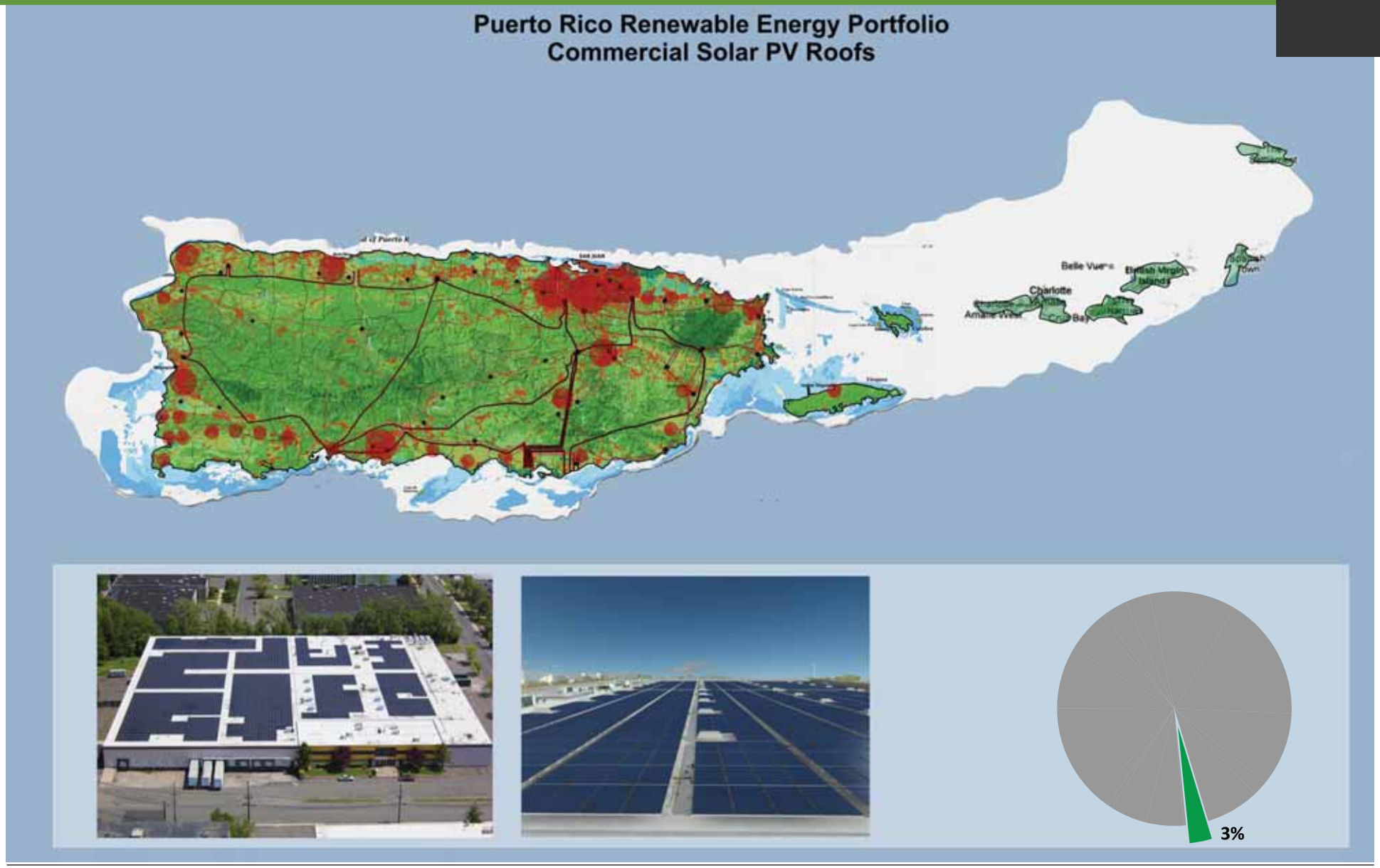
Variable Renewable Energy Systems should provide a large part of the required renewable energy mix for Puerto Rico self-sufficient in renewable energy. Given the large baseload overcapacity with fossil fuels in Puerto Rico today, very large variable renewable systems can be installed as far as the electrical production effects of short term environmental variations are dampened with storage and frequency control systems.



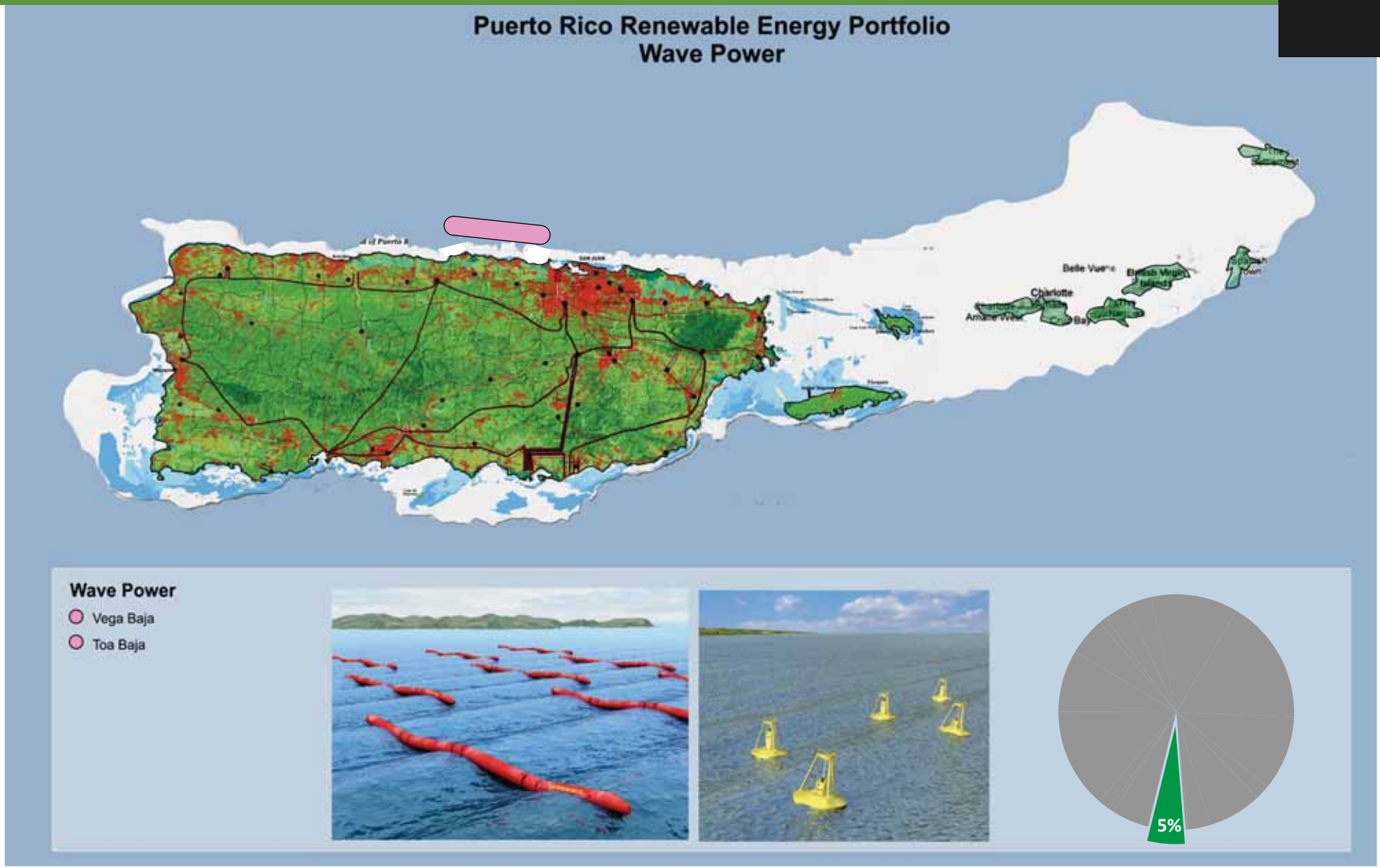
Offshore wind represents the largest single potential source of renewable energy for Puerto Rico. Even when the potential energy production capability at the shallow waters at the east coast of Puerto Rico is in the thousands of MW of effective capacity, the proposed effective capacity would be of approximately 300MW, enough to supply 10% of the projected Puerto Rico electrical energy demand. Given the offshore capacity factor of 30% this represents wind farms of about 900MW of installed capacity. This can be easily installed in just the Aguirre Offhore site.



The study proposed 1,000,000 PV systems of 1.2 kW each distributed throughout our urban sprawl. At an average capacity factor of 18% in the coastal urban centers, these systems should provide about 216MW or 11% of the required energy production. The capacity factor used comes from the average past experience with installed PV systems througout Puerto Rico. The 1.2 kW system size was selected because it minimizes the amount of energy that needs to leave the houses during the day.



In the Comercial PV Roofs, the proposed amount is of 2,000 commercial systems of 250 kW each or any equivalent combination. With a capacity factor of 18%, this will add up to an equivalent of 90MW, or 3% of the required energy production for Puerto Rico.

