MSc Program
Environmental Technology & International Affairs

Energy in the 21st Century
The Emergence of Microgrids in the Urban Environment

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
Em.O.Univ.Prof. Dipl.-Ing. Dr.-Ing Günther Brauner

Vicente Otto Mora

1027238

Vienna, 10.06.2012

Affidavit

I, **VICENTE OTTO MORA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "ENERGY IN THE 21ST CENTURY - THE EMERGENCE OF MICROGRIDS IN THE URBAN ENVIRONMENT", 79 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 10.06.2012

____

Signature

Abstract

Miami Dade County is a thriving metropolitan city with a population of approximately 3 million. This thesis analyzes the feasibility of a microgrid in its urban environment. Miami is in a location that is a hurricane hot spot and additionally rich in sunny weather. Applying a microgrid to a community in Miami, with a basic 5 kW PV system and a 2 kW fuel cell, would provide sufficient energy to the average household. The technology is available, but the policies in place are not welcoming. With better policies , Miami has significant potential to provide microgrids for energy security and independence.

Table of Figures

Table of Tables

1. Introduction

The fact that climate change is a real threat has been well documented. So much so, that an international organization (IPCC) has been created to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. They concluded that the climate is changing and that the world will see changes in the future. Based on the study, an agreement was made to set a goal for reducing green house gas emissions among the developed countries. The agreement was the Kyoto Protocol, and the targets were to reduce GHG emissions by 5% from 1990 levels. Every party to the treaty ratified it, except the United States. The U.S. believed that it would devastate the economy and industries domestically. While, it could be true that such abrupt measures can impair the economy, not acting could also have a price tag, especially in Florida. Climate Change is a real threat to Florida, and even more perilous to Miami. Miami is located in close proximity to sea level, and places it at a high risk of endangerment to inundation. Sea level rise is of great relevance in Miami, FL because of its proximity to the coast. Born and raised in Miami, I can tell share with you, that the beach is our most important natural resource. It brings the tourist, and that brings the money. The only problem is that our highest money generating machine is also the culprit of our peril.

A study conducted by Ackerman (2007) calculated the cost of inaction to climate change for the state of Florida. The results were daunting. The study found that:

- If sea level rises 23 inches by 2050, 70 percent of Miami Dade will be swamped.
- That means residential real estate, now valued at over $130 billion, will be affected, so will half of Florida's beaches, two nuclear reactors and 99 percent of all mangroves.
- The warmer climate will make Florida less attractive to tourists year-round, resulting in a $9 billion decline in tourism by 2025 and $40 billion by mid-century.
- Hurricanes will be more intense, resulting in more damage and higher costs -- estimated at $25 billion by 2050 -- and the cause of 19 additional deaths.

To ignore these findings would be preposterous, but unfortunately that's exactly what has been happening in Miami. To know that your history is at the brink of endangerment is an eye opening experience. It is for this purpose that I decided to enter this field of study because my history is at stake. My initial rationality was: "we are humans and we are an adapting species, so with the technologic breakthroughs we can find a solution". I still believe that, but the solution is not so clear. The next point that I considered was: "We can build levees to protect ourselves from the rise". Well, the Science and Technology Committee of the Miami-Dade County Climate Change Task Force noted, "the highly porous limestone and sand substrate of Miami-Dade County (which at present permits excellent drainage) will limit the effectiveness of widespread use of levees and dikes to wall off the encroaching sea." There went all my hope for a solution. With the lack of action from the local government, I gained my motivation to write this thesis.

This thesis is about the feasibility of a community to become energy independent using renewable energy technologies. I feel that if there is any way to produce change, it will have to come from the grass roots level. A successful deployment of grass roots campaigning is what put our current president in his position. Drawing from those tactics I believe that Energy Independence too, needs to come from the ground up. The first step has to occur at the community level. It is with this scope in mind that this thesis is written. The thesis is broken into four chapters. The first chapter covers the first hurdle in achieving independence, and that is decentralizing energy. The American Electricity Infrastructure was created on a centralized model and that has got to change in order to progress. The second chapter covers the legislation in place that accommodates independence. In order to facilitate change, policies need to be implemented. This was done by analyzing what the government has promoted in this arena. The third chapter covers the Microgrid concept; and that is the solution to independence. The Microgrid concept is not new, but the idea has not flourished in southern Florida. The fourth chapter covers the characteristics of the area of scope (Miami,FL). The final chapter entails the findings and a possible solution.

The goal of this thesis is to recognize the possibility, that a community in Miami could be energy independent. If this idea turns into reality, the benefits to Miami can be astronomical. While it is guaranteed that one energy independent community cannot extinguish the threat of climate change, what is guaranteed is that it can serve as a model and from there develop to a point that a difference could be made.

2. The Case for Decentralization

2.1 Centralized Paradigm

The blueprint that was drawn for energy systems has proved to be resilient and triumphant, but in the last decade there has been a strong criticism on the aging of the American grid. There have been two grave instances in the recent past where America has experienced a period in which electricity providers were unable to deliver their product to the designated customers. Two significant cases that were detrimental to the power grid occurred in California (2000's) and the North East (2003) of the United States. In California, there was a series of massive rolling blackouts that were caused by a manipulation of certain power generators that would cease production intentionally to cause an overload in the grid. Furthermore the outage in 2003, affected an area with an estimated 50 million people and 61,800 megawatts (MW) of electric load in the states of Ohio, Michigan, Pennsylvania, New York, Vermont, Massachusetts, Connecticut, New Jersey and the Canadian province of Ontario. But it was only the largest and most recent in a series of massive outages, including another blackout in the north-east in 1965 which left 30 million people without power for 13 hours; an outage affecting 9 million in New York City in 1977; and disturbances on the West Coast in 1982 and twice in 1996 leaving millions without power each time (US-Canada Power System Outage Task Force final report, April 2004)

Traditionally, a power system has a generating source which feeds into a transmission system, which then distributes the energy where necessary. To make this possible there has to be substations where the energy is converted to a usable voltage. This in essence is the grid of 20th century.

In the second half of the 20th century, the current electricity infrastructure was molded to better suit a system that is keener on providing higher concentrations of energy production and a facilitated integration for centralization. The United States Department of Energy provided some factors that contributed to this situation:

- The steam turbine was pivotal in providing a new way of electricity generation that would increase output at a lower cost. Allowing a Reaching of a larger base and costing considerably less, this would serve as the modus operandi for the immediate future. This concept that if you grow in size, you can get more out of what you currently have is known in microeconomics as **Economies of Scale**, and this was heavily adopted in the 20th century.

- With the growth of facilities another aspect that was closely analyzed was the potential for **higher efficiency**. A simple way to achieve higher efficiency was to increase temperature and pressure capabilities of steam engines. This would only provide sufficient increase for a limited time. The increase in maintenance and operation cost would eventually offset efficiency gains due to the inability of materials to withstand such intense conditions over a long period.

- Initially, power generators were limited in the distance that electricity could be transmitted due to voltage restrictions on the lines. This proved to be very inefficient and would involve massive losses over a long distance. The introduction of inverters would allow currents to be **alternated for transmissions** over long distances with a noteworthy reduction of losses.

- **Reliability** was a major concern for not only the provider, but for the consumer. The transmission networks were dependent on the generating facilities to exploit their usefulness. The congregation of resources would allow for the system to be less dependent on one generator and would allow complimentary generators to compensate each other if necessary.

- As Environmental awareness increased, the ability of electricity generators to relocate to a distance far from the desired point of use; aided the **removal of the visibility of pollution**, increasing atmospheric clarity in city centers that was unattainable beforehand.

- At the time there were also **regulations** in place that would favor large generating facilities.

This was a system that has proved durable and resistant, but with the advent of renewable energy there has been a great deal of scrutiny involving the current state of our energy infrastructure, with magnified awareness of the currently outdated grid system of the United States.

2.2 Centralized Problem

Bouffard and Kirschen (2008) argue that a centralized energy system is vulnerable to many threats. Among those threats, they highlight these factors of supply infrastructure that are at risk:

- Important energy infrastructure can be a main target for *terrorist attacks*. The interconnectedness between the supply and transmission elements of an energy system, can cause a massive disrupt to not only the providers but also to the end-users. This can potentially affect prices in an unwelcomed way. In 2011 a computer virus was targeted on one of Irans nuclear facilities; which caused the system to shut down. That same virus was later on reported to also target key energy players. (Williams 2011)

- *Natural Disasters* are always a threat to energy systems. One of the characteristics of climate change is the increase in frequency of extreme weather. In 2005 on the Gulf of Mexico, Hurricane Katrina froze all oil and gas production for a significant period, causing a disruption on the supply.

- Primary energy exporting actors and transit countries can place a threat to an energy system for *geopolitical reasons*. In the winter of 2005/06 Russian owned natural gas company Gazprom had a dispute with its Ukrainian partner and completely cut off all gas that traveled through the Ukraine. In 2009 the conflict resurfaced, but it subsequently affected 18 European countries also.(Reuters 2009)

- Infrastructure is a highly complex system, specifically with regards to the electricity supply and transportation equipment. This equipment like any other has a lifetime, and most of them are reaching their end. Infrastructure is connected in such an intricate way, that it is not uncommon for a fault to travel lengthy distances before it becomes restricted. In the United States in 2003, as explained earlier a problem that started in one state, ended up affecting a whole region. This was partially witnessed in Europe in 2006, where there was a controlled electricity cut-off due to an imbalance in the grid.. These events allowed us to witness how disruptions in the system can be wide spread and have socio and economical implications.

- Another important demise to the current centralized system is the growing concerns of green house gases. A common source of energy is coal, oil, and gas (all which have a devastating impact on the environment); these sources of energy pose a potential risk to the climate and are main contributors to *climate change*. Generally, these plants are inefficient and produce significant amounts of waste heat, coupled with expansively long transmission lines that additionally squander energy.

- The energy industry today is becoming increasingly competitive and is evolving at a rapid rate. The *regulatory and economic risk* - associated with building new large and central electricity plants - are escalating due to the complex approval processes and the immense sum of capital needed to successfully complete a power plant.(Bouffard,2008)

These risks are all a prime example as to why the current energy system requires a robust makeover that can reduce the vulnerability of system as we know it. One solution that has been gaining steam is the principle of providing energy through decentralized means. This can be accomplished in numerous ways, but for the purpose of this study we will concentrate on the resourcefulness of distributed generation (DG). In figure.1 we see a diagram of if what decentralization would entail.

Figure 1 Decentralized Energy Diagram

Source: Electric Power Research Institute

2.3 Decentralization

Decentralized energy (DE) is a term that is frequently used interchangeably with Distributed Generation (DG), decentralized resources (DR), micro-generation (MG), etc. To put it simply: when energy is distributed it becomes decentralized. Coming up with a clear definition was not easy. There are many classifications that were initially taken into consideration when the first Working Group on distributed generation met at the International Conference on Electricity Generation. There was not an immediate consensus but rather different classifications that were considered, some used voltage levels, while others emphasized proximity to customer load, and others used primary mover or dispatch situations. (CIRED,1999)

The US EPA defines it as: “small, modular, decentralized, grid connected or off-grid energy system located in or near the place where energy is used”.

There is a cluster of differences in the academic community about the definition of microgrids. Some limit the definition in reference to the capacity and its proximity to its load and the exclusion from the centralized system. (Dondi, 2002).Others, put a limit on the least amount of distributed capacity (30kW). (Chambers, 2001) Additional authors place emphasis on the characteristics of the energy generation (Papermans, 2005). There was one author who fittingly created a definition that encompasses a wide variety of technologies, capacities, and the majority of distributed generators; down to one sentence. “Distributed generation is an electric power source connected directly to the distribution network or on the customer site of the meter”. (Ackermann, 2001).

All these factors contribute to the characterization of distributed energy. In the contemporary concept and for the theme of this study we will underline the prominent contribution that renewable energy (RE) can provide for distributed energy systems. However, DG is not limited to RE, DG can involve the use of generators to provide an output of up to 100MW, this would not require the use of high-voltage grid, but instead low voltage local networks that supply homes and offices. One of the advantages of having electric generation close to its consumers is that the efficiency of the plant can be increased by using waste heat that is produced during the combustion process to be distributed in buildings nearby. This system is known as cogeneration or combined heat and power (CHP) system. Systems like these have a higher efficiency with the energy that is input in comparison to its centralized counterpart. DE can also be disconnected from the grid by the owner or by the utilities, if it is at the choice of the owners it is considered a standalone (SA) system; if the utilities decides to disconnect it is called Island Mode. Industries can also produce their own energy, where they consume the waste heat on site and any surplus electricity can be sold back to the grid.

D.P. Kaundinya et al (2004) have identified some of the important features of GC systems, and they are as follows:

- Being connected to grid implies that you provide energy into the transmission and distribution system from a decentralized source.

- Capacity to operate is determined by supply. Functionality is dependent on the availability of sources.
- Supply being the main indicator of operation, when there is no availability of supply the demand from the grid is irrelevant.
- The system can be used for local demand and surplus could be fed back into the grid, or it could be feeding the grid constantly.
- Grid interconnectivity can allow larger system to operate, because the grid can handle the load, improving the economic viability of the operation.
- In a grid-connected power system the grid acts like a battery with an unlimited storage capacity. So it takes care of seasonal load variations. As a result of which the overall efficiency of a grid-connected system will be better than the efficiency of a stand-alone system, as there is virtually no limit to the storage capacity, the generated electricity can always be stored, and the additional generated electricity need not be ‘‘thrown away’’.
- There is not only an initial cost, but also a cost for interconnectedness.
- For systems operating on renewable sources like biomass, wind and solar PV, there will be a high pressure on these renewable sources, as the system usually operates at high scales and need more biomass for its operation.(pp. 2042)

The benefits of having a decentralized system were well documented by Greenpeace in a paper published in 2005 called “DECENTRALISING POWER: AN ENERGY REVOLUTION FOR THE 21ST CENTURY”. Although the paper primarily addresses the problems in the United Kingdom, there are a few noteworthy facts about the advantages of decentralization. They argue decentralized energy would:

- slash CO_2 emissions
- bring down energy consumption levels
- deliver enhanced energy security
- drive technological innovation and real competition in energy markets
- foster the inherent economic advantage of renewable technologies
- save consumers money in the longer term
- increase public involvement in tackling climate change
- increase opportunities for local political leadership in the energy sector

- reduce the influence of vested interests
- incubate and export technologies which are safe for global dissemination and urgently required for international development. (Green Peace, 2005)

The advantages of decentralizing are clear, and a viable solution would be the proper incorporation of Micro Grids to either compliment or potentially replace the centralized grid.

3. Legislation

This chapter is a review of legislation that has been passed in the United States that have relevance for microgrids.

3.1 Purpa

The Public Utility Regulatory Act (PURPA) was passed in 1978, during a time that energy was at a heightened sensitivity, which put the industrial world in a predicament. Price of oil of was predicted to sky rocket, so congress acted to reduce the dependency on foreign oil, and to encourage the use of alternative energy sources and increase energy efficiency, with intention to diversify the electrical power industry.

The law effectively created a market for the production and purchase of power from non-utility producers. Prior to the legislation, it was only utilities that can participate in the electricity market and own electricity generating plants. This legislation created a new class of generators that would join the market. PURPA would require that utilities purchase electricity from the independent companies or qualified producers (QF) that would purchase the power at the avoided cost rate.

This basically means that if a company/producer can provide power for a lower cost than what the utility pays, the utility is required to purchase it from them. PURPA's QF status applied to existing as well as new projects. By the end of 1998, existing and new projects totaled 12,658 megawatts of QF renewable capacity. Of this, two-thirds (8,219 megawatts) of QF capacity was biomass.(Gielicki,2001)

3.2 Electricity Modernization Act

In 2005 the legislative branch of the United States passed a law that would provide guidance in reform of policy in relation to energy. Within this law there is electricity provisions which are included under Title XII, "Electricity Modernization Act of 2005." Title XIII, "Energy Tax Incentive Act of 2005," also includes tax incentives targeted toward electricity generation or transmission properties. Things included in the act are: the creation of mandatory reliability standards to be administered by certified "electric reliability organizations", the period for capital recovery of new transmission and distribution assets would be depreciated from 20 to 15 years, and an expansion of the amortization of pollution control equipment for coal-fired plants from 5 to 7 years.

3.3 Security Act

In December 2007, Congress passed, and the President approved, Title XIII of the Energy Independence and Security Act of 2007 (EISA). EISA provided the legislative support for DOE's smart grid activities and reinforced its role in leading and coordinating national grid modernization efforts. Key provisions of Title XIII include:

Section 1303 establishes at DOE the Smart Grid Advisory Committee and Federal Smart Grid Task Force.

Section 1304 authorizes DOE to develop a "Smart Grid Regional Demonstration Initiative." Requires the development of advanced techniques for peak loading and energy efficiency from smart meters, demand response, distributed generation, and electricity storage systems be implied EISA of 2007 s1304 (a)(1). Additionally requiring an investigation in means for demand response, distributed generation, and storage to provide ancillary sources EISA of 2007 s1304(a)(2).

