NHH - Norges Handelshøyskole and HEC Paris

Renewable Energies in the French DOM-TOM

A study of the costs and benefits of transitioning from fossil fuels to renewable energies in the French Départements d'Outre Mer et Territoires d'Outre Mer.

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Abstract

The French Départements d'Outre Mer et Territoires d'Outre Mer (DOM-TOM) are not the most populous region of France. Nor are they the most prosperous, the most important, or even centers of industrial production. Rather, the DOM-TOM possessions have a unique value in French culture: they represent the past glory of the state and its people, and the courage that lead French explorers and settlers to roam the world. Unfortunately, the DOM-TOM represents an ever-growing burden upon French taxpayers.

Sun-drenched and wind-kissed, the DOM-TOM possesses an enormous potential to attain its energy needs from renewable sources. And yet, with electrical grids based upon fossil fuels imported from great distances, the French taxpayer is not only subsidizing an inefficient method of producing electricity, but also directly encouraging pollution in the form of Green House Gas emissions that are changing our environment.

In this paper I will analyze the political, economic, and environmental benefits to replacing fossil fuel power plants with renewable sources in the DOM-TOM, and will attempt to describe and evaluate the criteria that will influence decision-making. Finally, I will also attempt to develop recommendations and policies to encourage and support renewable energy systems in the DOM-TOM. In doing so I will present the potential costs and benefits of employing increased amounts of renewable energies. While few will argue the environmental merits of replacing fossil fuel power plants with renewable energy systems, a transition will not be made unless employment levels are maintained or expanded, costs to the state and its people reduced, and the long term benefits clearly explained.

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Introduction

Since the 1600s, France has owned a number of colonial possessions scattered throughout the world. Ranging from the Caribbean to the Pacific Ocean, these possessions tend to be small, isolated islands located in tropical or sub-tropical climates. These post-colonial possessions are commonly known as the DOM-TOM (Départements d'Outre Mer et Territoires d'Outre Mer: Overseas Departments and Overseas Territories). While these possessions provided valuable harbors and natural resources in the past, they have become increasingly impoverished and unproductive in recent years, due in part to their extreme isolation. Because of this increasing poverty, the French national government has been forced to provide various subsidies on numerous products and services, ranging from production support for the sugar cane industry on La Réunion to providing all-inclusive medical care as part of the French health care system.

Unfortunately, in the post-2008 financial crisis world, the French are among the many governments seeking to reduce their annual expenditures in order to balance their national budgets. With a new need to reduce their expenditures, the French have obviously begun to cast a critical eye over the large (but often necessary) subsidies that they provide to the DOM-TOM region. While some efficiencies might be found in various social or civil programs, the size of the reductions there will most likely be limited, as it is difficult to imagine the voting population of the DOM-TOM accepting reduced medical support or reductions of subsidies designed to aid struggling industries. However, one area that might lend itself readily to fiscal modification is the use of petroleum to provide electricity.

While the majority of electricity produced in continental France comes from nuclear power plants, the DOM-TOM is much more reliant on conventional oil and natural gas power for electricity generation. This electricity is generated by EDF (Electricité de France), which is mostly owned (and supported) by the French government. EDF provides electricity to DOM-TOM citizens at prices that are lower than they would be without government support, and which also does not take full advantage of the DOM-TOM's natural advantages: copious amounts of sun light, wave energy, and steady winds.

In this paper, I will analyze the advantages and disadvantages of converting electricity production from fossil fuel based power plants to renewable sources using multi-criteria decision making processes to help understand the difficulties involved in deciding how the French government and the DOM-TOM should proceed in the future. The multi-criteria decision making processes will allow the comparison of various factors such as job creation or destruction, emission reductions, environmental impacts, financial costs to the French government, EDF, and investors, and other potentially important criteria. It is of paramount importance to utilize a multi-criteria decision process in this analysis due to the inherent complexity of the current situation and the need to find solutions that will be supported by all involved stakeholders.

After a review of the current situation in the DOM-TOM region, I will then provide an in-depth analysis of the potential technologies available to replace conventional fossil fuel plants. This analysis will cover wind, hydro, solar, and biomass energy generation, as well as a short discussion of the storage of the energy produced from renewable sources. After clarifying the technologies available, I will analyze two cases, featuring one island with an already well-developed system of renewable energy systems, and one island highly dependent on imported fossil fuels. I will conclude my analysis of the DOM-TOM with an examination of policies that can be used in a cost effective method to encourage energy efficiency and renewable energy growth.

Section I

DOM-TOM: An Overview of the Current Situation, Local Energy Production, and tools for assisting with complicated decisions

A. Multi-Criteria Decision Making

While an in-depth discussion of Multi-Criteria Decision Making (MCDM) is outside the scope of this paper, it is necessary to explain the underlying principles that guide the process and make MCDM relevant. MCDM are useful in assisting in resolving the conflict that arises through the existence of multiple, often conflicting objectives. Put another way, instead of seeking to merely provide a yes/no or lowest cost response, MCDM works to enable decision makers to create compromises between their various objectives. Criteria for making a decision are identified and then given various weights of importance. In the case of the DOM-TOM, stakeholders might wish to reduce Green House Gas (GHG) emissions, increase or at least maintain employment level, lower the costs of subventions to the DOM-TOM, and acquire increased voter support by their measures. However, while politicians might give a higher weight to voter support and lowering subventions, DOM-TOM locals might give a greater priority to maintaining employment levels. Thus the criteria and their assigned weights must be both identified and agreed upon by all relevant parties before the process of analyzing the situation can truly begin.

MCDM methods are particularly relevant for areas such as the evaluation of technology investment and energy planning.[i] In his paper to UNEP, J.P. Painuly lists the following as important criteria for consideration:

- An adequate resource base

- Available technologies and their costs
- Commercial viability and financing
- Environmental impacts and benefits
- Socio-economic impacts, including job creation
- Coverage of both centralized and decentralize options[ii]

Additionally, the model must permit rapid processing in order to allow for timely and relevant decisions. As explained in depth by Pohekar and Ramachandra in their paper on the subject, MCDM usually follows a continuously refining cycle of improvement and revision. Beginning with the selection of criteria, the evaluation process then moves to the selection of the decision process, performance evaluation, and the creation of decision parameters. These actions feedback upon each other and with the formulation of options, which in turn leads through application of the method to a stage of result evaluation followed by either continued refinement or a final decision.[iii]

In this paper, I will merely present the important criteria involved in the situation, without attempting to provide them with a weight or priority. I believe it is necessary to work in this manner due to the complexity of assigning priorities to the various criteria, and the impossibility of replicating the desires and conflicting objectives of the numerous stakeholders would normally be involved in the decision process of such a large scale and important project.

B. Current DOM TOM Status

The DOM-TOM consists of French-administered territories around the world, many of which have been administered from Paris since before the end of the French monarchy. With a population of roughly 2.6 million inhabitants spread through the Pacific, Atlanta, and Indian Oceans, the 11 inhabited areas consist of a land area of roughly 120,000 km^2. While the various DOM-TOM possessions served as important anchorages or resupply ports in the past, their value has been mostly reduced today to serving as tourist destinations and growing tropical crops such as sugar cane or pineapples for export to continental France.

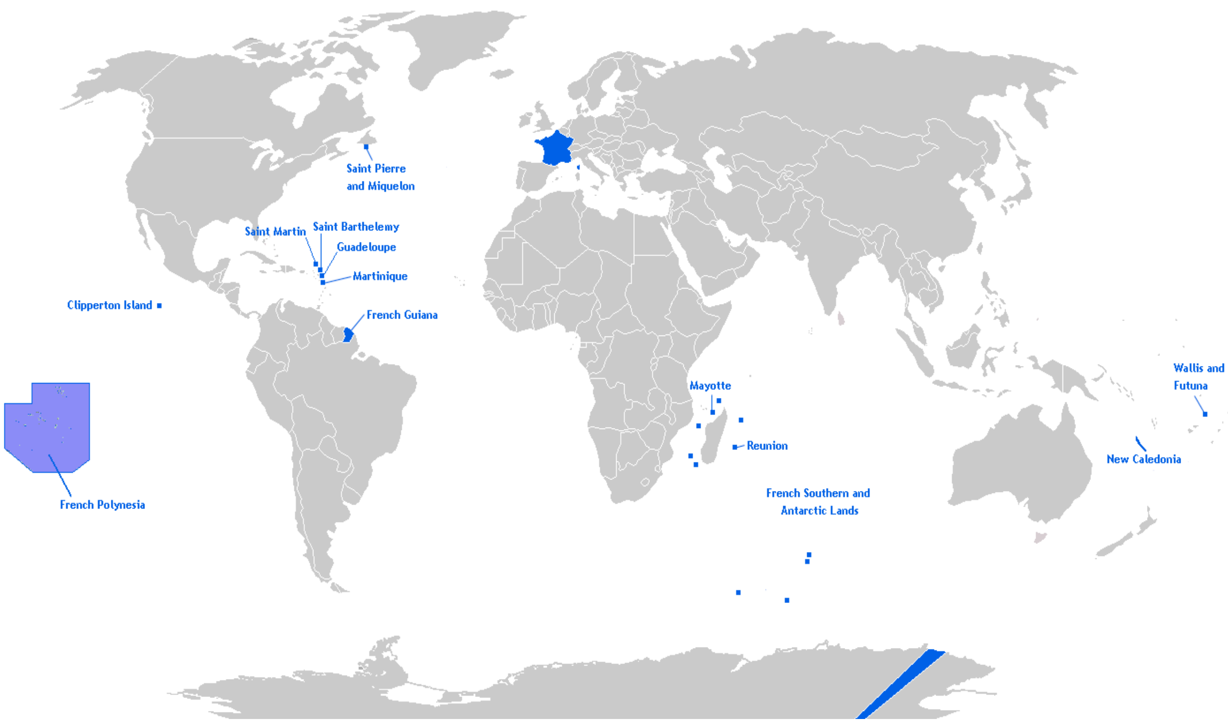


Figure 1: DOM-TOM Map

The DOM-TOM currently generates the majority of its electricity by the burning of fossil fuels in either thermal plants (i.e., burning coal heats water into steam, which in turn drives a turbine connected to a generator) or through diesel generators. For example, the old EDF Vazzio plant on Corsica featured seven RND90M Sulzer diesel generators providing 18.9 Megawatts (MW) each before being closed in 2007.[iv] Further, the power plants used in the DOM-TOM tend to be smaller than those used in continental Europe due to the lack of demand and available space, which in turn reduces plant efficiency. With the exception of Corsica, which has two undersea interconnection cables (to Italy and Sardinia), the DOM-TOM is entirely reliant on energy produced in situ. While renewable energy technology such as solar panels and wind turbines are found on some of the DOM-TOM islands (most notably La Réunion), most areas are forced to import significant quantities of various fuels. In addition to heavy fuel oils and coal used for electricity generation, the islands also import large amounts of diesel (for vehicles and electricity) and gasoline for vehicles. These fuels not only produce important (and rising) amounts of Green House Gases, but also require the expenditure of other fossil fuels for shipment from distant locations. Finally, as will be discussed later, these fuels carry a steep economic cost, which is heavily subsidized by taxpayers in continental France.

EDF is the principle producer of electricity in the DOM-TOM, with an installed capacity of 1850 MW, of which only 390 MW comes from renewable sources (mostly hydro). [v] Normally, EDF imports diesel, heavy fuel oil, or coal to burn in its DOM-TOM power generation plants. This is due to the lack of existing fossil fuels available for exploitation in proximity, lack of refining capability in the case of existing fuels, and/or the lack of a significant amount of developed alternative energy sources. For example, Guyana imports 97% of refined fuel products from Trinidad and Tobago.[vi] This importation comes at a price- not just in terms of higher costs for the operation of the regional power plants, but also in terms of additional pollution emissions. A look at New Caledonia (Nouvelle Calédonie) best illustrates the amounts imported:

Dénomination du produit	Pays d'origine	Volume importé (tonnes)	Distance avec la Nelle-Calédonie (km)	tonnes-km
Essence	Singapour	68 411	10 000	684 113 050
Gazole	Singapour	173 775	10 000	1 737 750 950
Kérosène	Singapour	38 994	10 000	389 944 000
Avgas	Singapour	320	10 000	3 200 000
Fioul lourd	Singapour	483 183	10 000	4 831 830 000
GPL	Australie - NZ	3 875	2 000	7 750 080
TOTAL		**768 559**		**7 654 588 080**

Table 1: Fuel Imports for Nouvelle Calédonie

Thus we can see that in 2006, the island imported roughly 483,183 tons of heavy fuel oils from Singapore (approximately 10,000 kilometers distant). [vii] In order to ship these fuels from abroad, various tanker vessels emitted rough 28 million kilograms of equivalent Carbon (1kg C being equal to 3.55kg of CO2).[viii]

	tonnes-km	Consommation de carburant (fioul lourd ; en tep)	FE avec amont fioul lourd (kg eqC/tep)	Emissions totales (kg eqC)
Essence	684 113 050	2 454	1 016	2 493 753
Gazole	1 737 750 950	6 233	1 016	6 334 510
Kérosène	389 944 000	1 399	1 016	1 421 030
Avgas	3 200 000	11	1 016	11 661
Fioul lourd	4 831 830 000	17 331	1 016	17 613 154
GPL	7 750 080	28	1 016	28 251
TOTAL	**7 654 588 080**	**27 455**		**27 902 359**

Table 2: Fuel Import Emissions for Nouvelle Calédonie

In addition to the pollution generated by shipping of various fuels to the DOM-TOM, there are the additional emissions generated by extraction, refinement, and consumption. Ignoring the Green House Gases and other environmental effects of oil extraction and production or refinement due to the complexity of the subject (emissions can vary enormously depending on the original source of the oil and its physical properties), we instead will concentrate on the emissions produced in the use of the fuels imported to the DOM-TOM. Several important statistics suffice to present us with an understanding of the situation within the region. First, a report released by the French government in 1997 reported that the DOM-TOM had emissions of 3 million metric tons carbon (MMTC) in 1995 (less than 2% of total

French emissions). These emissions had grown by 25% from 1995 to 1997, but assuming a more conservative estimate of a five percent (5%) growth rate from 1995 to 2010, the DOM-TOM would be producing roughly 6.2 MMTC.[ix]

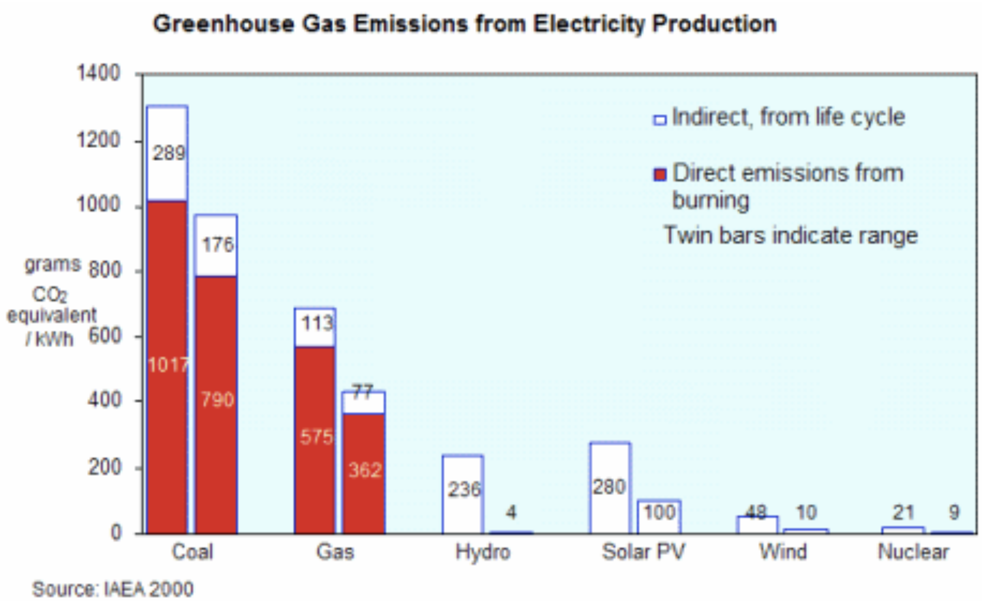


Figure 2: Green House Gas Emissions from Electricity Production

La Réunion demonstrates many of the problems currently facing the region. With a current reported growth rate of fuel consumption of 8% in the La Réunion, we can develop an estimate of total carbon emissions for the DOM-TOM in the vicinity of 9.52 MMTC. In the last 20 years, energy consumption in La Réunion has risen by 350%, reaching a level of 2079 GW/H in 2003. And again for La Réunion, these emissions have been projected to rise 156% from their 2005 levels in a business as usual case due to continuing economic growth.[x] Further, due in part to the high-use of automobiles, La Réunion was of 2005 roughly 83% dependent on oil and coal to generate electricity (the rest being provided either various renewable energies). With the largest DOM-TOM population of roughly 800,000 people, one could argue that La Réunion is an exception to the DOM-TOM norm due to its sizable population. However, the safer argument would perhaps be that La Réunion is more of a demonstration of things to come as the population in the DOM-TOM continues to grow and increase its consumption of goods and energy.