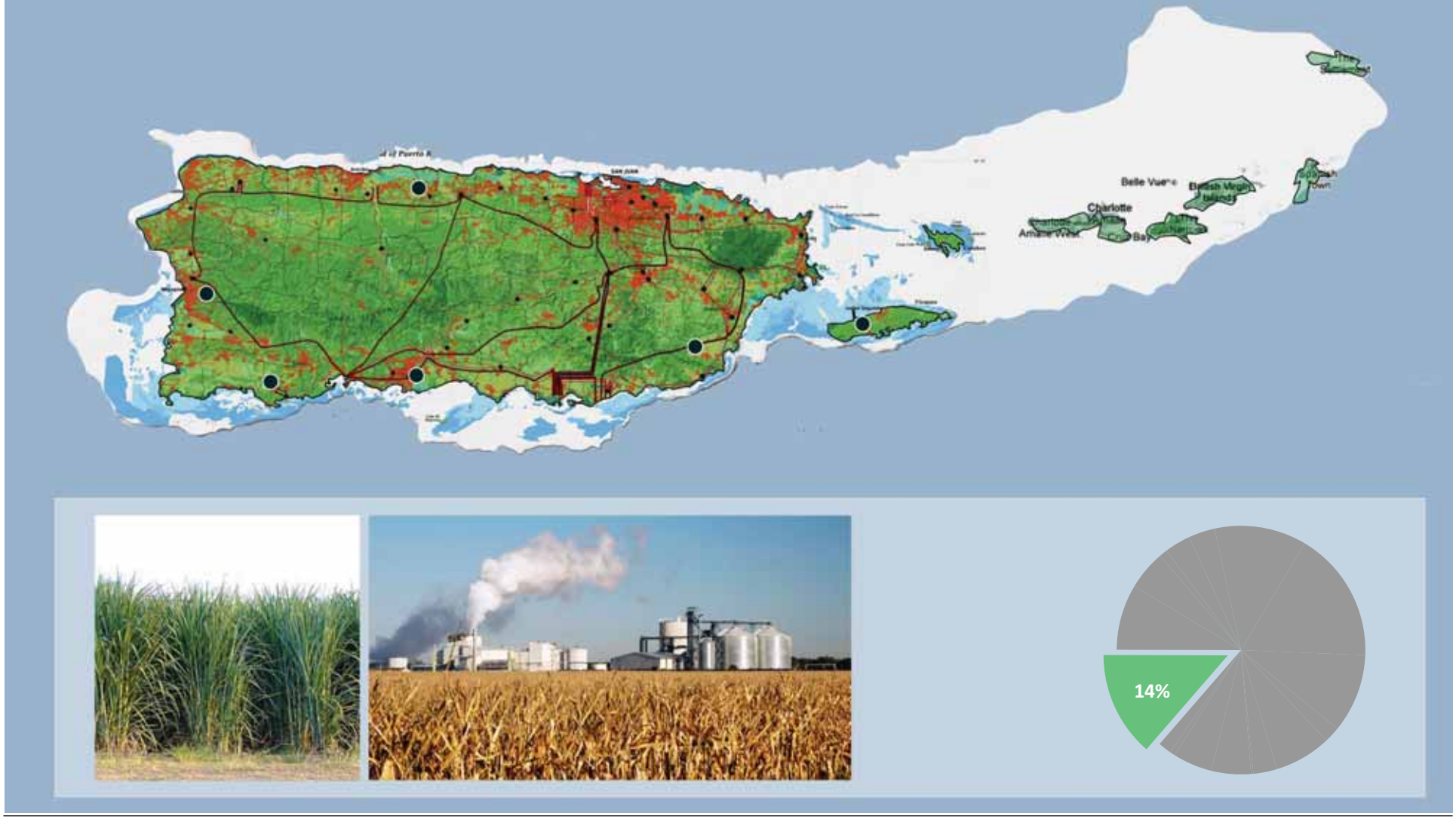


The wave power systems proposed will be based on best technology available. The proposed location would be beyond eyesight in the waters over Vega Baja and Toa Baja. The proposed effective capacity will be of approximately 150MW, about 5% of the electrical energy needs. The effective lenght of shore necessary for this energy source is of about 20 miles.

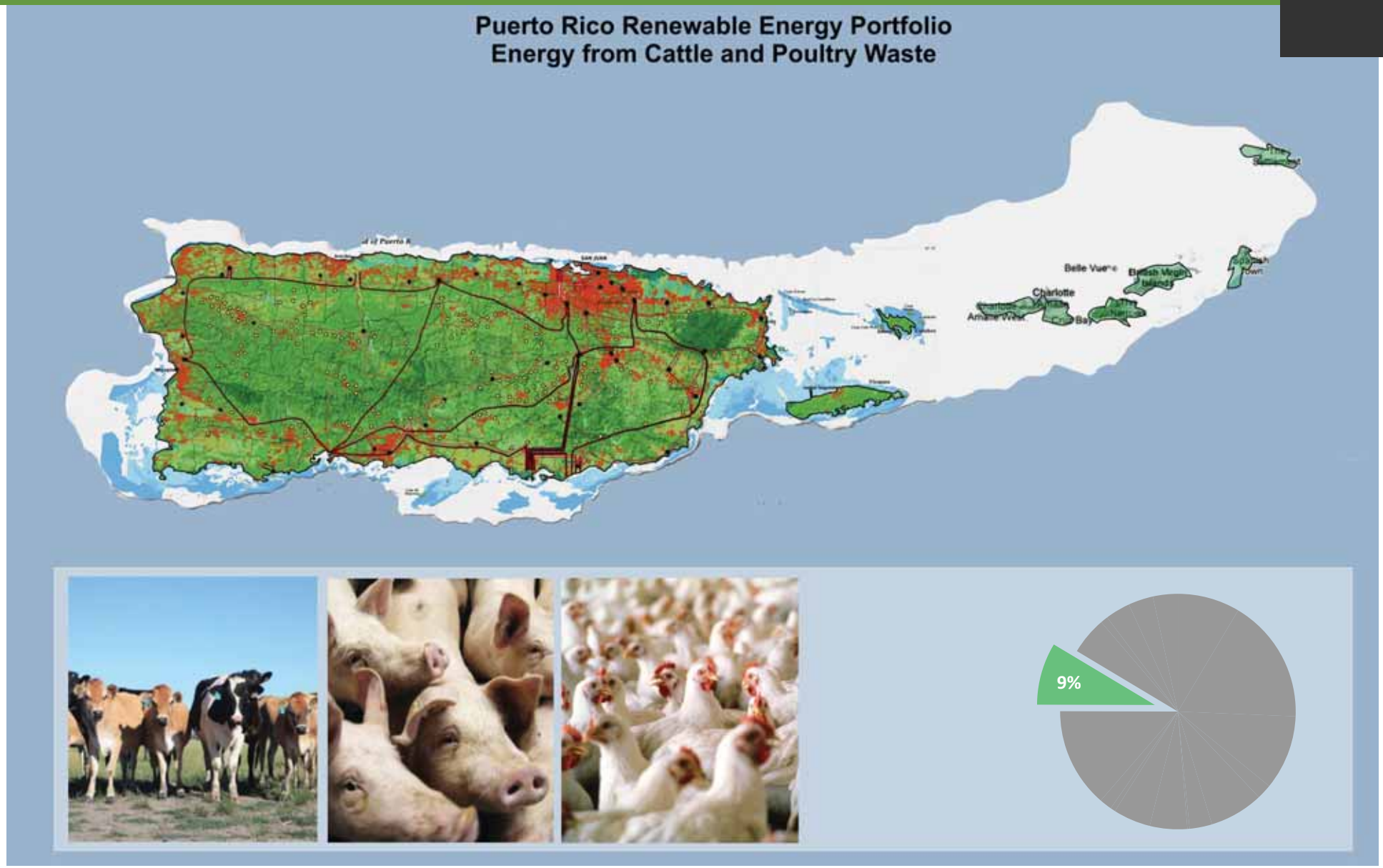
Baseload Renewable Energy Production

The baseload renewable energy production capacity of Puerto Rico is significant. Most of it comes from the processing of biomass. Being located at a tropical setting, the biomass production capability of the island is impressive given the high intensities of sun and rain.

Puerto Rico Renewable Energy Portfolio
Strategic Crops and Biomass

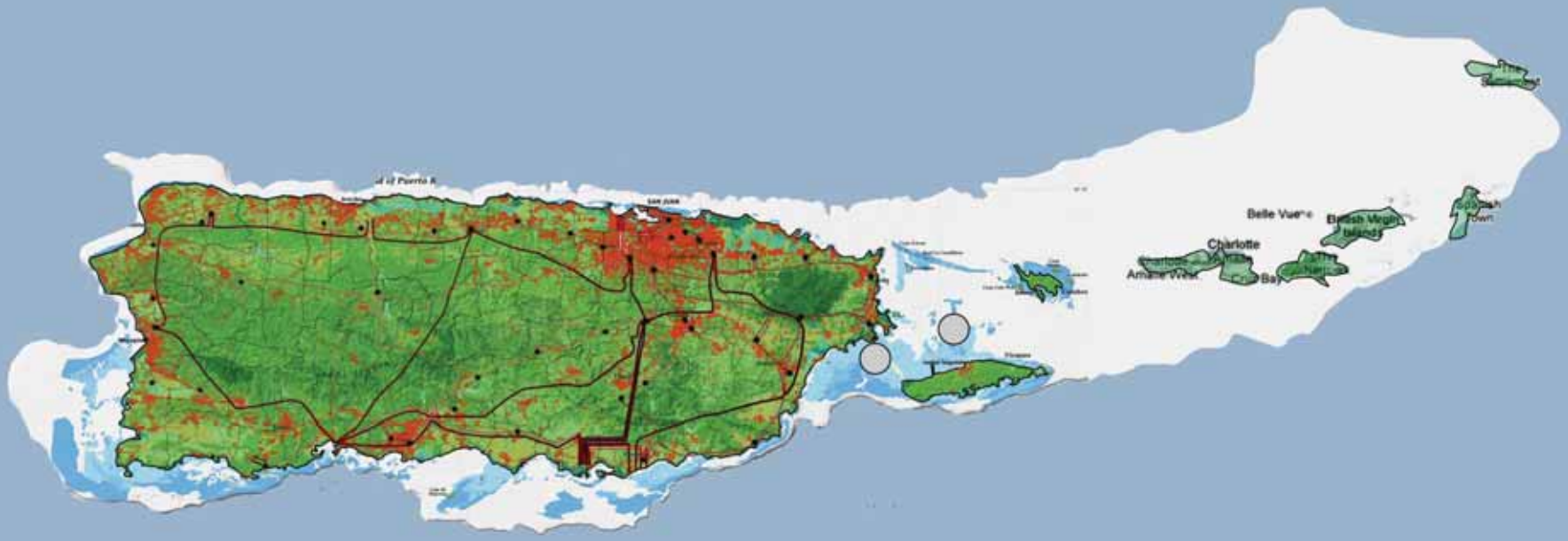


The single largest source of energy will be from biomass harvesting and its use through biorefineries. A total of 400 MW of effective power, equivalent to 14% of the electrical energy requirement will be produced through biorefineries that also produce electrical energy. The biorefineries will be able to produce electricity only or a combination of biofuels or other bioproducts.