Section 1305 directs the National Institute of Standards and Technology (NIST), with DOE and others, to develop a Smart Grid Interoperability Framework.

Section 1306 authorizes DOE to develop a “Federal Matching Fund for Smart Grid Investment Costs"

3.4 ARRA

The American Recovery and Reinvestment Act of 2009 is the stimulus package that passed Congress on February 2009, and signed by the president in the ensuing days. As of February 2011, the Congressional Budget Office estimated the act will cost $821 billion in spending and tax provisions through 2019. The Recovery Act provided the Department of Energy (DOE) more than $41.7 billion--$35.2 billion for projects and activities and $6.5 billion in borrowing authority--in areas such as energy efficiency, renewable energy, and environmental cleanup. This included about $3.2 billion for the Energy Efficiency and Conservation Block Grant program, about $3.1 billion for the State Energy Program, and about $5 billion for the Weatherization Assistance Program . As of March 10, 2011, DOE reported that it had obligated $33.1 billion (94 percent) and spent $12.5 billion (36 percent) of the $35.2 billion it received under the Recovery Act for projects and activities. (Rusco, 2011). The Recovery act provides more than $90 Billion through government investment and tax incentives to create a foundation for a clean energy economy (CEA, 2010). With such a high appropriation of funds, the clean energy industry is destined to see a hike in job creation along with economic growth that stems from the projects covered under the Recovery Act (U.S. Congress, 2009).

The funds available from the Recovery Act for climate and energy programs is distributed among several federal agencies with jurisdiction over specific areas, the two largest agencies to receive funds that deal with clean energy were unsurprisingly, the department of energy and the department of transportation(CEA, 2010). $41.6 billion from the ARRA funds was appropriated to the DOE, of the $41.7: Approximately $35.2 billion for direct grants and the rest ($6.5 billion) in loan authority. (Subcommittee on Oversight and Investigations Staff, March 15, 2011).

The Office of Electricity Delivery and Energy Reliability (OE) is the main agency who supports smart grid initiatives and serves as an advisor for state and local governments on for electricity policy review, transmission planning and analysis, and workforce development.

Funding primarily supports previously unfunded provisions in the Energy Independence and Security Act (EISA) of 2007 that aim to improve electricity transmission and develop the smart grid. Specific EISA provisions receiving ARRA funds are:

Sec. 1304. Smart Grid Regional Demonstration Initiative, which solicits and funds projects through competitive funding opportunity announcements for large- scale smart grid demonstration projects that verify technology viability, quantify costs, and validate smart grid business models at scale so they can be replicated. This project was authorized $0.68 billion.

Sec. 1305. Interoperability Standards and Framework, which aims to set development and implementation standards for smart grid technologies to ensure effective and consistent applications. This project was authorized $12 million.

Sec. 1306. Smart Grid Investment Matching Grant Program, which creates a competitive, merit- based matching- funds grant program that can cover up to 50 percent of investments planned by electric utilities and other entities for the deployment of smart grid technology. This project was authorized $3.5 billion, by far the most funding out of all OE projects (Wuzzelman, 2011).

3.5 IEEP Interconnection Standard

The Institute of Electrical and Electronics Engineers (IEEE) is an organization composed of engineers, scientists, and students. The IEEE is best known for development of standards for the computer and electronics industry. They were designated under The USA Federal Energy Policy Act of 2005, which calls for state commissions to consider certain standards for electric utilities. Under Section 1254 of the act: "Interconnection services shall be offered based upon the standards developed by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems, as they may be amended from time to time."(IEEE Std 1547)

IEEE Std. 1547 defines a set of uniform requirements for the interconnection of DR to the distribution segment of the electric power system (EPS). Currently, there are seven complementary standards designed to expand upon or clarify the initial standard, three of which are published. The other four are still in the development phase. A complete listing of the 1547 series of standards is shown in Figure 2:

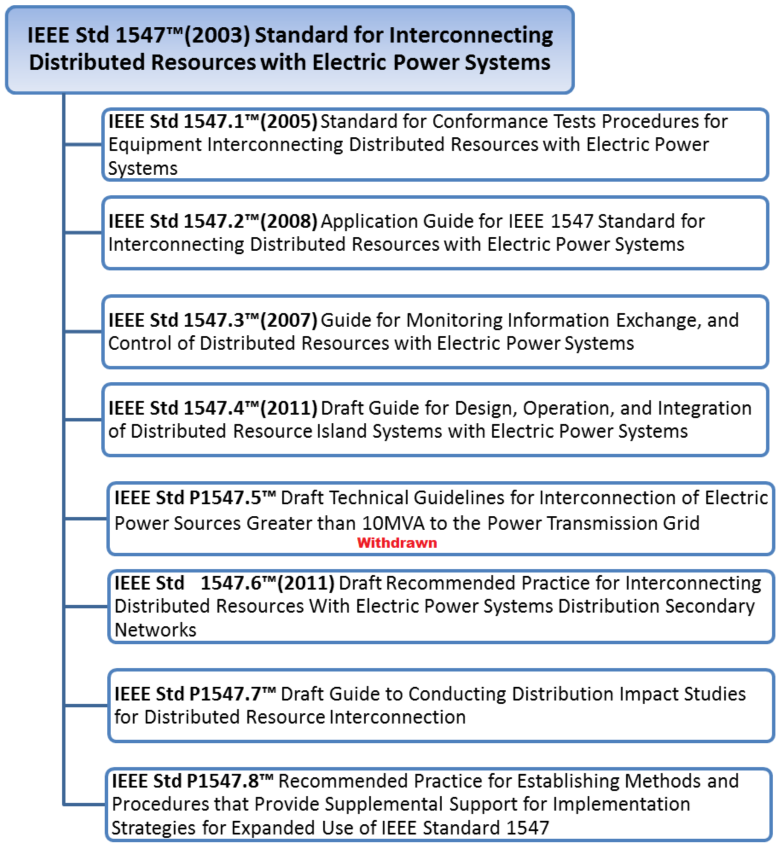

Figure 2 Progression of IEEE Standards

Source: IEEE

In October of 2011, IEEE approved the new standard for IEEE 1547.4 which provides alternative approaches and best practices for designing, operating, and integrating distributed resource (DR) island systems with electric power systems (EPS). Although they are several classifications of a distributed resource island system, the one thing that they all have in common is that they can generate their own electricity, and the ability to connect/disconnect from the grid. Distributed resources comprise energy storage technologies, as well as generators.

Micro grids can also be referred to as DR islands, because they essentially are generating power and distributing to areas normally in proximity to the generation and typically independent from the larger grid infrastructure. Characteristically microgrids present a system that can easily adapt to an assortment of energy sources-renewable energy compatibility- and its capacity to reduce carbon footprints, has propelled its popularity in the last decade. Producing and storing power locally, allows the system to act autonomously on command. The ability to distribute control and the choosing of power quality with the parties involved in the microgrid has given it a magnetism, which has also contributed to its popularity. Due to the complexity of the infrastructure of microgrids when islanding, and its interconnections to/from the grid, requires careful planning in order to be successful, something that the IEEE 1547.4 has facilitated.

3.6 RPS of States

Renewable portfolio standards (RPS) also referred to as renewable electricity standards (RES), are policies designed to increase the amount of electricity that originates from renewable resources. They require or encourage electricity producers to supply a certain minimum share of their electricity from designated renewable sources. Renewable energy that is considered under the RPS scheme include wind, solar, geothermal, landfill gas, municipal solid waste, tidal energy, and a limited number of hydroelectricity. There have been a couple of proposals that have made the rounds through the legislative branch of the US Government, but there is yet to be an established national policy. As of Jan 2012, there are 30 states that have an enforceable or some sort of renewable energy implementation plan. There are some states that have voluntary renewable generation goals, but every program is adjusted to each individual states requirements. They tend to vary widely in structure, size, and enforcement and application.

Policies that are under the RPS umbrella cover a broad range. Generally, the requirements set forth by the RPS have a goal date to be accomplished. The states that do participate in the RPS programs normally have a set of goals that are unique to the state, and are feasible to accomplish. If there is a specific industry within the renewable energy field that states have interest in maturing. States can set targets that would promote the development and use of said technologies. If cost increases to a point where it is unbeneficial, some states have "escape clauses" in place to withdraw if need be.

A useful tool and feature of many state policies are renewable electricity credit (REC), with a trading system structured to lessen the expenditure of fulfillment. With a trading scheme in place, if an energy producer generates surplus renewable energy, they can then sell or trade their excess to others who need it to fulfill their RPS requirements.

Table 1 Top 10 States with Grid Tied Connections

Top 10 States for New Grid-Tied Solar Electric Installations in 2009*

Capacity Installed in 2009			Cumulative Capacity in 2009		
1	Calif.	220	1	Calif.	1,102
2	N.J.	57	2	N.J.	128
3	Fla.	36	3	Nev.	100
4	Ariz.	23	4	Colo.	59
5	Colo.	23	5	Ariz.	50
6	Hawaii	14	6	Fla.	39
7	N.Y.	12	7	N.Y.	34
8	Mass.	10	8	Hawaii	27
9	Conn.	9	9	Conn.	20
10	N.C.	8	10	Mass.	18
	Others	29		Others	78
Total		**441 MW**	**Total**		**1,653 MW**

* Includes all grid-tied PV and CSP.

Source: SEIA

New Jersey had more residential installed PV than Florida (Table.1), and that could be attributable to the participation of the state in a carbon reduction scheme. In the northeast of the United States there is a Regional Greenhouse Gas Initiative (RGGI) which is America's regional cap and trade.

The RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusettes, New Hampshire, New Jersy, New York, Rhode Island, and Vermont. Together these ten states have capped and will reduce power sector CO2 emissions by 10 percent until 2018.

RGGI is composed of individual CO2 Budget Trading Programs in each of the ten participating states. Through independent regulations, on a model created by RGGI, each state's CO2 Budget Trading Program limits emissions of CO2 from electric power plants, issues CO2 allowances and establishes participation in regional CO2 allowance auctions.

Regulated power plants can use a CO2 allowance issued by any of the ten participating states to demonstrate compliance with an individual state program. In this manner, the ten state programs, in aggregate, function as a single regional compliance market for CO2 emissions.

Polluters pay for emissions and the revenue gets invested in clean renewable energy projects. Since New Jersey joined the program in 2005, they have investments through RGGI that have already eliminated the need for 52,000 MWh of electricity generated from fossil fuel sources each year—enough to power nearly 6,000 New Jersey homes. RGGI has led to the installation of approximately 7.5 megawatts of solar energy in New Jersey and the creation of nearly 1,800 job-years of employment in the state. (Schneider and Elliot, 2012)

RPS serves as a mechanism to encourage the development of renewable energy. States with RPS policies have seen an increase in the energy derived from renewable resources. Federal incentives, state programs, and market conditions have also encouraged development of renewable energy, even in the states that do not have an RPS scheme in place.

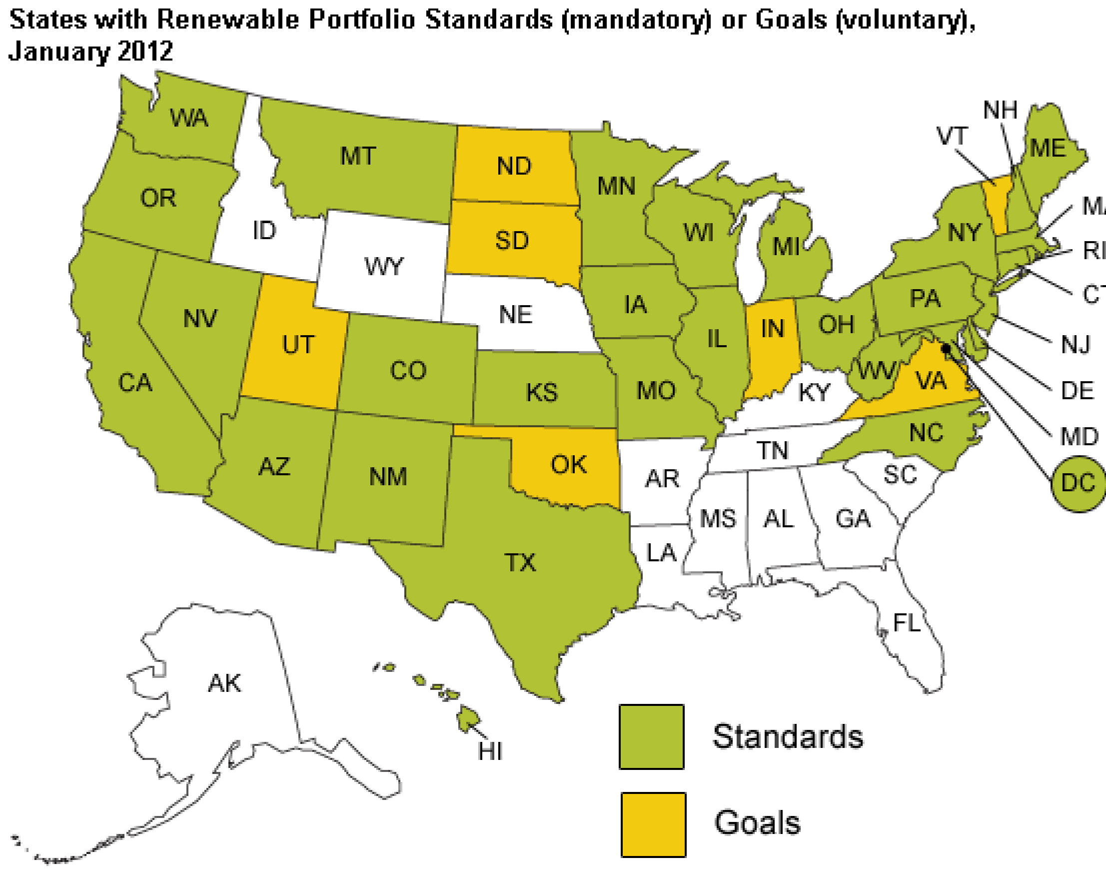

Figure 3 States RPS Distribution

Source: Interstate Renewable Energy Council, Database of State Incentives for Renewables & Efficiency, January 2012. EIA.com

3.7 Funds for Green Technology R & D

With the American Recovery Act, as highlighted earlier there was a special emphasis on development within the renewable energy sector as well as research into modernizing the grid. The amount of funds available for research in a sector is a useful indicator, to analyze where government policy is attracted. The United States is unique in the sense that when faced with an economic recession the government was able to inject funds into the economy, in hopes of stimulating the country. Very strong emphasis was placed on development specifically by the department of Energy. Table 2 has a breakdown on the allocation funds that have been invested in relation to research and development for the grid.

Table 2 Research and Development allocation from Government Funds

Fiscal year	2009	2010	2011	2012	ARRA	*Total*
By Technology Area						
Electricity	**$170.90M**	**$205.20M**	**$215.53M**	**$220.60M**	**$705.94M**	**$1,518.17M**
Grid	$170.90M	$205.20M	$215.53M	$220.60M	$705.94M	$1,518.17M
By US Govt. Agency						
Department of Commerce	$0.00M	$7.40M	$5.00M	$5.00M	$0.00M	$17.40M
Department of Defense	$94.10M	$90.00M	$94.76M	$117.70M	$8.00M	$404.56M
Department of Energy	$76.80M	$107.80M	$115.77M	$97.90M	$697.94M	$1,096.21M
Department of the Interior	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M
Department of Transportation	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M
Environmental Protection Agency	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M
National Aeronautics and Space Administration	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M
National Science Foundation	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M
Department of Agriculture	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M	$0.00M
By Innovation Phase						
RD&D	$170.90M	$205.20M	$215.53M	$220.60M	$705.94M	$1,518.17M
Total by Fiscal Year	$170.90M	$205.20M	$215.53M	$220.60M	$705.94M	$1,518.17M

Source: Energy Innovation Tracker

3.8 Feed in Tariffs

Feed in Tariffs are a policy options that allows power generators to be compensated for power that is exported locally. As figure 4 shows, the locations within the United States that have F.I.T. policies in place. Payments can be of electricity alone or of electricity packaged with renewable energy certificates. A typical FIT contract is valid from 15-20 years. They can be recognized as an advanced form of production based-incentive (PBI), where a payment is awarded for the amount of electricity produced ($/kWh). Whereas, capacity based incentives like rebates, are awarded based on the amount of capacity installed ($/watt). (Cory, 2009)

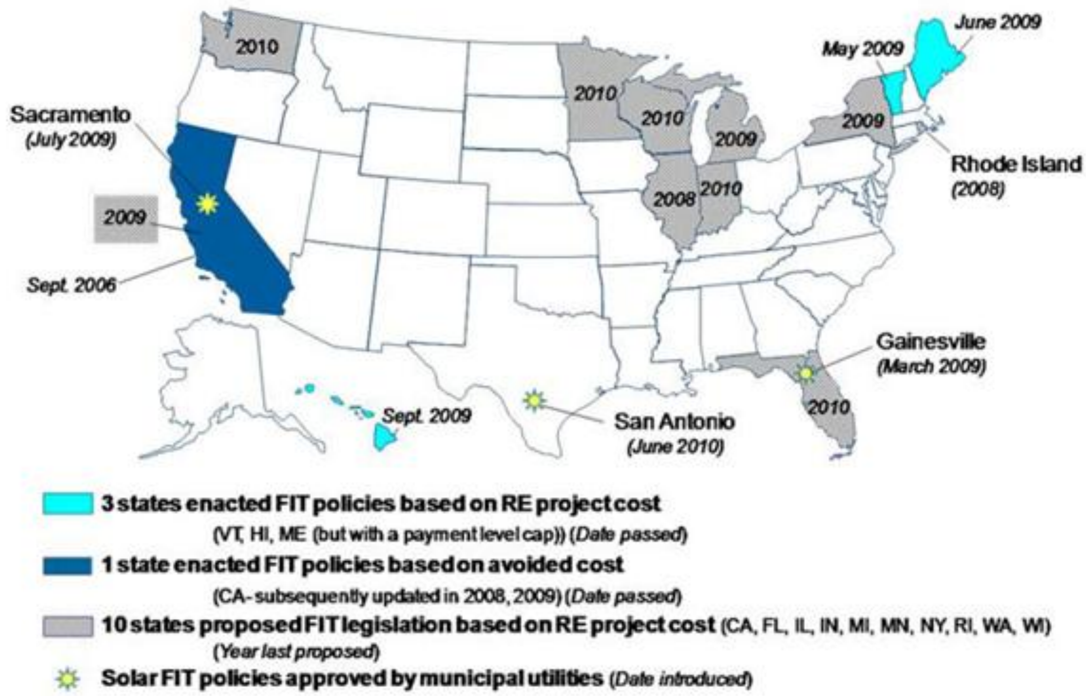

Figure 4. Feed in Tariff Policy Application within the United States

Source: NREL 2010

FIT payments can be determined in 3 ways: based on the actual levelized cost of regeneration, based on the utilities avoided cost, or offered as a fixed price incentive.