Electricity production in the DOM-TOM region is heavily subsidized, with prices averaging roughly 11-12 Euro centimes, while the average price in France is around 12.05 Euro centimes. The CERNA (Centre d'Economie Industrielle or the Center of Industrial Economics) estimates that a price of 12 cents in the DOM-TOM only covers approximately 63% of the costs of production for EDF. This parity in pricing is even more shocking when we consider that nuclear plants generate the vast majority of electricity produced in France. Their high construction costs are often subsidized by the state, and they are often the first producers in electricity production order of precedence, while fuel oil or coal plants tend to be much cheaper to build but more expensive to operate (due to fuel costs). Thus we should not be surprised to find that in order to maintain electricity prices roughly equal to those in France, the government must subsidize EDF and the cost of electricity production by approximately 430 million Euros per annum.[xi] French taxpayers, of course, directly pay for these costs. In addition to their direct costs, they also result in the secondary costs related to pollution and environmental degradation- not just Green House Gases, but also the impacts of extraction and shipping.

It would, however, be unfair to paint fossil fuels in a completely negative light. They provide obvious benefits in the form of a high caloric energy density, are easily transportable, provide a ready and constant source of energy, and also are a source of employment. The number of personnel directly and indirectly employed by fossil fuel plants can vary dramatically depending on the technology employed, the age of the facility, and the amount of energy produced. For example, the coal-fired Ghent plant in Kentucky, USA, employees 230 employees, was built in 1973, and produces 2000 megawatts of electricity,[xii] while the Lagoon Creek Combined Cycle Gas Turbine plant in Tennessee, USA, employees just 30 employees, was built in 2002, and generate 550 megawatts.[xiii] In the DOM-TOM, the Société Anonyme de Raffinerie des Antilles (Antilles Refinery Company, LLC) maintains a refinery and two thermal power plants in conjunction with EDF on Martinique, producing 585 million kW while employing 900 people and 17, 840 barrels of oil per day (of which 16,300 was crude oil for refinement).[xiv] Thus, fossil fuels also represent an enormous social benefit in the creation of employment (and tax revenues) throughout the region. This is especially important in light of the elevated and chronic unemployment in the region. In 2004, the unemployment rate was 24.1% for La Martinique, 26.8% for La Guadeloupe, 38.3% for La Réunion, and 28.5% for La Guyane.[xv] The number of people employed by fossil fuel related industry expands dramatically if we consider those working at gas stations, driving fuel trucks, or serving on tanker vessels, just to name a few. Thus, in a region facing overwhelming unemployment and in which fossil fuels provide long-term work possibilities, any attempts to change to renewable energies must first consider how to maintain or create new employment.

It must be mentioned in closing that while fossil fuels are currently in plentiful supply and traded worldwide as commodities, many scientists, economists, and other researchers believe that they will soon become much more rare. Both the United States and the German military have recently published papers predicting the arrival of peak oil within the next ten years, while other researchers have pointed to the ever-growing demand for coal from China and current supply inefficiencies to forecast sharply rising prices and potential shortages.[xvi] The impact of peak oil and rising fuel prices will be discussed in greater detail later in this paper.

Besides drastically driving up prices (and thus the amount spent by the French government in fuel subsidies), unavailability of resources may actually lead to a shortage of supply in the DOM-TOM, causing prolonged blackouts. Further, if energy resources become scarce, many governments will be forced to consider the use of military force to ensure the fuels that provide a life-blood to their economies and societies. Thus, the French people will be confronted with not only hardships wrought by electricity shortages in the DOM-TOM, but also the possibility of needing to resort to military intervention in order to ensure the continued supply of these fuels.

C. Alternative Energy Solutions

Due to the ever increasing cost both financially and environmentally of subsidizing the consumption of fossil fuels in the DOM-TOM, a new, more permanent solution must be found. Thankfully for France and the inhabitants of the DOM-TOM, the various possessions are located almost entirely in tropical or sub-tropical regions. These regions tend to be the beneficiaries of copious amounts of sunlight, consistent winds, and hydropower potential in the form of waves energy and small, elevated dams. Further, due to their climate, the damned for energy for heating purposes other than hot water is fairly minimal. Finally, the climate of the various DOM-TOM members is often very beneficial for the production of fast growing plants such as elephant grass for use in biofuels or for biomass to fire boilers for energy production. However, each alternative energy source comes with its own advantages and disadvantages that have limited their potential in the past. While increased interest and investment in recent years have served to lead to a rapid decrease in costs and improvements in efficiency, there is as of today no single renewable energy source that by itself can readily and effectively replace fossil fuels in the DOM-TOM.

1. Solar Energy Systems

The sun is the dominant source of energy within our solar system, and has the potential to provide for all of man's energy needs through the conversion of its radiated energy waves into electricity. Currently, two dominant forms of solar power exist: photovoltaic and solar thermal. While both are used to generate electricity, their employment and markets are markedly different. Photovoltaic systems rely on highly technical solid-state systems to capture the sun's energy, while solar thermal systems instead focuses the sun's energy to boil water, that in turn is used to drive a turbine to create electricity. While other systems such as solar chimneys and solar ponds exist, they tend to be tailored to specific situations and are thus niche market systems.

While the exploitation of solar energy as a means of generating electricity has developed slowly, investment has recently increased dramatically. The three major issues of high oil prices, national security, and concern over global warming have resulted in massive investment into solar technologies and these now show real promise. This new investment, coupled with carbon caps and taxes, has resulted in a dramatic reduction in the price of solar power. This is particularly important when considered alongside the anticipated rising costs of fossil fuels. As the world reaches peak oil and stricter environmental/carbon regulations drive up the cost of operating polluting oil, coal, and natural gas plants, falling solar energy prices will invite further investment by everyone from governments to private investors.

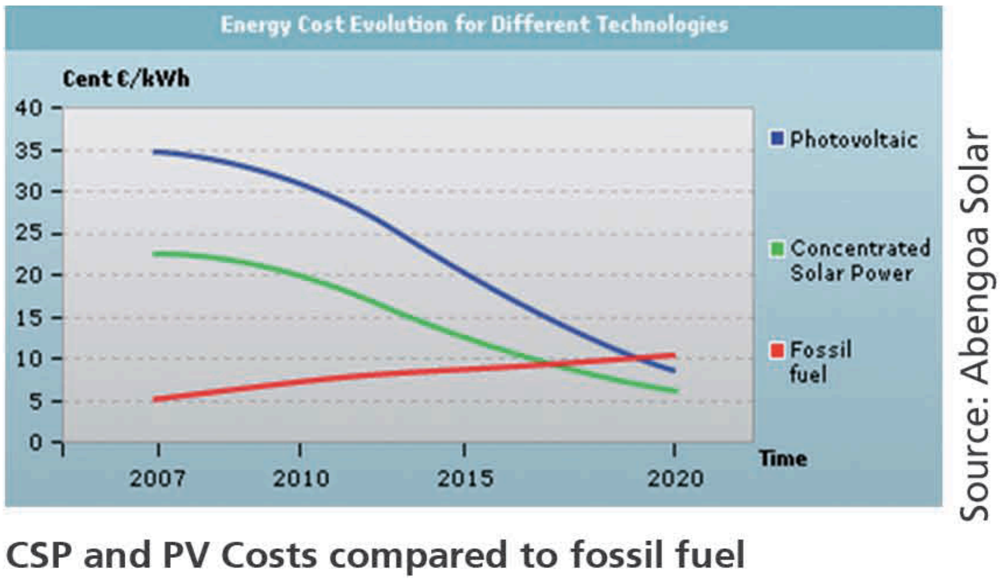


Figure 3: CSP and PV Costs

Although currently more expensive, PV costs are falling rapidly and are expected to soon fall below those of CSP. Grid parity is expected in 2015, and PV efficiencies are already surpassing those of CSP.

A solar PV cell is probably the simplest and most elegant of all forms of power generation available. These solid-state devices have no moving parts and can be deployed easily for both distributed generation and utility generation applications. However, they do demand high technology manufacturing processes and this has tended to keep prices high. Most solar cells manufactured today are made from polycrystalline silicon but new thin film materials such as cadmium telluride are showing great promise as a means of making cheaper solar cells in large volumes, more easily. There is a clear trend in terms of disruptive innovation, mostly occurring in the area of materials. With the amount of R&D effort going into this area, the technology cycles are short and only last a few months before the next disruption occurs. At the point of emergence of a dominant design, a clear increase in efficiency is witnessed. PV efficiencies currently stand between 12-18% for industrialized versions, although R&D labs have touched 40%. Interestingly, Boeing recently announced that it has begun commercial scale production of concentrating photovoltaic solar panels with an average efficiency of 39.2%, a first for the industry and an excellent illustration of the constantly improving technology and its rapidly reducing costs.[xvii] Emergence of a dominant design also reduces cost; PV has a steeper cost reduction curve than CSP. Industry experts believe that PV will become cheaper within the next 5 years.

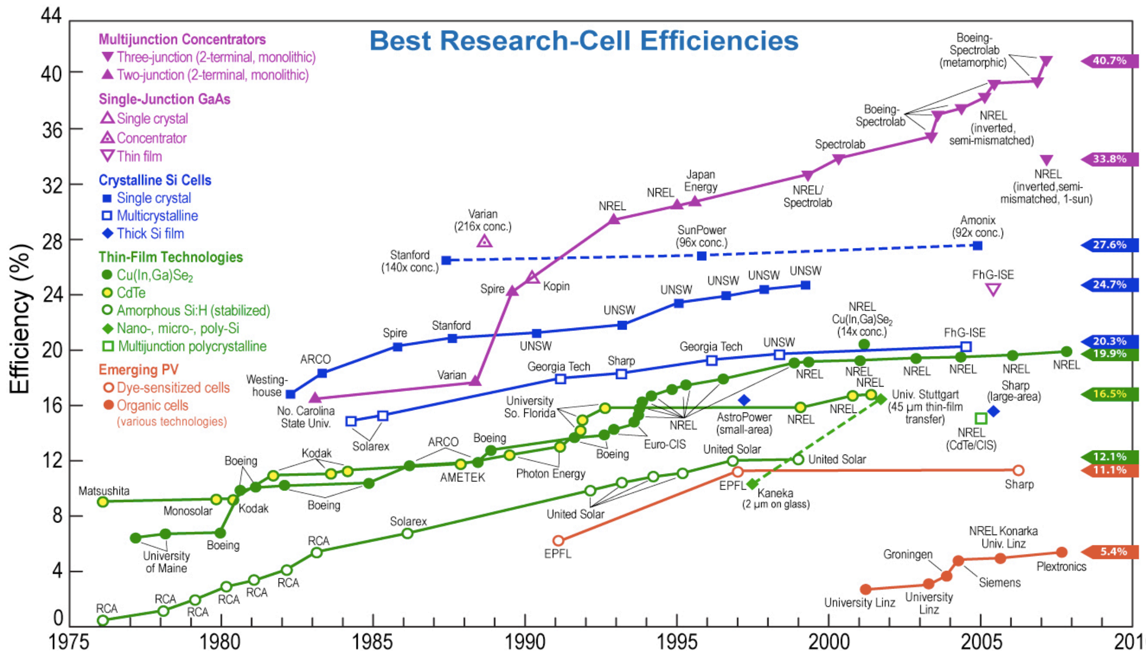


Figure 4: Best Research-Cell Efficiencies

Concentrated solar power generation treats sunlight as a source of heat, which it uses to drive a turbine in a generating plant. Three primary arrangements have been developed for concentrating the heat and each is the basis for a different type of solar thermal power plant. A Solar Tower uses a large field of heliostats, which focus sunlight onto a central receiver located in the middle of the heliostat field. A Parabolic Trough power plant uses special parabolic reflectors, which are deployed in long-trough shaped modules while Solar Dishes use individual parabolic dishes, each fitted with a power generating Sterling Engine unit at its centre. Each system offers its own advantages and disadvantages, and is selected for each project after careful consideration of the project needs and restrictions.

Traditionally, PV and CSP have been used for different applications. CSP is typically used for utility-scale plants of a minimum size of several tens of megawatts; where as most of the growth in solar PV systems has been driven by domestic and commercial demand. This was due to PV's suitability for distributed generation: portability, safety and ease of installation. However, there are signs that utility photovoltaic are starting to become attractive too, particularly with systems of concentrated PV. These systems involve installation of plants with capacities ranging from hundreds of kilowatts to tens of megawatts. Again, both systems offer different benefits and restrictions that require that every project be carefully analyzed to select the technology best suited for the customer's needs. Finally, while some may argue that solar power is an intermittent power source (due to cloudy weather and nightfall), it is in fact highly predictable and dependable. Coupled with systems such as thermal storage or new fuel cells to provide stored power over night, new solar plants of both CSP and PV types can be used to generate reliable, constant levels of electricity 24 hours a day.

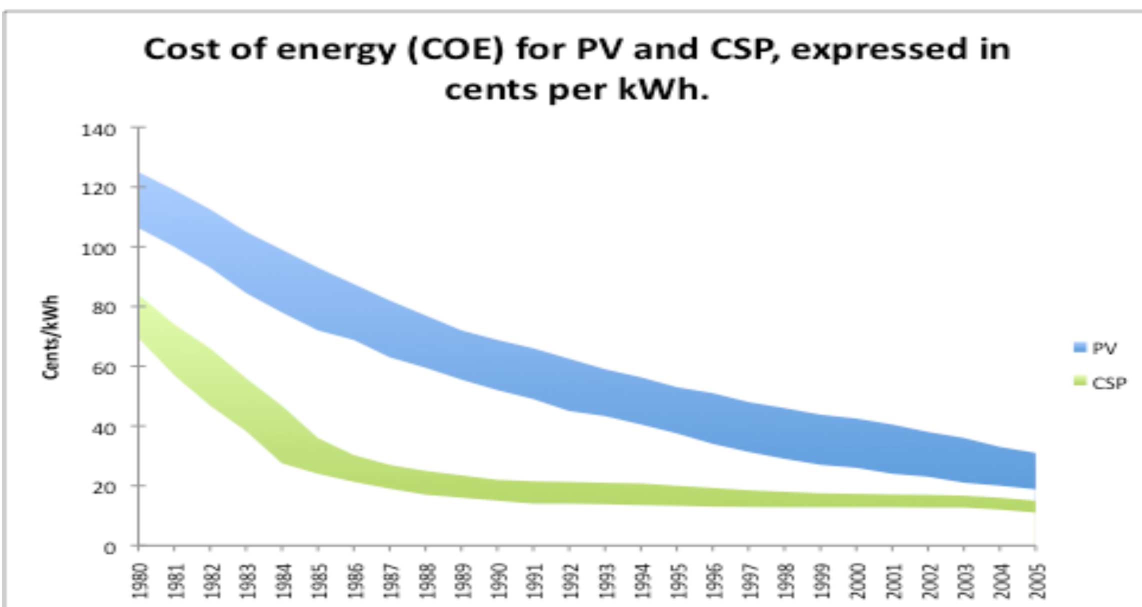
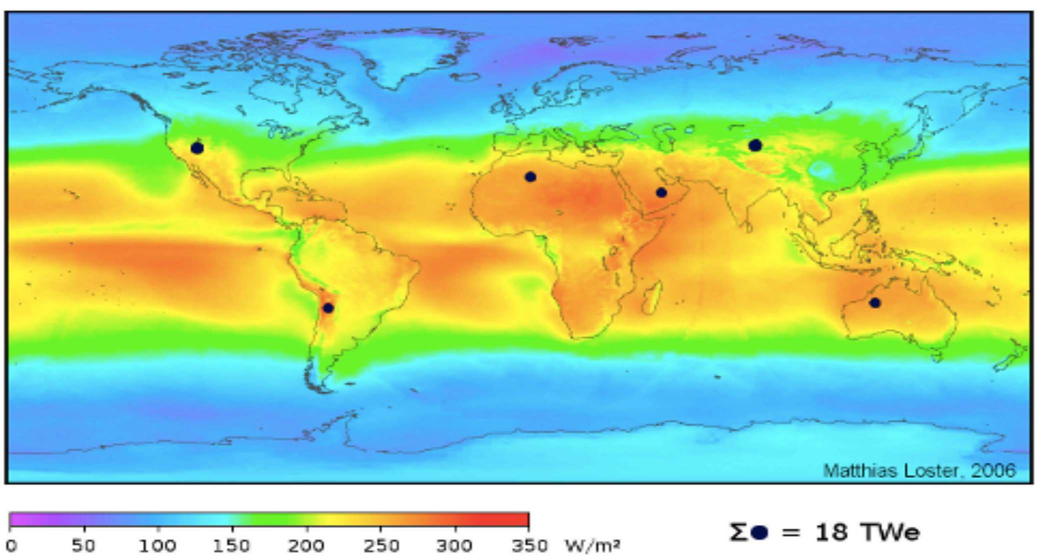


Figure 5: Cost of Energy of PV and CSP in Cents per KWH

The DOM-TOM possessions are especially blessed in terms of potential for solar radiation and thus electricity generation. Given their general position near the equator, the DOM-TOM possessions are in prime location to not only produce electricity from solar power, but to do so at a higher efficiency than countries such as Germany, which receive on average far less direct solar energy. To look at La Guadeloupe for a specific example, we find that the island receives on average 5.2 kwh/m^2 of energy[xviii], compared to roughly 3 kwh/m^2 in Germany.[xix] Besides the strong positive impact this amount of solar radiation will have on electricity generation, it also means that solar water heaters will be particularly effective. Combined with energy efficiency mechanisms and electricity produced from the sun, solar water heaters could drastically reduce the consumption of fossil fuels in general and the even more specifically the amount of energy dedicated to heating water for civilian use.



