Chapter 6 Biomass Energy Resource

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6.1 Introduction

The Biomass Research and Development Act of 2000 (P.L. 106-224; Title III) defines biomass as "any organic matter that is available on a renewable or recurring basis, including agricultural crops and trees, wood and wood wastes and residues, plants (including aquatic plants), grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials." [Schnepf] Biomass is the single renewable resource that has the potential to supplant the US liquid transportation fuels now and help create a more stable energy future. It should also result in new economic opportunities across the US nation. It is unique among renewable energy resources in that it can be converted to carbon-based fuels and chemicals, in addition to electric power.

In his 2007 State of the Union address, President Bush challenged the nation to support a goal to reduce gasoline consumption by 20 percent in the next 10 years (20 in 10) to "reduce our addiction to oil." Meeting these goals will require significant and rapid advances in biomass feedstock and conversion technologies; availability of large volumes of sustainable biomass feedstock; demonstration and deployment of large-scale, integrated biofuels production facilities; and development of an adequate biofuels infrastructure.

Biofuels are liquid fuels produced from biomass. Types of biofuels include ethanol, biodiesel, methanol, and reformulated gasoline components. They are primarily used as transportation fuels for cars, trucks, buses, airplanes, and trains. As a result, their principal competitors are gasoline and diesel fuel. Unlike fossil fuels, which have a fixed resource base that declines with use, biofuels are produced from renewable feedstocks. Furthermore, under most circumstances biofuels are more environmentally friendly (in terms of emissions of toxins, volatile organic compounds, and greenhouse gases) than petroleum products. Supporters of biofuels emphasize that biofuel conversion plants generate value-added economic activity that increases demand for local feedstocks, which raises commodity prices, farm incomes, and rural employment. The conversion technologies refer to a wide array of biological, chemical, thermal (excluding incineration) and mechanical technologies capable of converting post-recycled residual solid waste into useful products and chemicals, green fuels such as hydrogen, natural gas, ethanol and biodiesel, and clean, renewable energy such as electricity. [Schnepf]

6.2 Agricultural Biomass Energy Resource

As mentioned in the previous section biomass is defined as "any organic matter that is available on a renewable or recurring basis, including agricultural crops and trees, wood and wood wastes and residues, plants (including aquatic plants), grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials." In this section waste (municipal, animal and other) will not be considered. In section 6.3, municipal solid waste will be discussed in detail.

6.2.1 Availability of the Resource

According to PUTPR (Plan de Uso de Terrenos de Puerto Rico) there are several categories assigned to the potential land usage in Puerto Rico that is not available for urban developments. The two major categories are:

Suelo Rustico Especialmente Protegido (SREP): *Suelo no contemplado como urbano por su valor estético, arqueológico, ecológico, agrícola y natural.* These are protected due to their archeological, ecological, agricultural and/or natural value.

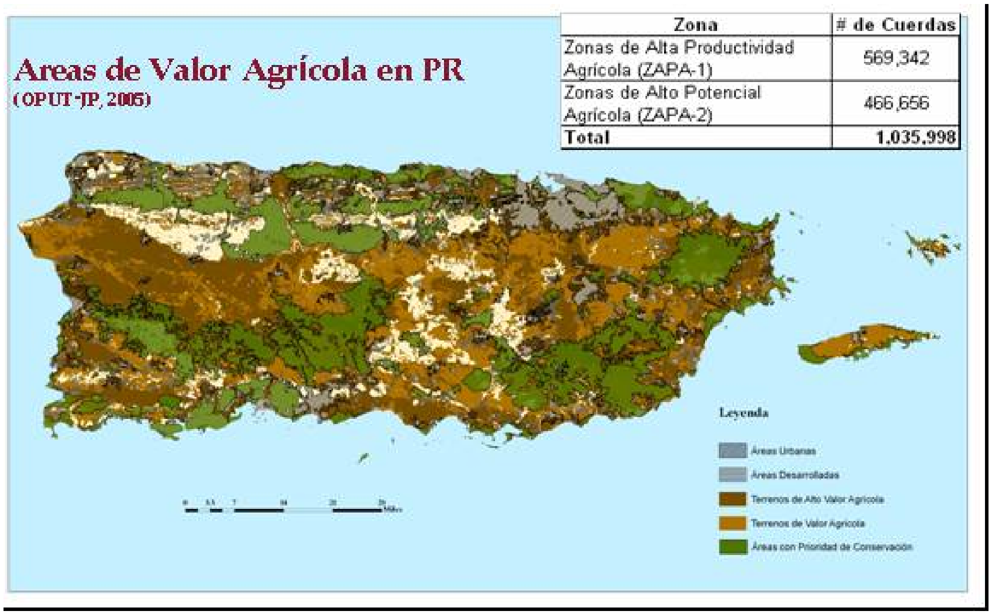
Suelo Rustico Común (SRC): *Suelo no contemplado para uso urbano ya que hay suelo destinado para el uso urbano esperado.* Different to SREP these lands are not protected even though they can not be used for urban development.

In addition, there are two additional categories related to the agricultural potential of a particular zone. These are referred to as:

Zonas de Alta Productividad Agrícola (ZAPA-1): *ZAE's (Zonas Agras Ecológicas) que por la fertilidad, profundidad e historial de rendimiento agrícola* *se consideran áreas de alto valor para la producción agrícola.* These are considered of high productivity potential given their historic performance.

Zonas de Alto Potencial Agrícola (ZAPA-2): *ZAE's con suelos de alto potencial agrícola que bajo buenas practicas de manejo y conservación pueden alcanzar rendimientos similares a ZAPA-1.* Contrary to the previous category these zones could become of high productivity if excellent agricultural practices are implemented.

The following map shows all the zones according to PUTPR. In general, they have identified approximately 570,000 and 465,000 cuerdas as ZAPA 1 & 2, respectively. These correspond to approximately 650,000 and 530,000 acres.



Zona	# de Cuerdas
Zonas de Alta Productividad Agrícola (ZAPA-1)	569,342
Zonas de Alto Potencial Agrícola (ZAPA-2)	466,656
Total	**1,035,998**

Figure 6.2.1-1. Zones with agricultural potential in Puerto Rico.

Regarding the lands that are protected as of February 2006 they are given in the following table:

Table 6.2.1-1. Land use for Puerto Rico, 2006.

Uso de Suelos	# de Cuerdas	% Total de Puerto Rico	% Total de la Categoria
Area de Valor Natural	701,992	32.276%	
Protegidas	238,149	10.950%	33.92%
Sin porteccion	463,843	21.326%	66.08%
Areas de Valor Agricola	1,065,481	48.988%	
Protegidas	86,083	3.958%	8.08%
Sin porteccion	979,398	45.030%	91.92%

Fuente: Plan de Uso de Terrenos - Febrero 2006

Notice that only 4% (86,000 cuerdas) of the agricultural land is protected. In another relevant classification, the Department of Agriculture in 2002 determined that there were approximately 690,000 cuerdas of potential agricultural land without including the agricultural central region. This is shown in the following table. We believe this was their last inventory study.

Table 6.2.1-2. Potential agricultural land, 2002.

Region	Cuerdas	%
Arecibo	160,552	23.25%
San Juan	96,868	14.02%
Caguas	99,141	14.35%
Mayaguez	160,169	23.19%
Ponce	173,963	25.19%
Total	690,693	100%

Fuente: Anotaciones sobre la agricultura de Puerto Rico, Censo de Agricultura, Puerto Rico 2002

Another interesting study was presented by agronomist Jessica Medina Muñiz from the Guaynabo Experimental Station and Colegio de Ciencias Agrícolas from UPRM on November 28, 2007 at the 1er Conversatorio Agrícola - Cumbre Social, Inc.. She included the central region and her other regions were different than those mentioned by the Department of Agriculture shown above. Notice, however, that overall they identified over 500,000 cuerdas as agricultural soil around the island.


Gráfica 1: Uso de suelos agrícolas por región
Puerto Rico (2002)

Fuente: Censo Agrícola Federal 2002, National Agricultural Statistics Service (NASS Area del Caribe)

Figure 6.2.1-2. Agricultural Land use by region.

On a related presentation, agronomist Luis Conte, on January 25, 2008 gave a presentation to the UPRM Biorefinery team where he discussed the agricultural lands from the west region that has immediate potential for agricultural use. He proposed the following:

EUREKA	11,000 CUERDAS
IGUALDAD	2,500 CUERDAS
COLOSO	1,800 CUERDAS
LAJAS	12,000 CUERDAS
TOTAL	27,300 CUERDAS

It should be mentioned that agronomist Conti has been working very closely with the Department of Agriculture and Land Authority identifying alternatives for the agricultural land in the west region especially in Aguada. Their focus, however, has been towards sugar cane production.

Based on the above data, estimates were made regarding the potential production of crops in those areas. For example, notice in the next table that the maximum ethanol production from sugar cane is approximately 1,250 gallons/cuerda-year. This only considers the glucose or sugar component of the sugar cane.

Table 6.2.1-3. Ethanol production by products.

	Min (kL/(hec*año))	Max (kL/(hec*año))	Min (gal/(cuerda*año))	Max (gal/(cuerda*año))
Caña de Azucar	3.8	12	395	1,246
Yuca	0.5	4	52	415
Sorgo	1	5	104	519
Fuente:Biofuels Refining and Performance				

Those productivities were used in the next table to calculate the ethanol production potential for both ZAPA regions. Also, on this table the lignocellulosic component of the sugar cane was included in the calculation of potential ethanol conversion. This results in an overall production of 3.9 billion gallons per year assuming a 3:1 conversion factor in order to include the lignocellulose versus sugars alone.