The most common and successful form of FIT has been the first type discussed previously. The reason it is so successful, is because it provides investor and guarantee on investments. In Europe it is the most common design used, on the contrary in the United States they tend use the other two methods. (Cory, 2009)

In the United States the first FIT policy to be implemented was in the state of Florida. It was a MOU (Municipal Owned Utility) called the Gainesville Regional Utilities, which serves the city of Gainesville in the northern part of Florida. It was a PV feed in tariff program that had a cop of 4 MW of allowed solar through 2016.

Although it focuses on a single technology, the Gainesville program is a robust feed-in tariff for solar. The prices are based on the cost of generation plus a small profit, are differentiated by both size and the location (roof-mounted or free standing) and contracts are for 20 years. The initial price for a building/pavement-mounted or smaller than 25 kW free standing PV array was $0.32 per kWh. Free standing solar arrays larger than 25 kW received $0.26. The prices decrease on a schedule through 2016, to $0.23 and $0.19, respectively. (ILSR, 2010)Feed in Tariffs are a very valuable tool, in promoting participation among consumers, because it provides an incentive to switch to renewable energy.

3.9 Florida Subsidies

Currently Florida has two forms of subsidies that customers can take advantage of. They are a 30% renewable energy tax credit and Rebate program.

Rebate:

Residential rebates are provided on a flat rate of $2 per DC watt nameplate rating for PV systems and $1,000 per system for solar water heating. Business customers who utilize eligible solar water heating systems are eligible for a rebate of $30 per 1,000 BTUh per day[1]. The business rebate for PV systems provides $2 per DC watt nameplate rating for systems up to 10kW, a rebate of $1.50 per DC watt nameplate rating for systems 10kW - 25kW, and $1 per DC watt nameplate rating for all systems larger than 25 kW. Business customers may accrue rebates in a cumulative fashion, whereby a customer with a 30 kW system can receive $2 per DC watt for the first 10 kW of capacity, $1.50 per DC watt rebate for the next 15 kW and $1 per DC watt rebate for the final 5 kW. (DSIRE,2012)

[1] 1,000 BTUh = 293 kWh

Residential Renewable Energy Tax Credit:

A taxpayer may claim a credit of 30% of qualified expenditures for a system that serves a dwelling unit located in the United States that is owned and used as a residence by the taxpayer.

4. Microgrids

4.1 Definition

A Micro Grid can have many different alias dependent upon where you conduct your research. Earlier in the paper we discussed some terms associated with decentralized energy. These terms tend to be interchanged sparingly with terms like: “micro generation”, “embedded generation”, “decentralized generation”, “decentralized energy planning”, “multi generation”, and “smart grid”.

Like distributed energy, microgrids share similar characteristics but have some unique elements. Microgrids can be determined on the range of power that they are intended to produce. It can range from as small as 25kW up to 100kW. Though these ranges are not exhaustive, they tend to be the most common. Providing power in the low range spectrum, contributes to the fact that they are most commonly found in underdeveloped urban areas or equally small industry. Within a microgrid you can find sources of energy that can vary (micro sources) these normally include diesel or gas driven motor gensets, fuel cells, and renewable energy like solar, wind, or gas and biofuel driven micro turbines. (Lasseter, 2002)

The concept behind microgrids is to detach from the centralized energy system, which provides energy primarily from fossil fuels. It is of no surprise that the main drivers behind microgrids be renewable energy, which unlike fossil fuels have lower emissions and could possibly cost less. An efficient microgrid would provide both energy and heat simultaneously. Due to the decrease size of units, microgrids have a mobility that allows it to be positioned in the most efficient way. To exploit the resourcefulness of small scale generation, it is most useful to have cohesion among loads and units. Similar to a regular grid, this can only be accomplished by using inverters to interface with the distribution system. When properly applied, the efficiency of the system can substantially increase suitably for the utilization of waste heat for heating of water, or spaces. (Lasseter, 2004)

The operation of a microgrid can serve two purposes. Off grid or grid tied. When a microgrid is off grid it is independent of the grid. The power that is generated is either used or stored without grid interference. Off grid connections commonly includes more than one source of energy and ample storage capacity. If coupled together they can provide energy to the local load or to storage unit.

When a microgrid is grid tied, it is constantly supplying power to the grid. The utility can decide to include it as its load or use it as a backup system. Having a backup system is of great assistance to the grid when there is an emergency that causes the grid to fail for any reason. Batteries are an important facet of microgrids because they allocate a supply of energy to be used at a later instant. They are useful to store any excess energy produced as well as a form of support when loads increase. Dependant on the size of a system, batteries can provide different capacities of storage. Microgrids would ideally maintain the batteries full when they are grid tied, incase that there is an emergency they would be readily available. Grid-tied means that the microgrid has the ability to feed the local load constantly. If there is a surplus of energy, the excess amount gets fed into the grid. Conversely, if there is a deficit of energy needed, it absorbs energy from the main grid. Power gets generated in direct current (DC) and gets used in alternating current (AC), therefore inverters play an essential role of any microgrid system; either grid tied or stand alone. (Lasseter, 2002)

4.2 Technology Involved

Distributed Generation

Distributed Generation are small (in comparison to centralized) sources of energy located at or near the point of use. The technologies involved typically include photovoltaic (PV), wind, fuel cells, microturbines, and reciprocating internal combustion engines with generators. It is not strictly renewable energy but at times can also derive from fossil fuels. Distributed Generation is the backbone of Microgrids because it is the provider of the power to be used. The different types of generation will be briefly explained further.

4.2.1 PV

Photovoltaic Systems are one of the most common renewable energy technologies that are integrated into microgrids and the regular distribution network. The sun is available indiscriminately and the ability to harness its energy is relatively easy. PV is easily deplorable on rooftops (Figure.5) or any flat surface, making it an attractive addition to any location. Most microgrids will have PV as a generation source and some microgrids are built solely on PV generation. PV doesn't require much study on the location for small scale generation so it is very practical. PV does have some pitfalls: over generation at noon and no generation at night, and if used alone requires storage capacity. In the next chapter PV will be explained in more detail.

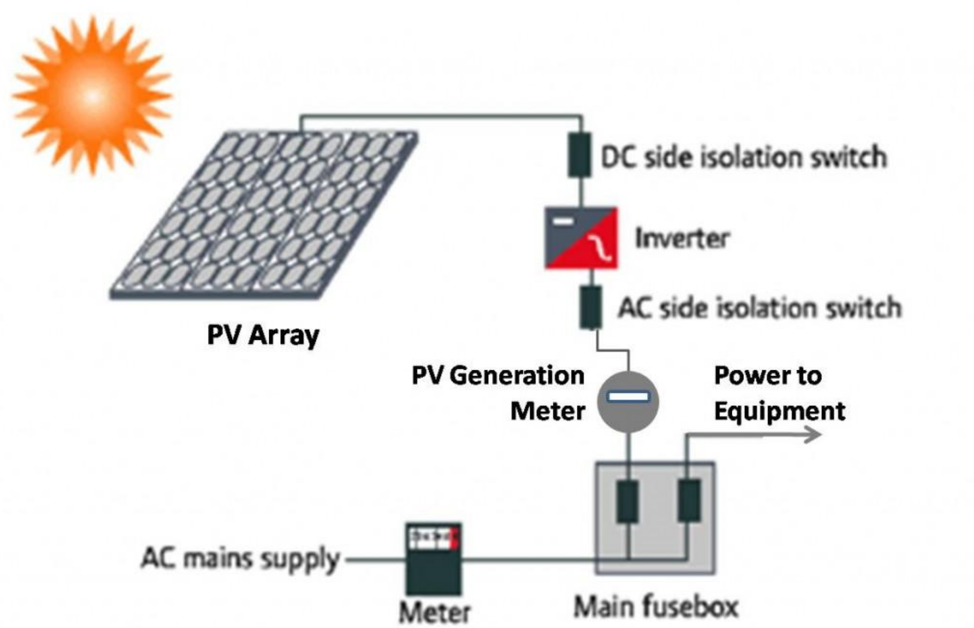

Figure 5 Typical PV Residential Arrangement

Source: Mapawatt.com

4.2.2 Wind

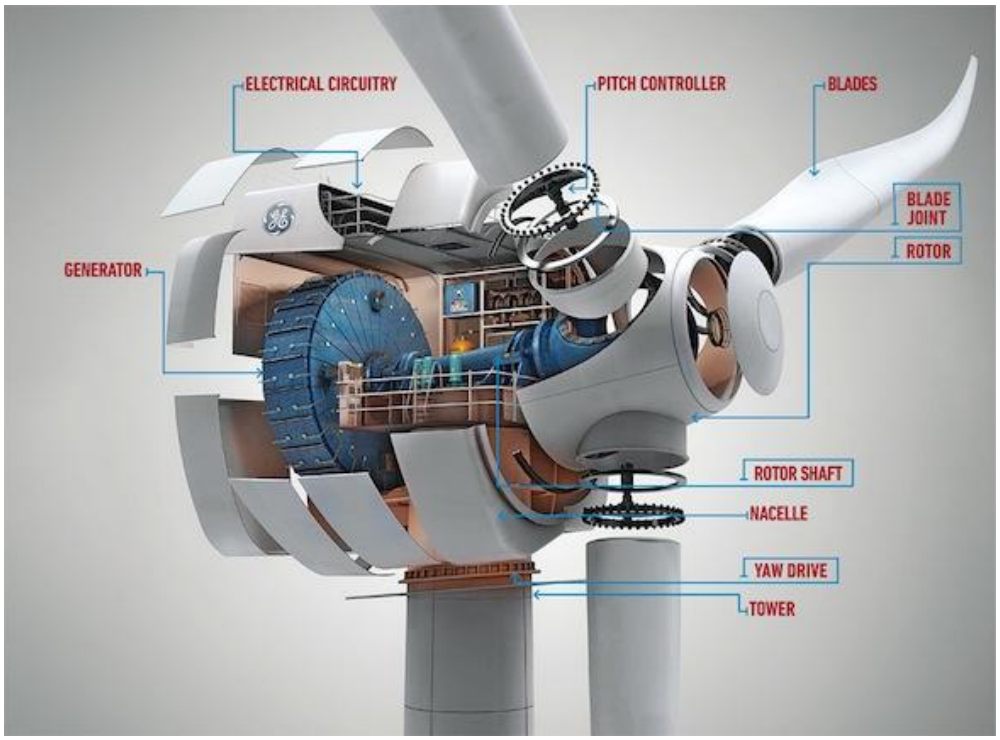

Figure 6 Wind Turbine Components

Source: General Electric

Wind Power is a great compliment to PV, because unlike the sun, wind can be available at all times of the year. Wind power as a generating source has a history that dates back before the industrial revolution. In a microgrid setting wind power can be the additional source of energy generation when the sun is not out. Certain geographical regions have an advantage over others, because strong winds are prevalent in those areas. Wind turbines come in small scale and large utility scale. Of interest to the microgrid are not only massive turbines (Figure.6), but also the easily deployable small variety.

Small Wind Turbines are electric generators that use the energy of the wind to produce clean, emissions-free power for individual homes, farms, and small businesses. With this simple and increasingly popular technology, individuals can generate their own power and cut their energy bills while helping to protect the environment. Unlike utility-scale turbines, small turbines can be suitable for use on properties as small as one acre of land in most areas of the country.

On average, a typical American home would require a small turbine with a 5-kilowatt (kW) generating capacity to meet all its electricity needs. A machine of this size has a diameter of approximately 18 feet. The exact size needed to power a home, however, can range from 2 kW to 10 kW (12-25 ft. diameter) based on a home's energy use, average wind speeds, and the turbine's height above ground (which affects its productivity). Location is really vital for wind energy harnessing. It is essential to have a site with unobstructed access to winds, which most often requires higher towers, larger land lots, and non-urban locations. Currently, less than 1% of all small wind turbines are used in urban applications partly due to zoning restrictions, but mostly because wind quality is much poorer in densely built environments. (AWEA,2012)

4.2.3 Fuel Cells

Figure 7 Bloomberg Solid Oxide Fuel Cells

Source: BloomEnergy

Fuel cells (Figure.7) are electrochemical devices that convert a fuel's chemical energy directly to electrical energy with high efficiency. With no internal moving parts, fuel cells operate similar to batteries. An important difference is that batteries store energy, while fuel cells can produce electricity continuously as long as fuel and air are supplied. Fuel cells electrochemically combine a fuel (typically hydrogen) and an oxidant without burning, thereby dispensing with the inefficiencies and pollution of traditional energy conversion systems. Fuel cells forego the traditional fuel-to-electricity production route common in modern power production, which consists of heat extraction from fuel, conversion of heat to mechanical energy and, finally, transformation of mechanical energy into electrical energy. (NFCRC,2012)

The different types of Fuel Cells are:

Alkaline

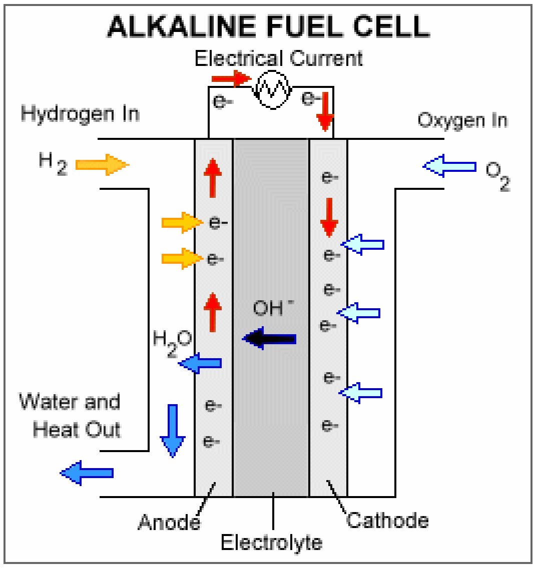

Figure 8 Alkaline Fuel Cell

Source: U.S. Department of Energy

The AFC has the advantage of exhibiting the highest electrical efficiencies of all fuel cells but it works properly only with very pure gases which is considered a major restraint in most applications. The KOH electrolyte which is used in AFC's (usually in concentrations of 30 - 45 wt.-%) has an advantage over acid fuel cells which is that the oxygen reduction kinetics are much faster in alkaline electrolyte than in acid making the AFC a very attractive system for specific applications. The AFC was one of the first fuel cells used in space. The AFC was used in the Apollo missions, the Space Shuttle program and was planned to be used in the European Hermes Project.

AFCs contain a potassium hydroxide (KOH) solution as the electrolyte. AFCs operate at temperatures between 100°C and 250°C (211°F and 482°F). Higher temperature AFCs use a concentrated (85wt%) KOH solution while lower temperature AFCs use a more dilute KOH solution (35-50wt%). The electrolyte is contained in and/or supported by a matrix (usually asbestos) which wicks the electrolyte over the entire surface of the electrodes. A wide range of electro-catalysts can be used in the electrodes (e.g., Ni, Ag, spinels, metal oxides, and noble metals). The fuel supplied to an AFC must be pure hydrogen. Carbon monoxide (CO) poisons an AFC and carbon dioxide (CO_2) reacts with the electrolyte to form potassium carbonate (K_2CO_3). Even the small amount of CO_2 in the atmosphere (about 370 ppm) must be accounted for operation of an AFC (Hirschenhofer et al., 1998).