Sunlight hitting the dark discs could power the whole world: If installed in areas marked by the six discs in the map, solar cells with a conversion efficiency of only 8 % would produce, on average, 18 TW electrical power. That is more than the total power currently available from all our primary energy sources, including coal, oil, gas, nuclear, and hydro. The colors show a three-year average of solar irradiance, including nights and cloud coverage.

Figure 6: Average Solar Radiation

With roughly 20 GW of installed Solar Thermal[xx] and 14 GW[xxi] of installed PV in place in 2008, the World Watch Institute estimated the creation of roughly 800,000 jobs in the industry, with roughly 2/3rds of those jobs coming from the manufacturing sector. This gives us a figure of roughly 7.5 jobs per MW of installed capacity, which may be excessively conservative given that some researchers have estimated 15 jobs per MW. While many of these positions will require specialized training, the majority will require only the basic construction or transportation skills that most workers already possess. This is important to note because it suggests that workers currently performing low-skilled jobs for fossil fuel companies (truck drivers, basic construction, low level maintenance) should be able to transition fairly seamlessly into projects developed by renewable energy programs. Those who will be hardest hit by the transition are the skilled engineers involved in fossil fuel power plants, as their highly specialized training will not necessarily translate over to renewable projects without further follow on training.

One area where solar power is at a disadvantage in the DOM-TOM is its need for space. Whereas a fossil fuel plant can be easily scaled from a small, man-portable generator to large, industrial scale facilities, solar thermal plants need large amounts of level ground in order to generate electricity. Even industrial scale PV systems require substantial amounts of terrain in order to be effective. Further, this land must be situated in a position that will ensure maximum sunlight and flat terrain is often preferred in order to prevent one solar panel from masking another as the sun moves through the sky. Unfortunately, the few large, flat areas in the DOM-TOM are often already in use for a variety of other purposes, such as residential zones or for farming. A potential solution for this problem might be the decentralized installation of solar panels on individual homes. However, even this solution may be difficult to implement due to the need for much greater involvement of individual homeowners and the requirement that EDF function in a much more decentralized manner. Finally, dispersed electrical production will likely also require an upgraded electrical distribution network to balance the various inputs and outputs that result from decentralized production.

Even with continuously falling prices, electricity generated by solar power systems still tend to be substantially more expensive than that generated by coal or oil. As we see below in this graph, the cost per kilowatt-hour of solar energy is near $.40, while that of coal is closer to $.01. Thus, without substantial government support, the solar power will remain underdeveloped. In the DOM-TOM, the French government has decided to enact a mandatory feed-in tariff of .40 Euros/KWH with a 20-year contract. There are additional tax incentives to encourage the purchase of solar panels in the DOM-TOM that make it quite advantageous for homeowners to invest in small scale systems

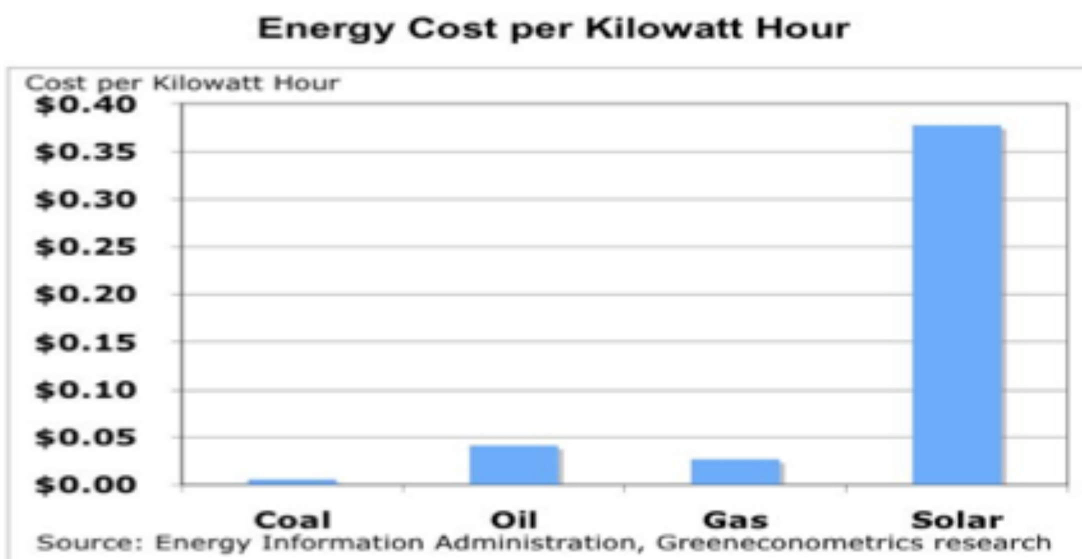


Figure 7: Energy Costs per KWH

One last topic worth discussing under solar power is the use of solar water heaters. Also known as Solar Domestic Hot Water Systems, these heaters reduce the consumption of electricity by using the sun's thermal warmth to heat exposed plates or tubes, which in turn heat the water needed by the consumer. There are a wide variety of systems, ranging from passive to active pumps, and from direct water heating to the use of a transfer fluid. The costs of these systems vary tremendously based upon the complexity, but many can be bought or made very cheaply using readily available plumbing pipes and simple part fabricated from sheet metal. These systems are already in widespread use in the DOM-TOM, with roughly 83,000 square meters of coverage in 2003, or roughly 22,000 installed systems. This translates into an energy savings of roughly 12 million liters of equivalent oil and 34,000 tons of carbon emissions per year.[xxii] While these savings are significant, they could easily be much larger if programs promoting the purchase of solar water systems are encouraged. With prices beginning at just USD 500, solar water heaters could prove to be a cheap and efficient method to quickly reduce consumption of fossil fuels and their related emissions while spurring job creation in the DOM-TOM.

2. Wind Energy Systems

Wind power has seen a surge in investment similar to solar power in recent years, especially in northern Europe. With a worldwide installed capacity of 159 GW at the end of 2010,[xxiii] it is expected to continue to grow rapidly throughout the coming years.

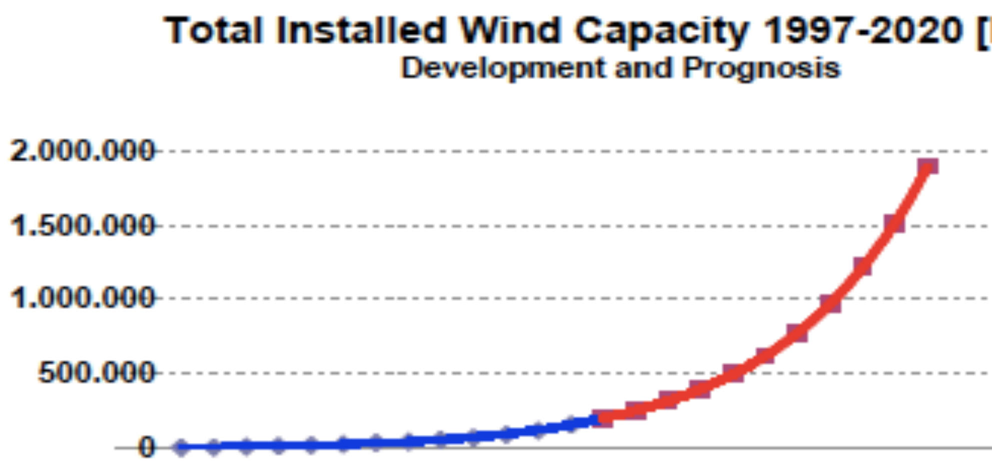


Figure 8: Total Installed Wind Capacity

As investment continues and the installed base grows, the price for individual units should continue to fall in a predictable rate. While high demand has encourage the rapid growth of the industry, it has also led to some bottlenecks in supply and production, though these should be self-resolving in the future if growth continues as anticipated. With continuing rapid expansion, learning curves and increased economies of scale will drive down production costs, while more powerful and more reliable turbines will operate at reduced costs.

Unlike solar power that has seen a sizable investment in decentralized installation (i.e., homeowner use), the grand majority of electricity generated from wind turbines comes from large, industrial-scale parks. This is mainly due to the physical constraints of wind turbines. First, turbines need to be emplaced in locations that will provide steady, continuous amounts of wind and that need to be free of turbulence. Further, larger turbines generate more power, but also require more space.

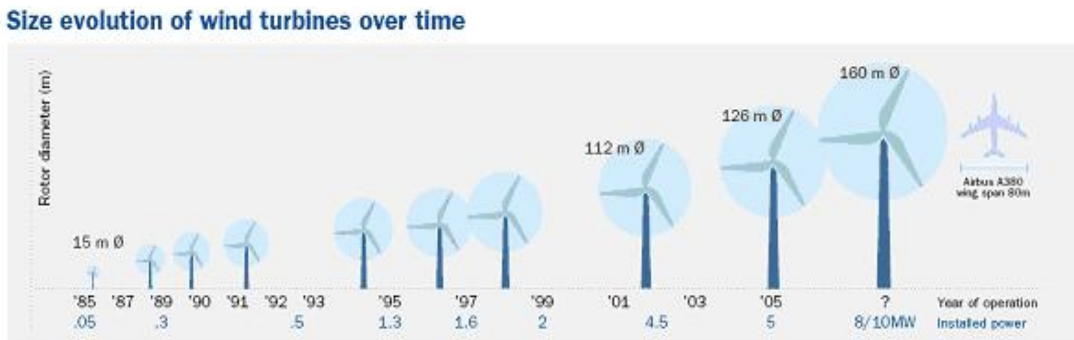


Figure 9: Size Evolution of Wind Turbines

An average turbine of 500kW to 2MW vary in diameter from 40 to 90 meters, with most planners also seeking to build the highest towers possible due to the accompanying increase in wind speeds and power as described by the Wind Power Profile Law. The table below simply illustrates the greater power generated at faster wind speeds and at higher altitudes, which in turn results in lower operational costs.

Class	10 m (33 ft)		30 m (98 ft)		50 m (164 ft)	
	Wind power density (W/m^2)	Speed m/s (mph)	Wind power density (W/m^2)	Speed m/s (mph)	Wind power density (W/m^2)	Speed m/s (mph)
1	0 - 100	0 - 4.4 (0 - 9.8)	0 - 160	0 - 5.1 (0 - 11.4)	0 - 200	0 - 5.6 (0 - 12.5)
2	100 - 150	4.4 - 5.1 (9.8 - 11.5)	160 - 240	5.1 - 5.9 (11.4 - 13.2)	200 - 300	5.6 - 6.4 (12.5 - 14.3)
3	150 - 200	5.1 - 5.6 (11.5 - 12.5)	240 - 320	5.9 - 6.5 (13.2 - 14.6)	300 - 400	6.4 - 7.0 (14.3 - 15.7)
4	200 - 250	5.6 - 6.0 (12.5 - 13.4)	320 - 400	6.5 - 7.0 (14.6 - 15.7)	400 - 500	7.0 - 7.5 (15.7 - 16.8)
5	250 - 300	6.0 - 6.4 (13.4 - 14.3)	400 - 480	7.0 - 7.4 (15.7 - 16.6)	500 - 600	7.5 - 8.0 (16.8 - 17.9)
6	300 - 400	6.4 - 7.0 (14.3 - 15.7)	480 - 640	7.4 - 8.2 (16.6 - 18.3)	600 - 800	8.0 - 8.8 (17.9 - 19.7)
7	400 - 1000	7.0 - 9.4 (15.7 - 21.1)	640 - 1600	8.2 - 11.0 (18.3 - 24.7)	800 - 2000	8.8 - 11.9 (19.7 - 26.6)

Table 3: Wind Power Profile Law

Second, given the highly variable nature of the wind, large industrial parks are needed to ensure a constant, reliable generation of electricity. Whereas a single turbine might become becalmed due to a lack of wind, a large field covering a sizable area helps to ensure that the majority of turbines encounter wind at any given time. Finally, unlike solar panels that can be easily installed by homeowners with a minimal amount of assistance, wind turbines are extremely large and heavy, and require substantial foundations and towers in order to ensure their stability in strong winds. Thus, while some small-scale turbines (normally considered as anything up to 50kw) may be privately owned, the majority of wind power systems around the world are either owned by corporations or collectives.

Wind speeds (and thus power) tend to be highest offshore, where the lack of landmass allows wind to flow freely and gather speed. Fortunately for the French, the DOM TOM consists entirely of either islands or land possessions with sizeable coastlines. As this image demonstrates, the areas in which the majority of the DOM-TOM possessions can be found tend to receive consistently strong winds, which in turn will allow for greater and more consistent electrical production.

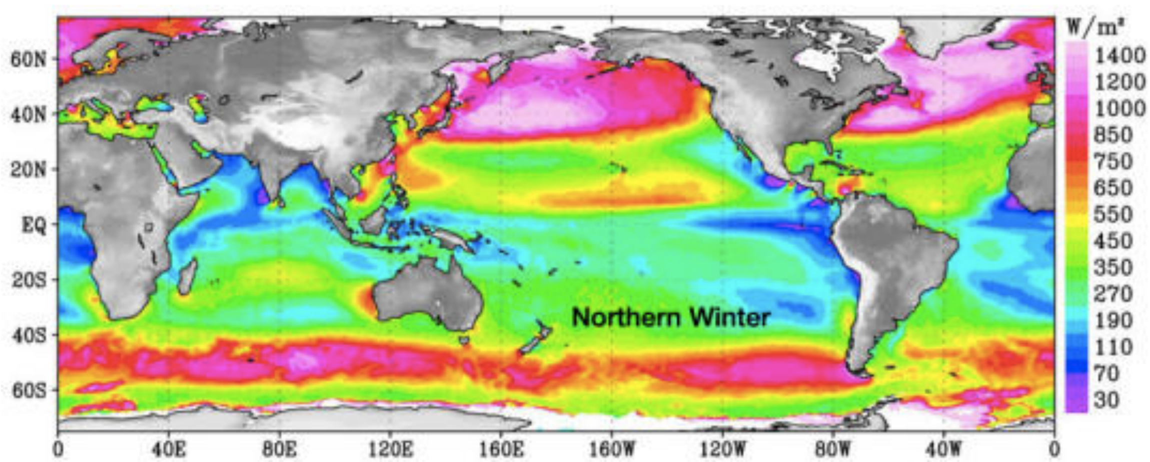


Figure 10: Wind Energy Worldwide

While offshore wind farms tend to be significantly more expensive than onshore farms (approximately 1650 Euros per KW offshore vice 700-1000 Euros per KW onshore[xxiv]), these costs are quickly offset by the greater size (up to 5 MW), stronger winds, and greater wind reliability. These advantages translate into more electricity being produced more often, which in turn generates more funding. Offshore wind farms also require greater and more complicated maintenance, due to their more exposed positions in the ocean and their design. Interestingly, while the costs of the equipment tends to be greater for offshore turbines, installation is often cheaper and easier, due to the ability rapidly emplace large barges and cranes which are not feasible for use on land. Currently, offshore wind turbines are normally positioned in waters shallower than 30 meters. New research is pushing the limits of offshore, with Norway currently leading efforts with the emplacement in 2009 of a floating turbine in waters up to 200 meters deep. [xxv] While significant concerns remain about the environmental impact of offshore turbines and their durability and survivability (especially in regions prone to storms and hurricanes), it seems that the future of large wind turbines is offshore.