The waste from cattle, poultry, and pigs will be digested in anaerobic digestors to produce biogas for the production of electricity. This will be combined with silage and other agricultural wastes to produce a total of about 250MW of baseload electricity. This represents 9% of the Puerto Rico electrical energy needs. It is proyected that a twofold increase in cattle population will be developed along with the digestion systems. Digesters allow higher concentrations of cattle and poultry populations with diminished environmental effects.

Puerto Rico Renewable Energy Portfolio
Macro Algae

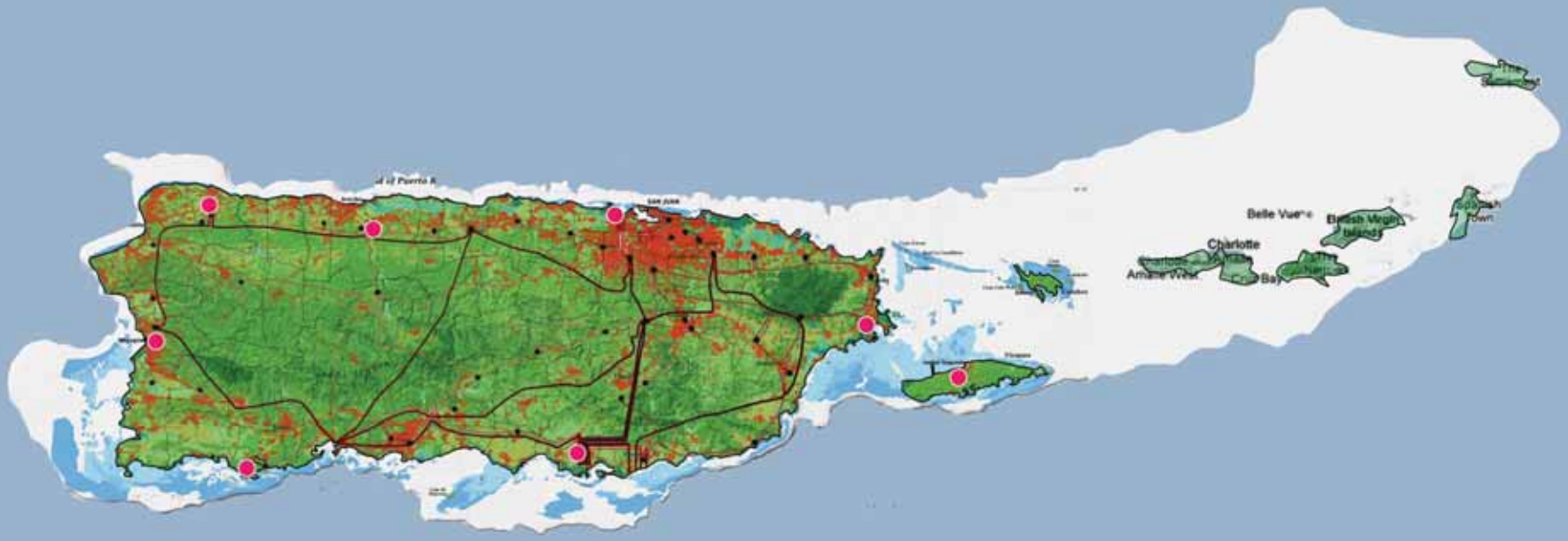


Macro algae sites are proposed for the shallow waters at the east of Ceiba, Vieques and Culebra. Combined with the harvest of micro algae, Macro algae production facilities would produce enough oil for the production of 150MW of electricity, about 5% ouf the projected electricity needs. Macro algae harvesting can be integrated to offshore wind facilities. The algae oil will be burned at the present fossil fuel facilities.

Renewable Energy Storage Systems

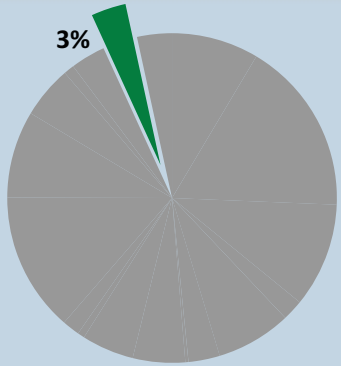
The storage systems are devices for the control of electrical frequency changes. All of them respond very quickly to load variations allowing the installation of very large variable renewable energy production systems.

Puerto Rico Renewable Energy Portfolio
Network-Attached Storage

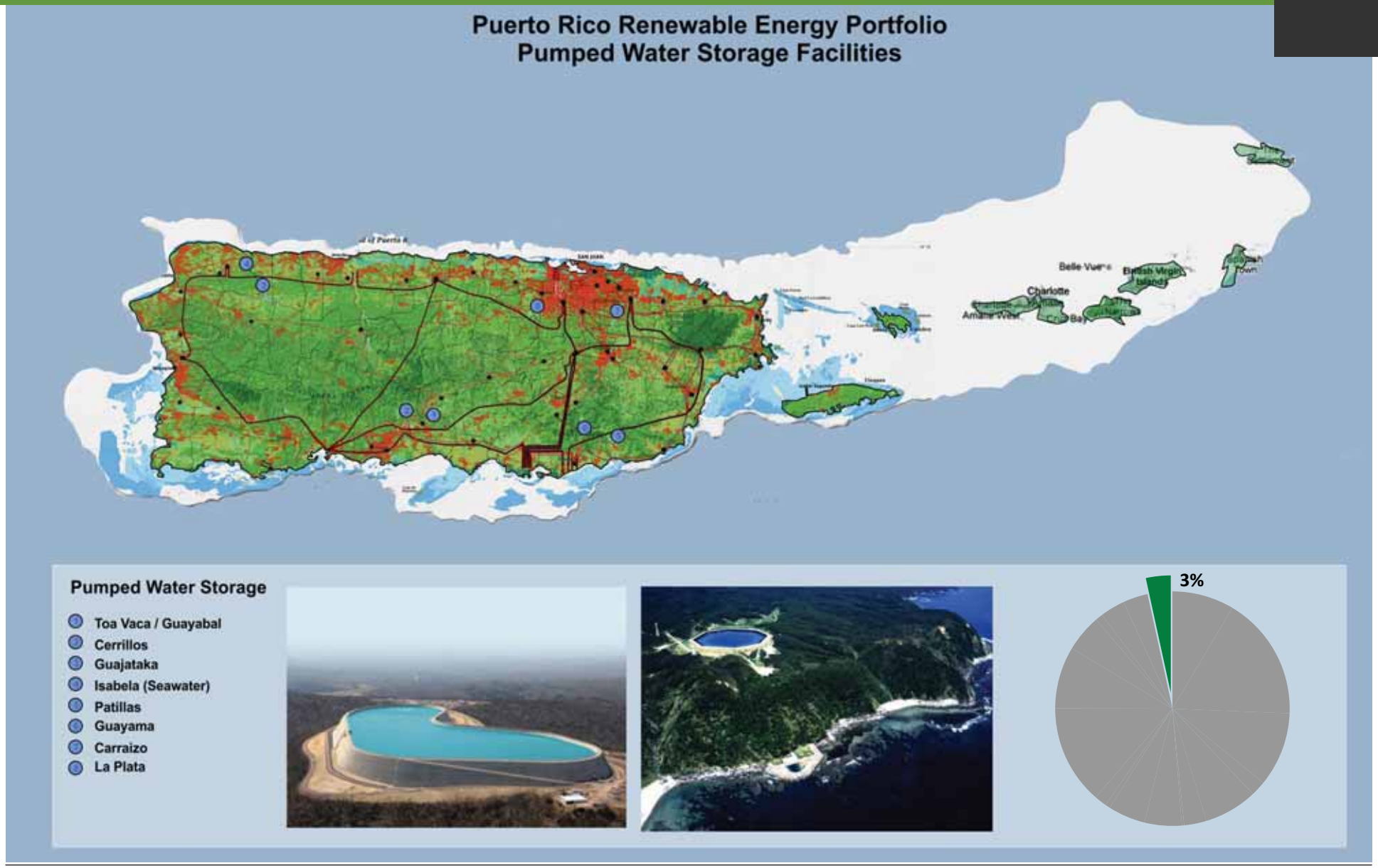


Network Attached Storage

- Guayanilla/Peñuelas
- Mayaguez
- Aguadilla
- Arecibo
- San Juan
- Ceiba
- Vieques
- Salinas



Network attached storage is used along with large variable renewable energy production sources to assure the control of frequency in the grid. These will not add net energy production but are storage devices with the capability of fast response to large variations in the production of energy through solar, wind or wave power. The proposed amount of storage is of about 3% the total electrical energy production.