Molten Carbonate

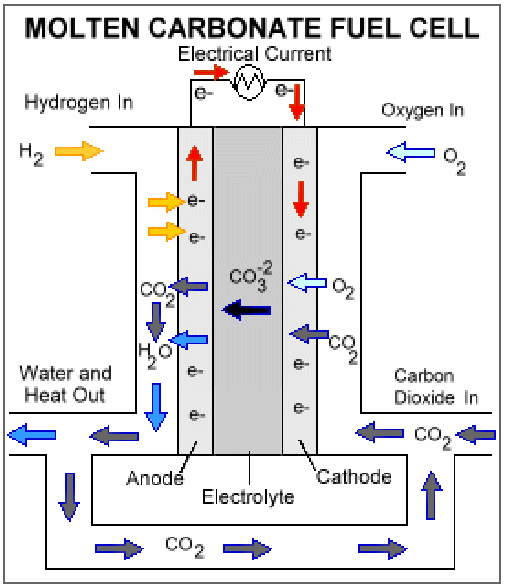

Figure 9 Molten Carbonate Fuel Cell

Source: U.S. Department of Energy

Full-scale demonstration plants are now testing molten carbonate fuel cells (MCFCs). The electrolyte in an MCFC is an alkali carbonate (sodium, potassium, or lithium salts, i.e. Na_2CO_3, K_2 CO_2, or Li_2CO_3) or a combination of alkali carbonates that is retained in a ceramic matrix of lithium aluminum oxide ($LiAlO_2$). An MCFC operates at 600 to 700°C where the alkali carbonates form a highly conductive molten salt with carbonate ions (CO_3=) providing ionic conduction through the electrolyte matrix. Relatively inexpensive nickel (Ni) and nickel oxide (NiO) are adequate to promote reaction on the anode and cathode respectively at the high operating temperatures of an MCFC (Baker, 1997).

MCFCs offer greater fuel flexibility and higher fuel-to-electricity efficiencies than lower temperature fuel cells, approaching 60 percent. The higher operating temperatures of MCFCs make them candidates for combined-cycle applications, in which the exhaust heat is used to generate additional electricity. When the waste heat is used for co-generation, total thermal efficiencies can approach 85 percent.

Phosphoric Acid Fuel Cell

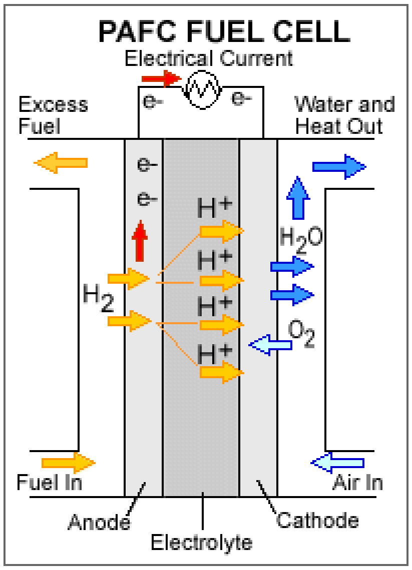

Figure 10 Phosphoric Acid Fuel Cell

Source: U.S. Deparment of Energy

Phosphoric Acid Fuel Cell (PAFC) technology is the most mature of the types in use today. PAFCs use a concentrated 100% phosphoric acid (H_3PO_4) electrolyte retained on a silicon carbide matrix and operate at temperatures between 150 and 220°C. Concentrated H3PO4 is a relatively stable acid, which allows operation at these temperatures. At lower temperatures, problems with CO poisoning of the anode electro-catalyst (usually platinum) and poor ionic conduction in the electrolyte become problems (Hirschenhofer et al., 1998). The electrodes typically consist of Teflon™-bonded platinum and carbon (PTFE-bonded Pt/C).

PAFC fuel cells produced by UTC Fuel Cells (previously named ONSI and International Fuel Cells) were the world's first commercially available fuel cell product

(King and Ishikawa, 1996). Turnkey 200-kilowatt plants are now available and have been installed at more than 200 sites in the United States, Europe, and Asia (principally Japan). Operating at about 200°C, the PAFC plant also produces heat for domestic hot water and space heating, and its electrical efficiency is 36-40 percent. The development and implementation of this commercial fuel cell product is a result of several years of research development and demonstration by the U.S. Department of Energy, U.S. Department of Defense, and the Gas Research Institute.

Proton Exchange Membrane Fuel Cell

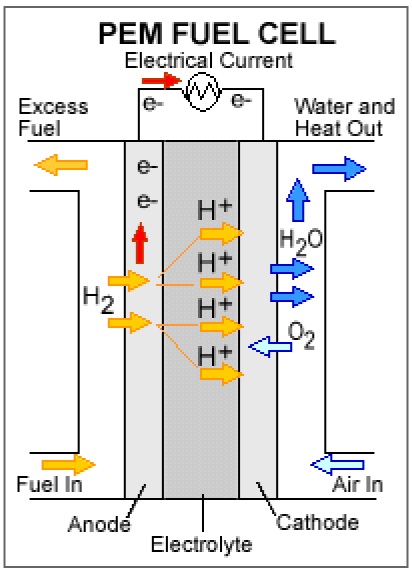

Figure 11 Proton Exchange Fuel Cell

Source: U.S. Department of Energy

The proton exchange membrane fuel cell (PEMFC) is also known as the solid polymer or polymer electrolyte fuel cell. A PEMFC contains an electrolyte that is a layer of solid polymer (usually a sulfonic acid polymer, whose commercial name is NafionTM) that allows protons to be transmitted from one face to the other (Gottesfeld and Zawadinski, 1998). PEMFCs require hydrogen and oxygen as inputs, though the oxidant may also be ambient air, and these gases must be humidified. PEMFCs operate at a temperature much lower than other fuel cells, because of the limitations imposed by the thermal properties of the membrane itself (Appleby and Yeager, 1986). The operating temperatures are around 90°C. The PEMFC can be contaminated by CO, reducing the performance and damaging catalytic materials within the cell. A PEMFC requires cooling and management of the exhaust water to function properly (Gottesfeld and Zawadinski, 1998).

Solid Oxide Fuel Cell

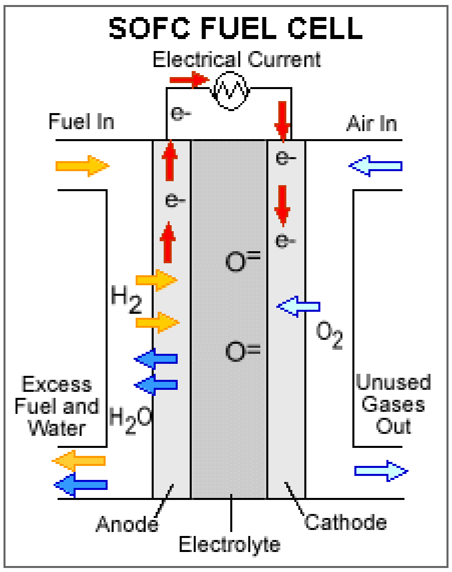

Figure 12 Solid Oxide Fuel Cell

Source: U.S. Department of Energy

Solid Oxide Fuel Cells (SOFCs) are currently being demonstrated in sizes from 1kW up to 250-kW plants, with plans to reach the multi-MW range. SOFCs utilize a non-porous metal oxide (usually yttria-stabilized zirconia, Y_2O_3-stabilized ZrO_2) electrolyte material. SOFCs operate between 650 and 1000°C, where ionic conduction is accomplished by oxygen ions (O=). Typically the anode of an SOFC is cobalt or nickel zirconia (Co-ZrO_2 or Ni-ZrO_2) and the cathode is strontium-doped lanthanum manganite (Sr-doped $LaMnO_3$) (Singhal, 1997; Minh, 1993).

SOFCs offer the stability and reliability of all-solid-state ceramic construction. High-temperature operation, up to 1,000°C, allows more flexibility in the choice of fuels and can produce very good performance in combined-cycle applications. SOFCs approach 60 percent electrical efficiency in the simple cycle system, and 85 percent total thermal efficiency in co-generation applications (Singhal, 1997).

Direct Methanol

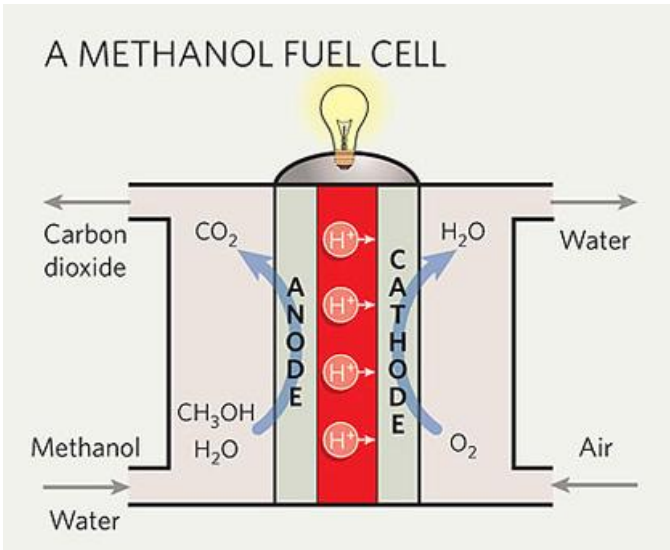

Figure 13 Direct Methanol

Source: Machine-History.com

The direct methanol fuel cell is a special form of low-temperature fuel cells based on PEM technology. It operates at temperatures similar to PEMFC although it is usually operated at slightly higher temperatures in order to improve the power density. In the DMFC, methanol is directly fed into the fuel cell without the intermediate step of reforming the alcohol into hydrogen. Methanol is an attractive fuel option because it can be produced from natural gas or renewable biomass resources. It has the advantage of a high specific energy density (since it is liquid at operating conditions) and it is assumed that the existing infrastructure for fuels may be adapted to methanol. The DMFC can be operated with liquid or gaseous methanol/water mixtures. (Carrette et al,.2001)

4.2.4 Microturbines

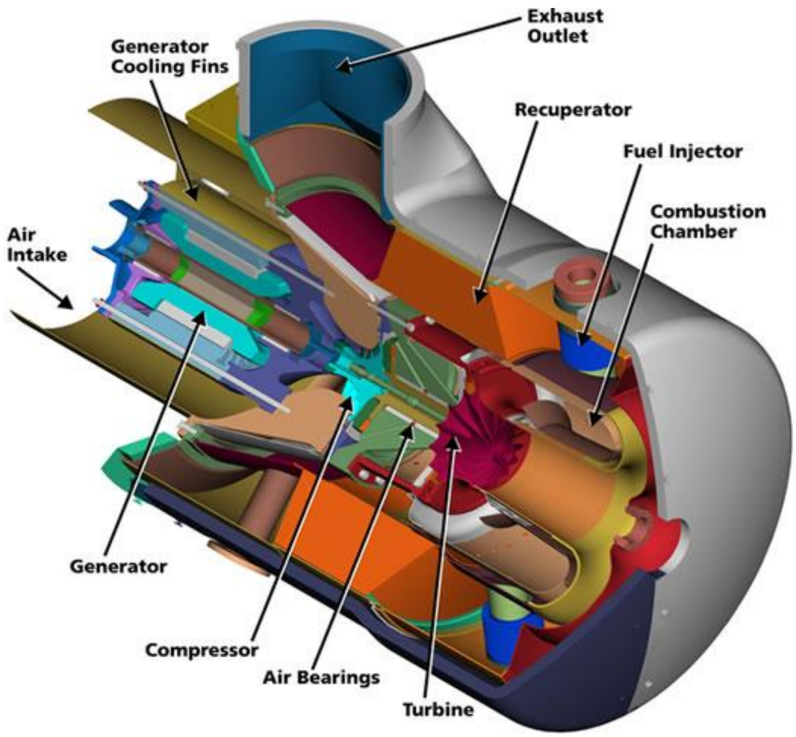

Figure 14 Microturbine Components

Source: Capstonemicroturbines.com

Microturbines (Fig.14) are new combustion type turbines that are intended for distributed generation appliances. Small in scale- to the equivalency of a household refrigerator- and a capacity to produce from 25-500 kW of energy on site, allow this technology to be ideal in places that are restrictive in area. The ability that microturbines present by collecting waste heat that can be used for heating, cooling or energy production allow it to reach energy efficiency levels that are greater than 80 percent.

Microturbine generator units are comprised of a compressor, combustor, turbine, alternator, recuperator, and generator. In a simple-cycle turbine (without a recuperator), compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. Recuperated units use a heat exchanger (recuperator or regenerator) that recovers some of the heat from the turbine exhaust and transfers it to the incoming air stream for combustion in the turbine. By using recuperators that capture and return waste exhaust heat, existing microturbine systems can reach 25 to 30 percent cycle efficiency. (DOE,2012)

When advanced materials such as ceramics and thermal barrier coating are incorporated, the efficiency of system is increased due to the ability of the system to handle higher temperatures. Microturbines are the opposite to most renewable energy technologies discussed so far, because they offer a consistent production of power in any situation. It is attractive due to its compact size and mobility, and it serves as reliable backup power, with additional ability to peak shave.

Microturbines use gas as fuel to operate. One of the advantages is the ability to use different types of gas like those coming from renewable sources like landfill gas, or biomass gasification.

4.2.5 Micro Storage

A storage system is necessary when the generation does not meet the load demand required. Distributed storage serves as a bridge between power and energy required in a microgrid. Storage capacity is defined in terms of the time that the nominal energy capacity can cover the load at rated power. Storage capacity can be then categorized in terms of energy density requirements (for medium- and long-term needs) or in terms of power density requirements (for short- and very short-term needs). Storage units enhance the overall performance in microgrids. They allow the generation units to run at a constant and stable output, irrespective of the loads fluctuations. It also allows the capability of the microgrid to properly handle dynamic variations of its primary energy sources like solar, wind and hydropower. It also allows a distributed generation to operate seamlessly as a dispatchable unit. Moreover, energy storage can benefit power systems by damping peak surges in electricity demand, countering momentary power disturbances, providing outage ride-through while backup generators respond, and reserving energy for future demand.

Among some of the technology available as storage for microgrids, the battery is the most common and conventional solution for energy storage. Batteries store electrical energy in the form of chemical energy for later use. Batteries are regularly DC power system but they allow energy to be converted from DC to AC. Many utility connections for batteries have bidirectional converters, which allow energy to be deposited or withdrawn at any time.

There are also supercapacitors or ultracapacitors as a storage device. These devices offer high power density and extremely high cycling capability. Flywheels have also emerged, and have been considered extensively due to their ability support critical load during grid power interruptions. The ability of flywheels to respond quickly puts them at an advantage over electrochemical energy storage. The development of flywheels has been facilitated by the advancement in power electronics and digital controlled fields, and this has given them a competitive advantage in the market contributable to cost-effective improvements. Typically, an electric motor supplies mechanical energy to the flywheel and a generator is coupled on the same shaft that outputs the energy, when needed, through a converter.

4.2.6 Inverters, Converters, and Change Controllers

The point where the microgrid gets connected to the distribution system is called the interconnection switch or point of common coupling (PCC). New technology in this area consolidates the various power and switching functions (e.g., power switching, protective relaying, metering, and communications) traditionally provided by relays, hardware, and other components at the utility interface into a single system with a digital signal processor (DSP). Grid conditions are measured both on the utility and microgrid sides of the switch through current transformers (CTs) and potential transformers (PTs) to determine operational conditions. The IEEE has set standards (IEEE 1547) that minimize the possibility of custom engineering and allow for approval processes to be expedient and lower priced. The United States also has a standard (UL 1741) to meet for interconnectedness. To maximize applicability and functionality, the controls are also designed to be technology neutral and can be used with a circuit breaker as well as faster semiconductor-based static switches, which are applicable to a variety of DG assets with conventional generators or power converters.

Converters are responsible for voltage and frequency compatibility with the electric power system to which the microgrid is connected. It also contains necessary output filters. The power electronics interface can also contain protective functions for both the distributed energy system and the local electric power system that allow paralleling and disconnection from the electric power system. These power electronic interfaces provide a unique capability to the DG units and can enhance the operations of a microgrid.