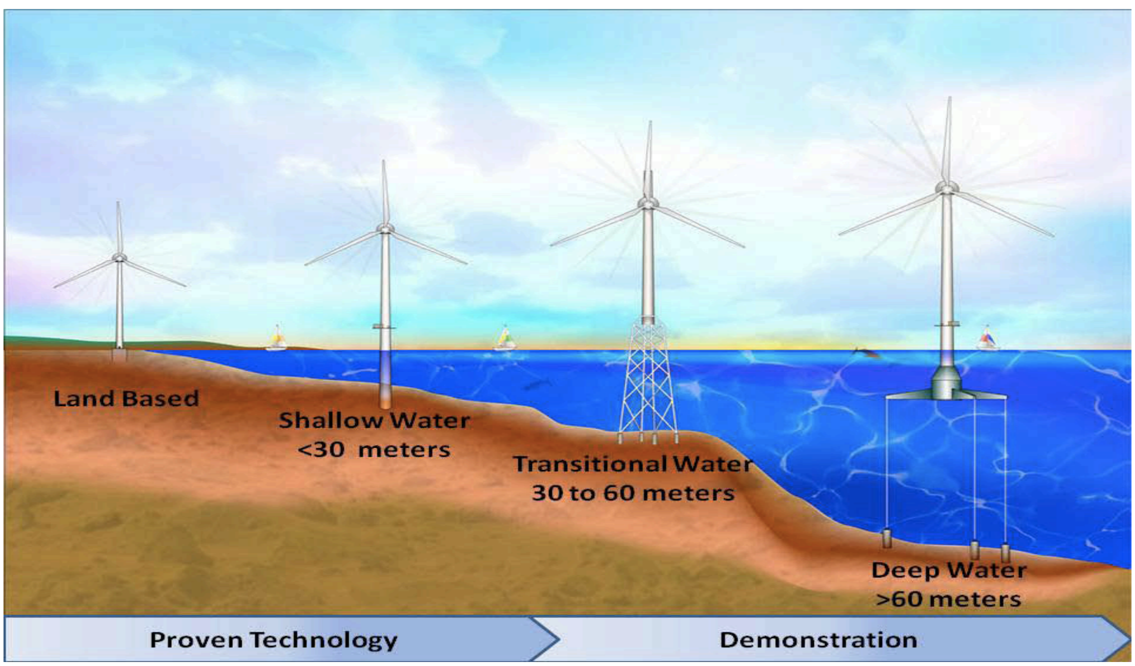


Figure 11: Wind Turbine Growth

Costs for energy from wind farms tend to be slightly lower than those of solar fields, with prices typically ranging from $.025 per KWH to $.055 per KWH, making wind competitive with other forms of energy production. Additionally, a study by the University of California at Berkley posits that roughly three jobs are created per MWH of installed wind capacity, though other sources have placed this number as high as 18 jobs (including manufacturing).[xxvi] Finally, the excellent graph below demonstrates not just the rapidly falling costs, but also the increasing reliability and size of turbines, though improvements have already rendered this chart outdated.

*Wind Energy Technology Status**

Technology Characteristic	Cost/kWh	Operating Life	Capacity Factor (average)	Availability	Turbine Size
Before 1975	$0.50 – $1.00	1 – 5 years	10%	60% – 70%	< 20 kW
Current	$0.05 – $0.035	30 years	25%	98%	300 – 700 kW
2000	$0.04 – $0.025	30 years	35%	98%+	500 kW –1.5 MW

** For a wind site with an annual average wind speed of 7.0 m/s (15.5 miles per hour) measured at a height of 30 meters (100 ft). The low-end cost of energy assumes municipal utility financing.*

Table 4: Wind Energy Technology Status

Even with the current economic downturn, the industry and its technology continue to evolve rapidly. Gamesa, a Spanish producer of wind turbines, recently announced an alliance with several other major players in the industry such as Alstom Wind and Acciona Wind to develop next-generation, 15 MW offshore wind turbines.[xxvii] With continued growth and investment, operating and production efficiencies will advance rapidly, leading to lower costs and improved performance.

3. Hydropower Energy Systems

Hydropower is already well established in the DOM-TOM region, with numerous small scale facilities capturing the high average rains on the often-mountainous islands to control flooding and generate electricity. While these facilities are often fairly old, new technologies and employment techniques allow the DOM-TOM to squeeze increased efficiency and productivity out of these resources. For example, new techniques such as building small, successive dams one after another along the same river allow for greater generation of electricity. Combined with wind power during off-peak hours, pump-storage dams can also pump water back up hill to serve as a kind of liquid battery to better adjust for potential demand or for load balancing.

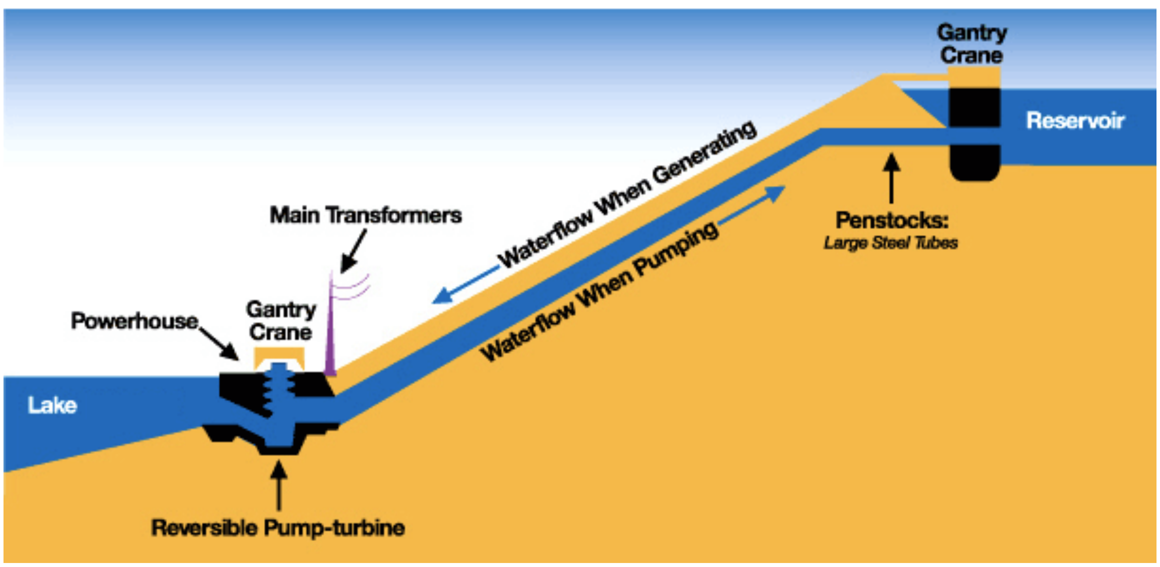


Figure 12: Hydro Pump Storage System

Despite the high costs of construction, hydro power from dams tends to be extremely cheap, due in large part lack of fuel costs and the long life span of most dams (many dams have been in operation for 50 to 100 years). Thus, electricity costs from hydroelectric dams can range from $.005 to $.01 per KWH.[xxviii]

Unfortunately, the best sites for hydropower have already been used, and new technologies and techniques can only increase efficiency so much.

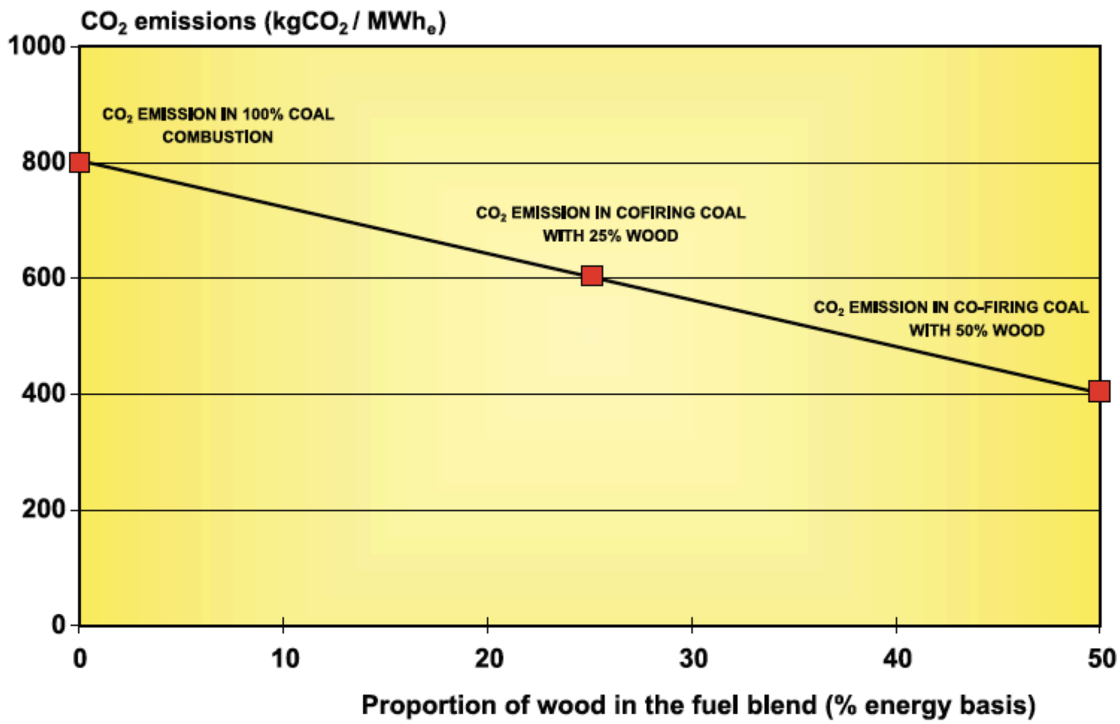
One area where the DOM-TOM has sufficient room to grow in hydropower is from offshore, wave-generated electricity. A fairly new technology still in development, wave power uses the ocean's motion to drive a variety of different actuators to create electricity. Typically, one of three methods is selected to generate the electricity: paddle, turbine, or snake-like. The paddle system uses a large, moving panel mounted on the seabed. The movement of waves and currents forces the paddle to descend upon a hydraulic ram, which in turn is connected to a generator to create electricity. The turbine system features a multi-bladed rotor mounted on the ocean floor, which is turned by the force of currents or waves. These systems rotor systems have already been installed to some effect in several major rivers, including in New York City. Finally, the snake-like system floats on the surface of the ocean, and generates electricity through its movement across and through large waves. The Pelamis Wave Energy Converter, employed in Scotland since 2004, is a successful example of this type of technology. A floating buoy moored to the ocean floor can also be used as an alternative to the Pelamis system, using the upward motion of waves to exert tension upon hydraulic rams to generate electricity.

Although many analysts predict that prices will one day drop to $.02-.04, the cost of electricity from wave power sources is currently much higher, in the vicinity of $.24-.88 per KWH.[xxix] These high costs are due in large part to the fact that the technology has not yet progressed beyond the second technological demonstration phase (that is to say, the second generation of feasibility prototypes are now in testing). Until production becomes much more widespread, costs will remain significantly higher than those associated with other types of electricity production methods. However, despite these high costs, it may prove beneficial for the DOM-TOM to invest now in wave power technology. Given that most of the DOM-TOM possessions are islands, they are exposed to strong currents and steady amounts of wave energy. In an area suffering from high unemployment, wave technology research may prove to be an ideal method of creating jobs while spurring further investment in future technologies. Due to its infant state, there are no real studies concerning the number of jobs created by wave power energy devices. However, given the technological, industrial, and investment similarities between wave and wind power, I believe that we can assume that estimates for long-term job creation applied to wind energy will also remain relevant for wave energy (thus, three long-term jobs will be created for every MW installed capacity). On limiting factor to employment of these wave systems may be the need to provide adequate channels and space for shipping. Finally, due to the intense storms that many of the DOM-TOM possessions encounter on a yearly basis, implemented wave technology systems must be sufficiently rugged as to be capable of surviving strong ocean surge.

4. Biomass Energy Systems

Biomass is another area in which the DOM-TOM has strong potential production capabilities. With its copious amounts of sunshine, high yearly rainfall levels, and often fertile, volcanic soils, the DOM-TOM witnesses rapid growth of a number of indigenous and imported plant types. In particular, the DOM-TOM is known as a major grower of sugar cane, with the resulting production of sugar being the number one export of several of the islands, such as La Réunion. With the production of sugar cane and other crops comes large amounts of organic waste materials- the stems, leaves, and other parts of the plant that are not used in the production of an end product. These waste products are often either shredded and returned to the growing fields to act as fertilizer or simply burned to quickly dispose of them. However, due to the significant and year round production of these by products, it is entirely feasible that they could be burned in a controlled environment and then used to produce electricity and heating.

At the end of the harvest, farmers could allow an outside party to collect the remaining biomass by products, which will be shredded and then pelletized. The pellets can then either be burned directly or added to a coal plant in what is known as "co-firing." By adding biomass directly with coal to generate electricity, producers can simultaneously reduce their fuel costs and their carbon emissions. Additionally, co-firing plants tend to achieve greater efficiencies than straight biomass plants, with some co-generation plants (heat and electricity) achieving astounding efficiencies of 80-90%.[xxx] While co-generation plants are more commonly seen in colder climates such as Scandinavia, where the heat created as a by product of electricity product is captured to warm homes and offices near the plant, industrial applications may be found in the DOM-TOM. Refitting coal plants to operate as co-fired systems is relatively cheap, with prices ranging on average from $50-300 per KW. And while fuel supply remains the most important factor in the operation of these plants, the DOM-TOM appears to offer low cost, low-shipping sources with high reliability due to the high annual growth rates of various organic products such as sugar cane.[xxxi] Additionally, due to the combustibility of most organic materials, the addition of biomass to a coal plant can lead to a dramatic reduction in CO^2 and NOX emissions at a very limited cost.



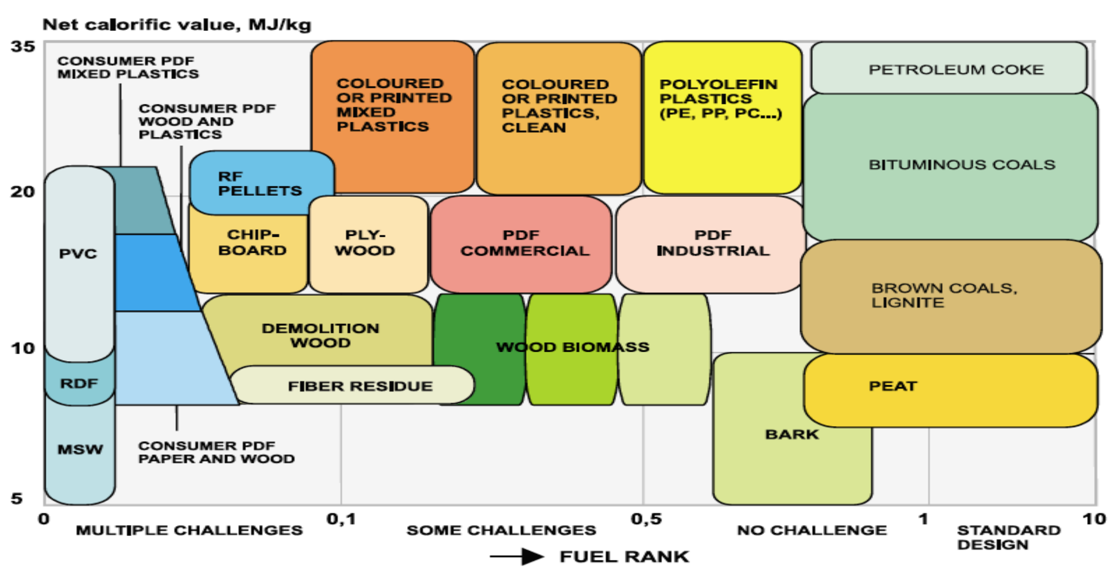
Theoretical decrease in CO_2 emissions by co-firing of wood with coal. VTT Processes.

Figure 13: Impact of Fuel Blend upon Co-Firing Emissions

While biomass power plants are more environmentally friendly than straight coal or gas plants in terms of their emission life cycles, they are never 100 percent emission free. In addition to the emissions produced through the burning of the biomass (much of which can be captured and recycled if desired), the production and shipment of biomass typically results in some emissions. Thus, while biomass plants are not as clean or emission free as wind or hydropower, it is still a significant improvement from the carbon emissions that come from a straight coal plant. Additionally, the use of biomass presents several advantages over its renewable energy cousins.

First, biomass plants can be run consistently, without fear of interruption from fickle weather conditions. Second, co-fired plants allow for existing facilities to remain in operation after limited modification, which reduces the cost of transitioning. These costs are further reduced by the limited need for employee re-training, since the basic functioning of the plant remains unchanged. Finally, while the ramp-up time for increasing electricity production is rather significant in large coal plants, smaller, decentralized biomass or co-fired facilities may be able to more rapidly increase production and thus serve to load balance for other renewable energies.

Due to the similarities between a traditional coal plant and biomass/co-fired plants, we can safely assume that employment levels will remain stable if the DOM-TOM transitions to biomass plants. Finally, the issues related to modifying existing coal fired plants for co-firing and retraining workers are well understood, as demonstrated in the graph below which illustrates the influence of fuel choice on boiler design.



Influence of fuel characterisation to boiler design. Courtesy of Foster Wheeler and VTT Processes.