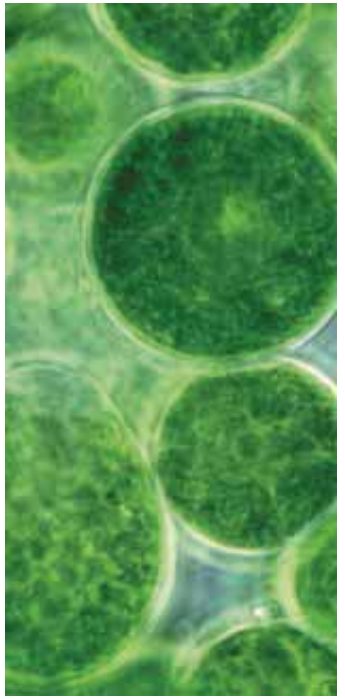


There are 8 pumped water storage facilities planned as part of the roadmap. These are of different kinds and are also part of an emergency water storage infrastructure. Pumped water storage systems store energy by pumping water to an elevated reservoir. When needed, the water in the reservoir is allowed to flow through a hydraulic turbine. These systems add capacity in an intermittent way by storing excess energy produced by other sources. It adds up to instant capacity as required.

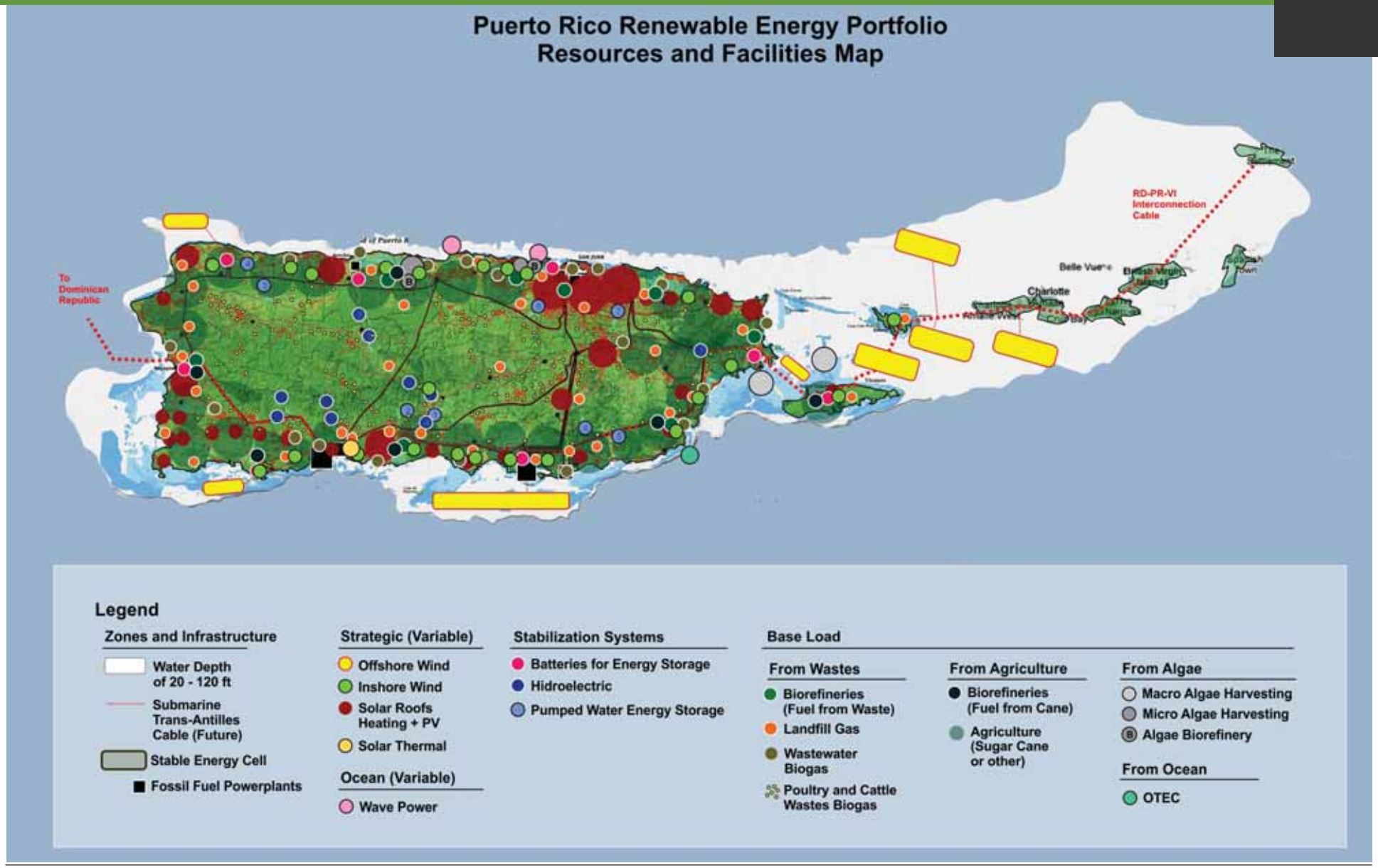
The Complete Portfolio





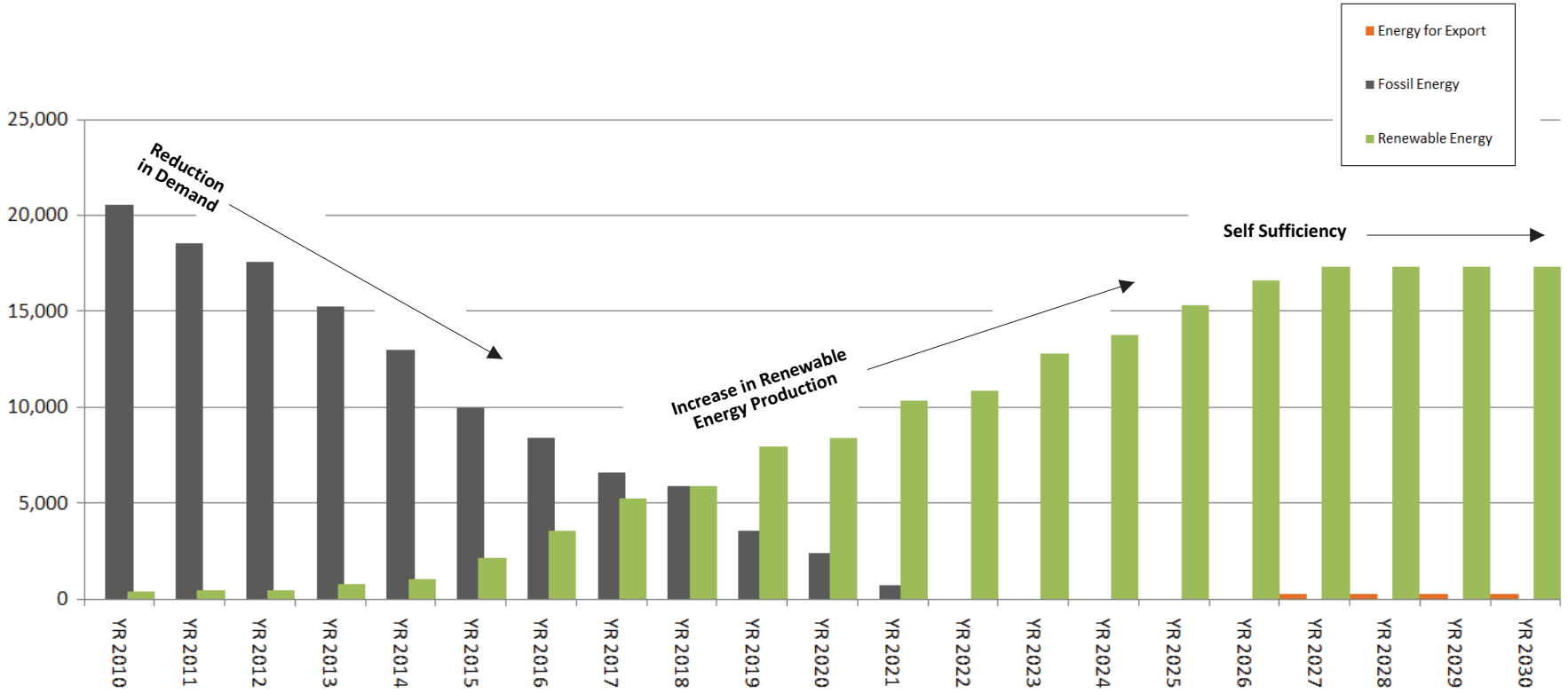


The complete portfolio provides with Puerto Rico of self-sufficiency in renewable energy.