4.3 Microgrid Control

Microgrids have three critical components that allow it to perform its function properly they are:

- Local microsource controllers
- System optimizer
- Distributed protection

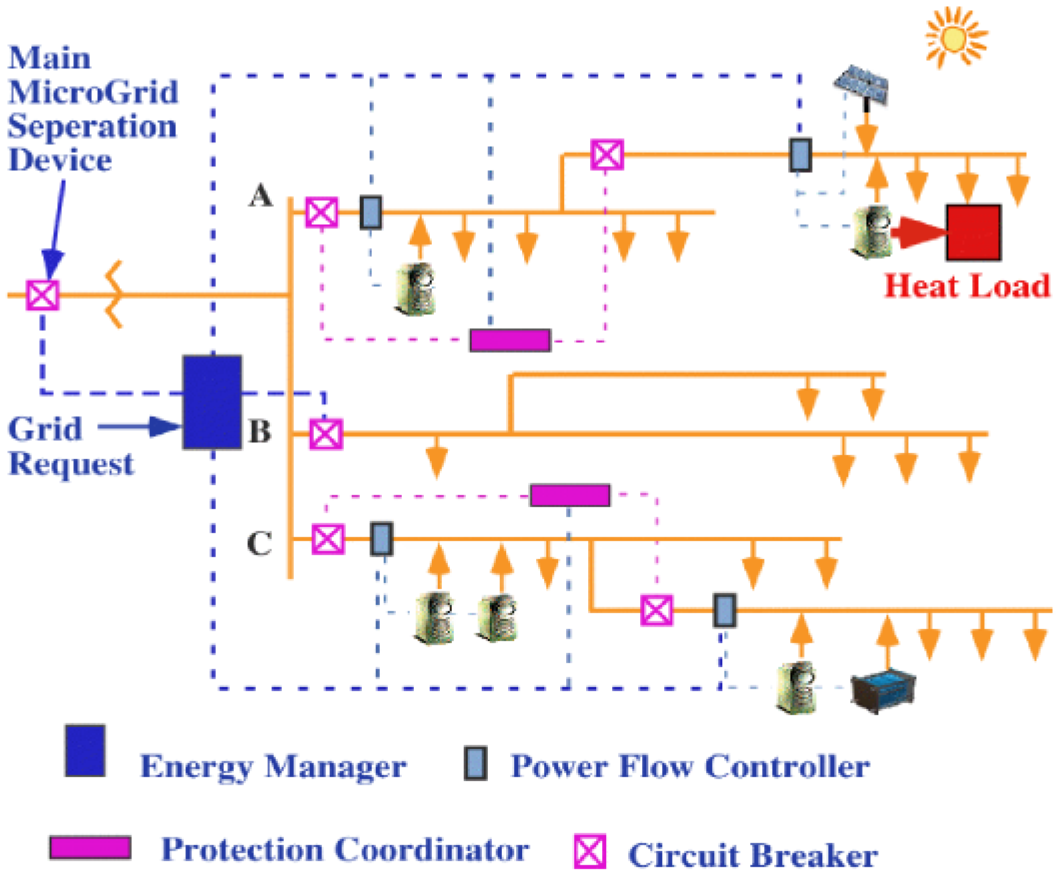

Figure 15 Microgrid Architecture

Source: Lasseter, 2002

Figure.14 illustrates the basic MicroGrid architecture. In this example the electrical system is assumed to be radial with three feeders A, B and C and a collection of loads. The radial system is connected to the distribution system through a separation device, usually a static switch. The feeder voltages at the loads are usually 480 volts or less. Feeder A indicates the presents of several microsources with one providing both power and heat. Each feeder has circuits breakers and power flow controllers. Consider the power flow controller near the heat load in feeder A. This controller regulates feeder power flow at a level prescribed by the Energy Manager. As loads downstream change the local microsources increase or decrease their power output to hold the power flow constant. In this figure feeders A and C are assumed to have critical loads and include microsources, while feed B is assumed to have non-critical loads which can be shed when necessary. For example when there are power quality problems on the distribution system the MicroGrid can island by using the separation device shown in the figure. The non-critical feeder can also be dropped using the breaker at B.(Lasseter, 2007)

One of the most vital components of a microgrid infrastructure is the Microsource controller. During all events this controller uses local information and has the ability to respond within milliseconds. Microsources do not need to communicate to function, and this is one of the key elements. Inverters have the ability to respond to load changes without communication of data from other locations or sources, this gives them the ability to "plug and play". A microsource could be added to a system without changes to control and protection of units within the system, hence plug and play. There are two basic inputs for this controller P (steady state set points for output power) and V (local bus voltage). When the numbers of microsources increase- which is a characteristic of Microgrids- it becomes impossible without P-Q controls. In order to have stability and reliability locally, the voltage has to be regulated. A common reaction of systems that have high penetration of microsources and no local voltage control, are voltage/reactive power oscillations. By having voltage control it eliminates the possibility of circulating reactive currents between sources. It is very similar to the same issues that large synchronous generators encounter. The possibility of circulating currents is greatly reduced in the power grid due to the impedance between generators. Microgrids are typically radial; therefore they have a enormous likelihood of large circulating reactive currents. If there are small errors in voltage set points the circulating current can exceed the ratings of the microsources. To avoid this situation a voltage vs reactive current droop controller is necessary. It is essential to have the voltage set point according to the current; if the reactive current from the microsource becomes capacitive then the voltage set point is reduced, if it becomes more inductive then it is increased.

In order to run the system optimally the use of an energy manager is critical. The manager uses the local information on the need for heat and the electrical load, also the quality of power necessary, the cost of gas and electricity, the needs of wholesale/retail services, the special grid needs, the demand side management request, congestion levels, etc. to determine the amount of power the microgrid should draw from the distribution system.

Some key functions of the Energy Manager are:

- Provide the individual power and voltage set point for each power flow/microsource controller
- Insure that heat and electrical loads are met
- Insure that the MicroGrid satisfies operational contracts with the transmission system
- Minimizes emissions and system losses
- Maximize the operational efficiency of the microsources.
- Provides logic and control for islanding and reconnecting the MicroGrid during events.

There should be protection from both systems in case one was to become faulty. One way to protect the Microgrid from faults that occur in the regular grid is to isolate itself from the utility as rapidly as possible to protect the loads of the Microgrid. Dependent on the customers load, is what determines how speedy isolation should occur. Sometimes sag compensation can be utilized, eliminating the necessity to isolate from the distribution system to protect critical loads. If there is a fault within the grid then the protection coordinator isolates the smallest possible section of the radial feeder to eliminate the fault.(Lasseter,2007)

4.4 Smart vs Micro

Smart grid is a very buzzing word in the last decade among all flights of life, from politicians to entrepreneurs, and everything left out and in-between. Even with all its popularity, if you take a survey of 100 individuals and ask what a smart grid is; chances are you will get 100 different answers. So, what really is a smart grid? Sioshansi(2011) defines it as: “A Smart Grid is any combination of enabling technologies – hardware, software, or practices – that collectively makes the electric power sector’s delivery infrastructure – the grid – more reliable, more versatile, more secure, more accommodating, more integrated, more resilient, and ultimately more useful to consumers”. (Sioshansi, 2011)

He goes on to highlight six areas of concern that must meet the demand of the future grid in order to function sufficiently. A Smart Grid must be more reliable, integrated, and accommodating to the inclusion of intermittent resources; it must facilitate the integration of distributed generation; it must act as a flexible two-way conduit between load and generation; and it must enable “prices-to-devices”[2] revolution to permeate beyond meters. (Sioshansi, 2011)

The Smart Grid is more about making the grid a lot more resilient and reliable; by improving the communication between load and generation. It is more about integrating new technologies into an outdated system; whereas, a micro grid, can function as part of the grid, or independently. The Microgrid is more of system within a system. Momoh(2012) put it bluntly: “think of the Microgrid as a local power provider with limited advanced control tools and the smart grid is a wide area provider with sophisticated automated decision support capabilities.”(Sioshansi, 2011)

[2] Cost reflective dynamic prices, delivered through smart meters to electricity-consuming devices within customers’ premises, can – in principle – lead to more rational use of electricity.

5. Miami Profile

Miami-Dade County, Florida is the most populous county in the southeastern United States and the eighth largest in the nation by population. The City of Miami has a population of 400,000 and is part of Miami Dade County that has a population of approximately 2.5 million.

5.1 Solar Potential

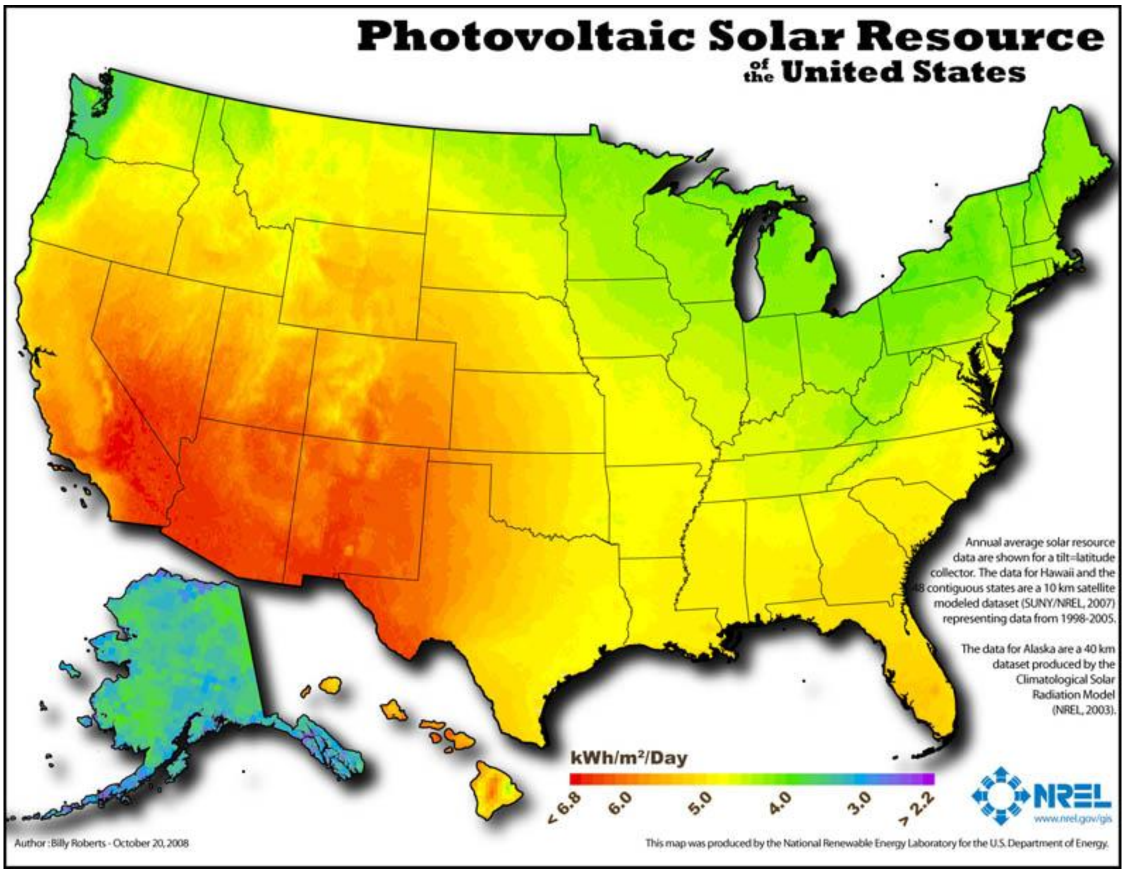

Figure 16 Solar Resource of U.S. States

Source: National Renewable Energy Laboratory

Although Florida calls itself the Sunshine State, it only receives 74 sunny days a year. Miami has 74 clear days, 175 partly cloudy days, and 115 cloudy days per year. (NOAA,2010) Miami has an average global horizontal annual solar resource that is between 4.1-6.15 kWh/m^2/day. (Figure. 15)

5.2 Hurricane Probability

Florida is known for its "nice" weather all year long, and "snow birds"[3] are a common sighting in Florida, this is due to its proximity to the equator; Florida is hot and humid, where the weather is hot, chances are the water in the ocean is hot, and this makes it extremely vulnerable to natural disasters, especially hurricanes. A hurricane gets its power from the moisture and heat of the tropical oceans. The result can be a storm so powerful that the potential for havoc is extremely high. Not surprisingly, because of its location relative to the warm waters of the North Atlantic (including the Gulf of Mexico and the Caribbean Sea); Florida is more likely to get hit by a hurricane than any other state in the union, and Miami has a the highest probability within the state (Figur3.16) . In the U. S., 40 percent of all major hurricanes have battered Florida, and 83 percent of category 4 or 5 hurricane strikes have pummeled either Florida or Texas (Blake et al., 2007).

Figure 17 Florida Hurricane Coastal Strike Probability

Source: Floridahurricane.net

[3] Snowbirds are typically retirees, and business owners who have a second home in a warmer location or whose business can be easily moved from place to place

Pompe and Haluska created a scale that measures the vulnerability of hurricanes in coastal areas. They created a hurricane vulnerability index (HVI). HVI is a rank on the susceptibility of coastal areas to hurricane damage, which is a composite of elements that contribute to damage. They are: 1) level of exposure 2) physical susceptibility to the hurricane, and 3) hurricanes frequency and intensity. Each element is comprised of several indicators of risk. The seven indicators employed in the study are: population, number of housing units, house value, probability of hurricane strike, building code effectiveness, building age, and vulnerability to sea-level rise. Figure.17 is a chart of their findings.

County	HVI Value
Miami-Dade, FL	5.52
Dare, NC	1.10
Charleston, SC	1.34
New Hanover, NC	0.42
Bay, FL	0.19
Harrison, MS	0.69
Galveston, TX	0.71
Orleans, LA	0.78
Cameron, TX	0.68
Chatham, GA	0.11
Mobile, AL	0.65

Figure 18 HIV for sample counties

Source: Pompe and Haluska

In the U. S., 40 percent of all major hurricanes have battered Florida, and 83 percent of category 4 or 5 hurricane strikes have pummeled either Florida or Texas (Blake et al., 2007). Hurricanes and power lines don't mix well. When a hurricane hits an area it devastates the power grid, especially the distribution network. When distribution networks are damaged the first to feel it are the customers of the grid. In Miami, hurricanes are synonymous with power outage normally for days.

A study was conducted on the reliability of power utilities in Florida after a hurricane, and results indicates that the average time to restore power after a hurricane is 22 hours with a mean cost of 110 million dollars per investor-owned utility. In Florida, the mean value for power outage time is roughly 22 hours with a standard deviation of 20 hours. The maximum average time was 76 hours and the minimum was 1 hour (Monaghan, 2008). A universal reason for outages to last so long is due to the lack of decentralization of energy.

5.3 Energy Profile of Miami

Electric load demands normally cycle, in accordance with human activity. In the morning when the majority of workers are preparing to go to work; demand is high. In the evening when they arrive from work and cook dinner; demand is high. During the winter when heating demand perceptibly increases.

As of lately, the load demand in Florida has been characteristically unusual. In the summer, customer demand begins to increase in the morning and peaks in the early evening, a pattern which corresponds to the sun heating buildings and the resulting increase in air conditioning loads. In contrast, the winter load curve has two peaks, the largest in midmorning, followed by a smaller peak in the late evening. Both winter peaks correspond to heating loads. In the past few years, Florida has experienced a trend in which the winter peak demand has exceeded summer peak demand (Figure.18). For example, in 2010, Florida's winter peak demand was 48,872 MW compared to 48,385 MW in the summer of 2010. (FPSC,2012)

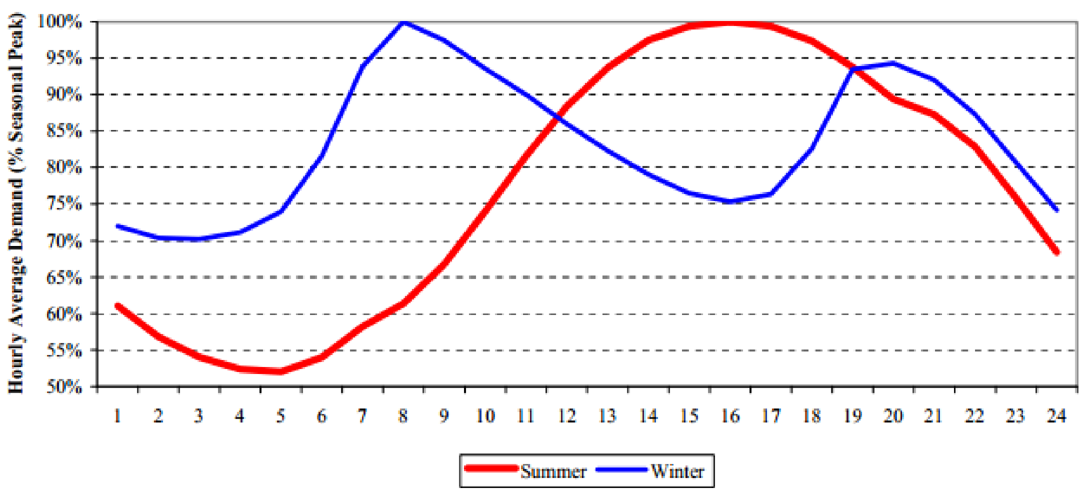

Figure 19 Daily load shape curves for typical summer and winter days in Florida

Source: Florida Public Service Committee

To better understand load behavior, we have to consider behavior of the common consumer. The Florida Solar Energy Center conducted a study on the on the effect that central air condition affects energy demand. As an example of a regional data set that may help better determine the range of expected electrical use in a given area for a given home size, data from ten homes is evaluated.