Table 6.2.1-4. Ethanol production by zone.

Zona y potencial para Caña de Azucar	Zonas de Alta Productividad Agrícola (ZAPA-1)	Zonas de Alto Potencial Agrícola (ZAPA-2)	Total Zonas agricolas
# de Cuerdas	569,342	466,656	1,035,998
Potencial de produccion con azucares y almidones (MM galones)	710	582	1,291
Potencial de produccion con Lignocelulosa (MM galones)***	2,128	1,744	3,873
*** Lignocelulosa = Azucar / Almidon * 3			

Another potential resource are microalgae derived products. Microalgae represent a novel and effective source of biomass and oil for the manufacture of bioethanol and C10+ biofuels. These are microscopic photosynthetic organisms found in marine and freshwater environments. Microalgae are known to accumulate high levels of natural oils and use CO_2 as their sole carbon source [1-4]. Algal biodiesel is one of the only avenues available for high-volume re-use of CO_2. The algae are classified according to their pigmentation, life cycle and basic cellular structure. The four most abundant are Bacillariophyceae, Chlorophyceae, Cyanophyceae and Chrysophyceae. They are also referred to as diatoms, green algae, blue-green algae and golden algae. Microalgae biomass contains three main components: protein, carbohydrates and natural oils. In addition, these organisms are more efficient than higher plants utilizing solar energy because of their simple cellular structure. Because the cells grow in aqueous suspension, they have more efficient access to water, CO_2, and other nutrients and *are capable of producing 30 times the amount oil per unit area of land, compared to terrestrial oilseed crops.* This is shown in the next table. According to National Renewable Energy Laboratory (NREL), two hundred thousand hectares (less than 0.1% of climatically suitable land areas in the U.S.) could produce one quad of fuel. Microalgae systems also use far less water than traditional oilseed crops.

Table 6.2.1-5. Productivity of different crops.

Crop	Kg oil/ha	Litres oil/ha	Lbs oil/acre	US gal/acre
Avocado	2,217	2,638	1,980	282
Coconut	2,260	2,689	2,018	287
Oil palm	5,000	5,950	4,465	635
Chinese tallow	5,500	6,545	4,912	699
Algae	79,832	95,000	71,226	10,000

The characteristics of the algae to be used include the ability of the strains to grow rapidly and have high C10+ productivity when growing under high light intensity, high temperature, and in freshwater or saline waters, indigenous to the area in which the commercial production facility could be located. In addition, because it is not possible to control the weather in pond facilities, the best strains should have good productivity under fluctuation of all of these factors. Algae technology provides a means for recycling waste carbon from fossil fuel combustion.

On a related topic diesel consumption in Puerto Rico is approximately 500 million gallons per year. The following graph shows the extensions of land in terms of municipalities that would be required to meet that demand. For example, assuming 1.4 million gallons/year-1000 hectare (~600 gallons/acre-yr, palm oil) would require approximately 11 municipalities. A topography factor of 2.5 was assumed which is very aggressive regarding land availability. With microalgae the land requirements would decrease to 1/15 of that area or less than a municipality.

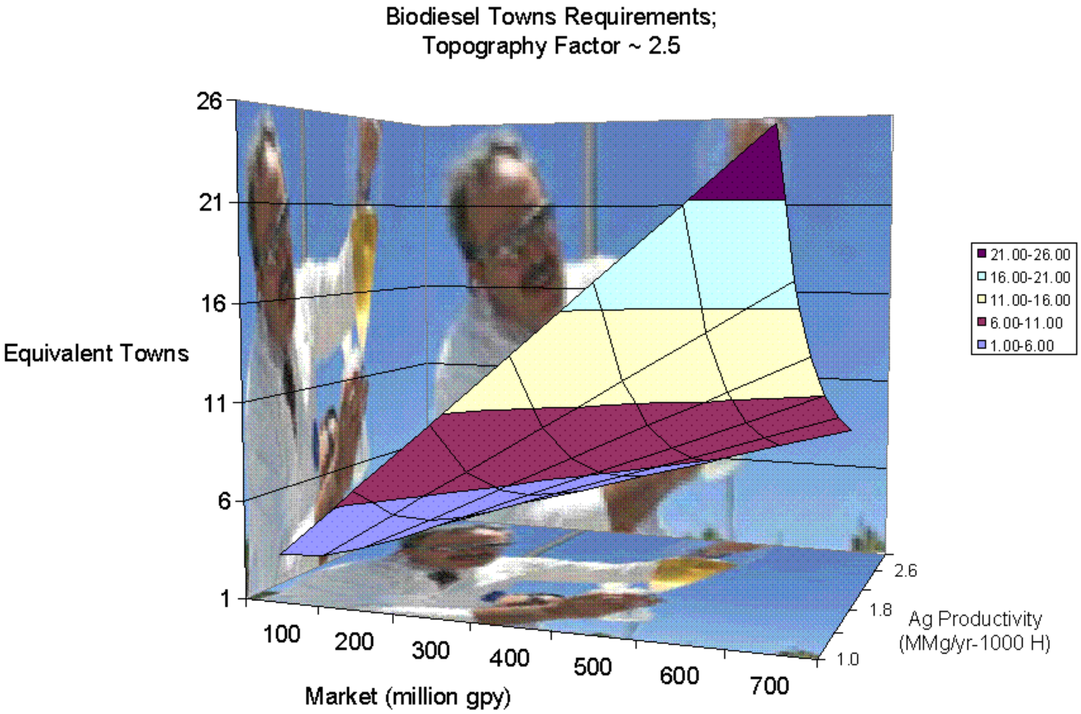


Figure 6.2.1-3. Biodiesel town requirements.

6.2.2 Variability of the Resource

In the Appendix A a chart is provided with the schedule of different crops during the year. It should be mentioned that microalgae derived products is a year round activity.

6.2.3 Available commercial and prototype conversion technology to produce electricity using the resource

Presently there are two technologies that are advancing at a fast pace targeting the lignocellulocic component of the biomass, Fischer Tropsch Fermentation. The former is illustrated in the following figure:

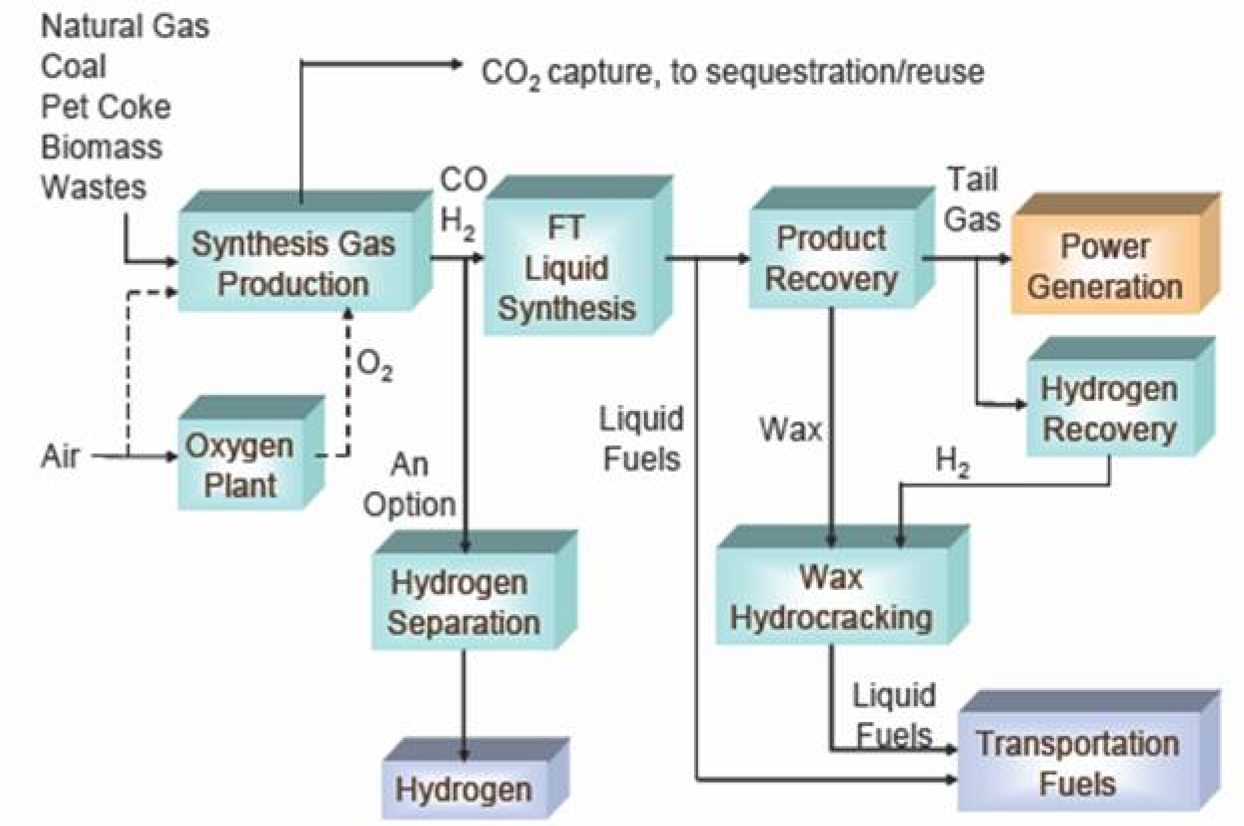


Figure 6.2.3-1. Fischer Tropsch Fermentation.