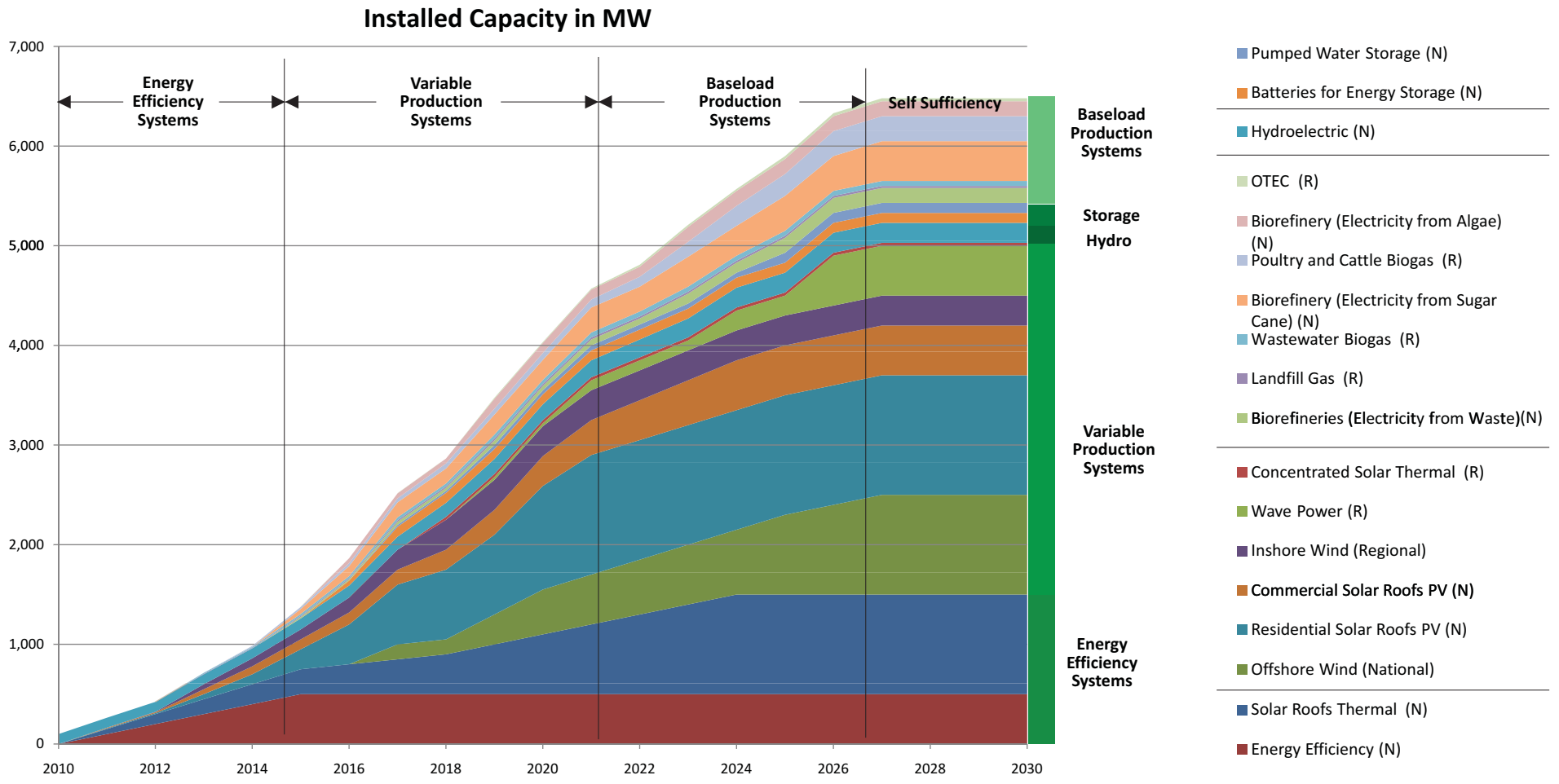
The combination of all the renewable systems add up to 2,925MW of effective power with a total production of 17,000 million of kWhr per year, this represents 100% of the electrical energy requirements projected, every year, for the next 20 years.

Transition to Self Sufficiency



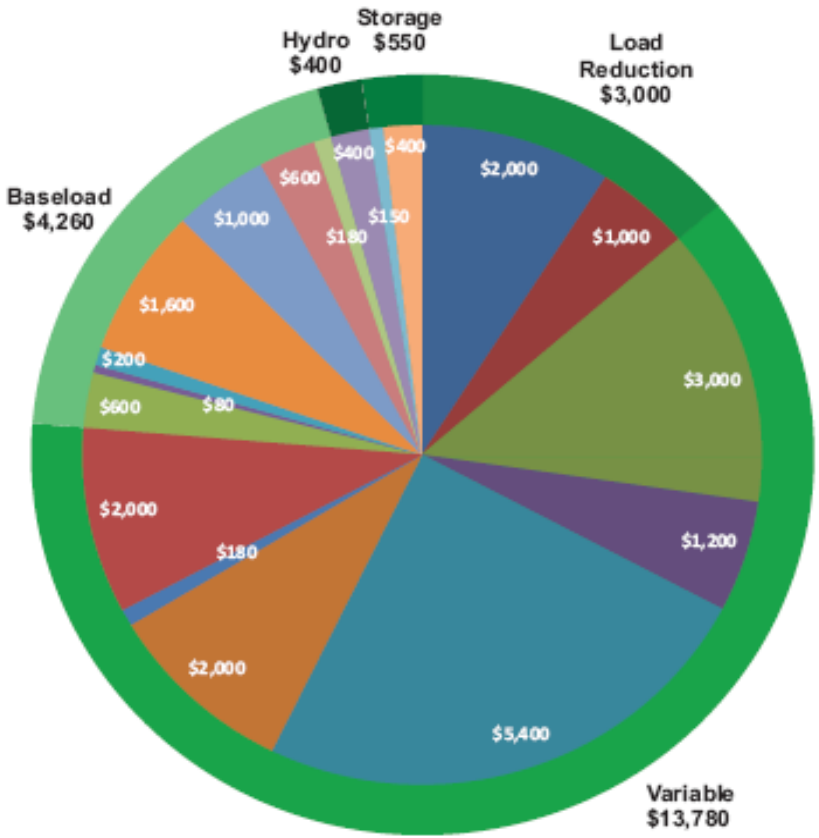
The main purpose of the roadmap is the complete elimination of our dependency in fossil fuels. The transition to self-sufficiency should start with an islandwide energy efficiency strategy that will decrease the electrical demand and the need of fossil fuels. This initial phase will be based in the installation of energy efficiency systems followed by the implementation, for the following 15 years, of systems for the production of renewable electrical energy. Self sufficiency should be attained after year 2027.

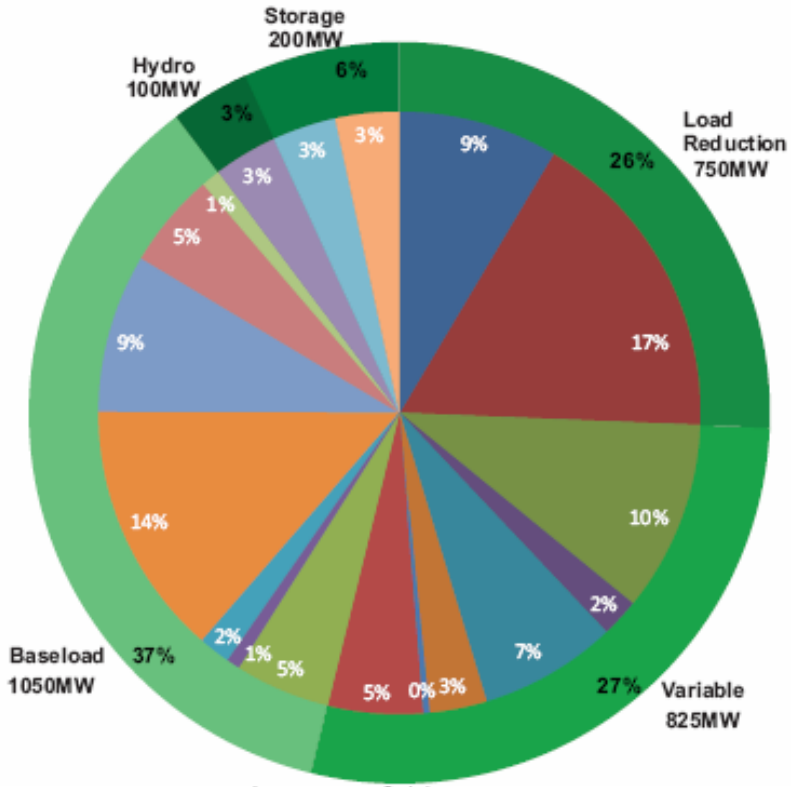
Implementation Schedule



The implementation of the proposed systems can be divided in four broad phases that start with the implementation of energy effciciency systems. The second phase consists mostly of the installation of large numbers of variable renewable energy systems that are supported by a baseload capacity based on fossil fuels. The third phase will be dominated by the installarion of renewable baseload systems. The final phase is the self sufficiency phase where all the electrical energy needs are satisfied with renewable energy.