Figure 14: Influence of Fuel Choice on Boiler Design

The US Energy Information Agency reported in 1997 that a 300 MW coal plant employs, on average, 50-60 personnel (down from nearly 80 due to increased operating efficiencies). These are, of course, only the employees directly employed by the plant, and this number does not include those indirectly involved in operating the plant- i.e., the coal shippers, electricians outside the plant, etc.[xxxii] Thus, besides the ease of transition from straight coal facilities to co-fire or biomass plants, the use of organic waste products seems to offer an efficient method to increase the use of renewable energies in the DOM-TOM at a very limited cost.

5. Energy Storage Systems

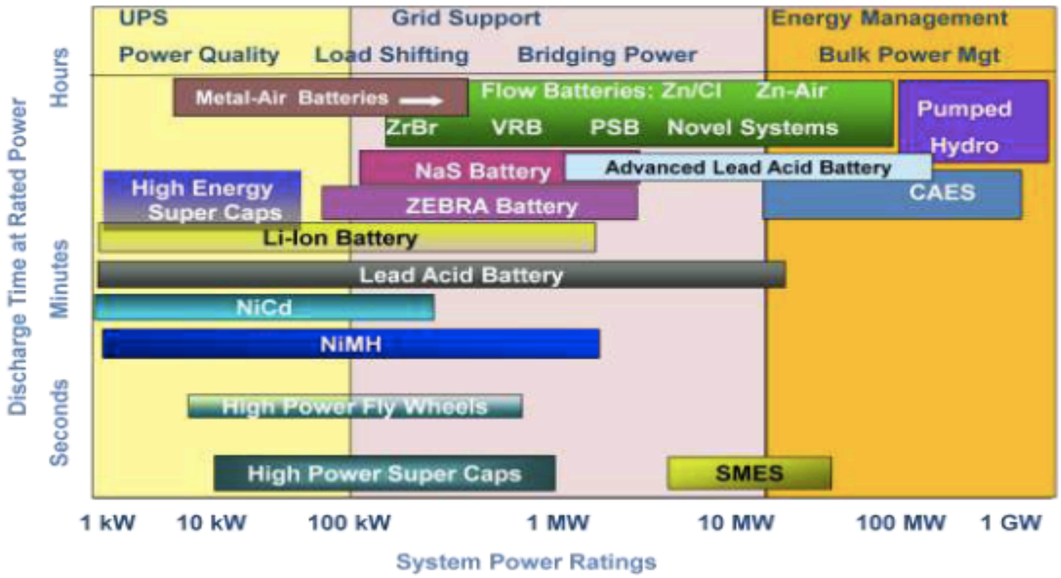
Energy storage is an important subject to discuss when considering the use of renewable energies such as wind or solar power. Despite the numerous advantages of solar, wind, and wave power, they all share on very important drawback- reliability. When the sun is not shining or the winds are not gusting, renewable energy systems are unable to produce electricity. Inversely, sometimes the production of energy is greater than the demand from consumers, leading to waste. During these times of mismatched production, it is important to have a method to quickly and efficiently balance the load demand. There are several ways to balance this demand. As discussed before, one method involves using extra wind, wave, or solar energy to pump water back uphill to storage reservoirs, from which the water will be released into hydroelectric dams on demand to generate electricity. Other methods for balancing load include maintaining spare production capacity by keeping extra power plants or generators online in a standby mode or using energy storage methods to house spare energy. Methods for storing energy typically fall along three lines: chemical, kinetic, and battery.

A. Chemical storage methods rely upon the conversion of excess electricity into chemical compounds that can later be reconverted into electricity when demanded. For example, water (H2O) may be transformed into pure Hydrogen (H) during periods of excess wind power, which will then be used to drive Hydrogen motors during lull wind periods. Other commonly used chemicals include the use of molten salts (typically used in solar thermal projects as a heat transfer agent due to its ability to absorb high temperatures and slowly off-put heat throughout the night), or ice storage (whereby ice is produced at night or in off peak hours for later use in cooling systems during the day). These systems tend to be fairly rare though their use is growing.

B. Kinetic storage relies upon converting excess electricity into mechanical motion. This is a rapidly growing field, with a large focus on flywheels, springs, and compressed air. Flywheel Energy Storage (FES) works by using electricity to rapidly spin a large, heavy rotor. When energy production drops, the rotor's deceleration returns energy to the grid. Due to their ability to rapidly spool up, flywheels are becoming increasingly popular for both energy storage and load leveling. As demand increases, new technological breakthroughs have continued to increase the efficiency and storage potential of flywheels. Unfortunately, flywheels are limited in terms of the total amount of energy they can store and in the length of time that they can store this energy. Rather, they seem to be best suited for short-term power interruptions (thus earning their place in the UPS pantheon- Uninterruptible Power Supply) and are particularly useful in load balance wind energy systems, where gusts can vary 6% or more within a 15 minute time frame.[xxxiii]

Spring systems are very similar in operation and impact to flywheel systems, although the spinning rotor is replaced by repeated mechanical deformation of a metal or carbon nanotube based spring. While new research is increasing the size, efficiency, and potential stored energy of spring storage technology, it is currently best suited for provide small amounts of quickly released energy. Thus, without significant investment and growth in the technology, it will remain suitable only for providing load smoothing and limited uninterruptible power supply.

The graph below from the International Energy Agency depicts the various different types of energy storage techniques available, their discharge times, and their power ratings. It is important to note that even high power fly wheels (and spring-based systems) are only capable today to provide, at a maximum, Grid Support. This means that without substantial investment and improvement, these systems will not be able to truly compensate for production shortages from renewable energy sources.



Source: EPRI, 2008.

Figure 15: Energy Storage System Power Ratings

Compressed Air Energy Storage (CAES) is another rapidly growing technique for storing electricity in kinetic form. Using high-powered air pumps, CAES systems force air into large storage chambers (normally underground caverns) during periods of excess electrical production. During periods of high demand or low production from renewable sources, the compressed air is allowed to escape its storage space to turn a turbine and generate electricity. These systems have several important advantages over flywheels and springs. First, it is a well-developed technology with proven techniques that has been employed for over 100 years in cities around the world. Second, the system allows for a greater concentration and storage of kinetic energy than flywheels and springs, and thus is more suitable for providing power during prolonged lulls in wind or at night.

The two main drawbacks to this technology are the cost of building a suitable storage site and the difficulty in maintaining proper pressure to maximize generated electricity. Since most storage sites are underground, sizeable investments must be made to ensure the integrity and safety of the containment chambers. Interestingly, the use of new, inflatable bladders designed for employment in seabed anchored storage systems could effectively reduce costs while increasing capacity. Since efficiency drops as air pressure decreases, methods must be employed to maintain constant levels of pressure and to standardize the temperature of the air pumped into the system. Again, some of these problems may be more easily corrected through the use of deepwater storage bladders off the coast of the DOM-TOM.

C. Batteries have existed in various forms for centuries, but have witnessed a renaissance in recent years as investments have skyrocketed due to the need for high capacity, high performance batteries for electric vehicles. These advances have also benefited the static battery industry, with new industrial batteries achieving performances unheard of just ten years ago. While the work horse lead acid battery still provides emergency power in a variety of duties, new technologies have increased both capacities and life spans for batteries used to provide support to the grid and in coordination with renewable energies. As with the chemical and kinetic methods of energy storage, batteries are typically charged during off-peak hours or during moments of excess production. They are then called to service to assist with peak demand or production lulls from renewable sources.

Nickel-Metal Hybride, Lithium-Ion, and Nickel-Cadmium batteries have seen significant new investment in recent years, leading to improvements in a variety of areas. In addition to simply building bigger batteries or combining ever growing numbers of batteries for more power, some companies are actively researching combining batteries with capacitors and other technologies to improve performance. One interesting new idea is to use parked electric vehicles as mobile batteries, ready to assist the grid during peak hours and available for recharge at night. Regardless of the compositions used, battery technology is currently in a stage where innovation is occurring faster than mass production processes can handle.[xxxiv] This means that while batteries will continue to improve over the coming years, consumers may witness an extended period of excessively high prices and low production as new processes are developed and dominant technologies emerge. Unfortunately for renewable energies, this means that it will prove more expensive and difficult to develop suitable storage systems to guarantee uninterrupted power throughout the day.

Although not technically batteries (since they consume an external reactant that must be periodically replenished), fuel cells play a similar role in a wide variety of applications, and may prove to be more suitable for storing energy developed from renewable sources. Interestingly, several projects are already underway to use fuel cells to store energy provided by renewable sources. For example, the Stuart Island Initiative in the United States has developed a program where solar panels generate the hydrogen for a fuel cell used to provide full electric backup.[xxxv] However, the technology for fuel cells remains relatively young, and thus comes with a very high price to power ratio. Further investment and refinement is necessary before fuel cells can reliably serve as a back up to renewable energy generation.

The graph below shows typical costs for various storage devices, though it is worth noting that the cost of CAES may be lower than depicted here if inexpensive deepwater storage bladders are employed in place of the typical use of reinforced caverns. In the end, it seems that no single system is fully capable (in and of itself) of completely resolving the load fluctuation issues that come with renewable energy and the need to provide large amounts of electricity over long periods. While compressed air and pumped hydro can satisfy the demands of lull production periods, they are not as adapt at covering short-term variations, as can flywheels, batteries, and fuel cells. Finally, while many of these technologies are extremely promising, most require significant continued development in order to mature the technology a point at which mass production will be both feasible and cost-effective.

Storage Type	Power	Duration of Discharge	Efficiency (%)	Lifetime	Total Capital Cost (USD/kW)
CAES (100-300 MW, Underground)	15-400 MW	2-24 hrs	54 (Eff_{NG}=1)* 76(Eff_{NG}=0.54)* 88(Eff_{NG}=0.39)*	35 years	600-750
Pumped Hydro	250 MW >1 GW	12 hrs	87	30 years	2700-3300 Upgrade:300**
Li Ion	5 MW	15 min to several hrs	90 (DC)	15 years	4000-5000
Lead Acid	3-20 MW	10 sec to several hrs	75-80 (DC) 70-75 (AC)	4- 8 years	1740-2580
NaS	35 MW	8 hrs	80–85 (DC)	15 years	1850-2150***
VRB Flow Cell	4 MW	4-8 hrs	75–80 (DC) 63–68 (AC)	10 years	7000-8200
ZnBr Flow Cell	40-100 kW, 2 MW	2-4 hrs	75–80 (DC) 60–70 (AC)	20 years	5100-5600
High Power Flywheel	750-1650 kW	15 sec to 15 min	93	20 years	3695-4313
ZEBRA	<10 MW	Up to 8 hrs	80-85 (DC)	Over 1500 cycles shown	1500-2000***
Fe/Cr Flow Battery	<10 MW	2-4 hrs	50-65	20 years	200-2500***
Zn/Air	20 kW-10 MW	3-4 hrs	40-60	a few hundred cycles	3000-5000***
SMES	1-3 MW	1-3 sec	90	>30,000 cycles	380-490
SMES****	100 MW-200 MW	100 sec (MWh) 0.5-1h (100MWh) 5-10 hr (GWh)	90	>30,000 cycles	700-2000
Ultra capacitors	10 MW	Up to 30 sec	90	>500,000 cycles	1500-2500

Table 5: Energy Storage Types

Section II

Cost and Benefit Analysis

A. Comparison of Two DOM-TOM Possessions and Potential Renewable Advantages

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1. Introduction

Although the DOM-TOM is currently heavily dependent on imported fossil fuels to generate electricity, efforts have been made to increase energy efficiency and the use of renewable power sources. Due to the sizable differences between the different DOM-TOM possessions, a detailed analysis of state of each territory's energy situation and the potential for renewable energies would require a much greater investment of space than I have been provided. Thus, in this section, I will analyze two distinct DOM-TOM islands to present the contrast between proactive efforts and to also show the long-term benefits of such actions. I will show the current state of affairs on each island, present the long term costs and benefits under a Business As Usual (BAU) scenario, and also the possible savings, costs, and benefits to switching to a system nearly entirely based on fossil fuels.

2. La Réunion

La Réunion is the most populous island in the DOM-TOM, with just over 800 thousand inhabitants spread over 2,500 km^2. 36% of the 2500 GWh (with an anticipated demand of 4500 GWh in 2030) of electricity produced in 2008 came from renewable sources, making La Réunion the poster child for renewable energies in the DOM-TOM.[xxxvi] The island features the use of every type of renewable energy, from hydroelectric dams to photovoltaic solar panels, wind turbines, and even a

1MW underwater turbine. Despite these efforts, the majority of electricity is still produced by conventional (specifically coal and gas powered) fossil fuel plants.

Interestingly, unlike on the other DOM-TOM islands, EDF only accounts for 40% of the electricity produced. While it remains the largest producer of electricity on La Réunion, the high rate of solar panel installation on private homes, and the development of numerous, small private producers (such as co-fired plants feed from sugar cane biomass and coal). Despite its reduced position on La Réunion, EDF still employs roughly 700 workers, who focus on fossil fuel and hydro plants and on the management and maintenance of the islands electrical network. 50% of EDF's electrical production comes from carbon plants, with an additional 13% being produced by gas turbine systems, and 24% coming from hydroelectric dams.[xxxvii] While biogas, solar, and wind still make up less than 1% of EDF's production capacity at the moment, they are rapidly growing despite the obvious problems with inconsistent production. Finally, significant studies have been executed by EDF to ascertain not only the feasibility of increased wind and solar reliance, but also to develop methods for storing and ensuring adequate supply during production lulls.

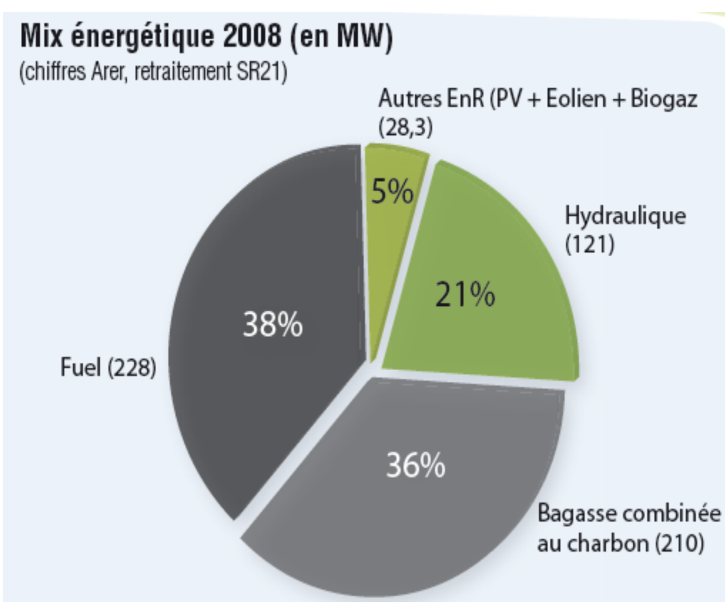

Figure 16: La Réunion Energy Mix, 2008

2008 Energy Mix for La Réunion.

Fuel: 38%
Others (include PV, Wind, and Biogas): 5%
Hydro: 21%
Co-fired (coal and sugar cane residue): 36%

Numbers in parenthesis indicate the quantity in MW

Why has La Réunion been so successful to this point in encouraging the growth of renewable energies? Much credit must go first of all to local officials, who have actively encouraged the development of long-term energy plans and planned urban growth. Additional credit is due to the French national 2007 Grenelle law, which mandates sharp reductions in emissions and increased energy efficiency as part of the European 20/20/20 vision for reducing emissions. Finally, President Sarkozy has directly supported the efforts such as GERRI (Green Energy Revolution Reunion Island or Grenelle de l'Environnement à La Réunion: Réussir l'Innovation) in order to support not just Europe-wide efforts to lower reductions, but also renewable energies as a method to reduce costs and increase employment on La Réunion. The GERRI program has integrated stakeholders at every level, ranging from the French national government to local citizens on La Réunion, to consensually build a long-term plan for the growth of renewable energy on La Réunion and reduce the impact of fossil fuels.

3. Guadeloupe

Guadeloupe shares many factors in common with La Réunion. Located in the Lesser Antilles of the Caribbean, the island features roughly half the population, size, and energy consumption of La Réunion at 400,000 citizens, 1,600 km^2 of surface, and 1612 MWh (anticipated to grow to 2800 MWh in 2025) of electricity produced in 2008.[xxxviii] The vast majority of energy produced in situ comes from either carbon-fired plants (18%) or from fuel/gas power plants (70%). Interestingly, the remaining energy sources come from a mix of renewable energies: 1% from hydroelectric dams, 4% Geothermal, 2.5% wind, 3% biomass, and a small amount of solar.[xxxix] Even EDF, the primary producer of electricity in the archipelago, believes that renewable energies could play a much more important role in electricity production, citing the numerous rivers that could support hydroelectric dams, the ample sunshine and wind, and the ample reserves of geothermal energy.