The Fischer-Tropsch process is a catalyzed chemical reaction in which carbon monoxide and hydrogen are converted into liquid hydrocarbons of various forms. Typical catalysts used are based on iron and cobalt. The principal purpose of this process is to produce a synthetic petroleum substitute, typically from coal, natural gas or biomass, for use as synthetic lubrication oil or as synthetic fuel. This process was developed by Franz Fischer & Hans Tropsch in Germany circa 1920. There is a consensus in the chemical industry that this process can compete versus petro-oil derived fuels and chemicals at $50/barrel of oil.

Another promising technology is fermentation or bioprocessing utilizing microorganisms to convert biomass to valuable chemicals and/or biofuels. Notice that the biomass refers to the lignocellulosic component and not sugars and/or starches. Biomass is a very complex raw material composed of a wide variety of compounds with C5 and C6 sugars and phenolics building blocks. This variety has made it very difficult in identifying microorganisms capable of processing these materials. In the *Solid Waste Biomass Energy Resource* section these and other technologies are discussed in more detail.

The technology for growing and harvesting microalgae is obviously very different than their soil counterparts. Typically, Algae, water and nutrients circulate around a racetrack as shown in the figure. Paddlewheels provide the flow.

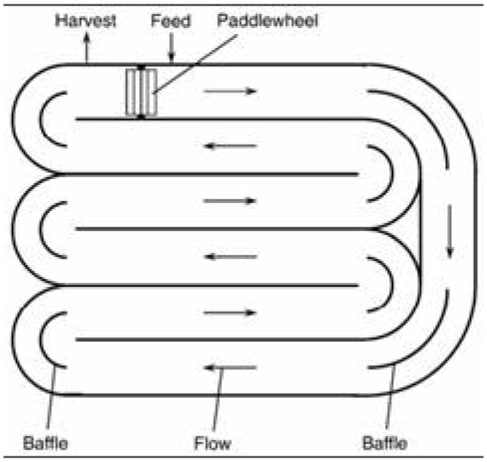
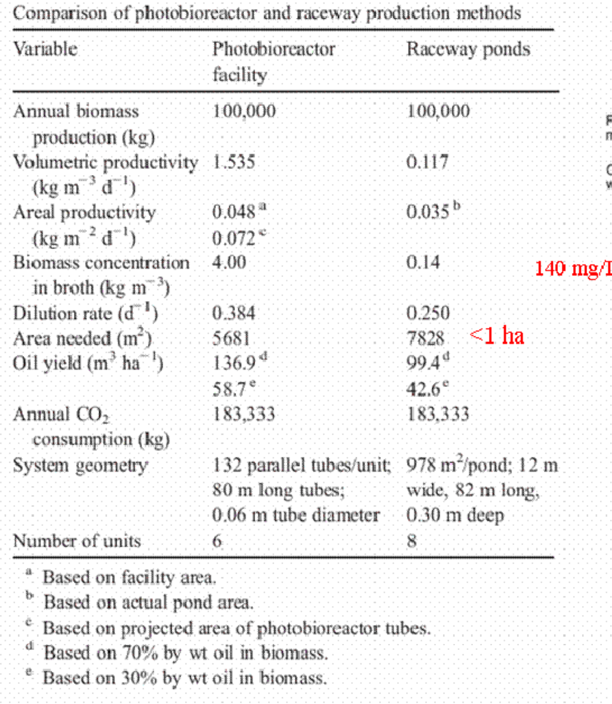


Figure 6.2.3-2. Racetrack for growing microalgae.

The algae are thus kept suspended in water. Algae are circulated back up to the surface on a regular frequency. The ponds are kept shallow because of the need to keep the algae exposed to sunlight and the limited depth to which sunlight can penetrate the pond water. The ponds are operated continuously; that is, water and nutrients are constantly fed to the pond, while algae-containing water is removed at the other end. Some kind of harvesting system is required to recover the algae, which contains substantial amounts of natural oil”. Another alternative is using biophotoreactors which in theory could result in higher productivities and better control. A comparison between raceway ponds and biophotoreactors is shown in the next figure.



Comparison of photobioreactor and raceway production methods

Variable	Photobioreactor facility	Raceway ponds
Annual biomass production (kg)	100,000	100,000
Volumetric productivity ($kg\ m^{-3}\ d^{-1}$)	1.535	0.117
Areal productivity ($kg\ m^{-2}\ d^{-1}$)	0.048^{a} 0.072^{c}	0.035^{b}
Biomass concentration in broth ($kg\ m^{-3}$)	4.00	0.14
Dilution rate (d^{-1})	0.384	0.250
Area needed (m^2)	5681	7828 <1 ha
Oil yield ($m^3\ ha^{-1}$)	136.9^{d} 58.7^{e}	99.4^{d} 42.6^{e}
Annual CO_2 consumption (kg)	183,333	183,333
System geometry	132 parallel tubes/unit; 80 m long tubes; 0.06 m tube diameter	978 m^2/pond; 12 m wide, 82 m long, 0.30 m deep
Number of units	6	8

[a] Based on facility area.
[b] Based on actual pond area.
[c] Based on projected area of photobioreactor tubes.
[d] Based on 70% by wt oil in biomass.
[e] Based on 30% by wt oil in biomass.

140 mg/L, 140 ppm

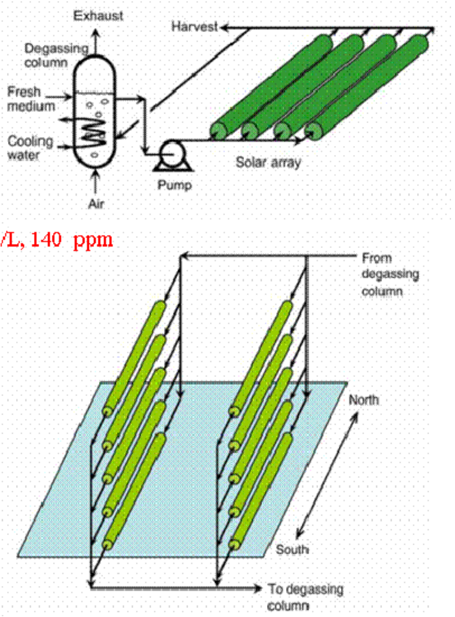


Figure 6.2.3-3. Comparizon of photobioreactor and raceway production methods.

It is important to mention that both biophotoreactors and racetrack ponds are still in the development sage especially for production facilities in the hundreds and thousands land requirements. Presently, commercial microalgae facilities are used for producing specialty chemicals such as nutraceuticals, nutriceuticals, β-carotene, vitamins, amino acids, omega acids, etc. These are typically in the 50 – 100 acre range. Notice that nutriceuticals are defined as one of a class of agents advertised as having nutritional value as well as having an effect on biologic functions. Also, nutraceuticals is a chemical substance or group of substances that for legal purposes is defined as a nutrient but that is marketed and used for the prevention or treatment of disease.

Based on the above discussion it is recommended that an integrated approach is used for production and conversion of biomass to value added chemicals and products including energy. This is known as a biorefinery. It is defined by the

National Renewable (NREL) as a facility that integrates biomass conversion processes and equipment to produce fuels, power or chemicals from biomass. UPRM in collaboration with Sustainable AgroBiotech Inc is proposing the model below for Puerto Rico which integrates land crops with microalgae developments for producing a wide variety of fuels and chemicals.

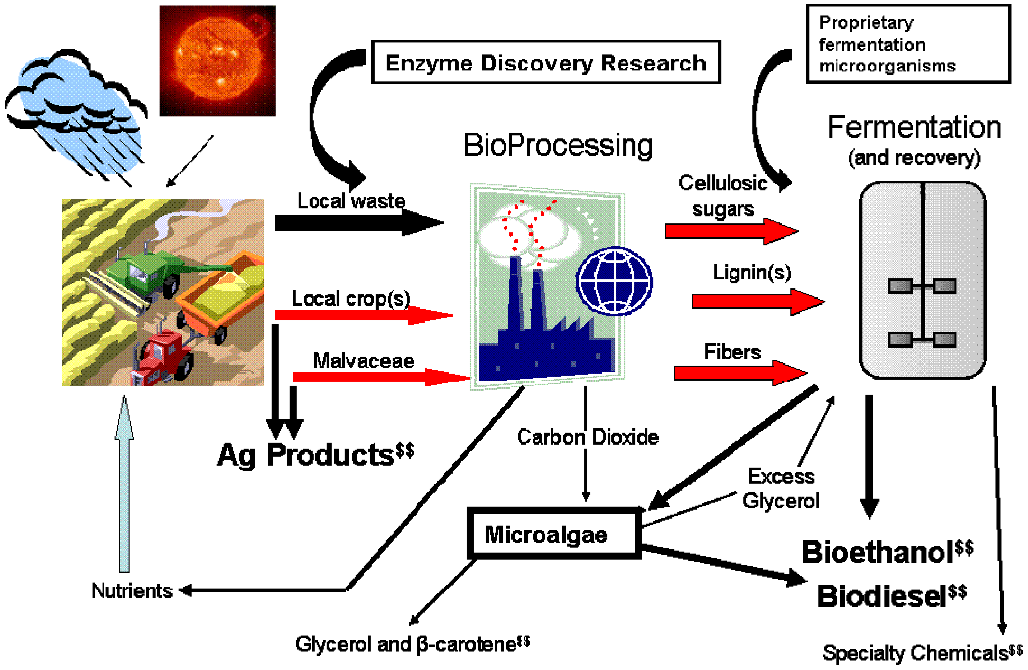


Figure 6.2.3-4. Biorefinery Model.