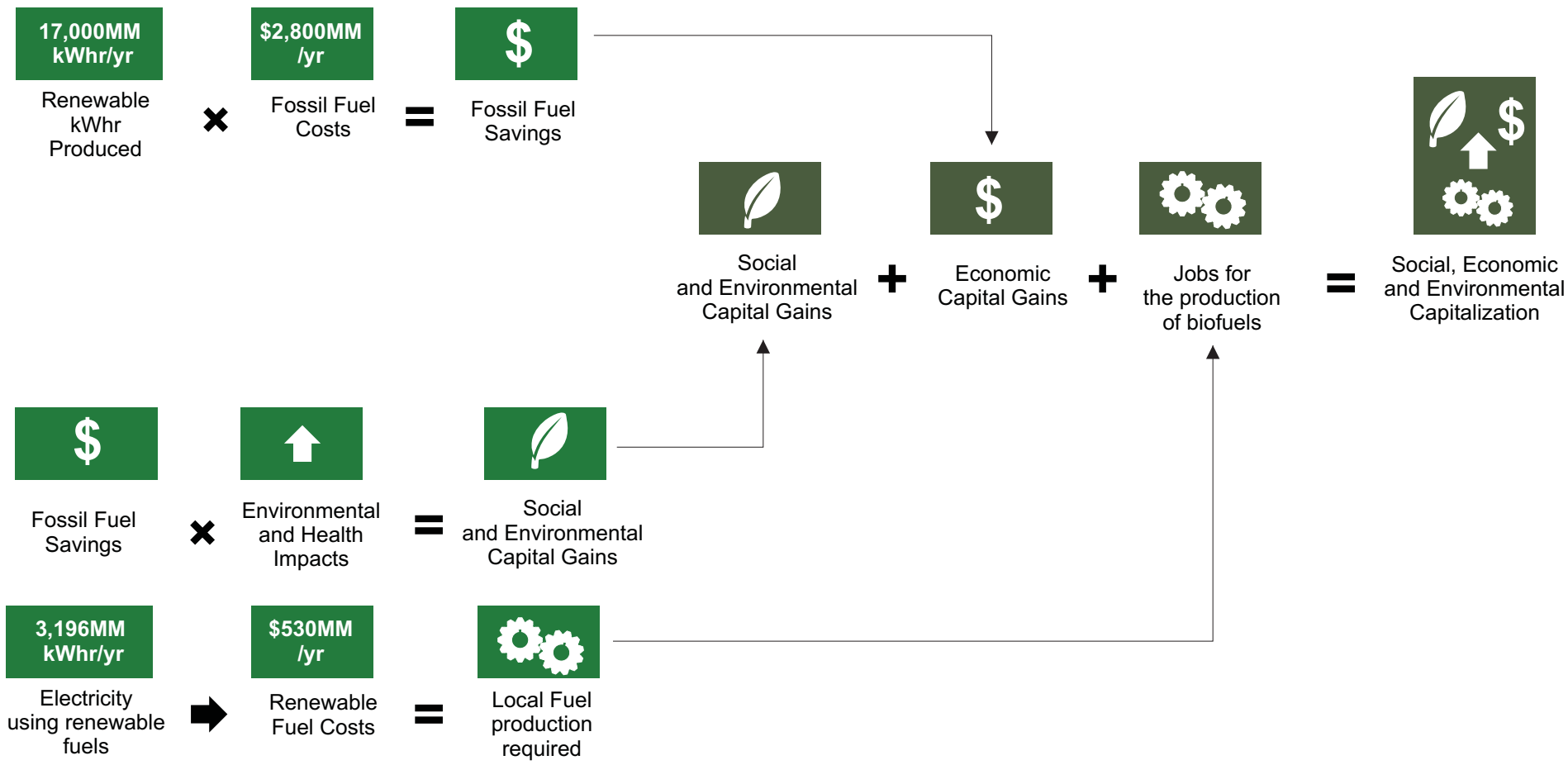
Total Renewable Investment (millions)





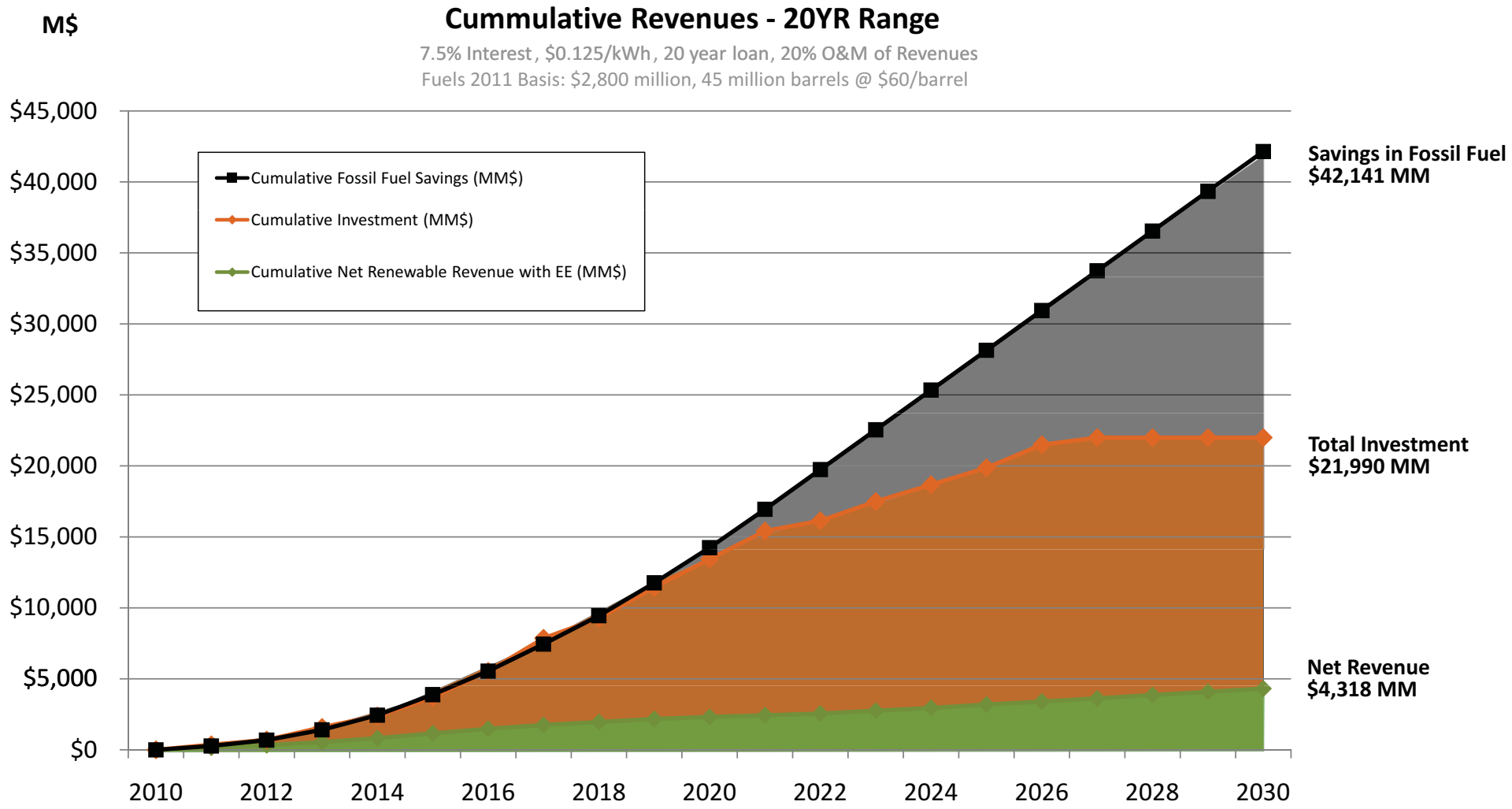
The investment required for all the renewable systems necessary for self sufficiency add up to $21,990 million. Variable energy production systems has the largest share of the investment with 63%, or $13,738 million, of all the investment required. The highest cost of the systems based in sun, wind and water is compensated by the fact that these systems do not need fuels for operation.

Economics - Puerto Rico Perspective



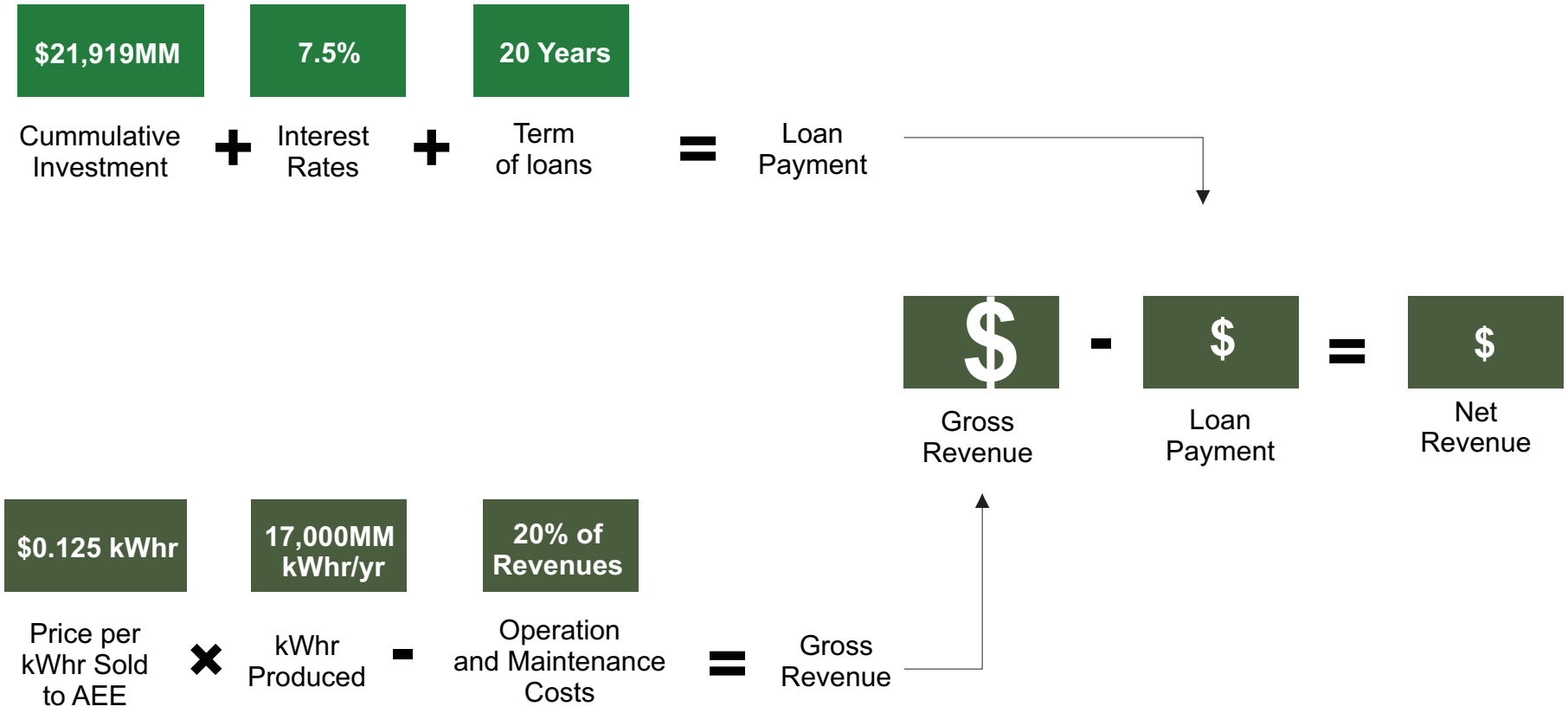
From the Puerto Rico perspective, completing the roadmap to renewable energy self-sufficiency represents a significant capitalization in the social, economic and environmental aspects. The huge savings in fossil fuels for the production of electricity, combined with the socil gains and job creation represents a second revolution in the social, economic and environmental aspects. Even the need of producing renegable fuel represents over 10,000 well-paid jobs (20 jobs per million dollars).