It is therefore surprising to see how limited a role renewable energy sources play given such potential. For example, if EDF estimates in their 2009 annual production report that the region may have up to an additional 70 MWs of geothermal energy, why not increase production past the current 15 MW? Similar questions can be asked regarding solar power (mostly confined to one farm of 5 MW), wind (26 MW of installed capacity, but mostly in smaller, outdated turbines scattered throughout the archipelago), and mini-hydroelectric dams (13 sites producing less than 10 MW).[xl]

There are two answers to this question, the first of which is location. Situated in the Caribbean, it is much cheaper for Guadeloupe than for La Réunion to import the coal and fuels it needs to generate electricity, thus removing a large incentive for EDF to change its practices. Second, Guadeloupe has not benefited the degree of integrated planning that La Réunion has witnessed. Without the GERRI program to integrate stakeholders at all levels and to aid in the creation of long-term development plans, Guadeloupe has been unable to create cohesive programs to encourage change while building consumer support.

4. Future Growth and Fuel Concerns

Both islands are expected to continue to grow in the near future, with populations reaching 1 million on La Réunion and possibly even 600,000 on Guadeloupe by 2030. Energy consumption will also grow, with La Réunion consuming an estimated 4500 GWH of electricity in 2030 and Guadeloupe 2800 by 2025. At the same time, the price of coal, liquid natural gas, and oil, the primary energy sources used to generate electricity in the DOM-TOM, remain highly volatile. In 2004, analysts predicted that oil would cost roughly $24 per barrel up till 2050, only to see the price violently jump in 2008 to nearly $150 a barrel. Currently at $85 a barrel in 2010, many analysts are predicting another climb in prices as demand increases and supply diminishes due to the peak oil effect. Coal prices have climbed from roughly $20 per ton in the early 2000s to over $130 in 2008 before settling at roughly $100 per ton today, driven by increasing demand in China and India and from transportation inefficiencies. This uncertainty will be a driver in encouraging the replacement of fossil fuel plants in the DOM-TOM with renewable energies, as EDF and by extension the French government will be forced to confront the impossibilities of planning for fuel purchases in such as highly instable and volatile situation. Further, even if prices do stabilize, most analysts predict them to continue to trend upwards, meaning that planners will be confronted with not just an ever increasing level of fuel consumption, but also greater costs for the fuels used.

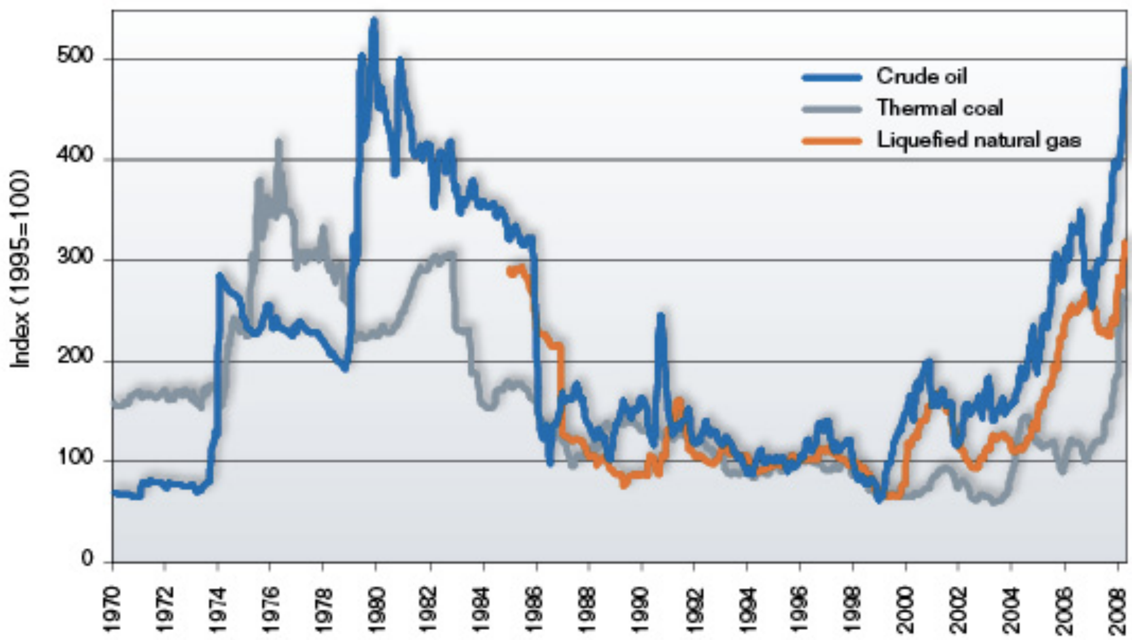

Figure 17: Long Term Fuel Prices

In addition to the growing cost of fossil fuels, many nations now view the acquisitioning of these resources as a matter of national security. Many have argued that France's move towards nuclear power for electricity generation was due as much to the desire to acquire nuclear weapons for security reasons, as it was due as a response to the threat of future oil shocks. Others will point to the US defense of Kuwait as less an exercise in protecting the freedoms of the Kuwaitis, as it was a move to protect the important oil production sites in Kuwait and Saudi Arabia. Thus, as world demand for fossil fuels increases and supplies diminish, it will become even more important to either devote significant financial and military resources to ensuring supplies or to find alternatives to replace fossil fuels.

5. Transitioning to Renewable Energy Sources

Multi-Criteria Decision Models were discussed briefly in the beginning of this paper. These models are often highly elaborate and complex, allowing the input and evaluation of numerous variables in order to help arrive at a decision tenable for all involved parties. The creation of these models can take months as stakeholders enumerate the variables that they perceive as important and the various parties argue over the importance of the weighting assigned to each criteria. Due to my ignorance in such a complicated and important subject, I shall not attempt to replicate the highly detailed and precise work that goes into the creation of a Multi-Criteria Decision Model. Instead, I shall merely attempt to present what I perceive to be the most important criteria involved in this report, without actively searching to assign a specific value to each variable. That is to say, I shall present several important criteria (pollution, employment, cost) without attempting to assign a preference or priority to each one, whereas a French politician might rank maintaining employment levels as more important than reducing pollution.

A. Pollutants

Renewable energy sources present a clear advantage over fossil fuels in terms of pollutants emitted during the production of electricity. I will assume for the sake of simplicity that emissions during construction and fabrication of both fossil fuel and renewable energy sources are equivalent, and I have taken the further step of ignoring these emissions for the purposes of this paper. With the exception of biomass and geothermal, renewable resources produce no pollutants. While biomass does produce CO^2 and other typical Green House Gases (GHG), these emissions will typically be produced regardless- the biomass will either be burned in situ in a field for disposal, in a waste disposal unit, or put to positive use in a biomass power plant. Further, burning biomass in a plant allows for the more efficient capture and treatment of GHG emissions through scrubbing systems than controlled burning in a field. While Geothermal does produce some GHGs, they are a product of the chemicals inherent in the groundwater used by the facility, and thus vary tremendously from one site to another. Additionally, these emissions tend not only to be fairly miniscule, but are also easily captured during the electricity production cycle. Further, these captured emissions can even provide additional revenue sources- trapped ammonia from geothermal production can be sold to local markets, alleviating storage or treatment concerns.[xli] In the chart below, compiled from data from the US Environmental Protection Agency, the benefits of renewable energies in terms of avoiding emissions are striking.

Generation System	Emissions (pounds CO2 per MWH)	Emissions (pounds Sulfer Dioxide per MWH)	Emissions (pounds Nitrogen Oxides per MWH)
Fuel Oil	1672	12	4
Gas Turbine	1135	.1	1.7
Coal	2249	13	6
Wind Onshore	0	0	0
Wind Offshore	0	0	0
Solar (PV, 1000m² space)	0	0	0
Wave	0	0	0
Biomass (from Municipal Solid Waste)	2988	.8	5.4
Hydroelectric	0	0	0
Nuclear	0	0	0
Geothermal	0	0	0

Table 6: Emissions by Generation System

The data for biomass comes, in this case, from the burning of municipal solid wastes to generate electricity, and thus may be presented as more polluting than would be the case if organic waste from crops were to be used instead. The arguments in favor for renewable energies as a means of avoiding climate changing emissions are even forceful when we exam a practical example using La Réunion and Guadeloupe. Below we see the year production for the two islands (Total GWH), the installed capacity (Total MW), and the percentages of production derived from Coal and Thermal sources (For simplicity, Thermal is assumed in this case to be derived from fuel oils). The final two columns depict the total installed MW of Coal and Thermal for each island. Renewable energies including biomass have been excluded from this chart in order to concentrate on the emissions derived from fossil fuels.

	Total GWH	Total MW	Coal (%)	Thermal (%)	Coal (MW)	Thermal (MW)
La Réunion	2500	408	50	13	204	53
Guadeloupe	1600	242	18	70	44	170

Table 7: Emissions by Generation System, La Réunion/Gaudeloupe

From these figures, I was able to compute the yearly pollutants derived from these two methods of production using the EPA's data on emissions per energy source. Again, in order to simplify the process, I have considered all thermal sources to be fuel oil based, and to be without scrubbers or other technological improvements (or operational problems) that would alter their emissions.

		Total Emissions (lbs)	Coal (Pounds)	Thermal (Pounds)
La Réunion	CO2	547412	458796	88616
	Sulfur Dioxide	3288	2652	636
	Nitrogen Oxide	1436	1224	212
Guadeloupe		**Total Emissions (lbs)**	**Coal (MW)**	**Thermal (MW)**
	CO2	383196	98956	284240
	Sulfur Dioxide	2782	572	2210
	Nitrogen Oxide	944	264	680

Table 8: Yearly Pollutants, La Réunion/Gaudeloup

These figures, while only approximate, will only continue to grow as demand for energy grows in La Réunion and Guadeloupe. At a time when the European

Union is actively working towards reducing its emissions by 20% by 2020, the idea of replacing the emissions above with the zero emissions of renewable seems compelling. While perhaps miniscule compared to the pollution produced from emitters such as China or the United States, reductions here can significantly aid France to achieve its emissions goals while promoting other goals.

B. Employment

Unemployment continues to be a major problem for the DOM-TOM, with rates reaching 36.8% in La Réunion and 29.3% in Guadeloupe.[xlii] Unemployment has many impacts upon societies, ranging from loss of tax revenue, higher costs for welfare programs, and decreased social cohesion, and higher crime levels. Any program to encourage renewable energy will flounder and fail if it does not at least maintain current employment levels. Although there remains significant debate over the true amount of jobs created by new renewable resources, by comparing various data sources we can create a rough estimate of the number of full-time, permanent positions created per MW by each time of energy sources.

Generation System	Jobs per MW
Fuel Oil	.20
Gas Turbine	.20
Coal	.20
Wind Onshore	3
Wind Offshore	3
Solar (PV, 1000m² space)	7.5
Wave	3
Biomass	3
Hydroelectric	1
Nuclear	.6
Geothermal	1.7

Table 9: Job Creation by Generation System

This estimation does not include the number of short-term positions created for construction, nor does it include the secondary posts created per MW. That is to say, it does not consider the positions created to mine and transport coal, nor those created in the fabrication of parts for individual systems. Further, these numbers do not include indirect positions created by employment- for example, the restaurants that open locally due to increased demand from employees.

Renewable energies, due to their diffuse nature and the immaturity (and thus the lack of efficiency of the technology) tend to have significantly higher levels of employment. Additionally, many fossil fuel plants are now highly automated; requiring only limited human supervision outside of scheduled maintenance periods. It is worth noting that many of the jobs created by renewable energies may be lower paying, somewhat menial positions. For example, solar installation and cleaning require very limited training, whereas the operation of a nuclear facility depends upon highly educated and well-trained personnel. However, this may actually be beneficial for the DOM-TOM: with extremely high unemployment levels, it seems better to employ large numbers of low-skilled workers rather than a few highly paid employees. In the graph below, I have taken the fossil fuel utilization for La Réunion and Guadeloupe and compared the current levels of employment with a situation in which all of this power was replaced by solar and wind systems (split evenly between the two). It is rather staggering to see the potential for job creation with solar power. So much so that I revisited the Energy Information Agency website, which confirmed that a 300 MW coal fired plant averages roughly 43 employees, down from a peak of nearly 80 in the 1980s and also helped to verify the predicted employment numbers for various renewable energy sources. [xliii]

	Coal (MW)	Thermal (MW)	Coal Jobs	Thermal Jobs	Wind	Solar
La Réunion	204	53	40	11	384	960
Guadeloupe	44	170	9	34	321	800

Table 10: Job Creation by Generation System, La Réunion/Gaudeloupe

Obviously, this increased employment comes with a significant cost in terms of higher electricity prices due to wages and less efficient production systems. Further, the number of jobs created per MW of renewable energy is likely to fall in the future as the industry becomes more efficient. And some of the workers currently employed in fossil fuel plants will simply shift to renewable plants: coal workers can be quickly retrained and employed in biomass plants. Finally, it is also worth noting that fossil fuel plants will not disappear over night- even under the most aggressive scenarios, it will take years for renewable energies to expand to take place of fossil fuels. As demand for energy increases, one can reasonably expect that renewable energy systems will be employed to cover this increase, with only the worst polluting fossil plants taken out of production before the end of their life-spans.

In summary, while it appears that there are strong employment arguments in favor of renewable energies, these must be treated somewhat conservatively. Efficiencies will grow, reducing employment opportunities (much as we have already seen in mature fossil fuel technologies), existing workers will be retrained, industries or businesses heavily reliant on cheap energy (such as aluminum production, scarce in the DOM-TOM due to its industrial make up) will suffer, and many existing fossil fuel positions will remain for an extended period. Finally, it is worth also mentioning that in many ways, creating employment through renewable energies is social welfare by another name. Rather than directly paying the unemployed through welfare checks, the state will instead subsidize their employment by encouraging investment in renewable energies and by directly paying to lower the costs of installed capacity.

C. Renewable Energy Costs

One area in which renewable energy sources continue to underperform versus their conventional, fossil fuel peers, is in cost per MWH. Oil and coal have well earned reputations for high calorific levels and ease of transportation. Additionally, they have long since been commoditized and standardized, ensuring that plant operators can ensure a ready supply of fuel optimized for their facility. At the other end of the spectrum, solar power is notorious for its lack of concentrated energy, and the difficulty with which converted solar energy is stored or transported. Despite the fact that the sun quite literally provides us with more than enough energy to power our world, the bulkiness and low efficiencies of solar power, coupled with its high cost (and the cost of electricity) storage, place it a decided disadvantage against its competitors.

However, not all costs are the same. While renewable energy sources are typically fairly expensive in terms of installation costs, their operational costs are often close to zero, since their primary fuel source (wind, waves, sunshine) are free. Inversely, fossil fuel plants may appear cheaper during construction, but if fuel costs rise significantly, these same plants may suddenly be too expensive to operate. Further, operational costs determine the order of merit (or precedence) which describes when each system produces. Renewable energies, with the near zero operating costs, typically produce before nuclear power, which in turn produces before fossil fuels with their expensive fuel requirements. The graph below depicts the cost for various energy production systems. Of importance is to note the Levalized Costs, which shows how much most be paid to cover the costs per MWH in order to pay for the costs of construction and lifetime operation.

Generation System	MW Produce per Unit	Cost per Unit in millions of USD	Total System Levalized Costs (DOE, USD per MWH)
Fuel Oil	300	500-700	100
Gas Turbine	300	300-500	139
Coal	300	700-1.2 Bn	100
Wind Onshore	3	3.9-4.5	149
Wind Offshore	5	7.5	191
Solar (PV, 1000m² space)	1	4.5	396
Wave	1	1.5	191
Biomass	50	150	111
Hydro-electric	10	10-30	119
Nuclear	1600	8-12 Bn	119
Geothermal	15	50	115

Table 11: Cost by Generation System

While solar, wind, and wave power come out particularly bad in this aspect; it is worth noting that the cost per MWH for these systems is rapidly diminishing. Grid parity, or the idea that renewable energy sources will be able to produce at the same price as conventional fossil fuels, is anticipated for wind and solar within the next 5-15 years. This is due in large part to rapidly expanding production and operating efficiencies within the renewable energy industries, and also due to rising fuel costs (and carbon taxes) for fossil fuel plants. The European Union Emission Trading System (ETS) currently features a price of roughly 15 Euros per ton CO^2, a price which is directly added onto the operational costs of fossil fuel plants, but non-applicable for renewable energies.