6.2.4 Conversion Technology footprint

The major component of the footprint regarding Biomass Energy Resource is by far the land and area requirements for the production of the biomass. This applies to both soil crops and microalgae. These area requirements were discussed in the previous section.

6.2.5 Estimate of capital cost

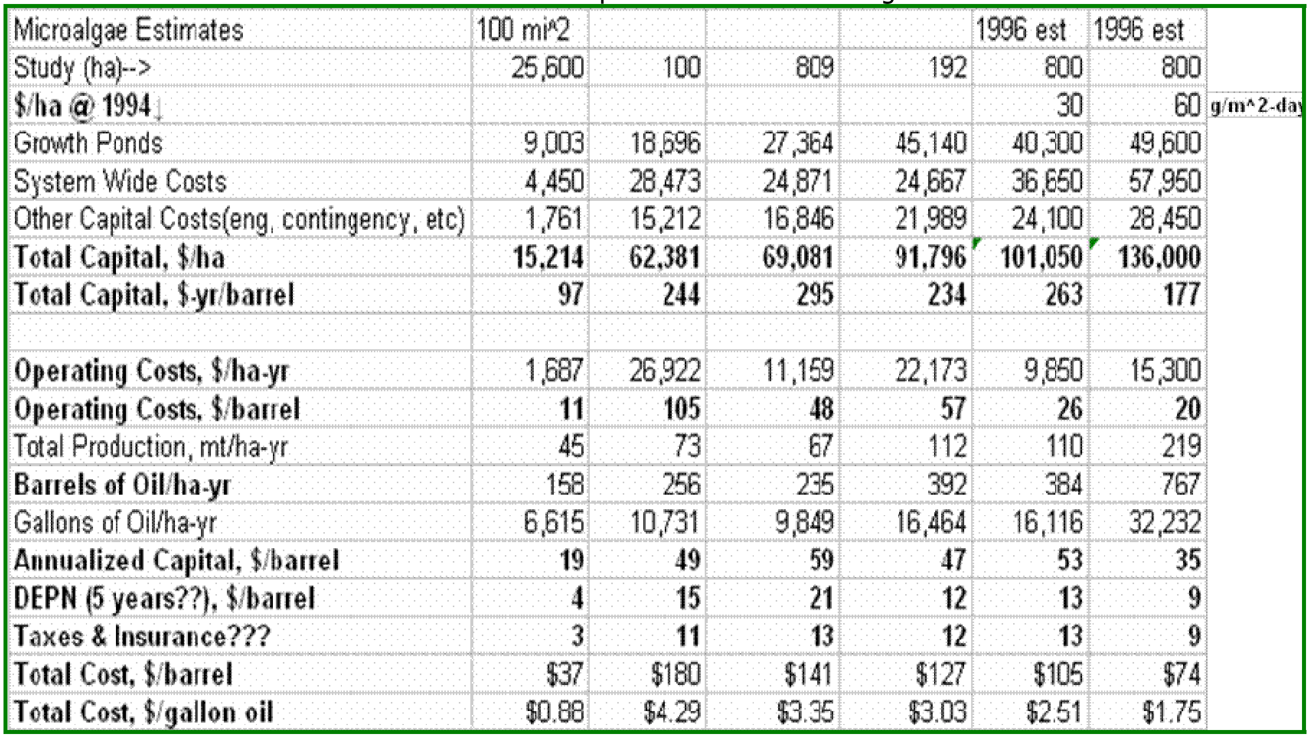
As mentioned above, the production of biofuels and/or chemicals from biomass is being considered using a biorefinery strategy. These developments have advanced rapidly in the last three to five years given the increase and instability of crude oil. However, they are in the development/scale up stage. For example, DOE announced on recently (February 2008) that it will invest $114 million in four small-scale biorefinery projects over four years. These small-scale biorefineries will use a wide range of feedstocks to test conversion technologies for the production of cellulosic ethanol. The new biorefineries—to be built in Colorado, Missouri, Oregon, and Wisconsin—are expected to produce about 2.5 million gallons a year of ethanol, as compared to the 20-30 million gallons that a full-sized facility can produce. The news follows the February 2007 announcement that DOE was investing $385 million for the development of six commercial-scale biorefineries. The six full-scale biorefineries are employing near-term commercial processes, while the four small-scale facilities will experiment with diverse feedstocks and novel processing technologies. A summary of these investments is provided in the table below.

Table 6.2.5-1. Investments in Biorefineries By DOE.

Biorefineria	Inversión en Millones	Plantas	Millones por planta	Producción en millones de galones por año	Costo por galón
A pequeña escala	114	4	28.50	2.50	11.40
A gran escala	385	6	64.17	30.00	2.14

Another area where capital and operating costs require further studies are microalgae. In the following table the results from several cost estimate studies for biofuel production from microalgae are summarized. Notice that the capital costs are divided in three main components; growth ponds, system wide costs and other capital. The latter applies standard percentages based on the former two costs. Notice the wide range in total cost calculated based on $/gallon of oil. This includes both capital and operating costs.

Table 6.2.5-2. Costs for biofuel production from microalgae.



Microalgae Estimates	100 mi^2				1996 est	1996 est	
Study (ha)-->	25,600	100	809	192	800	800	
$/ha @ 1994					30	60	**g/m^2-day**
Growth Ponds	9,003	18,696	27,364	45,140	40,300	49,600	
System Wide Costs	4,450	28,473	24,871	24,667	36,650	57,950	
Other Capital Costs(eng, contingency, etc)	1,761	15,212	16,846	21,989	24,100	28,450	
Total Capital, $/ha	**15,214**	**62,381**	**69,081**	**91,796**	**101,050**	**136,000**	
Total Capital, $-yr/barrel	**97**	**244**	**295**	**234**	**263**	**177**	
Operating Costs, $/ha-yr	1,687	26,922	11,159	22,173	9,850	15,300	
Operating Costs, $/barrel	**11**	**105**	**48**	**57**	**26**	**20**	
Total Production, mt/ha-yr	45	73	67	112	110	219	
Barrels of Oil/ha-yr	158	256	235	392	384	767	
Gallons of Oil/ha-yr	6,615	10,731	9,849	16,464	16,116	32,232	
Annualized Capital, $/barrel	**19**	**49**	**59**	**47**	**53**	**35**	
DEPN (5 years??), $/barrel	**4**	**15**	**21**	**12**	**13**	**9**	
Taxes & Insurance???	**3**	**11**	**13**	**12**	**13**	**9**	
Total Cost, $/barrel	$37	$180	$141	$127	$105	$74	
Total Cost, $/gallon oil	$0.88	$4.29	$3.35	$3.03	$2.51	$1.75	

This is better summarized in the following figure. Notice that there is no consensus whether operating or capital expenditures dominate the cost structure of this business. In addition, all the cases were analyzed for 1,000 acres or less.

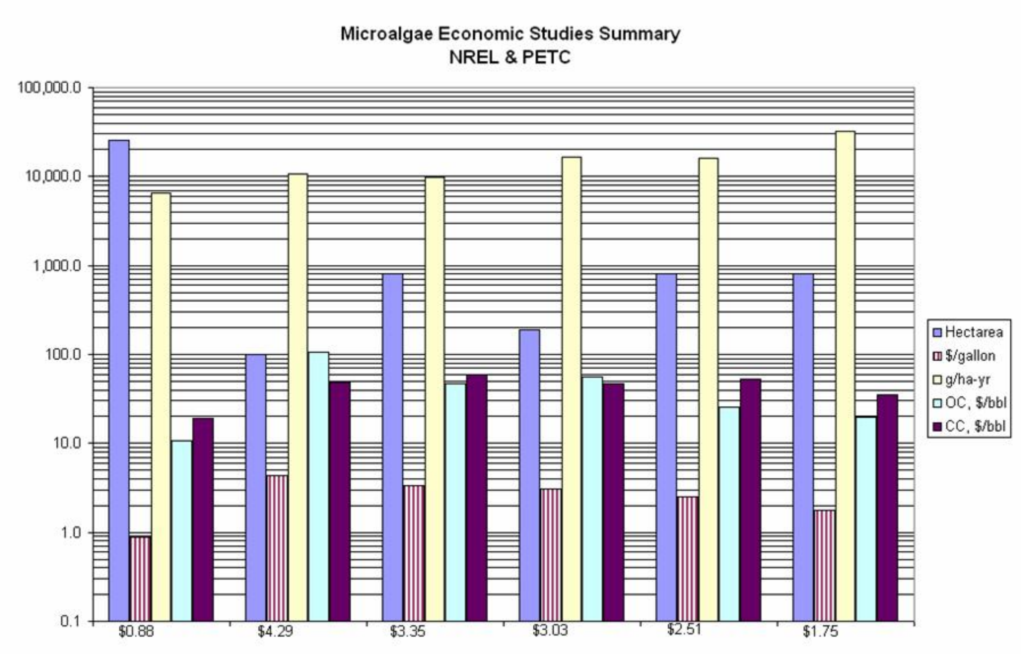


Figure 6.2.5-1. Microalgae Economic Studies Summary.

The previous data was used to estimate the total costs for producing oils in larger ponds (>1,000 acres). This is shown in the following figure. Notice that the $2/gallon threshold apparently will require microalgae plantations that exceed 1,000 hectare.