Economics - Puerto Rico Perspective



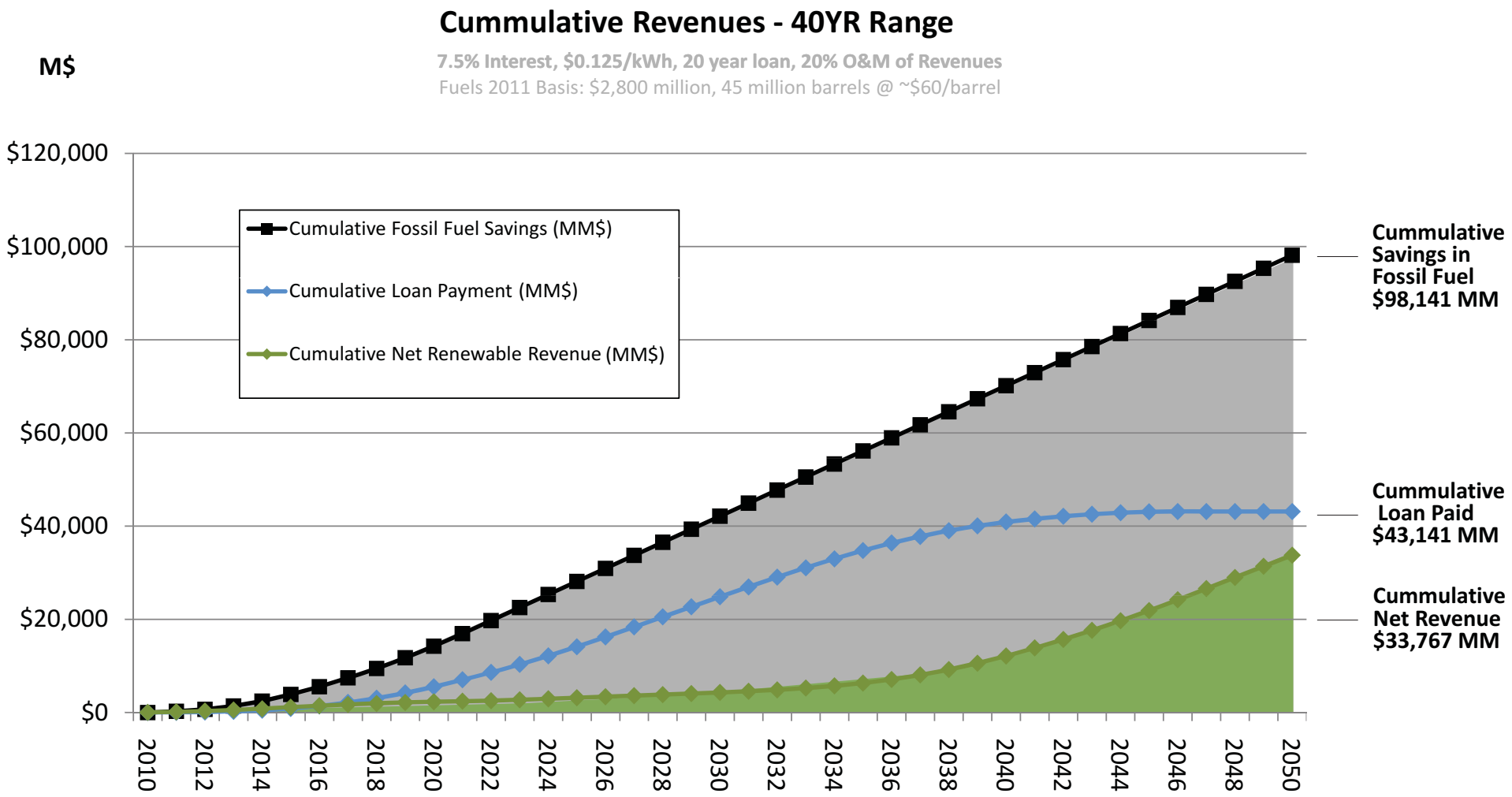
The transition to renewables self-sufficiency is financially self sustainable. The savings in fossil fuels are much higher than the required investment. From the Puerto Rico point of view this is a profitable endeavor since most of the cash now being sent abroad will stay in the island feeding a productive industry.

Economics - Investor Perspective



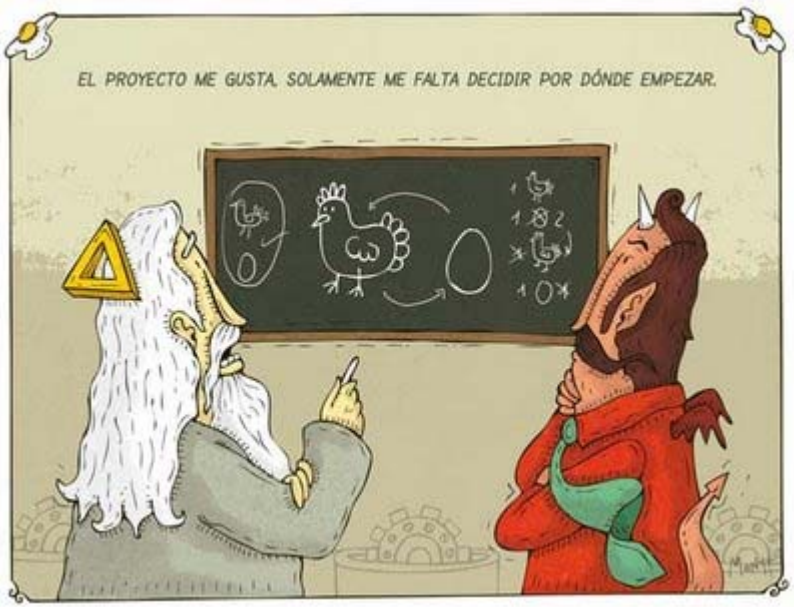
The investor perspective is based on the potential of net revenues. The roadmap calculated the cummulative net revenue based on a pre-established set of conditions that are typical in todays renewable energy projects. The calculations showed that the transition to a Puerto Rico with 100% of its electricity produced with renewable energy is a very attractive endeavor for investors.

Economics - Investor Perspective



While significant financial advantages are evident in the 20 year period of the roadmap, larger margins and profits will be seen if a 40 year range is considered. The huge amounts of cash diverted from being sent abroad to be left in the local economy represents a revolution in our economy.