One argument that is often promoted by supporters of fossil fuels is that renewable energies need massive subsidies in order to be viable, and thus are "non-starters"- that is to say, not worthy of investment. This avoids the fact that many technologies have required significant government support to become viable. Further, this also ignores that fossil fuels currently receive government support in the form of subsidies and tax breaks. As we have witnessed previously in this paper, the French government directly subsidizes EDF in the DOM-TOM (directly for fuel imports, and with other indirect subsidies such as tax breaks or near-monopolies) in order to allow for lower cost electricity. Additionally, the IEA reported that in 2009, the world spent $312 billion on subsidies for fossil fuels, with only $57 billion dedicated for renewables. Further, the IEA predicted that subsidies would rise to $600 billion for fossil fuels by 2012, while renewable energies will receive only $100.[xliv] These subsidies and tax breaks play a direct role in lowering the costs of production of electricity for fossil fuels, making them more competitive against renewable energies. Besides the financial burden placed upon taxpayers, some have estimated that the cost of subsidies for electricity in the DOM-TOM is directly responsible for some 1.4 million tons of CO^2 emissions.

Direct Investment Costs						
	Coal (MW)	**Thermal (MW)**	**Cost Coal (Millions USD)**	**Cost Thermal (Millions USD)**	**Cost Wind (Millions USD)**	**Cost Solar (Millions USD)**
La Réunion	204	53	475-816	88-124	964	578
Guadeloupe	44	170	103-176	283-397	803	482

Table 12: Direct Investment Costs

In the above graph, I calculated the costs for the existing fossil fuel plants on La Réunion and Guadeloupe and for replacing the same quantity with renewable energies using the Cost per Unit data provided in the previous chart. I split the replacement of coal and thermal (considered to be fuel oil) equally between wind and solar, and also used the more expensive offshore wind for my calculations (this seemed more natural given the lack of space for onshore wind farms in the DOM-TOM). While renewables are rapidly becoming less costly, they are shown here to be significantly more expensive in terms of capital expenditure. In the conclusion, as the graph above depicts, the costs of investing in renewable energies are, for the time being, much higher than those of fossil fuels in terms of direct capital investment costs. However, as previously stated, operational costs tend to be significantly higher for fossil fuel plants, and with rising (and often unpredictable) fuel prices, a greater up-front investment may prove more attractive for long-term investment.

D. Environmental Impact

Renewable energies and fossil fuel power plants each create significant environmental impacts, though these are often also very specific to each type of plant. These impacts can extend far beyond the release of climate changing Green House Gas emissions, and decision makers must consider these impacts when selecting projects for future development. Ignoring the impacts of Green House Gases, which have been discussed prior to this and also at great length in other papers, I will concentrate instead on the environmental impacts directly affecting the DOM-TOM.

i. Fossil Fuels

Fossil fuels emit not only Green House Gases, but also other emissions that can be harmful or deadly to humans and other living organisms. These emissions have been directly linked by various health and environmental agencies around the world to increased human mortality, higher risk of heart attack, acute vascular dysfunction, and many other medical maladies.[xlv] Further, due to the need for extraction of the fuels for these power sources, the environmental consequences can range through the entire spectrum of energy production. However, concentrating a bit more narrowly on just the DOM-TOM, environmentalists are concerned first of all with the transport of coal, gas, and oil, which involve the use of large tanker vessels. These ships not only emit significant amounts of emissions, but they also encourage the spread of microorganisms and invasive species that may impact the health of the water based eco-systems of the DOM-TOM. Further, the fuels themselves can be toxic to the environment or animals if spilled or not properly treated. Finally, the construction and daily operations of fossil fuel plants may incur a significant disturbance on local flora and fauna.

ii. Renewable Energies

Each renewable energy source brings with it its own environmental issues. Geothermal production sites not only release small amounts of gases such as ammonia, but also require the drilling of deep wells, which may disturb local ecosystems. Further, the water used during steam production may become tainted with the various chemicals embedded in the rocks, thus require treatment or reuse in order to avoid harming wildlife. Finally, some scientists have raised concerns that geothermal power production may encourage earthquakes in geologically sensitive areas. While most scientists believe that this issue is resolvable, it must still be considered and discussed when selecting energy sources.[xlvi]

Solar power impacts the environment in two negative ways- land use and from the toxic chemicals used for its fabrication and operation. Due to the low production efficiencies currently inherent in solar power, a vast amount of space is required in order to generate sufficient quantities of usable energy. This requirement can be offset by installing photovoltaic panels on building instead of in the countryside and by avoiding the construction of solar thermal plants. Solar thermal plants often use molten salts or oil as a heat exchange agent, which requires rigorous safety procedures to ensure safe handling. Solar panels are fabricated using chemicals such as arsenic and cadmium, and contain large amounts of silicon. If inhaled or ingested, these chemicals can pose serious health problems for humans and other animals. However, properly handling and maintenance of panels should not result in the escape of inherent chemicals and subsequent exposure to living organisms. Finally, many existing solar systems require large amounts of water either to clean the photovoltaic panels or to act as a cooling agent for thermal towers. The acquisition and treatment of water for these purposes may pose significant environmental impacts in areas devoid of large quantities of clean water.[xlvii]

Wind turbines are often criticized for their negative impact on birds and bats, though it seems that these claims may be overstated. However, offshore turbines may disturb local ecosystems when their mooring systems are installed on the seabed. Finally, the noise and appearance of the wind turbines may be disturbing to citizens living within the area.

Hydroelectric dams have many known impacts upon the environment, ranging from preventing fish from spawning to causing soil impoverishment by preventing soil wash from drifting down river. Additionally, wave powered devices may disturb local ecosystems with their seabed moorings and during their operation, though this has not yet been proven.

Storage devices may require rare minerals for fabrication, or may contain materials hazardous to the environment if not properly treated. Additionally, they require additional space, which creates an impact of its own upon the local ecosystem.

In conclusion, it is worth noting that while all forms of human interaction result in damages to and changes in local ecosystems, it still appears that most renewable resources have smaller installation footprints and less operational impact upon the environment. While care must be maintained in the selection of sites and in installation of the systems, environmental degradation can be avoided or mitigated to a large extent through proper planning and thorough adherence to safety regulations. With zero emissions, smaller and more localized footprints, and easier to manage environmental impacts, it appears that today's renewable energy sources have significant ecological advantages over their fossil fuel peers. With increased investment to improve efficiencies and greater operational and installation experience, these impacts are likely to grow in the foreseeable future.

iii. Social Impact

Do renewable energies have impacts upon society? In terms of health, the answer is a clear "yes." As we saw in the environmental section, renewable energies produce zero pollution, which means human health is not impacted. Besides healthier, happier people, zero pollution means less money is spent on health care and medical bills, employees are able to work more (and to a better quality level), and the government is not forced to spend billions in cleaning up environmental degradation, as can be seen in the BP Gulf oil spill or the US superfund sites.

Renewables also appear to have a positive impact on employment levels, another important social consideration. As mentioned previously, high employment levels appear to lead to reduced crime and greater prosperity, as well as enhanced social cohesion. Renewable energies may also provide a method for better integrating various stakeholders, from local concerned citizens to the highest levels of government, due to the requirements for all parties to take part in creating growth and development plans. The GERRI initiative of La Réunion is a prime example of how renewable energies can be used to create a positive and lasting discussion between individual citizens and many levels of government.

Finally, many independent surveys have found that the general public attaches a strong, positive value to renewable energies. Many citizens find renewable energies to be an indicator of environmental and social concern from governments and from corporations, and that environmental stewardship is an indicator of an entity's loyalty to customers and employees.[xlviii] These views may be reinforced by the belief that the government is acting to ensure a long-term, stable supply of energy that does require military intervention.

B. Externalities: Secondary Costs and Benefits from Renewable Energies

In the previous section, I discussed the costs and benefits of replacing fossil fuels in the DOM-TOM, focusing on the environmental, economic, and social benefits. However, there will be secondary costs and benefits that are felt not only in the DOM-TOM, but also the rest of France. These impacts, both positive and negative, must be fully researched and analyzed in order to properly inform decision makers.

In environmental terms, employing increased amounts of renewable energies will lower France's overall emission levels. Further, doing so in the DOM-TOM region may prove to be a very cost-effective method of reducing emission levels in accordance with the European Union's 20/20/20 vision. This may prove beneficial to heavy industrial sectors located in France that require large amounts of emissions in order to operate. Rather than being forced to install expensive scrubbing and cleaning equipment or risking outsourcing of these emissions-intensive industries due to rising carbon costs, replacing the carbon emissions of the DOM-TOM with renewable energies might prove very cost effective.

Additionally, the installation of renewable energies in the DOM-TOM will likely qualify for Joint Implementation support under the Kyoto Protocol. Briefly, the Joint Implementation is one of three flexible mechanisms designed to encourage the reduction of Green House Gases. In this method, one developed country may invest in an emission reduction project in another developed country, vice doing so in a developing country or trying to reduce its own emissions. In return for its investment and support of this emission reduction project, the developed country receives carbon emission credits that allow it to continue to emit. Thus, by helping to pay for the installation of renewable energy sources to replace fossil fuel plants in the DOM-TOM, another European country will receive emission credits to be used to support continued production at an emissions-heavy industrial facility. Joint

Implementation projects in the DOM-TOM are a “win-win” for all involved parties: the DOM-TOM inhabitants receive clean, renewable energy sources, France lowers installs clean energy at a lower cost, and the investing country can continue to emit without the need for far more costly investment in emission reduction technology.

A secondary economic benefit of increased use of renewable energies in the DOM-TOM may be the expansion of these same industries in France, not just in terms of utilization, but also in fabrication. While the majority of French electricity is derived from nuclear power, a significant amount of peak production is provided by fossil fuel plants that can rapidly be spun up or down to meet varying demand levels. Replacing these fossil plants with renewable sources will not only create new jobs, it will further act to lower French Green House Gas emissions. Additionally, spurring investment in the production of these systems will create fabrication and installation jobs. Large scale purchases of renewable systems may lead to important advances in not just the improving system efficiencies while lowering costs, but also to advance production techniques. In short, these advances may become solid competitive advantages that allow French producers of renewable energies to compete on an international scale. Finally, technological advances in one field often bleed over to other fields- microchips developed for the US space program eventually lead to important developments for computers, cell phones, and other advanced technologies, creating millions of new jobs and billions in tax revenues. This will not just directly encourage and enhance French industry, but may also lead to a more positive international view of French market and environmental leadership, resulting in enhanced national prestige.

While the French people may still be required to provide substantial subsidies to encourage the growth of renewable energies in the DOM-TOM, the accompanying job creation in the region may enable the government to reduce other forms of unemployment and welfare subsidies. Further, the secondary social impacts of increased employment in the DOM-TOM may reduce problems typically associated with high levels of joblessness, such as crime and anti-government protests. Falling crime rates may in turn lead to greater local economic prosperity and reduced costs for the government. These benefits may all result in a positive political support for continued action by voters.

Negative secondary impacts may include increased pollution from mining or mineral extraction, increased pollution from the fabrication of renewable energy systems, higher prices for materials specific to renewable power sources (i.e., cadmium), a need to reinforce or replace existing electricity infrastructure to handle renewable production, a need to invest heavily in research and development, a need to invest in storage systems, and a need to retrain the workers of conventional electricity production systems. While all of these problems seem to be moderately easy to resolve on their own, they are worth researching in order to better understand their combined impacts upon the French economy, society, and environment.

C. Policy Proposals to Encourage Renewable Energy Growth

1. Introduction

Numerous policies already exist for encouraging the growth and development of fossil fuels and for enhanced energy efficiency. These policies typically take either a positively reinforcing or a negatively reinforcing approach. Positive encouragement policies include tax rebates for purchasing solar panels, government subsidies for companies investing in renewable energy development, and local land-development zoning laws that permit easy home installation of solar panels. Negative reinforcement policies can range from public fines for pollution, higher taxes for carbon-intensive industries, or even higher taxes for goods that have higher emissions. The idea behind both positive and negative reinforcement policies is to encourage behavioral changes in both producers and consumers. Ultimately, the most effective method of changing behaviors is the combined use of both positive and negative reinforcement policies, coupled with a consistent, stable, and long-term approach to achieving the desired objectives.

Perhaps more important than the actual selection of which policies to implement and enforce is the need to have a stable and enduring vision of the desired objectives to be achieved. While the tactical implementation will adjust as the circumstances on the ground change, a coherent, lasting approach to attacking the problem will allow for a consistent execution. This is important for several reasons. First, a consistent, long-term vision enables businesses and other entities to gradually adapt and adjust to a changing working environment. Rapid modifications or reversals will leave businesses hesitant to act, thus delaying the process. For example, if one administration announces significant investment in renewable energies and the next government scraps these actions, a mixed-message is sent which confuses businesses and investors, leading to increased caution and reduced action.

Second, as stated above, many of the actual policies that will be implemented will eventually be modified or abandoned. Regulations concerning the proper employment of wind turbines will most certainly change as the technology and our understanding of its employment evolves in the future. A long-term vision will enable policy makers, regulators, and local actors to best direct these changes to help obtain the desired end states. Third, consistent policies send a reassuring message to the civilian population, which encourages support and investment. Just as businesses are unlikely to invest in an industry that may disappear without government support, so are individual citizens hesitant to engage in a variety of actions (from investing in projects or companies to buying their own solar panels or acquiring specialized education) if they believe that the potential benefits will be none-existent. Finally, a consistent, long-term approach to policy employment will help to avoid confusion and misunderstanding, which in turn can negatively impact all the stakeholders involved in the issue.

2. Policies for Renewable Energies

There are a wide variety of policies, both positive and negative, that the French government can employ to encourage the growth of renewable energies. As stated above, the best recipe for success is to mix negative and positively reinforcing policies in a manner that delivers a coherent message with a long-term outlook. These policies can range from cost-free to quite expensive, but should be designed to overlap on many levels to create a self-reinforcing means of achieving the desired final end state.

a. Positive Reinforcement

Beginning at the highest level of government and working down to regional levels, positive reinforcement should seek to combine large, industrial scale efforts with local initiatives. Subventions for fossil fuels should be eradicated, replaced with subsidies for clean technologies. Research, and development for renewable energies should receive large amounts of government support, as well as tax incentives to for power generators such as EDF to replace fossil fuel plants with renewable sources. Government funding can also be used to provide low-rate loans or starter money to growing renewable energy corporations, as well as to provide capital for training and hiring new employees and to sponsor the creation of educational pathways concentrating on renewable energies.

Tax initiatives for corporations and private investors can also be modified to encourage the purchase of renewable energy sources or emissions-free energy, while cap and trade or carbon taxes can be employed to discourage the production of fossil fuels. The government should clearly state its long-term goals and objectives (e.g., 20% renewable power by 2020) and then support these goals with "green" legislation. Efforts should be made to improve access to government lands for the construction of renewable energy production systems, and finally, the government act to increase procurement of renewable energies. Since governments typically represent the largest and most wealthy actor in any society, plus the single-largest owner of land and facilities in a country, purchasing renewable energies for its buildings and offices represents a significant investment in clean technologies and will act as a tremendous catalyst for a fledgling market.

As we have seen with the GERRI initiative, national policies need to be merged with regional and local policies in a manner that will encourage support for actors at all levels. Thus the national government should directly coordinate with regional and local governments to synchronize activities and development. Regional governments can create policies reducing local taxes or providing funding for the development of new projects, modify zoning laws or building codes to encourage renewable energy installation, and assist lower level authorities with planning and education. Perhaps the most important action that local governments can undertake is communication in order to encourage adaptation. Many laws and policies are misunderstood by businesses and individuals when first published, and communication from local representatives can help to allay fears and promote adaptation.

b. Negative Reinforcement

Negative reinforcement policies to encourage increased use of renewable energies in the DOM-TOM will likely be targeted much more at producers than at consumers. Taxes and carbon caps should be emplaced to increase the costs of polluting, as well as the employment of additional taxes on the importation of fossil fuels. Regulations requiring a minimal production amount of energy from renewable sources can also be used to force investment in clean technologies. Additionally, stricter local regulations and protocols for the handling and treatment of fossil fuels will encourage producers to switch to more "user friendly" clean technologies. Stricter environmental and emissions laws will also reduce the leeway given to polluting companies. Finally, additional emphasis can be placed upon inspection and supervision by authorities in order to reduce emissions and pollution. In the end, while there are many other negatively reinforcing policies that can be employed, the use of positive techniques is the preferred technique for modify the behavior of producers, since it presents new opportunities for investment and growth while also providing significant room for each producer to find the growth and development strategy that fits it best.

3. Policies for Energy Efficiency

Policies for increasing energy efficiency are important because the permit the lowering of the overall consumption of energy, which in turn reduces the quantities produced. This in turn lowers total emissions levels and helps to alleviate pressure on producers attempting to grow the share of renewable energies in their production mix. As with the policies for increasing renewable energies, policies that deal with energy efficiency can be both negatively and positively reinforcing, and should be combined with a stable, long-term outlook. One example of an energy efficiency policy that is both positively and negatively reinforcing is the use of peak pricing. By establishing a variable pricing schemes for electricity, consumers can be encouraged reduced consumption during peak hours. If we imagine a higher price level during periods of increased use, and lower prices during periods of inactivity, informed consumers can better choose when to consume their electricity, thus smoothing demand. Combined with smart electric meters, consumers can also have a better understanding of their daily electricity consumption. Higher electric prices, while punishing to consumers, also encourage reduced consumption, while education about energy efficiency positively informs and aids both consumers and producers.