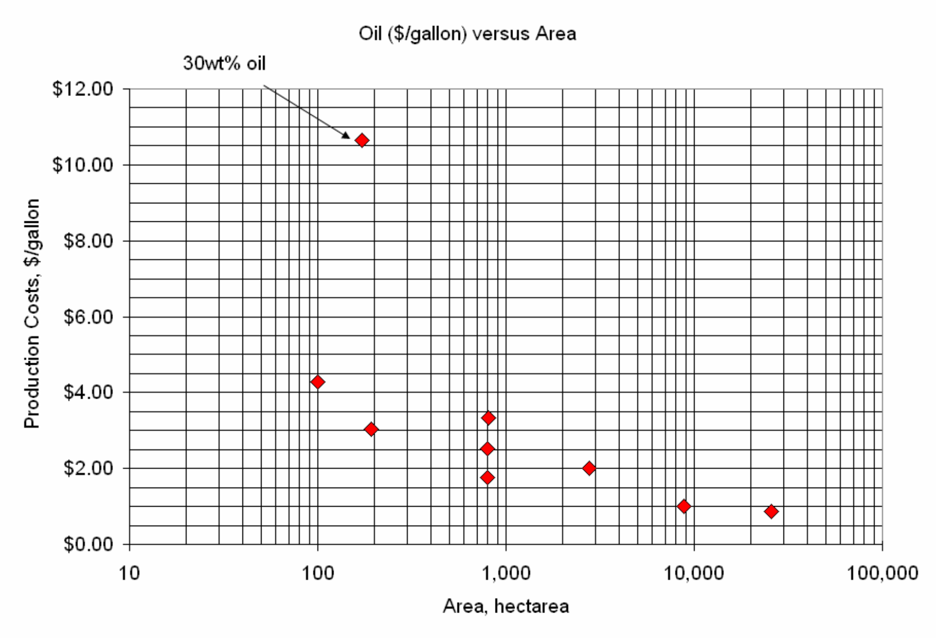


Figure 6.2.5-2. Total costs for producing oils in larger ponds (>1,000 acres)

On a related topic, carbon credits should be considered as a potential source of income for microalgae and other biobased fuels. In the following figure estimates are shown regarding the income that could be generated by a utility by selling their flue gas for these developments. Notice that a 400 MW facility could generate 50 million dollars per year at \$15/ton of CO_2. In Europe the carbon credit trading market already exceeds this value.

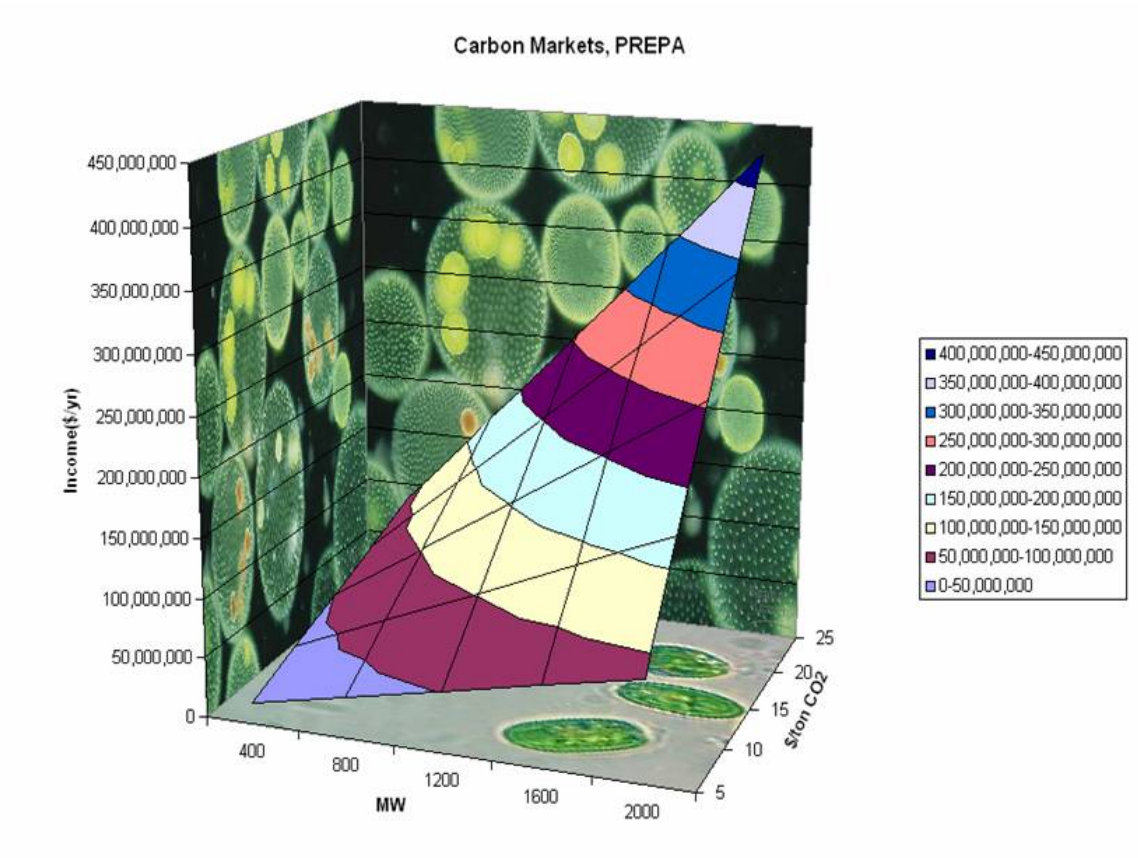


Figure 6.2.5-3. Carbon Market, PREPA

6.2.6 Estimate of potential electric energy contribution

Biomass is unique among renewable energy resources in that it can be converted to carbon-based fuels and chemicals, in addition to electric power. The previous discussion focused mainly on the conversion to carbon-based fuels and chemicals. However, biomass could be combusted directly and used for producing electric power. For example, using the two ZAPA zones as a basis, they would generate approximately 4.0 billion gallons per year of fuel. This translates into 4.5 GW generation potential. This is a very optimistic estimate that would require 1 million cuerdas in addition to assuming total utilization of the biomass generated. Utilizing biodiesel as an example, approximately 20% of the energy would be required for the harvesting and conversion. It must me emphasized that this analysis is very preliminary and required further elaboration.

6.2.6.1 References for Biomass Energy Resource and Technologies

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6.3 Solid Waste Biomass Energy Resource

6.3.1 Availability of the Resource

Most of the information provided here was obtained from the *Itinerario Dinámico* that was developed by the Puerto Rico Solid Waste Management Authority. For example, the next table shows the municipal solid waste profile in Puerto Rico in 2006 and projections thereafter. In addition to this resource Puerto Rico also has the municipal solid waste that is already buried in the landfills and agricultural waste.

Table 6.3.1-1. Municipal solid waste profile and projections in Puerto Rico, 2006.

			Proyecciones de generación de desperdicio sólidos (Toneladas/día)					
			2006	2010	2015	2020	2025	2030
Categoría		% del peso	10,998	11,204	11,427	11,599	11,716	11,833
Platico	Polietileno tipo 1	1.1	121	123	126	128	129	130
	Polietileno de alta densidad (HDPE) tipo 2	2.9	319	325	331	336	340	343
	Tipo 3-7 (PVC, LDPE, PP, PS, Mezclado)	6.5	715	728	743	754	762	769
Papel-Cartón	Papel de alta calidad	1.3	143	146	149	151	152	154
	Papel de baja calidad	8.7	957	975	994	1,009	1,019	1,029
	Cartón Ondulado	9.3	1,023	1,042	1,063	1,079	1,090	1,100
Metal	Metal ferrosos	9.4	1,034	1,053	1,074	1,090	1,101	1,112
	Metales no-ferrosos	1.1	121	123	126	128	129	130
Jardinería	Material vegetal	20.4	2,244	2,286	2,331	2,366	2,390	2,414
Orgánico	Material orgánico	12.9	1,419	1,445	1,474	1,496	1,511	1,526
C&D	Escombro de contracción y demolición	17.1	1,881	1,916	1,954	1,983	2,003	2,023
Vidrio	Todo tipo de vidrio	2.4	264	269	274	278	281	284
HHW	Desperdicio peligroso caseros	0.5	55	56	57	58	59	59
Otros	No definido de otra manera	6.4	704	717	731	742	750	757
Total		100%	10,998	11,204	11,427	11,599	11,716	11,833
Fuente: Itinerario Dinámico, 2007								

Based on the table, above it is estimated that approximately 11,000 tons/day of municipal solid waste is generated in Puerto Rico. On a per capita basis this translates into approximately 5.8 lbs/day-person which is one of the highest in the world. As will be discussed in the next sections only certain portions of this waste can be converted into energy directly and/or into fuels. The agricultural sector is another source of waste with energy/fuels potential possibilities. This was mentioned in the Biomass Resource section. Mainly the focus was that a biorefinery philosophy must be adopted in order to utilize all the biomass generated by crops. One interesting example of the pineapple industry. In 2004, they produce approximately 25,000 tons of *Red Spanish* variety pineapples per year. The total annual sales revenue was approximately six million dollars. However, the trees and processing produce approximately 170,000 and 10,000 tons per year of solid waste, respectively. This agricultural industry has a critical need for sound and efficient green approaches to minimize its inherent environmental impact especially in a small island like Puerto Rico. Again, a biorefinery operating philosophy should be seriously considered.

Regarding the material already deposited in the landfills, Dr. Colucci's group performed a preliminary study in 2001 estimating the potential of this resource for generating and recovering methane for electricity generation. The next pie chart shows that as of 2001 approximately 81.7 million tons were deposited.