Energy Efficiency System Implementation in PR



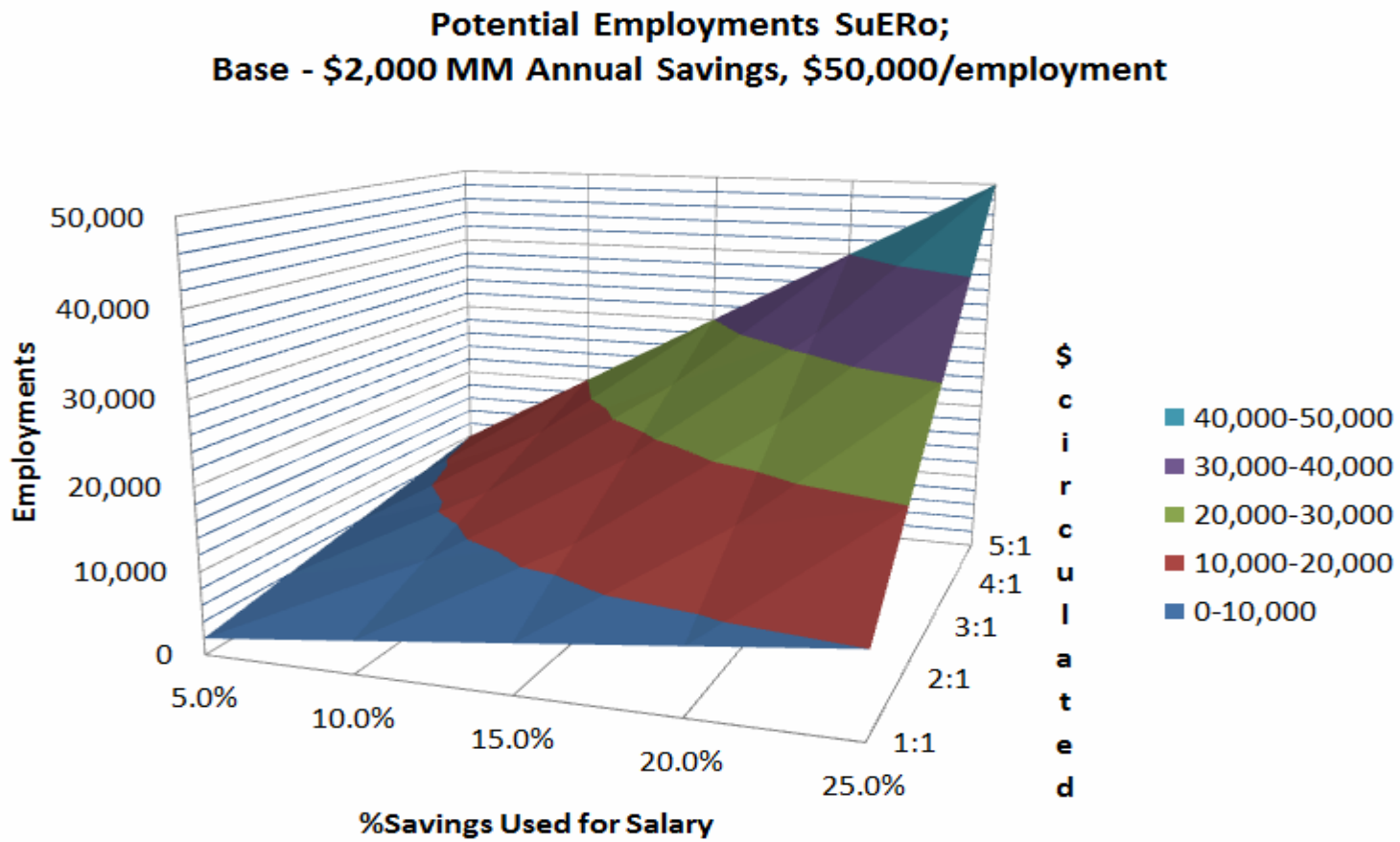
http://4.bp.blogspot.com/-FJSP2kHxXyI/Teims9rzlcI/AAAAAAAAAB0/lo7IezSZvms/s1600/house.jpg

UNCERTAINTY
Lack of Strong "Bottom up" Public Policy

Misconception & Misinformation

Key hurdles for energy efficiency implementation include "chicken and egg" dilemma regarding leadership role. A strong "bottom up" public policy is required. Also performance, financing and economic misconceptions must be clarified to increase acceptance in all the sectors.

Emerging Commercial Sectors

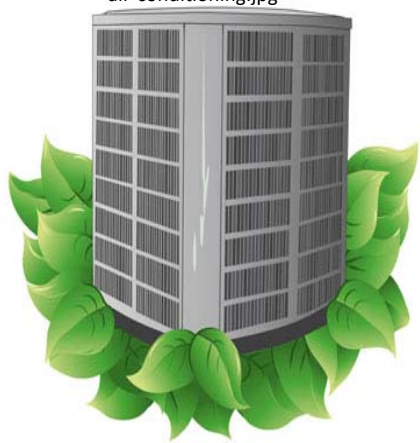


A key benefit from SuERo's implementation is the creation of both direct and indirect jobs. These can range between 2,000 to 50,000 depending on the % of the savings that is used for salaries and cash flow circulation of the savings. The latter will depend on the establishment of supporting renewable energy industries on the island. See next transparencies.

New Local Industries: Efficient Air Conditioner/Refrigerator Assembly

Base Quantity	1 MM
Opportunity Period	20 yrs.
Total Sales	$1500 MM
Sales/Year	$75 MM

http://www.enjoygoinggreen.com/wp-content/uploads/2011/06/green-air-conditioning.jpg



http://www.energyrefuge.com/blog/wp-content/uploads/Eco.jpg

Unit Price	$1500

Assuming an efficient air conditioner/refrigerator assembly industry has a window of opportunity of 20 years; using 1 million total brand new units as a base for calculation; unit price of $1500 dollars, the sales per year potential is $75 million dollars.

Efficient Marketing Campaign for Solar Heaters

Base Quantity	500,000 units
Opportunity Period	20 yrs.
Total Sales	$1000 MM
Sales/Year	$50 MM

http://ideastoenlighten.files.wordpress.com/2010/02/solar_heater1.jpg

Unit Price	$2000

An aggressive marketing campaign of solar heaters could help achieve annual sales of up to $50 million dollars. This is projected using 500,000 units as a basis for the calculation and selling them at a price of $2000 dollars.

Expanded Local Industries: Photovoltaic Panels

Base Quantity	100 MW/yr.
Opportunity Period	20 yrs.
Total Sales	$2000 MM
Sales/Year	$100 MM

Unit Price → $1/W

The assembly of photovoltaic panels for local electricity consumption takes as a calculation basis 100 MW per year (the government guarantees purchasing 50 MW/yr for the first five years @ breakeven costs). The unit price is $1/W. The projected annual sales are approximately $100 million dollars.

New Local Industries: Inverter Assembly

Base Quantity	1 MM
Opportunity Period	20 yrs.
Total Sales	$500 MM
Sales/Year	$25 MM

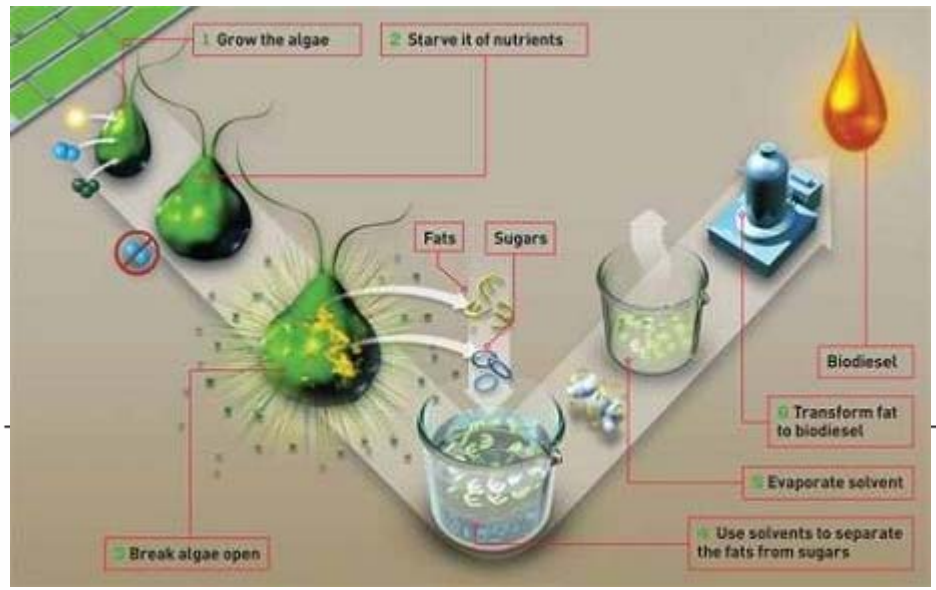
http://www.laptoptravel.com/images/product_images/acc_triplite_n18211.jpg

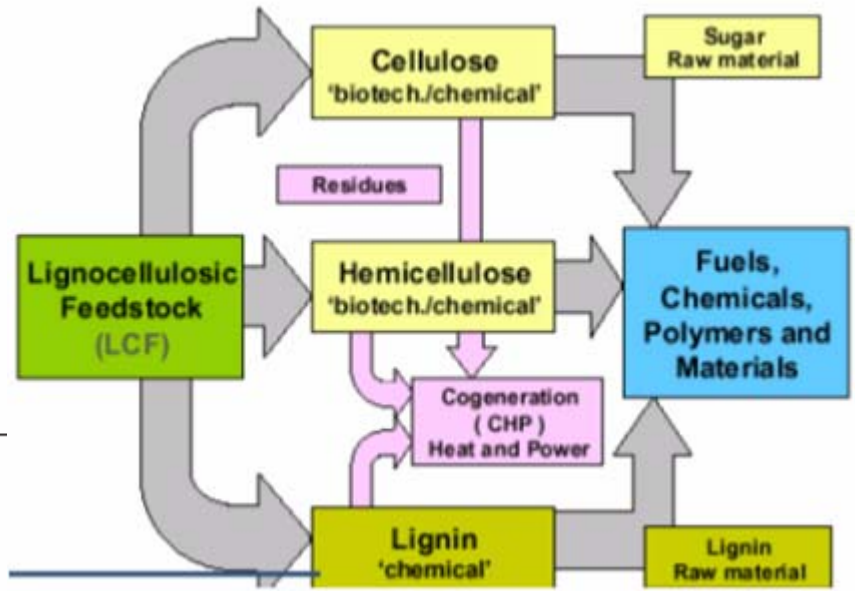
Unit Price	$500

Assuming the inverter assembly industry has a window of opportunity of 20 years; using 1 million total units as a base for calculation; a unit price of $500 dollars, the sales per year potential is $25 million dollars.

Biorefinery Based Industry, Strategic Crops (6F)

10,000 Hectareas	→	100 million gallons fuel/ year	→	700 million pounds high value products/year
Yearly Income	→	$300+ million/ year	→	$500 – 1,000 million /year





Respuesta de Representante de la Cámara

¡Nos queda grande Colucci!

Puerto Rico, Renewable Energy Self-Sufficiency Roadmap

White Paper Presentation

Puerto Rico Renewable Energy Self Sufficiency Committee
August, 2011