The Florida Solar Energy Center (FSEC) conducted a several year study (mid-1990) of "typical" affordable housing in the southern Florida region. The three bedroom homes have a conditioned floor area of 95.6 m^2; the four bedroom models total 110.5 m^2. The construction is conventional for south Florida: concrete block on an un-insulated monolithic slab with an exterior light colored stucco finish. The roofs are of standard (truss) construction with plywood decking and asphalt shingles. The concrete block walls are insulated with R-3 (hr•ft2•°F/Btu) insulation on the interior. The ceiling is insulated to R-19 with fiberglass batts. Single-hung, aluminum-framed single-glazed windows are used. The mechanical cooling system in the houses consists of 2.0-ton air conditioners in the three bedroom homes and 2.5-ton air conditioners in the four bedroom units. Both A/C units are rated at SEER 12.0. Heating is provided by 4.8 kW electric resistance elements (7.1 kW in four bedroom homes) located in the air-handling unit. (NAHB Research Center,2009)

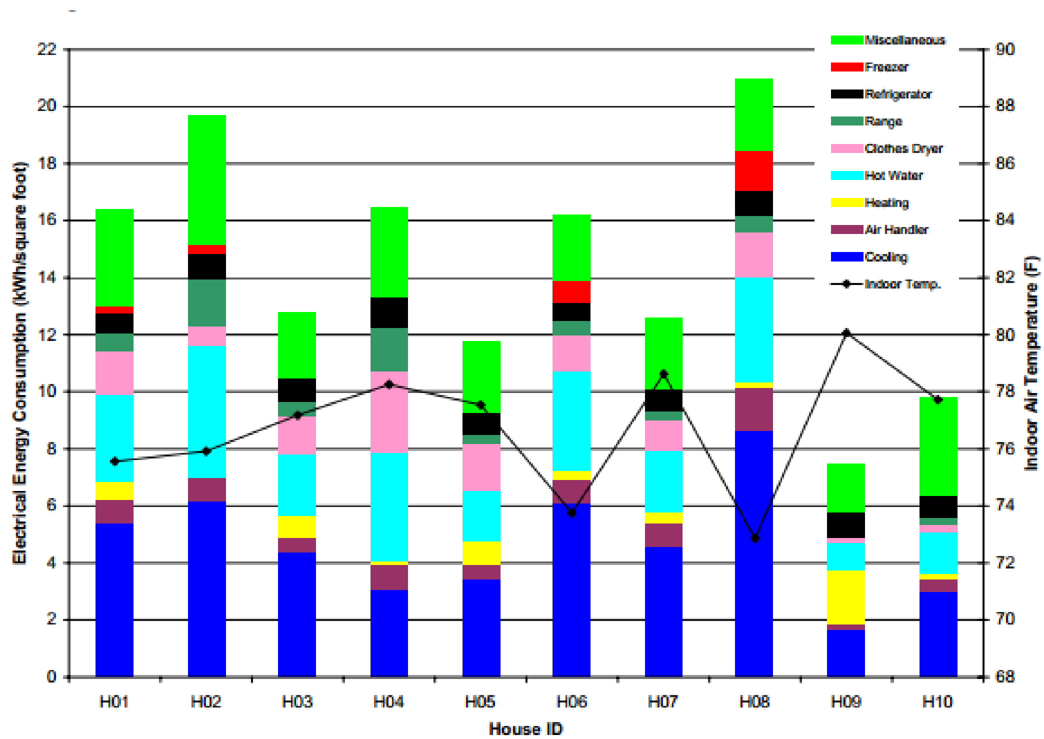

Figure 20 Summary of Electric Energy Consumption in 10 South Florida Homes

Source: Florida Solar Energy Center

Figure.19 describes the normalized total average annual consumption for the ten homes in the study. Each total is comprised of various appliance and space-conditioning electric energy use. The homes in the study used electricity for heating, cooling, hot water production, and cooking. The average annual energy use is about 156 kWh per square meter per year with a range from about 80 to 226 kWh per square meter per year. This is approximately 22% higher than the average of EIA data in the southern Region. Many differences exist especially related to the use of air conditioning including thermostat setting, occupant use of the blower, outdoor temperature, house construction, and occupant behavior. Another important consideration is that the cooling energy (excluding the blower energy) accounts for about 40% of the electric energy use. For these all-electric homes, energy for space conditioning and water heating accounts for approximately 60% of total energy (Table.3).

Table 3 Electric Consumption per Load Type Based on Florida Study

Electric Load	% of Total
Space conditioning	40
Domestic hot water	19
Clothes dryer	8
Range	4
Refrigerator	6
Miscellaneous	22

Source: Florida Solar Energy Center

5.3.1 FPL Record

The City of Miami has one electricity provider Florida Power and Light. This company has a long history in the state. Florida Power and Light started conducting business in Florida since 1925. The new company began its first year of service with:

- 76,000 electric and gas customer accounts serving 58 communities
- 230 miles of transmission lines
- 1,149 miles of distribution lines
- a generating capacity of 70 megawatts and
- an average price per kilowatt hour for residential service of 8¢.(FPL,2012)

And now the company holds the strongest areas in Florida, Their coverage spans across the whole eastcoast line (Figure.20).

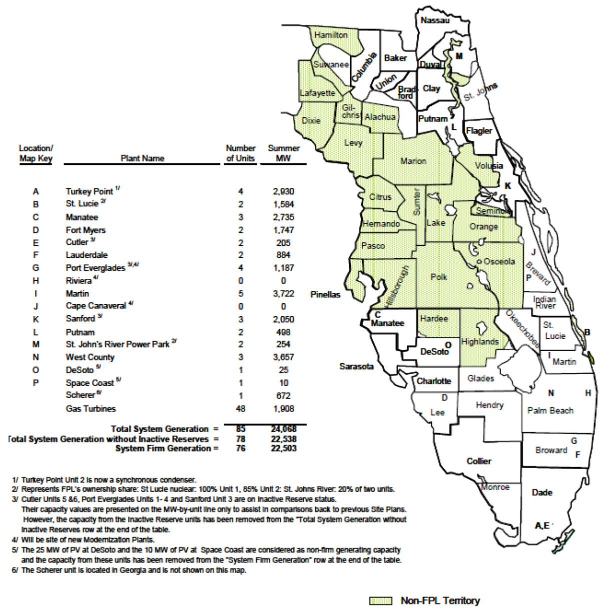

Figure 21 FPL Generating Resources by Location

Source: FPL

FPL has been serving Florida for a significant period, and isn't hard to believe that it is the largest provider of power for the state. Being in business for so long would obviously allow for a company to establish a strong understanding of the industry. Unfortunately for the customers, sometimes these companies know the system a little too well.

In the United States there are different institutions established to regulate electricity providers, and they vary on jurisdiction from federal to the state level. Utilities in the United States would often have an agreement with the regulators to be allowed to conduct business in their area of operation, also known as a regulatory compact. The Regulatory Compact is the traditional mode of regulation for the electric utility industry, also known as cost-of-service regulation. In this regulatory environment, the utility is recognized as a natural monopoly and is obligated to provide service to all consumers within its authorized footprint. It is regulated by a state utility commission. In return for its obligation to serve, the utility is given the opportunity to receive not only its investment and cost of providing service, but an opportunity to earn a fair return on its investment.(AEP, 2010)

Regulatory bodies called Public Utility Commission (PUC) or Public Service Commission (PSC) serve as a governing body that regulates the rates and services of a public utility. In some cases, government bodies with the title "Public Service Commission" may be civil service oversight bodies, rather than utilities regulators. During the last 20 years there has been a lot of negative attention directed towards Florida's PSC. There were numerous allegations that the regulators where "sleeping" with the regulated. There were cases of members of the PSC exchanging messages with each other, other cases involved a member of the commission attending a party hosted by a member of the utility that they are supposed to be regulated, and most of the times these events arose during a period where a rate hike was under consideration. With these types of allegations being claimed and investigated, it would not be implausible to believe that the commission was not acting in the interest of the ratepayers.

To add fuel to fire, while the rest of the United States was under a recession, FPL was recording record profits. During the third quarter of 2006 FPL net jumps 54.6% to Q3 record $524 mil(Carlsen, 2006), during the first quarter of 2008, FPL Group net jumps 66% to Q1 record $249 million (Carlsen, 2008) and during the first quarter of 2009, the reported fourth-quarter profit jumped 82 % , Profit climbed to $408-million (Financial Times, 2009). It is evident that the electricity industry is very lucrative, but what is a little puzzling is, if it is really necessary to swindle. Electricity production and distribution is a money-making business, but there are also the risks of incurring losses.

5.3.2 FPL Company Profile

The whole Dade County gets its energy from one supplier Florida Power and Light (FPL). FPL's service area contains approximately 71,600 km^2 and has a population of approximately 8.8 million people. FPL served an average of 4,547,051 customer accounts in thirty-five counties during 2011. (FPL,2012) Figure.21 is a map of the coverage area in relation to Florida.

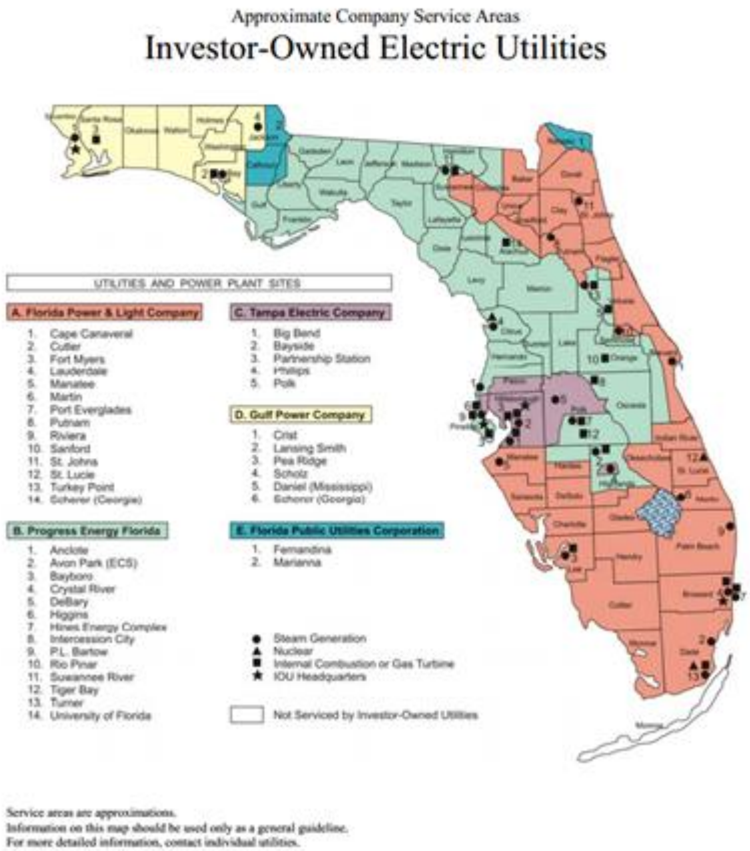

Figure 22 Area of Florida Covered by Investor Owned Utilities

Source: Public Service Commission

The Utility that services Miami,FL; Florida Power and Light (FPL) is a subsidiary of Next Era Energy. They have 34 generating plants, with a network that includes 1.3 million poles and more than 112,500 Km of overhead and underground transmission lines and distribution lines.(FPL,2012) FPL is an example of what you would call a vertically integrated utility. It is responsible for the generation, transmission, and distribution of power to retail customers. The facet of the electricity system that is most vulnerable to outages is the area that is closest to the customers. Excluding natural disasters, the main contributor to outages is the distribution system. According to Marnay, most power quality and reliability problems originate at the distribution level, 80-90% of U.S. outages are caused by distribution failures.

(Marnay,2007)Electricity distribution is very volatile in the industry and FPL is very familiar how to manage it.

5.3.3 FPL Distribution

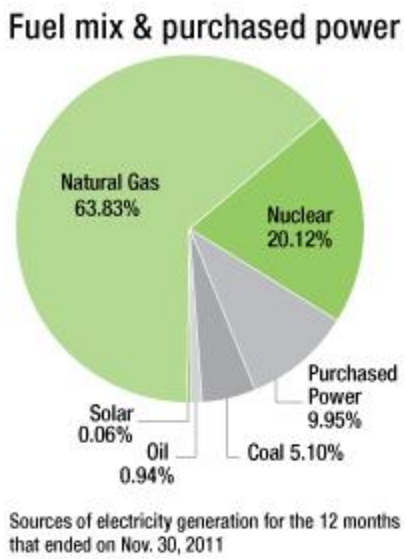

Figure 23 Energy Mix of FPL

Source: FPL

FPL has 34 generating plants. Most of its fuel comes from natural gas, then followed by nuclear (Figure.22). Each power plant serves as the main generator of energy and it supplies the electric system at a high voltage. Due to long distance between producer and consumer, the energy needs to be increased by a substation near the power plant to travel long distance. The substation increases the voltage to prepare it for transmission to the local networks.

Its basic grid network has the following components.

Transmission lines and poles:

In order to deliver energy, the energy goes from the substation near the plant to a substation located in service area. Transmission of power over large distances requires high-voltage transmission lines. (Power = *VI*, where *V* is voltage and *I* is current. For a given power requirement, increasing voltage reduces current requirement; power losses and inductance are accordingly lowered.) High voltage lines are more expensive to construct than low-voltage lines. They require higher transmission towers and wider pathways. Pathway rights are a key cost consideration in locations where land is expensive. For this reason, low-voltage lines requiring narrower pathways are often used over short distances and within population centers. Line voltages vary between 60 kV and 750 kV.(Mazer, 2007)

Substation:

Once the high voltage energy has reached the service area it goes directly to a substation that decreases the voltage, in order to be suitable for the local distribution lines. Here the electricity is transferred to the local area via substation. Transformers, circuit breakers, meters, and voltage support devices are often collocated at substation.

Distribution lines and transformers:

Distribution lines carry the electricity to a transformer; a device used for reducing voltage to a level that matches the level of your home. Distribution lines distribute power to communities. For example, the lines that are suspended along residential streets are distribution lines. The voltage of residential lines typically ranges between 4 and 12 kV. The voltage of distribution lines supplying an industrial customer may be significantly higher. However, the voltage of all distribution lines is substantially less than that of transmission lines.(Mazer, 2007)

Power flowing from the generator to a customer undergoes a series of voltage changes. Voltages between the generator, transmission lines, distribution system, and finally the customer, are all different. A transformer is a device that changes voltage between incoming and outgoing lines. (Mazer,2007)

Service Lines and meters:

Service lines are what actually provide electricity to the meter in homes. These lines can either be overhead or underground.

6. Microgrids for Miami

The purpose of this thesis is to analyze the feasibility of a Microgrid in Miami. This theoretical Microgrid would be created in an urban neighborhood, with some of the latest technologies.

6.1 Coral Gate Neighborhood

This is a neighborhood within Miami, FL that was selected for the basis of this microgird study. The reason that this site was attractive and ideal, is because it already has a defined geographical boundary (wall) that separates itself from the rest of the area. Additionally, most of the residences within this area are households. There is 644 residential units in this neighborhood. Figure.23 is an arial view of the proposed neighborhood.

Figure 24 Coral Gate Neighborhood

Source: NREL

6.2 PV Array (5 kW)

Photovoltaic (PV) systems are semiconductor devices that convert sunlight into electricity. They are able to provide electricity without noise or air pollution. In order to work optimally they require being in a place that is not shaded. The ideal location in an urban area is on rooftops (Figure.24). PV systems are very considerable in Florida because the average global horizontal annual solar resource is between 4.1-6.15 kWh/m^2/day (NREL,2012). This number is not the amount of energy produced. There are many factors that need to be considered for energy output calculations. There are various factors that can affect the performance of a system. Things that need to be taken into consideration are the type of collector, the tilt and azimuth of the collector, the temperature, and the level of sunlight and weather conditions. The PV systems creates voltage in Direct Current (DC) so it is necessary to have an inverter that can change the DC to alternating current (AC) which would make compatible to the actual building and the utility power system. The balance of the system consists of conductors/conduit, switches, disconnects, and fuses. If a system is grid-connected, it can feed power into the distribution network that is provided by the grid, and because of this the use of a battery system is not necessary.

Panels are made up of many individual cells that all produce a small amount of current and voltage. To amplify the output, they are connected in a series which allows them to produce larger currents. Shading is a strong issue when considering PV performance. In the event that a panel becomes obstructed (branch, leaves, shading) it becomes paralyzed to work. If an individual cell is shaded, it will act as a resistance to the whole series circuit, impeding current flow and dissipating power rather than producing it.