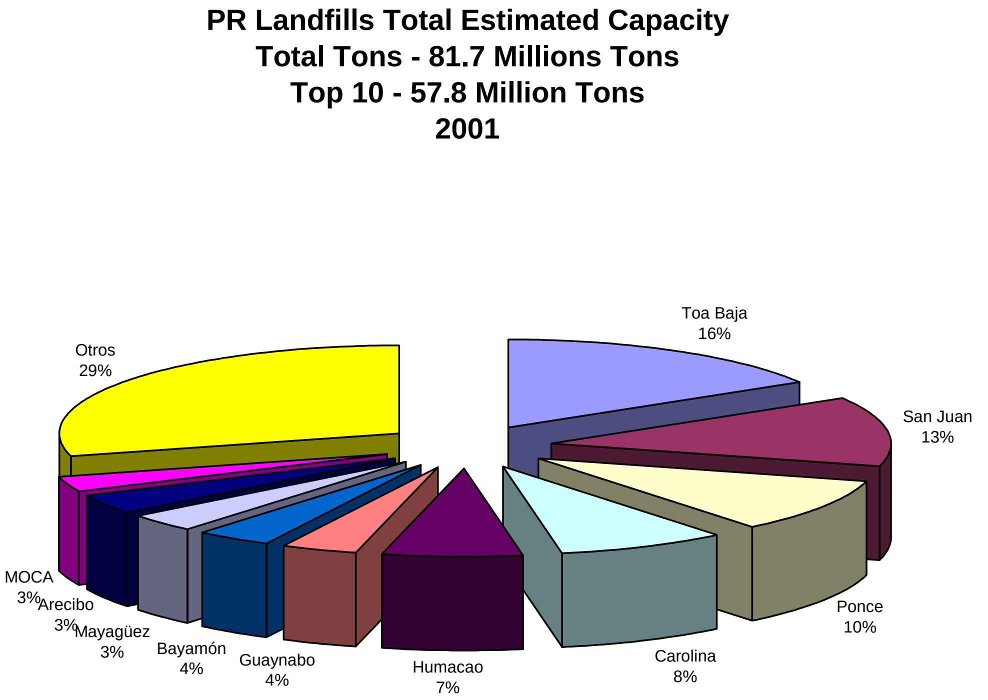
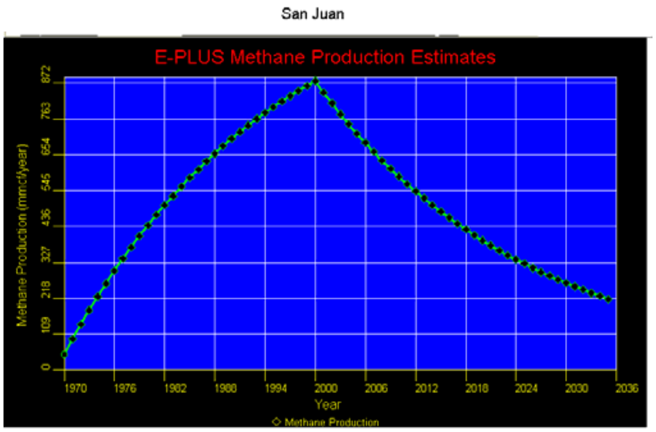
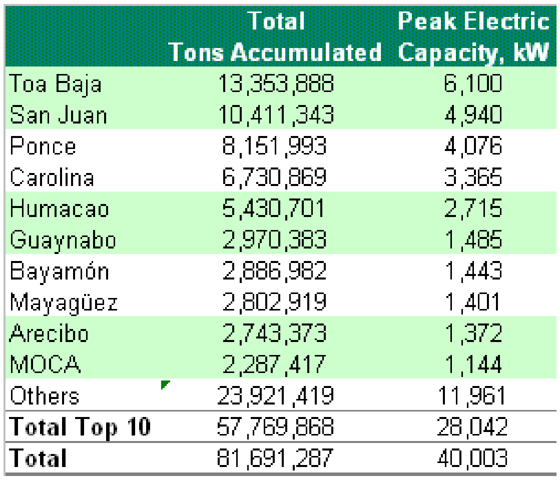


Figure 6.3.1-1. Potential of landfills for electricity generation

Using 10,000 tons/day and extrapolating forward from 2001 to 2008 will increase the capacity to 110 million tons. In this analysis the Energy Project Landfill Gas Utilization Software (E-Plus) from the Environmental Protection Agency was used to estimate the energy (via methane processing) generation potential of these landfills. The next figure shows a typical output if this program for the San Juan Landfill. In general, the generated methane is used to calculate the electric capacity potential of the landfills. In the overall analysis, a top ten approach was used, which are the ones shown in the chart and the following table. Notice that the top ten accounts for 70% of the total capacity. In the table also notice that peak electric capacity barely reaches 40 MW for all the landfills (28 MW for the top 10). Notice that this electric generation capacity corresponds to approximately 10 MW/1,000 tons/day, which is lower than the proposed 30 MW/1,000 tons/day for a fresh feed facility. For this comparison a 15 year lifetime was assumed for the operation of an energy generation facility in the landfill and only 30% was considered as digested to methane.





	Total Tons Accumulated	Peak Electric Capacity, kW
Toa Baja	13,353,888	6,100
San Juan	10,411,343	4,940
Ponce	8,151,993	4,076
Carolina	6,730,869	3,365
Humacao	5,430,701	2,715
Guaynabo	2,970,383	1,485
Bayamón	2,886,982	1,443
Mayagüez	2,802,919	1,401
Arecibo	2,743,373	1,372
MOCA	2,287,417	1,144
Others	23,921,419	11,961
Total Top 10	57,769,868	28,042
Total	81,691,287	40,003

Figure 6.3.1-2. Energy generation potential of these landfills

It should be mentioned that in the Itinerario Dinámico it is assumed that some of the material will be utilized for other applications such as compostas. This was taken into consideration in the analysis that was performed and discussed in future sections. PRSWMA proposes that three composting facilities are operated in the north, south and east zones. It is estimated that they will have a combined capacity of 500 tons/day.

Table 6.3.1-2. Composting facilities for Puerto Rico.

	Toneladas por día	Entra en operación
Planta Norte	200	2008
Planta Sur	200	2010
Planta Este	100	2010
Total	500***	
Fuente: Itinerario Dinámico, 2007		

6.3.2 Variability of the Resource

In the early 1990's Eco Futures performed a solid waste characterization study in Puerto Rico where they considered "wet and dry" season. Most likely they suspected that differences will be observed especially regarding the biomass component or *material vegetal.* The data that was readily available was from the former. The assessment study classified the garbage generated in Puerto Rico under ten major items: (1) paper, (2) cardboard, (3) yard waste, (4) putrescibles, (5) grit, (6) plastics, (7) ferrous metals, (8) non-ferrous metals, (9) glass, and (10) other (unclassified waste). The study quantified the amounts of garbage as classified in the ten items above for the municipalities of Aguadilla, Arecibo, Guayama, Guaynabo, Humacao, Jayuya, Mayagüez, Ponce, San Germán, Toa Alta, San Juan and Aibonito. The study also quantified the total MSW generated in 56 municipalities of the island, including the islands of Vieques and Culebra. It is not clear whether substantial differences were observed or even if the comparison was made between the wet and dry seansons. It should be mentioned, however, that based on conversations with Induchem personnel there are significant differences in the content of the scum of wastewater treatment plants between weekends and week days. Similar behavior is probably expected for solid waste generation.

6.3.3 Available commercial and prototype conversion technology to produce electricity using the resource

The conversion technologies available for Solid Waste Biomass Resource are very similar to the generic Biomass resource. This is part due to their similarities, solids, carbon containing materials, heterogeneity, etc. As mentioned earlier certain states even considered solid waste as a biomass. In general, **Conversion technologies** refer to a wide array of biological, chemical, thermal (excluding incineration) and mechanical technologies capable of converting post-recycled residual solid waste into useful products and chemicals, green fuels such as hydrogen, natural gas, ethanol and biodiesel, and clean, renewable energy such as electricity. They could effectively enhance recycling and beneficial use of waste, reduce pollution such as greenhouse gas emissions, and reduce dependence on landfilling and imported and domestic fossil fuels. The following provide a brief description of these technologies divided into **Thermochemical** and **Biochemical** conversion processes:

Thermochemical conversion technologies Gasification and Pyrolysis are technologies that use high heat that can treat nearly the entire organic fraction of municipal solid waste. Thermochemical processes can convert potentially all the organic portion of the waste stream that is currently going to landfill into heat and other useful products.

- **Gasification** is a process that converts solid or liquid carbon-based materials by direct or indirect heating at high temperatures, typically above 1300^{o}F. For direct heating, partial oxidation occurs where the gasification medium is steam and air or oxygen. Indirect heating uses an external heat source such as a hot circulating medium and steam as the gasification medium. Gasification produces a fuel gas (synthesis gas, producer gas), which is principally carbon monoxide, hydrogen, methane, and lighter hydrocarbons in association with carbon dioxide and nitrogen depending on the process used. It offers the capability of producing a broader array of products such as electricity, alternative fuels such as ethanol and diesel, and chemical precursors.

- **Pyrolysis** is also a high heat technology but differs from gasification in that there is no oxygen employed in the process. Temperatures for pyrolysis processes range from 750^{o}F to 1500^{o}F.

The following is a schematic from the Air Force Research Laboratory illustrating the production of jet fuel using either gasification combined with Fisher Tropsch or Pyrolysis with hydroprocessing.