Energy efficiency policies can also have significant financial incentives in order to encourage behavioral change. One striking example already employed in the DOM-TOM is tax rebates for the purchase of solar water heating systems. As explained in the section on solar energy, solar water heating systems use the sun's energy to heat water. With nearly 22,000 systems installed in the DOM-TOM, roughly 12 million liters of fuel equivalent is saved per year, with an accompanying reduction of 34,000 tons of CO^2 per year. [xlix] The sale of these systems is supported by tax rebates of 15-50%, depending on the specific case (location, size, type, etc).[l] While this is an impressive figure, additional efforts to support the installation of solar water heaters could easily spur the growth of this industry, leading not only to reduced electrical consumption and emissions, but also to higher employment and greater tax revenues.

4. Additional Supporting Policies

Given the limited surface area of the DOM-TOM, policies encouraging the use of electric vehicles (EV) might prove to be quite beneficial. Though EV range tends to be very limited at the moment (most EVs average around 30 miles between charges), the small size of the DOM-TOM means that most commutes are quite short. In addition to further reducing the consumption of imported fuels and the emissions of Green House Gases, EVs may also prove to be useful in supporting the local smart grid. Plug-in EVs and hybrids can lend their batteries to supporting the local grid when they are not in use, helping to support peak hour demand or to provide demand leveling. Known as Vehicle to Grid (V2G), some have estimated that plug in cars may provide a value of up to $4,000 a year to electrical companies in their ability to store and provide excess power.[li] Again, while supporting the purchase of new EVs may require significant government support (such as an initiative like the United States' Cash For Clunkers program), the initial costs to the government may be balanced out in the long run through job creation and other benefits such as reduced emissions from vehicles and increased support for French EV manufacturers. EVs will likely require more workers to support the smart grid in the DOM-TOM, and employ more factory workers in France for their production, leading to higher tax revenues, while at the same time resulting in lower emissions.

Biofuels may also be a worthy project to support with new policies in the DOM-TOM. While renewable energies can replace fossil fuels for electricity for homes, offices, and cars, they are not yet ready to power airplanes and most large ships. Thus, in order to encourage job creation and further reduce dependency on imported foreign oil, France can combine policies for energy efficiency and renewable power with those that support the growth of biofuel industries in the DOM-TOM. These fuels will be produced for consumption in airplanes, ships, and for emergency generators in situ if the need arises. While biofuels are equally polluting as regular gasoline when consumed, its production from organic means tends to result in biofuels being carbon neutral. Finally, even if biofuels never fully replace conventional fossil fuels for certain uses, policies encouraging their growth blend in well with other energy and environmental policies, reinforcing the overall impression of sustained and organized development while also creating local jobs.

In conclusion, we must remember that the exact policies employed are less important than the need to present a coherent, organized, and long-term outlook to individuals, businesses, and other actors to encourage lasting behavioral changes.

While the individual policies will change over time, a stable approach is needed to reassure investors and stakeholders and to encourage future development. While some policies might appear to be quite expensive in the short-run, decision makers should maintain a long-term outlook and consider policies to be not just an expense, but also an investment for the future.

Section III

Recommendations and Conclusion

A. Recommendations

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1. Introduction

Electricité de France (EDF) currently has somewhere around 1850 MW of installed electrical capacity, of which roughly 390 MW comes from renewable resources (mostly hydro, as discussed previously in the section on the DOM-TOM). Further, as we have seen with La Réunion and Guadeloupe, consumption of electricity is expected to grow in the coming years, nearly doubling by 2030. Assuming that this doubling of consumption is correct, EDF in the DOM-TOM will be forced to find cost affordable methods of producing roughly 3700 MW by 2030, while also constrained by potentially significantly higher imported fuel costs and additional carbon taxes on emissions in the range of 15-20 Euros per ton. France is today presented with the necessity of choosing between burdensome investments in renewable energies today or a future based upon high-priced and heavily polluting imported fossil fuels that may require substantial military intervention in order to assure supply.

While many point to the significant costs and the technological difficulties of renewable energies as dissuasive basis against investments, the arguments for renewable energies are too persuasive to ignore. I have divided my recommendations for the French people into two sections: actions generic for France (or more relevant for the mainland), and actions specific to the DOM-TOM. These recommendations are, quite obviously, not all-inclusive. However, they should serve as a solid basis for reflection and as a beginning point from which to more profoundly attack the problem of ensuring a reliable, clean, and cost efficient supply of electricity to the DOM-TOM.

No single renewable energy source will be able to provide all of the electricity that the DOM-TOM needs. Even if the potential for electrical generation exists, vagaries such as wind lulls or cloudy days will certainly nullify this potential. Thus, a mixture of renewables is required in order to ensure a constant supply. Further, these energy sources must be in turn supported by new infrastructure such as smart grids and power storage devices. Below, I have provided two different scenarios. In the first, fossil fuels continue to dominate electrical production the DOM-TOM, while the second represents a renewables-heavy portfolio.

Scenario 1: Fossil Fuel Dependant

Fuel Oil produces 3200 MW of electricity at a capital cost of $2.5 to 3.2 billion. Operating costs consist of fuel prices plus carbon taxes. Subsidies for fuel are likely to reach close to $1.5 billion based on today's price of fuel, but could be easily $3 billion or higher if oil prices increase drastically. Pollution is roughly 5.5 billion tons CO^2, requiring that other French industries reduce their emissions in order to permit the country to stay under EU Cap and Trade laws.

The remaining 500 MW of installed capacity is divided between various renewable energies. 380 MW are produced by hydropower, at no additional costs, and with roughly 400 workers. No emissions are produced, and operating costs are considered to be zero. The last 120 MW are divided equally between offshore wind (30 MW at a cost of $225 million, 90 workers), solar (30 MW at $135 million, 225 workers), wave (30 MW at $225 million 90 workers), and biomass (30 MW at $90 million, 90 workers). These production methods are considered to be zero carbon emitters (although biomass emits, the carbon intake involved during the life cycle of its organic fuels implies that it is carbon neutral).

Job creation remains fairly modest under this scenario, with between 400 and 700 total positions for the fuel oil plants, and roughly 1000 workers in renewable energies.

Thus, at a total cost of between $3.1 billion and $3.8 billion, with roughly 5.5 billion tons of CO^2, and with 1400-1700 jobs created or maintained, this option allows for a low capital expansion of electricity production. However, the operational costs are much less predictable due to volatile and increasingly rare fuel supplies, and could easily require double or triple the total amount of subventions from the French government as would be expected in a simple doubling of demand ($1.5 billion).

Scenario 2: Renewable Energy Mix (excluding geothermal for simplicity)

Offshore Wind: 30% of total production (1110 MW), at a cost of $8.4 billion. Zero emissions, a reduction of nearly 2 billion tons of CO^2 emissions from fuel oil. 3,330 positions are created.

Solar Photovoltaic: 30% of total production (1110 MW), at a cost of $5 billion. Zero emissions, a reduction of nearly 2 billion tons of CO^2 emissions (if used in place of fuel oil). 8,325 positions are created.

Hydroelectric Dams: 10% of total production (370 MW). Most of this already exists, and thus any new costs will be solely for renovation or the application of advanced technologies. Zero emissions. 400 workers employed.

Wave Power: 10% of total production (370 MW), at a cost of $3 billion. Zero emissions, replacing 600,000 tons of CO^2 emissions from fuel oil. 1,110 workers employed.

Biomass: 10% of total production (370 MW), at a cost of $1.2 billion. 620,000 tons of CO^2 emissions per year, but considered carbon neutral due to the carbon intake during the growth of the biomass.   1,110 workers employed.

Diesel Turbines: 20% of total production (740 MW). These plants already exists, and will be tasked with provide load balancing production and to serve as emergency power systems (explaining why the total for energy production equals 110%). 620,000 to 1 billion tons of CO^2 emissions are released, though they may be considered carbon neutral if Biodiesel is used. Biofuels may eventually replace the need for importing and storing diesel fuel. 150 workers employed.

In this scenario, we find capital costs are much greater at nearly $27 billion, but operational costs are almost zero. Additionally, pollution has been drastically reduced: even if we consider biomass and biodiesel to not be carbon neutral, CO^2 emissions are less than 1/5th that of the fossil fuel scenario. This will provide greater leeway for other French industries to work underneath the EU ETS system. Additionally, the workforce had dramatically increased, reaching nearly 15,000 workers. These numbers may increase further if energy efficiency policies are enacted as workers are added to sell and install solar water heating systems and other advanced systems. In an area with an average of 25% unemployment, the creation of 10,000 or more new posts will have important consequences for tax returns, social welfare programs, and in stimulating other economic growth. One obvious question is where does the salary for these new employees come from? The answer, of course, is that the elimination of fuel costs compensate for the growth in salary costs.

While $27 billion might seem exorbitantly high, it is important to remember that the renewable scenario permits France to dramatically reduce its dependence on imported fossil fuels. If we imagine that the cost of transitioning the DOM-TOM to a renewable electricity society costs $30 billion, and that subsidies for fuel prices could easily reach $1.5 billion per year due to carbon taxes and growing demand, then the DOM-TOM could have energy independence for the cost of just twenty years of fuel subsidies. Even if the price of renewable electricity reaches $40 billion, this only represents 27 years of fuel subsidies. Further, given the likely hood that fuel costs will rise exponentially over the next 20-50 years, scenarios including fuel subsidies of $5 billion a year are not unrealistic, and would only strengthen the arguments for switching to renewable energy.

In brief, arguments against renewable energies based on excessive costs are, at best, short-sighted and fallacious. Although they are capital intensive, France will end up paying their costs regardless: either through investment in renewable energies, or through subsidies for fossil fuels that grow ever more expensive every year, through the effects of pollution and unemployment, and finally through the costs of the military needed to insure future imports of dwindling fuel reserves. And while actions can be taken to improve the fuel efficiency of coal, oil, and gas plants, or to reduce the emission intensity of these plants, both of these issues fail to truly address the growing predicted rarity of fossil fuels. As even the US military has argued, it is extremely difficult to truly predict the impact such shortages will have upon society and the economy.[lii] Finally, as stated before, not only are fossil fuel power sources highly subsidized, but also renewable energies will continue to achieve ever-greater efficiencies and lower costs with continued investment and growth.

Thus renewable energies, though seemingly excessively expensive, are not just the best option to protect the environment, but they are also the best option to protect the French economy, its national security and to stimulate job growth in the DOM-TOM and in continental France. This paper must therefore recommend that the French government pursue a long-term plan to stimulate its renewable energy industries and the installation of new renewable systems by ensuring that all new installed capacity comes from renewable energies, and by creating a plan to slowly phase out existing fossil fuel plants at the end of their life spans with renewable power sources. An aggressive, long-term plan to create a DOM-TOM powered only by renewable energies will help to ensure energy independence, create new employments, reduce pollution, and over the long-run, reduce total state expenditures.

2. Recommended Actions for France

In the previous section on policies, I detailed a number of approaches that the French government could adapt to spur the growth of not just renewable energies, but also the entire related industry. As stated previously, I believe that the creation of a coherent, long-term, and well-defined global vision is more important then the details of which particular policy is employed and when. Thus, the French government should begin by creating a dialog including actors act all levels, both with-in and outside the DOM-TOM. Besides local, regional, and national politicians, this dialog should include environmentalists, manufacturers, EDF, and any other stakeholder who has a vested interest in subject. Based upon the input of these stakeholders, Multi-Criteria Decision Making tools can be employed to help develop a reasonable compromise to reduce the role of fossil fuels and develop renewable energies over an extend timeline. Upon the creation of this global initiative, efforts should be made to ensure that it is clearly explained to individuals, corporations, and other actors in order to help increase the effectiveness of the plan while easing the doubts and uncertainties inherent in any new sweeping program.

While the costs of replacing all fossil fuel plants in the DOM-TOM at once is far too expensive, a long-term approach that focuses on ensuring all new installed power is renewable and that slowly phases out fossil fuels over the next twenty years is far more viable. There are multiple benefits to such a program: first, it will allow time for increased investment in not just the technologies employed, but also the methods of fabrication to produce renewable power sources. Additionally, seeking to phase-in renewable energies over a longer time period will also allow for the time to develop educational programs, train workers, and develop a better understanding of the employment and impacts of renewable energies. Further, by supporting all renewable technologies without specifically selecting a preferred approach will encourage the development of numerous interrelated technologies and support a market-driven approach. Second, it will allow all the involved actors and stakeholders sufficient time to plan and react to the changing economic and energy environment of the DOM-TOM. This will help to calm fears of the coming changes and help to encourage long-term investment. Finally, taking a long-term approach to the installation of renewable energies in the DOM-TOM will allow for the continued use and slow phase-out of existing production centres when they are reach the end of their life cycle, a much more cost-efficient method of exchanging power generation types.

In the scenarios above I showed a detailed breakdown of power generation by source. However, I do not believe that it is truly necessary to establish precise goals for generation by type. Rather, it would be better to set ranges- for example, a goal of 20-40% generation by solar panels. This would allow for increased flexibility at all levels and also encourage a more market-based approach. Rather than inefficient, top-down direction, a bottom-up, market driven approach will permit individuals and corporations to exploit relative advantages to find the best energy mixes available.

3. Recommended Actions Specific to the DOM-TOM

While the French national government focuses on the “big-picture” of encouraging investment, development, and growth in renewable energy technology and production, and works to develop a long-term vision, the DOM-TOM possessions must focus on integrating national policies with local actions designed to spur education, investment, and smooth the way for long-term development. At the same time that local officials begin to plan and coordinate with regional and national authorities, they should also be aggressive working to explain their actions, the benefits and disadvantages of renewable energies, and to clarify the long-term process.

In terms of education, DOM-TOM officials should work not only to create new training programs for workers involved in renewable energies, but also to inform and educate existing workers, school children, and especially the general public. It is important that taxpayers and local citizens understand the potential costs and benefits to renewable energies, and that policies such as tax rebates on solar water heaters are clearly explained.

In terms of investment, officials should work not only to simplify the processes of building or buying new renewable energy sources, whether roof-mounted solar panels or offshore wind turbines, but also work to simplify and clarify the tax and incentive programs so that they are clearly understood and easily implemented. The most generous tax rebate system for the purchase of solar thermal systems will go under-utilized if not properly explained to and understood by the purchasing public. Additionally, carbon taxes, cap and trade schemes, feed-in tariffs, and pollution laws, and other financial and economic modifiers must be clearly published and explained. Investment policies should be coherent and dedicated towards a long-term vision in order to ensure that investors are confident in their ability to recuperate their investments. Finally, laws and regulations regarding the actual construction, installation, and operation of new technologies should be clearly defined.

B. Conclusion and Final Analysis

Transitioning to a DOM-TOM powered only by renewable energy will not be an easy or cheap process. Nor will it occur over night. Instead, this transition will occur over an extended time frame with new renewable power generation systems being installed to meet rising demand for electricity and will feature a slow and gradual phasing-out of existing power sources. While the costs to the French will be substantial, they will have significant secondary positive impacts, ranging from creating work in a region with an average of 25% unemployment, drastically reducing emissions related to electricity production, stimulating multiple industries in France, and alleviating dependence on imported foreign oil. Additionally, while the costs of spurring renewable energy growth may seem overwhelming, they may prove to be, in fact, far lower than a Business As Usual approach focusing on fossil fuels. Rising prices for oil, coal, and gas, plus increased volatility for these commodities, means that the cost of importing fuel for the DOM-TOM may double or triple in the coming years even as the amount of energy demand grows twofold. It must also be noted that some of the "excess" cost of renewable energies is illusionary, given that the state is already paying large amounts to support unemployment welfare that will be alleviated by increased employment, and also due to the likelihood of most renewables achieving grid parity in pricing within the next 5-15 years.

While the growth of renewable energies in the DOM-TOM and the transition to a clean energy society will require great efforts, detailed planning, and coordination on all levels, it is a feasible and attainable goal. Indeed, examples already exist of successes around the world and even in the DOM-TOM. A stable, forward-looking, and coherent policy, couple with strong political will and efforts to educate and inform the general public will help lead to a successful evolution of the DOM-TOM's energy supply. In the end, despite the high costs of investment and installation, the benefits will far outweigh the disadvantages. Renewable energies, despite their high capital costs, are simply far too advantageous and competitive to all to languish further. Thus, the future of the DOM-TOM should be clear to all: a future powered not by expensive, polluting, imported foreign fuels, but rather by wind and water turbines, solar panels, biomass plants, and geothermal systems designed, built, and operated by French citizens, and which provide clean, inexpensive energy with a minimal negative environmental impact and a strong, positive economic return.

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