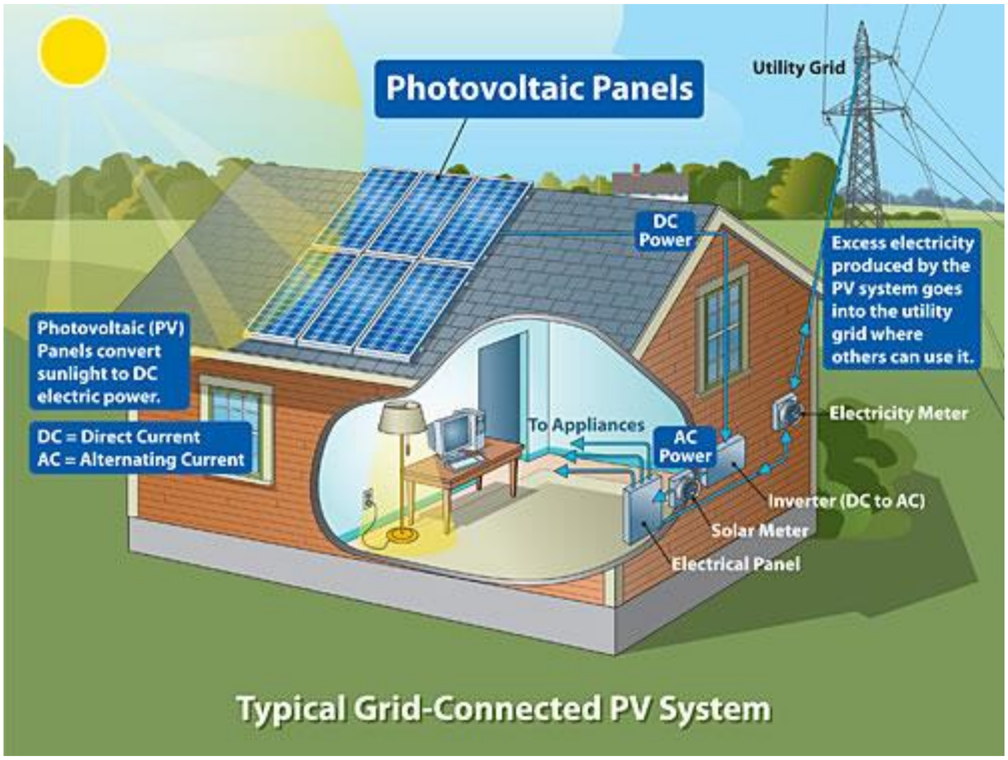

Figure 25 Rooftop PV System Diagram

Source: MassAduboun

PV System Components

- The actual panels, which convert light energy into DC electricity
- Inverters, which convert the DC to AC and provide functions that are essential to safety and monitoring, and for control functions.
- To put everything together there is mounting hardware, wiring and combiner boxes.
- Monitoring Equipment

PV Array

The primary of component of a PV system, the PV array, is what produces the electrical energy from the sun; every other component supports the PV and either conditions or controls the energy use. A PV array is comprised of numerous modules that can range in size anywhere from 50-300 peak DC-Watts. Peak watts are the optimal output that modules can perform under standard operating conditions.[4] Standard operating

[4] 25°C (77°F) and insolation of 1,000 watts/m²

conditions are rare in an actual setting, so taking into consideration typical environmental conditions; the actual output will be less. The actual modules themselves are the most reliable components of a system. They regularly have a life expectancy of 20-30 years, and manufacturers provide a warranty against excessive power degradation for 25 years. It is of no surprise that array is usually the most expensive component of the system, sometimes costing up to 1/3 of the whole system.

Inverters

The power provided by arrays comes in the form of a DC with the voltage dependent on the configuration and size of the array. This power is then converted to AC at the required voltage and number of phases by the inverter. The purpose of the inverter is to allow standard equipment (appliances, computers, motors, etc.) to consume the energy they need from the panels. Converter technologies can provide true sine wave power at a quality comparable or better than that of a serving utility. There is the ability to have inverters that can include most or all of the control systems required for operation, including some metering and data-logging capability. Inverters have to meet standard in order to connect to the grid, these standards provide operational and safety functions. The Institute of Electrical and Electronic Engineers, Inc. (IEEE) maintains standard *"P929 Recommended Practice for Utility Interface of Photovoltaic (PV) Systems*," which allows manufacturers to write "Utility-Interactive" on the listing label if an inverter meets the requirements of frequency and voltage limits, power quality, and non-islanding inverter testing. Underwriters Laboratory maintains *"UL Standard 1741, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems,"* which incorporates the testing required by IEEE 929 and includes design (type) testing and production testing.

For the purpose of this study every house in the microgrid was equipped with a 5kW system to provide energy for the household. Using online software created by the National Renewable Energy Laboratory an optimal PV output in the given location of the microgrid could be calculated. The results are shown in Table.4.

Table 4 PVWatts Calculation for a 5kW system in Coral Gate

Station Identification	
Cell ID:	0256413
State:	Florida
Latitude:	25.8 ° N
Longitude:	80.2 ° W
PV System Specifications	
DC Rating:	5.00 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.85 kW
Array Type:	Fixed Tilt
Array Tilt:	25.8 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	9.0 ¢/kWh

Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	4.87	536	48.35
2	5.35	533	48.08
3	5.37	593	53.49
4	6.13	649	58.55
5	5.59	595	53.67
6	5.31	541	48.80
7	5.26	557	50.25
8	5.24	556	50.16
9	5.38	546	49.25
10	5.13	547	49.34
11	4.57	484	43.66
12	4.36	482	43.48
Year	5.21	6619	597.10

Source: PVWatts

The amount of energy produced per household in this geographical location would be 6,619 kWh per year.

6.3 µCHP

One of the most difficult barriers to overcome when dealing with renewable energy is the characteristic of intermittency. When dealing with solar power, the sun is only available for a limited time every day. According to regions this can differ drastically. Wind power is also limited in time, as the winds don't blow constantly, but these too are prevalent in different geographical locations. When dealing with renewable energy, the power generated might not always match the demand. Additionally, inclement weather can render a PV array useless. These are issues faced with systems that use renewable energy as their primary source of energy.

One solution is the use of fuel cells to compliment RE systems. A company based out of Australia has developed a novel solution to the intermittency problem. They have begun commercially deploying ceramic fuel cells. They are actually Solid Oxide Fuel Cells (SOFC), and since characteristically these fuels cells can export thermal heat, they serve as a micro combined heat producer (µCHP). The name of the generator is called BluGen (Figure.25) and it is produced by Ceramic Fuel Cells Limited.

Figure 26 BlueGen Diagram

Source: BlueGen

Typically, BlueGen produces over 13,000 kilowatt-hours of electricity on-site per year. That's what the average Miami home needs, with any excess electricity exported to the grid. BlueGen's optional heat recovery system also generates domestic hot water, producing up to 200 liters of 'free' hot water per day – ideal for commercial operations or kitchens and bathrooms. BlueGen's high electrical efficiency means its cleaner, with carbon emissions substantially reduced compared to grid power alone. BlueGen even has lower carbon emissions than combined grid and solar Photovoltaic (PV) power. (CFCL, 2012)

BlueGen generates electricity all year round, rain, hail or shine, providing a constant, stable source of clean electricity when compared to renewable energy. Combined with solar panels, BlueGen's electricity output can be increased or decreased to suit specific needs. (CFCL,2012)

For example, its output can be increased during the evening when solar panels aren't producing electricity and decreased during the day when they are. This novelty provides a clear beneficial addition to any household.

7. Discussion

The geographical location of Miami is bittersweet. It is in an area that is hurricane intensive, while providing a prime location for solar power. The beaches in Miami attract the tourist, and the year round sun provides the rays. The warmth that is associated with the weather in Miami is both a curse and blessing. The Atlantic Ocean in comparison to its pacific counterpart is warm, because of this warmth it is a hot bed for hurricane activity. As explained earlier there is a high probability that if there is a hurricane in route to landfall, Miami is in danger. When hurricanes do hit Miami, the citizens are always advised to pack enough non perishable food for at least 2 weeks. It is not a surprise that when hurricanes pass through an area, the ensuing days after are associated with power outages. Power outages are not cheap. Not only when they are due to hurricanes, but also when they are due to malfunctions. The electricity industry loses more than 50 billion a year on blackouts, due primarily to disturbances in distribution system.

In Miami there is one company that is responsible for it and it is Florida Power Light. This company makes billions in revenue when the rest of the world is buckling down for a recession, and at the same time fraternizes with its regulators. The regulators are supposed to work in the interest of the ratepayers but in the past that has not been the case. The current grid that is in place in Miami is not adequate to withstand the threats of hurricanes. Decentralizing is a valid option to provide more resilience to an outdated grid. A big problem with the centralized model of power generation is the fact that the ratepayers always bear the brunt. Anytime that an improvement is introduced, request for rate hikes advance simultaneously. The interest of an investor owned utility is to provide its shareholders dividends first, rather than provide efficiency to its system. The case in Miami is special because it has the natural resources available to provide a significant amount of its energy from renewable sources. As a matter of fact, a study conducted for the National Renewable energy laboratory of the United States found that 42% of Florida's energy can be met solely from rooftop solar power. Figure.26 shows the potential by state of providing solar power with rooftop space.

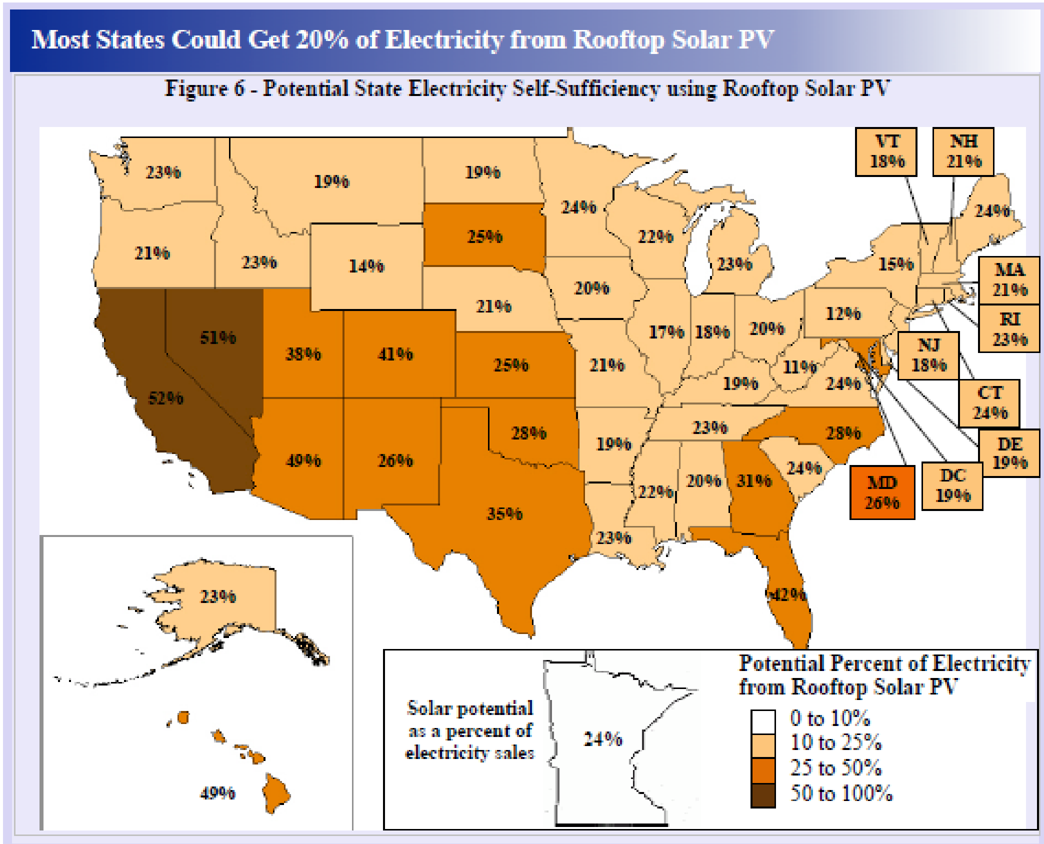

Figure 27 Rooftop Solar Potential as Percent of Energy Demand

Source: Institute for Local Self Reliance

From looking at the illustration you would assume that the state of Florida would have a booming industry in PV, unfortunately that is not the case. There are other states that are lower on this list, but have more installed rooftop capacity, that are increasing their energy mix; most notably New Jersey. California has the right idea when it implemented a law to reduce emissions, and it additionally has great potential for solar and wind. A conceptual Microgrid would flourish in Miami.

Microgrids share many beneficial characteristics that I have mentioned earlier. They provide reliability, they provide energy, they reduce the distance from generator to consumer, and they provide for a more resilient infrastructure. The veins of an electrical grid are the distribution lines, and it is because of these lines that power outages occur. They are the most vulnerable component of the system, and Microgrids reduce that limitation. Microgrids can serve the grid when it needs it most. If there is an outage, Microgrids can remedy an outage locally. Commonly a battery bank or a form of storage is standard for a microgrid system due to the intermittency of its sources. With new technology you can get rid of the intermittency problem and potentially provide support for the base load. There is technology that is available to have a power plant in your home, or rather a micro combined heat and power system.

The µCHP that is being produced in Australia is brilliant for Microgrids; Coupled with PV it can truly provide a household with energy independence. Not only would it provide independence but it can also provide revenue. Depending on the pattern of usage, a home built with a 5 kW PV system and a µCHP plant inside of it, should be able to provide for itself. Applying these technologies to the chosen demographic will yield specific results. For instance, a 5kW in Coral Gate would yield 6,619 kWh per year, when the average household consumes 13,000 kWh per year, that system wouldn't be enough to meet the base load. One of the parameters that is not considered in this thesis is the addition of energy efficient appliances to the households in the Microgrid. Appliances can affect consumption significantly, specifically in the cooling sector. Air conditioning is the main consumer of energy in the average Miamian household. The temperature outside is hot and humid, so air conditioning is necessary to maintain a comfortable home. The reason that appliances were not take into consideration is because the most efficient appliance, is not necessarily the most economical. The scope of this study was limited to the ability of homes to disconnect from the grid, and in order to achieve that it would require more than energy efficient appliances.

The true ace in the hole of this study is the µCHP system. This mini power station can produce up to 13,000 kWh per year. With this type of output, I found a solution to the rain.. and the night... and everything that deals with intermittency. These ceramic fuel cells are based on technology known as CHP combined heat and power stations. Not only do they provide power, but they also provide heat. With this station you can produce up to 200 liters (53 gallons) of hot water per day by recycling the waste heat into your boiler. The same station that is providing electricity is also providing hot water. The only drawback is that it requires gas to function. Opponents can argue that you are replacing one evil with another, because you are switching from utility scale natural gas/nuclear/to a natural gas distribution.

Yes this is true, but a very novel advantage of this µCHP is that it can run on various types of gas, among those gases are gas that originates from landfills, and solid waste, not leaving out biomass. Biomass in an urban environment can come from numerous sources; one of the suppliers that have yet to be realized is restaurants. In a metropolitan city like Miami, the selection of restaurants is extensive, let alone the hospitality industry, which is the backbone of the Floridian economy. Food Waste is another untapped source of energy that could contribute to a Microgrid. In an urban location the possibilities to create gas from waste are enormous. That field is still under development and applying that in urban setting has a clear future.

Having a surplus of energy can be a gift or a curse. Excess energy can be stored If there is storage available, or it could be fed into the grid. If none of these options are available then obviously it would go to waste. Feeding the grid should always be beneficial to the system, because it alleviates the stress on the system, but it could also aggravate the grid. Taken the example of Air conditioning, if the temperature outside increases, the loads demands also increases- because consumer behavior would be to turn down the thermostat to provide a comfortable living area- but that action done by every house hold at the same time could put a shock on the system. The same could apply to PV on a clear day, if there is high PV penetration, the system could experience a sharp rise in supply which could have negative effects if the demand is not there. . Needles to say, there is a long way before the effects of too much solar will be felt in Miami. What makes this dilemma so farfetched is primarily because of the lack of policy.

It is incredible that Miami has a strong affinity to the sun, but no renewable portfolio standard. It is unexplainable as to why 30 states in the US have R.P.S but Florida is not one of them. This is the same Florida than can provide 42% of its energy from rooftop solar; the problem lies in the legislation. Another ironic fact is that Gainesville, Florida was one of the first to implement F.I.T. in the United States. You would think that it would be easy for Florida to fulfill any renewable energy requirements with the amount of sun it receives. At least the state is giving subsidies to homeowners who install PV, and the utility is giving a rebate also. But subsidies could be detrimental. One of the most recent cases was that of a US based PV Firm called Solyndra. The company received $530 million in loans from the federal government, and ended up bankrupt. This was a clear blow to the industry, from a company that was receiving subsidies. This specific case serves as an example that the government is not in place to choose winners from losers in the marketplace. Additionally, when the government adds some of its weight to the market scale, it is the corporations who have a huge incentive to try to win the governments favor. My argument to that is why can't solar get a piece of the pie that fossil fuels have been dining on for so long, it's only fair. Subsidies are imperative for the blossoming of industries. There have been numerous subsidies that provide for "smart" grids, but none for Microgrids exclusively.

The federal government is aware of the outdated grid and attempted to repair it with the stimulus package. The federal stimulus funds were distributed to many sources in the United States, with the goals of modernizing the grid and increasing efficiency. In Florida a main beneficiary of this grant was FPL, who received 200 million for smart grid investments (Recovery.gov, 2012). Some of the investments went to smart meters, which are of no great importance to anyone but the utility. The meters that were distributed in the Miami area were made by General Electric and the boast the ability of each meter that comes equipped with various options for communications technology, home area network options, remote service switch, as well as a number of embedded features such as load profile, demand, and TOU tariff. (General Electric,2012) These are all factors that only benefit the utility, because fact of the matter is; that if a person didn't conserve energy before the meter was introduced, there is a low probability that their behavior will change after it.

There is an absence of policy in the state of Florida to require RE as a portion of production. As highlighted earlier in the thesis, Florida is one of the few states to adopt a RPS. The state has been especially nifty in excluding itself from regional activities that would require it to participate in unison with other states. Figures.26 and 27 give examples of partnerships that the state has excluded itself from.