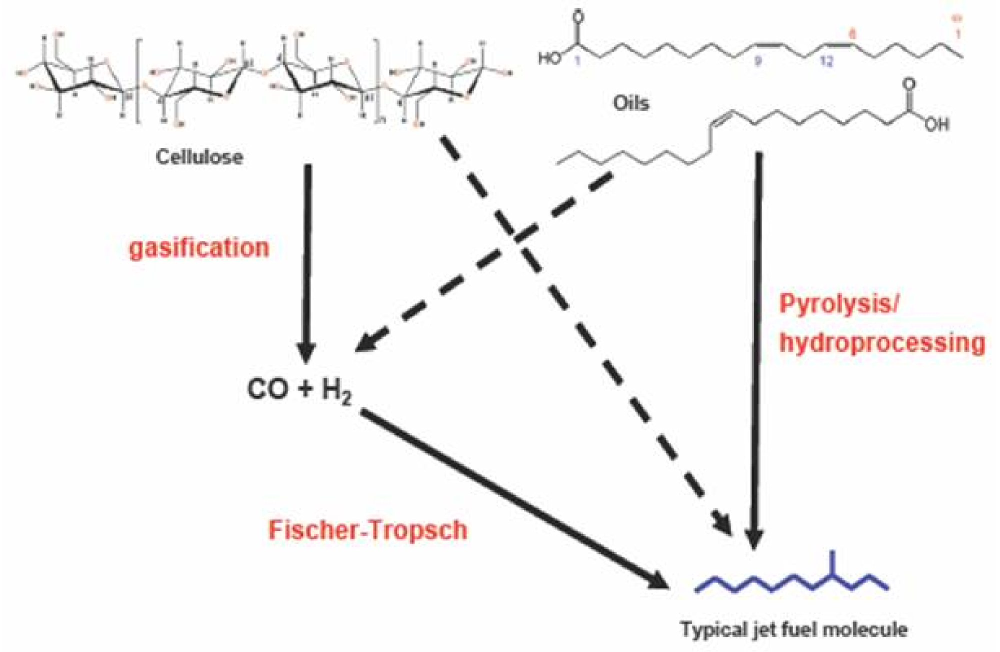


Figure 6.3.3-1. Production of jet fuel using either gasification combined with Fisher Tropsch or Pyrolysis with hydroprocessing.

Biochemical conversion technologies such as anaerobic digestion and fermentation operate at lower temperatures than thermochemical technologies. They are more limited in their application since they can only process biodegradable feedstocks.

- **Anaerobic** digestion is the bacterial breakdown of organic material in the absence of oxygen and can occur over a wide temperature range from 50° to 160°F. The reaction temperature has a very strong influence on the anaerobic activity, but there are two optimal temperature ranges in which microbial activity and biogas production rate are highest, mesophilic and thermophilic temperature ranges. Mesophilic systems operate at temperatures around 95ºF and the thermophilic systems operate at a temperature around 130ºF. Operation at thermophilic temperatures allows for shorter retention time and a higher biogas production rate, however, maintaining the high temperature generally requires an outside heat source because anaerobic bacteria do not generate sufficient heat. These biological processes produces a gas principally composed of methane (CH4) and carbon dioxide (CO2) but also has impurities such as hydrogen sulfide (H2S).

- **Fermentation** is also an anaerobic process and is used to produce alcohols and other chemicals. Feedstocks containing cellulose, a long-chain molecule made up of linked glucose sugar, need a treatment step called hydrolysis to break up the larger chain of sugars into basic sugars so yeasts and bacteria can process the sugars to make an alcohol such as ethanol. Cellulose and hemicellulose (a 5-carbon sugar) can be hydrolyzed using acids, enzymes, or a hydrothermal method called steam explosion.

The following table summarizes are typical products from the above processes:

Table 6.3.3-1. Biochemical conversion technologies

Conversion Technology	Primary Product	Secondary Products	Solid Residues	Value of secondary products	Feedstocks Processed
Complete gasification	Synthesis gas	Fuels, chemicals and electricity	Ash metals recycle or landfill	Very high and flexible	All organics low moisture
Incomplete gasification (See pyrolysis)	Fuel and synthesis gas	Electricity, some marketable fuels	Char ash metals recycle	Moderate may need refining at additional expense	All organics low moisture
Indirectly fired pyrolysis with drier & gasifier	Fuel and synthesis gas	Electricity, some marketable fuels	Char ash metals recycle or landfill	Moderate may need refining at additional expense	All organics low moisture
Anaerobic Digestion	Fuel Gas (CH_4 and CO_2)	Heat, Power, Fuels, Chemicals, Soil Amendment	Inorganics, metals, glass, undegraded biomass	Moderate to High	Biodegradable Components
Fermentation	Ethanol	Ethanol, Chemicals, Heat, Soil Amendment	Inorganics, metals, glass, undegraded biomass	Moderate to High	Biodegradable Components

It should be mentioned that the Los Angeles County in California recently evaluated several technologies to convert their solid waste into value added products. They narrowed down their search to five companies/technologies. These are shown in the following table. Notice that four out of the five are thermal conversion technologies. Also notice that the processing rage is between 200 to 400 tons per day per unit. In addition, the emphasis was on producing electricity. The anaerobic digestion system also produces composting material. One of the technologies produces renewable diesel.

Table 6.3.3-2. Technology Supplier.

Technology Supplier	Technology Type	Proposed Capacity	Major Products
Arrow Ecology and Engineering (Arrow)	Anaerobic Digestion	300 tpd	Biogas (Electricity) Digestate (Compost) Recyclables
Changing World Technologies (CWT)	Thermal Depolymerization	200 tpd	Renewable Diesel Carbon Fuel Metals
International Environmental Solutions (IES)	Pyrolysis	242.5 tpd @ 58.9% moisture 125 tpd@ 20% moisture	Syngas (Electricity)
Interstate Waste Technologies (IWT)	Pyrolysis / High Temperature Gasification	312 tpd (1 unit) 624 tpd (2 units) 935 tpd (3 units)	Syngas (Electricity) Mixed Metals Aggregate
Ntech Environmental (NTech)	Low Temperature Gasification	413 tpd	Syngas (Electricity)

6.3.4 Conversion Technology footprint

Centralized waste conversion processing facilities only required 10-50 acres depending on the buffering zone that is required and capacity. In general foot print is a lesser issue for these centralized units than the location. Depending on the technology, they can generate strong opposition from nearby communities as well as environmental groups. Concerns can vary from odors to health effects related to the formation of pathogens (digestors), dioxins and furans. The latter two are associated with thermal processing units such as gasification and incinerators.

“Local” conversion units such as those proposed for existing landfills require much less area than centralized facilities. This would include a building where the gas purification system and energy generation units will be located. It is suspected that the foot print of these local units is a minor issue given the large extensions of land available at landfills.

6.3.5 Estimate of capital cost

In general, waste to energy/products facilities are relatively expensive when compared to their chemical and/or petrochemical facilities. This is based on their raw material processing capacity. For example, a biodiesel production facility capital investment is approximately $0.05 – $0.15/pound versus $2.5 - $3.0/pound for a waste to energy facility. Operating costs are also much higher for the latter. This difference can be attributed in part to the stricter controls required for waste to energy facilities.

As a rule of thumb the investment for waste to energy facilities is approximately $200 - 250 Million per 100 TPD capacity. As with other large volume processing technologies they have benefit of scale although not as much as other processes. Preliminary estimates indicate that their scale up index is between 0.8-0.9 versus 0.6–0.7 for other chemically based processes. This is part due to the modularity of their line processing units. Notice in the previous section that processing lines are in the rage 200-400 tons per day. Additional capacity is obtained by adding processing lines with their respective down stream units.

Another important component of the cost structure of waste to energy facilities is the nature of their income. This is better explained with the next figure that shows the operating income lines required to recover the capital investment of different facilities. Most of the income of these facilities result either from tipping fees and electricity. In the graph the line TF=EI shows when both are equivalent. This is the case for $70/ton and approximately $0.10/kwhr. Above this line the facility would receive more income from electricity than tipping fees and vice versa below the line. Obviously as the capacity of the facilities are increased lower incomes on a unit per basis would be required to recover the investment.

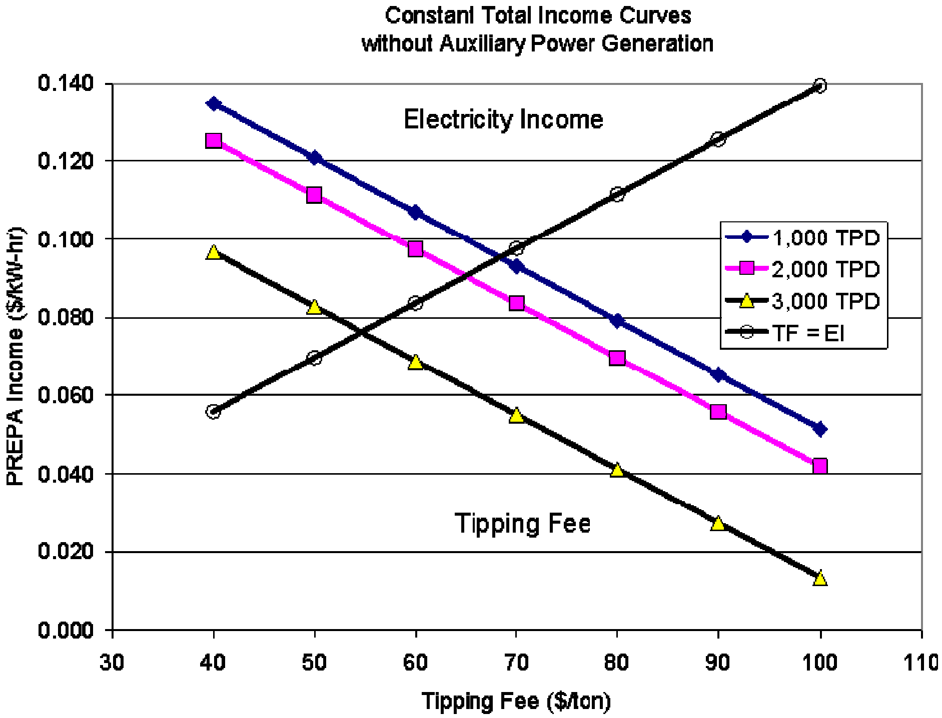


Figure 6.3.5-1. Operating income lines required to recover the capital investment of different facilities