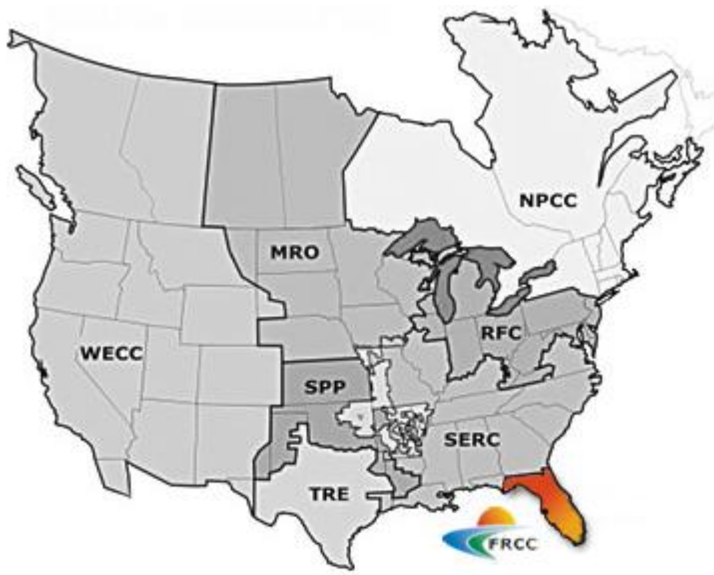

Figure 28 Regional Reliability Councils of the U.S.

Source: Florida Reliability Council

Reliability Council:

The purpose of the Florida Reliability Coordinating Council is to ensure and enhance the reliability and adequacy of bulk electricity supply in Florida, now and into the future.

FRCC serves as a regional entity with delegated authority from the North American Electric Reliability Corporation (NERC) for the purpose of proposing and enforcing reliability standards within the FRCC Region.

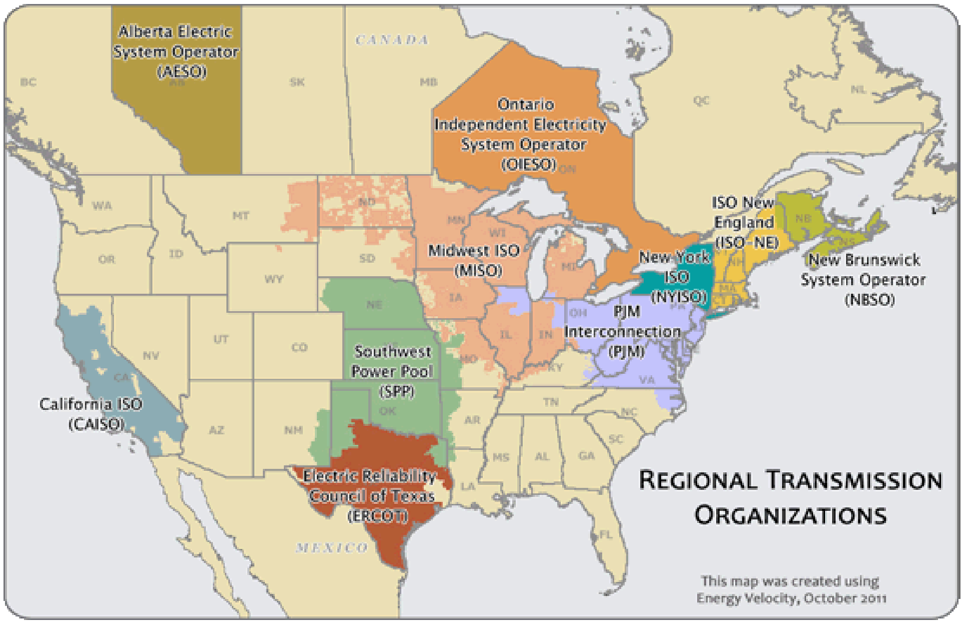

Figure 29 Regional Transmission Organizations

Source: Federal Energy Regulatory Commission

Regional Transmission Organizations:

Independent System Operators grew out of Orders Nos. 888/889 where the Commission suggested the concept of an Independent System Operator as one way for existing tight power pools to satisfy the requirement of providing non-discriminatory access to transmission. Subsequently, in Order No. 2000, the Commission encouraged the voluntary formation of Regional Transmission Organizations to administer the transmission grid on a regional basis throughout North America (including Canada). Order No. 2000 delineated twelve characteristics and functions that an entity must satisfy in order to become a Regional Transmission Organization. (FERC, 2012)

The location and technology is sufficient to realize Microgrids in Miami, but what is absent is the institutional support.

8. Conclusion

The United States is successful for its innovation. It has been able to retain confidence in the market, even through a recession. There is inadequate reasoning as to why energy independence is not plausible. The status quo in energy is in the verge of a revolution. With time, the policy necessary to bring about change in the energy sector will see the true value of decentralizing energy and only then will the energy sector reform. In defense of the United States, there are policies at the state level that are ambitious and excellent, but those are limited in scope. California is leading the way in GHG reductions, while other states are also implementing their own similar measures. As highlighted in this thesis, Florida is far behind. The state of Florida and its utilities are sitting comfortably in their positions and are not in a position to embrace change.
I have learned that if the policies in Miami can mimic others in the country, then the state could thrive. We have to resources, we have the location, and the only thing that is lacking is the will. The will of the people to demand change can bring about a revolution in the energy sector. It begins with a small community, if a small community can change the paradigm that is heavily engraved in Florida, the possibility for development are endless.

At the beginning of my research I was curious if it would be possible to disconnect from the grid, and I quickly learned that it is possible. I then was interested to learn not so much if, but how to accomplish independence from the grid, and now I know how. The next subject of inquiry was the possibilities in Miami, and Miami is a good candidate for Microgrids. My final concern was; why isn't it happening. I have learned that it is possible to create Microgrids in this day and age, but the financial barriers are of concern and the policies necessary are vital. I hope that with this thesis, I was able to form a sound judgment for the potential Miami has to lead the way in energy independence.

9. Bibliography

"18 Countries Affected by Russia-Ukraine Gas Row." *Reuters*. Thomas Reuters, 07 Jan. 2009. Web. 05 May 2012. <http://www.reuters.com/article/2009/01/07/uk-russia-ukraine-gas-factbox-idUKTRE5062Q520090107?sp=true>.

"2002 IEEE Power Engineering Society Winter Meeting. Conference Proceedings (Cat. No.02CH37309)," *Power Engineering Society Winter Meeting, 2002. IEEE* , vol.1, no., 27-31 Jan. 2002

"AEP - Regulatory Compact." *AEP - Regulatory Compact*. American Electric Power Co, Inc. Web. 05 May 2012. <https://www.aep.com/about/IssuesAndPositions/Financial/Regulatory/RegulatoryCompact.aspx>.

"Decentralising Power: An Energy Revolution For The 21st Century." *Greenpeace UK*. Web. 05 May 2012. <http://www.greenpeace.org.uk/media/reports/decentralising-power-an-energy-revolution-for-the-21st-century>.

"Florida Incentives/Policies for Renewables & Efficiency." *DSIRE: Incentives/Policies by State: : Incentives/Policies for Renewables & Efficiency*. Department of Energy, 2012. Web. 05 May 2012. <http://dsireusa.org/incentives/index.cfm?State=FL>.

"FPL Group profit soars on expanded capacity." *The Globe and Mail* (Canada). (January 28, 2009 Wednesday): 127 words. LexisNexis Academic. Web.

"IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems." *IEEE SCC21 Home Page*. Web. 05 May 2012. http://grouper.ieee.org/groups/scc21/1547/1547_index.html

"Our Fuel Cell Design." *BlueGen*. Ceramic Fuel Cells, 2012. Web. 05 May 2012. <http://www.cfcl.com.au/Fuel_Cell_Design/>.

"Solar FIT." *Gainesville Regional Utilities*. Web. 05 May 2012. <https://www.gru.com/OurCommunity/Environment/GreenEnergy/solar.jsp>.

Ackerman, Frank, and Elizabeth A. Stanton. "*Florida and Climate Change: The Cost of Inaction.*" (2007). Environmental Defense Fund. Web.

Ackermann, T., Andersson, G., S.oder, L., (2001). “Distributed generation: a definition”. Electric Power Systems Research 57, pp. 195–204.

Adenike Adeyeye, James Barrett, Jordan Diamond, Lisa Goldman, John Pendergrass, and Daniel Schramm *Estimating U.S. Government Subsidies to Energy Sources: 2002-2008* Environmental law Institute 2009

Baker, B.S., “Carbonate fuel cells — a decade of progress”, *191st meeting of the Electrochemical Society*, May 1997

Bouffard, François, and Daniel S. Kirschen. "Centralised and Distributed Electricity Systems."*Energy Policy* 36.12 (2008): 4504-508. Print.

Carlsen , Paul. "FPL net improves 24.9% to record $1.64 billion as NextEra jump more than offsets FP&L slump." *Electric Utility Week*. (February 2, 2009): 812 words. LexisNexis Academic. Web.

Carlsen , Paul. "FPL net up 1.1% to Q3 record $533 mil, reflecting '06 costs of Constellation deal." Electric Utility Week. (November 5, 2007): 724 words. LexisNexis Academic. Web.

Carrette, L., Friedrich, K. A. and Stimming, U. (2001), “Fuel Cells – Fundamentals and Applications”. *Fuel Cells*, 1: 5–39.

CEA. (2010). Recovery Act Third Quarterly Report - Supplement. Washington D.C.: Council of Economic Advisers.

Danny S. Parker. Maria D. Mazzara, and John R. Sherwin, *MONITORED ENERGY USE PATTERNS IN LOW-INCOME HOUSING IN A H O T AND HUMID CLIMATE* Proceedings of the Tenth Symposium on Improving Building Systems in Hot and Humid Climates, Fort Worth, TX, May 13-14, 1996

Dondi, P., Bayoumi, D., Haederli, C., Julian, D., Suter, M., (2002). “Network integration of distributed power generation”. Journal of Power Sources 106, pp. 1–9.

Fereidoon P. Sioshansi, “So What's So Smart about the Smart Grid?”, *The Electricity Journal*, Volume 24, Issue 10, December 2011, Pages 91-99

Flowers, Larry. "Small Wind Sytstems." *American Wind Energy Association*. Web. 05 May 2012. <http://www.awea.org/learnabout/publications/factsheets/upload/Small-Wind-FAQ-Factsheet-_-Updated-May-2011.pdf>.

Gielecki, M., F. Mayes, and L. Prete; “Incentives, Mandates, and Government Programs for Promoting Renewable Energy” in Renewable Energy Issues and Trends 2000, Energy Information Administration, DOE/EIA-0628 (2000), February 2001.

Gottesfeld, S. and Zawadinski, T., “PEFC Chapter”, *Advances in Electrochemical Scienceand Engineering*, Vol. 5, Alkire, R., Gerischer, H., Kolb, D., and Tobias, C., Eds.,Weinheim, New York, 1998

H.R. 6 (110th): Energy Independence and Security Act of 2007

Hirschenhofer, J. H. *Fuel Cell Handbook*. Orinda, CA: Business/Technology, 2000. Print.

Kaundinya, Deepak Paramashivan, P. Balachandra, and N.H. Ravindranath. "Grid-connected versus Stand-alone Energy Systems for Decentralized Power—A Review of Literature." *Renewable and Sustainable Energy Reviews* 13.8 (2009): 2041-050. Print.

King, J.M. and Ishikawa, N., “Phosphoric acid fuel cell power plant improvements and commercial fleet experience”, *Fuel Cell Seminar*, November 1996

Kroposki, B.; Lasseter, R.; Ise, T.; Morozumi, S.; Papatlianassiou, S.; Hatziargyriou, N.; , "Making microgrids work," Power and Energy Magazine, IEEE , vol.6, no.3, pp.40-53, May-June 2008

Kroposki, B.; Lasseter, R.; Ise, T.; Morozumi, S.; Papatlianassiou, S.; Hatziargyriou, N.; , "Making microgrids work," *Power and Energy Magazine, IEEE* , vol.6, no.3, pp.40-53, May-June 2008

Lasseter, R.H.; Paigi, P.; , "Microgrid: a conceptual solution," *Power Electronics Specialists Conference, 2004. PESC 04. 2004 IEEE 35th Annual* , vol.6, no., pp. 4285- 4290 Vol.6, 20-25 June 2004

Marnay, C.; "Microgrids and Heterogeneous Security, Quality, Reliability, and Availability," *Power Conversion Conference - Nagoya, 2007. PCC '07* , vol., no., pp.629-634, 2-5 April 2007

Mazer, Arthur. *Electric Power Planning for Regulated and Deregulated Markets*. Hoboken, NJ: IEEE, 2007. Print.

Miami-Dade County Climate Change Task Force (2007). *Statement on Sea Level in the Coming Century*.

Minh, N.Q., “Ceramic fuel cells”, *J. Am. Ceramic Soc*., 76(3), 563, 1993.
Momoh, James A. *Smart Grid: Fundamentals of Design and Analysis*. Hoboken, NJ: Wiley, 2012.

Monaghan, Mark Analysis of Contingency Logistics System Reliability for Power Utilities in Florida After a Hurricane 2008 Dissertation Walden University Walden University press

Monaghan, Mark. *Analysis of Contingency Logistics System Reliability for Power Utilities in Florida After a Hurricane*. Diss. Walden University, 2008. Walden: Walden UP, 2008.

NFCRC: How a Fuel Cell Works. National Fuel Cell Research Center. Web. 05 May 2012. <http://www.nfcrc.uci.edu/2/FUEL_CELL_INFORMATION/FCexplained/FC_howItWorks.aspx>.
Pepermans, G., Driesen, J., Haeseldonckx, D., Belmans, R., D’haeseleer, W., (2005). “Distributed Generation: definition, benefits and issues”. Energy Policy, 33, pp. 787- 798.

Perez, R. and M. Perez, (2009a): A fundamental look at energy reserves for the planet. The IEA SHC Solar Update, Volume 50, pp. 2- 3, April 2009

Piagi, P.; Lasseter, R.H.; , "Autonomous control of microgrids," *Power Engineering Society General Meeting, 2006. IEEE* , vol., no., pp.8 pp.

Preliminary Report of CIRED WG04—Dispersed Generation, CIRED, Brussels, June 1999.

REVIEW OF RESIDENTIAL ELECTRICAL ENERGY USE DATA. Rep. NAHB Research Center, Inc, 2001. Web. 05 May 2012. <http://www.toolbase.org/PDF/CaseStudies/ResElectricalEnergyUseData.pdf>.

Rusco, F. (2011). Recovery Act: Status of Department of Energy's Obligations and Spending. Testimony Before the Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives (p. 18). Washington D.C.: (GAO), Government Accountability Office.

Schneider, Jordan, and Matt Elliott. "How Cutting Pollution Protects New Jersey's Environment, Builds the Economy, and Reduces Energy Costs." *Benefits of the Regional Greenhouse Gas Initiative*. Environment New Jersey Research & Policy Center, Feb. 2012. Web. 5 May 2012. <http://www.environmentnewjersey.org/reports/nje/benefits-regional-greenhouse-gas-initiative>.

Singhal, S.C., "Recent progress in tubular solid oxide fuel technology",*Proceedings of the Fifth International Symposium on Solid Oxide Fuel Cells (SOFC-V)* , The Electro-chemical Society, Inc., Pennington, NJ, 1997.

Subcommittee on Oversight and Investigations Staff. (March 15, 2011). Hearing on "Oversight of DOE Recovery Act Spending". Washington D.C.: Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, U.S. House of Representatives.

U.S. Congress. (2009, February 13). American Recovery and Reinvestment Act of 2009

U.S.-Canada Power System Outage Task Force, *Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations*, April 2004, p. 17, https://reports.energy.gov/.

United States. National Renewable Energy Laboratory (NREL). *State Clean Energy Policies Analysis (SCEPA) Project an Analysis of Renewable Energy Feed-in Tariffs in the United States*. By Toby Couture and Karlynn S. Cory. Golden, CO: National Renewable Energy Laboratory, 2009. Print.

US DOE, (2007). "*The Potential Benefits of Distributed Generation and rate-related issues that may impede their expansion. A Study pursuant to Section 1817 of the Energy Policy Act of 2005*".US Department of Energy.

USA. State of Florida. Florida Public Service Commission. *Annual Report on Activities Pursuant to the Florida Energy Efficiency and Conservation Act*. 2012 ed. Web. 05 May 2012. <http://www.psc.state.fl.us/publications/pdf/electricgas/FEECA2012.pdf>.

Williams, Christopher. "Cyber Virus Is Unleashed on Nuclear Companies; 'Duqu' Is Thought to Have Been Spying on Secret Files of Key Energy Players." *The Daily Telegraph*. 20 Oct. 2011. Web. 05 May 2012.

Wuzzelman, Sam. *U.S. Department of Energy's Recovery Act Investments*. Rep. Pew Center on Global Climate Change, June 2011. Web. 05 May 2012. <http://www.pewclimate.org/docUploads/ARRA-White-Paper.pdf>.