6.3.6 Estimate of potential electric energy contribution

A modified version of the table shown in section 6.3.1 *Availability of the Resource* will be used here. Specifically the 2010 projections will be used. Notice the three columns that were added to the right, *Generación Eléctrica & Químicos (25 and 50%).* For all the rows these columns were calculated except for those components that are not carbon based and thus can not be oxidized. This includes metals, glass and construction debris. Overall, the potential electric energy generation is approximately 235 MW. This assumes 30 MW per 1,000 tons per day for conversion purposes. However, a highly successful recycling program would only leave gardening and organic material for energy generation. This decreases the energy generation potential to approximately 110 MW. In the *productos químicos* column two cases were considered, 25 and 50% yields. It is expected that the former is more realistic. Notice that 60 million gallons per year is equivalent to approximately 70 MW of electrical energy at 10 kW per 1 gallon per hour of feed. However, the energy necessary to convert the biomass to these compounds should be included in the analysis. Overall, if all the carbon based solid waste is considered for producing chemicals this will result in approximately 200 and 400 million gallons per year of organic compounds at 25 and 50% yield, respectively. With effective recycling programs this drops to 100 and 200 million gallons per year, respectively.

Table 6.3.6-1. Potential electric energy generation.

			Proyeccion de generación de desperdicios sólidos (Toneladas/dia)		Productos Quimicos MMGPY	
Categoría		% del peso	2010	Generacion electrica MW***	25%	50%
Platico	Polietileno tipo 1	1.1	123	4	3	6
	Polietileno de alta densidad (HDPE) tipo 2	2.9	325	10	8	17
	Tipo 3-7 (PVC, LDPE, PP, PS, Mezclado)	6.5	728	22	19	38
Papel-Cartón	Papel de alta calidad	1.3	146	4	4	8
	Papel de baja calidad	8.7	975	29	25	51
	Cartón Ondulado	9.3	1,042	31	27	54
Metal	Metal ferrosos	9.4	1,053			
	Metales no-ferrosos	1.1	123			
Jardinería	Material vegetal	20.4	2,286	69	60	119
Orgánico	Material orgánico	12.9	1,445	43	38	75
C&D	Escombro de contracción y demolición	17.1	1,916			
Vidrio	Todo tipo de vidrio	2.4	269			
HHW	Desperdicio peligroso caseros	0.5	56	2	1	3
Otros	No definido de otra manera	6.4	717	22	19	37
Total		100%	11,204	235	204	409
Fuente: Itinerario Dinámico, 2007						
*** 1000 Toneladas al dia de desperdicio equivale a 30 MW						

6.3.7 References for Solid Waste Biomass Energy Resource

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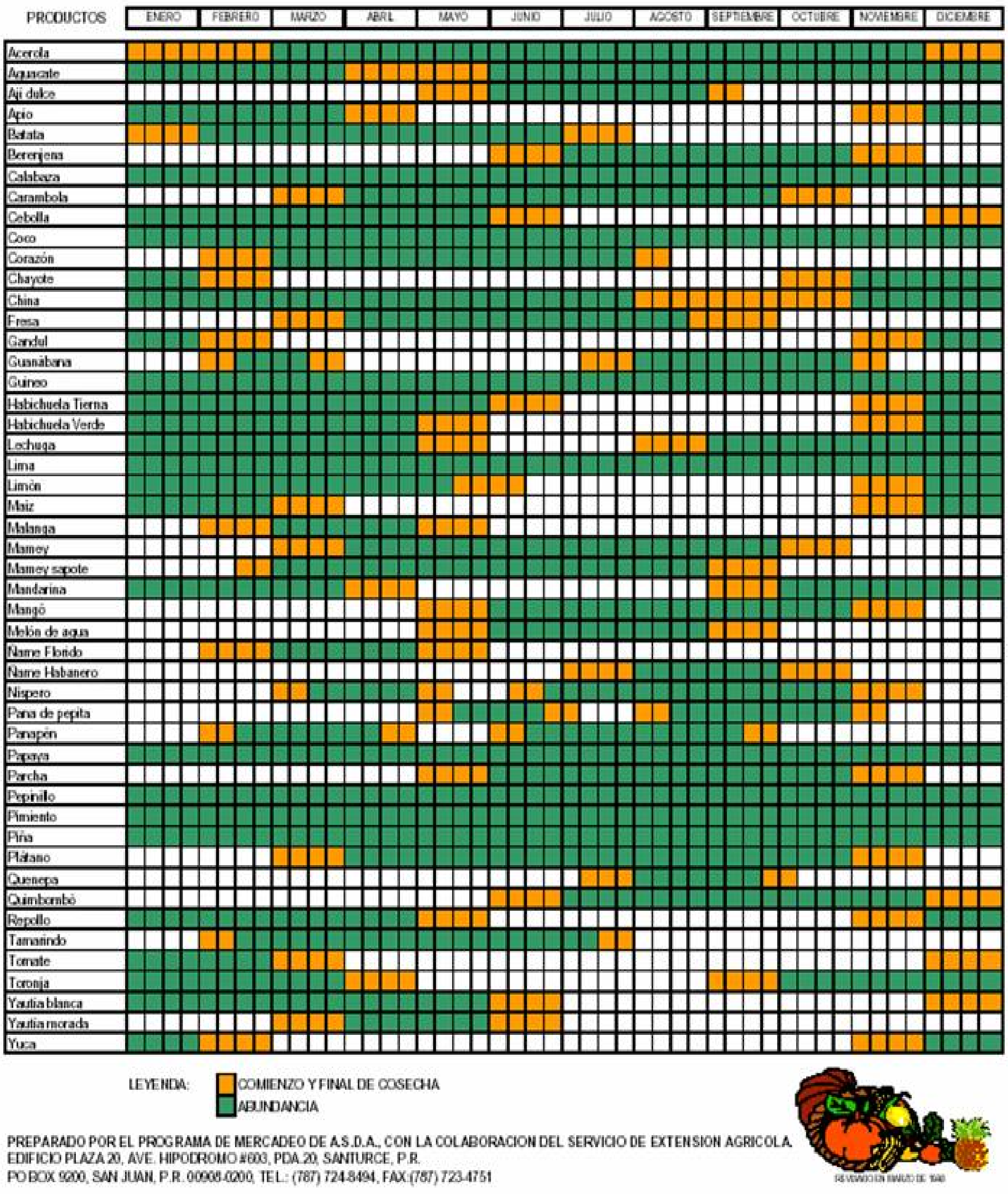
Appendix A



PRODUCTOS	ENERO	FEBRERO	MARZO	ABRIL	MAYO	JUNIO	JULIO	AGOSTO	SEPTIEMBRE	OCTUBRE	NOVIEMBRE	DICIEMBRE
Acerola	🟧🟧🟧🟧	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧
Aguacate	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Aji dulce	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Apio	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩
Batata	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Berenjena	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜
Calabaza	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Carambola	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜
Cebolla	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧
Coco	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Corazón	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Chayote	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩
China	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	🟧🟧🟧🟧	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩
Fresa	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟧	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Gandul	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩
Guanábana	⬜⬜⬜⬜	🟧🟧🟩🟩	🟩🟩🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧⬜⬜	⬜⬜⬜⬜
Guineo	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Habichuela Tierna	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩
Habichuela Verde	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩
Lechuga	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Lima	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Limón	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟧🟧	🟧🟧⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩
Maiz	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩
Malanga	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Mamey	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜
Mamey sapote	⬜⬜⬜⬜	⬜⬜🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Mandarina	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Mangó	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜
Melón de agua	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Ñame Florido	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Ñame Habanero	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜
Nispero	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟩🟩	🟩🟩🟩🟩	🟧🟧⬜⬜	⬜🟧🟧🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜
Pana de pepita	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟩🟩	🟩🟩🟩🟧	🟧⬜⬜⬜	🟧🟧🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧⬜⬜	⬜⬜⬜⬜
Panapén	⬜⬜⬜⬜	🟧🟧🟩🟩	🟩🟩🟩🟩	🟩🟩🟧🟧	⬜⬜⬜⬜	🟧🟧🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Papaya	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Parcha	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜
Pepinillo	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Pimiento	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Piña	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Plátano	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜
Quenepa	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟧	🟧⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Quimbombó	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧
Repollo	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩
Tamarindo	⬜⬜⬜⬜	🟧🟧🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Tomate	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧
Toronja	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩
Yautia blanca	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧
Yautia morada	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜
Yuca	🟩🟩🟩🟩	🟧🟧🟧🟧	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	⬜⬜⬜⬜	🟧🟧🟧🟧	🟩🟩🟩🟩

LEYENDA:
🟧 COMIENZO Y FINAL DE COSECHA
🟩 ABUNDANCIA

PREPARADO POR EL PROGRAMA DE MERCADEO DE A.S.D.A., CON LA COLABORACION DEL SERVICIO DE EXTENSION AGRICOLA.
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