Renewable Energy Solutions for The Ray

Final Project Report

GT 4813: Project in Energy Systems

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Introduction

In July 2014, the State of Georgia honored Ray C. Anderson by dedicating a 18-mile stretch of I-85 highway between LaGrange and West Point, Georgia in his name. This road, now known as the Mission Zero Corridor, has been designated to be the first completely carbon neutral highway in the world, through pollution reduction initiatives and offset with clean, renewable energy sources. In Spring 2016, the Georgia Tech Project in Energy Systems minor capstone class accepted the challenge and has designed renewable energy solutions that would reduce the carbon footprint of the highway and completely offset the carbon dioxide generated from traffic by the year 2030. This report summarizes the work done over the past four months and provides suggestions for the corridor to reach the goal of net zero carbon emissions. It also explains the details behind how each potential solution offsets vehicle emissions, which solutions are feasible to achieve in the next 15 years, and an estimated cost for the final product.

Background

Corridor Traffic and Carbon Footprint

Before looking at ways to offset emissions, the amount of carbon dioxide produced by the highway was calculated using traffic data from the Georgia DOT [1] and fuel economy information from the EPA and USDOT [2]. Every gallon of gasoline produces 8.8 kg of carbon dioxide, while a gallon of diesel fuel produces 10.07 kg [3]. Using this data, daily traffic counts and average fuel economy were predicted through the year 2035. Daily carbon output was calculated with the equation:

$$m_{CO2} = l\left[\frac{E_g T_c}{MPG_c} + \frac{E_d T_T}{MPG_T}\right]$$

where m_{CO2} is mass of carbon dioxide, l is the length of the highway (18.4 miles), E_g and E_d are the emissions from one gallon of gasoline and diesel, T_c and T_T are the daily traffic estimates of cars and trucks, and MPG_c and MPG_T are the average fuel economies for cars and trucks. With an estimated 26,800 cars and 6,500 trucks travelling on the highway every day, total carbon output for 2016 is 365,400 kg/day (about the same as one round trip flight from Los Angeles to Sydney) [4]. The full results of the calculations are displayed below:

Table 1: Carbon Projections

Year	Car Traffic	Truck Traffic	Car MPG	Diesel MPG	CO_2 (kg/day)
2016	26,800	6,500	24.0	6.52	365,400
2020	28,700	7,200	24.7	6.61	388,800
2025	31,000	8,000	25.5	6.71	417,000
2030	33,300	8,800	26.3	6.82	444,000
2035	37,700	9,600	27.1	6.93	470,000

While investigating the carbon footprint of the highway, electric vehicle growth was also considered. The cost of electric vehicles is set to drop significantly within the next 10 years and is expected to be similar to gasoline powered vehicles by 2022 [5]. Currently, there are around 400,000 electric vehicles on the road, which is a small fraction of the 245 million total cars on the road. That number is expected to grow to seventeen million by the year 2020 and continue to trend upwards [6]. While this is a substantial portion of the total car market, over 80% of electric vehicles are used in major urban areas [7]. As a result, approximately 1% of the cars in the Lagrange area is expected to be electric by 2030, which does not have a significant impact on corridor emissions.

Topics Considered

Biomass and Anaerobic Digestion

Growing biomass is a useful technology for offsetting carbon dioxide emissions because plants take in carbon dioxide from the atmosphere for photosynthesis and convert it to organic carbon. Switchgrass is a perennial, warm-season grass, and it grows well in the Georgia climate and soil. It is a valuable energy crop with low maintenance and fertilizer requirements. An average annual switchgrass yield of 8 tons per acre (18 tonnes per hectare) was used to do all calculations [13]. In order to offset the carbon footprint with switchgrass, we looked at using anaerobic digestion to produce biogas, a renewable source of methane [12]. Biodegradable materials produce methane naturally as they decompose, but anaerobic digestion speeds up this process through the use of bacteria. Biogas can be used in the same way as conventional natural gas; it just has a renewable source of production because switchgrass is a perennial grass. We looked at building an anaerobic digester at the landfill in Lagrange, GA, because the landfill already has the pipeline infrastructure in place to send biogas to nearby businesses, such as Interface. These businesses could use the biogas for heating and power generation. An estimated production of 450 m^3 of methane per tonne of switchgrass from anaerobic digestion was used [14].

Biodiesel

Biodiesel is produced from oil via transesterification with glycerin as byproduct. Many different types of oilseed crops are used to produce biodiesel currently, such as soybeans, canola seeds, and rapeseeds. The main problem with using these sources is the fact that they compete with the food market and using them for energy production remove them from the food system and raise prices. Due to this complication, an oilseed crop that is not edible and has the same high oil content is used. The chosen oilseed for production is Carinata (*Brassica carinata),* also known as Ethiopian mustard, because it fits all the possible requirements for growing along the side of the highway. Carinata is similar to canola and thus has the same fertility, weed, and pest control options as canola [8]. Carinata is also known for being rather strong seeds and very resistant to pod shattering, which makes it a good crop to grow so close to moving vehicles. This crop is best grown during the winter months with planting during mid to late November, based on growth studies from Florida [9]. The value used for the growth rate of carinata is 3500 lbs/acre, which is based on a November planting, and an improved genotype and 25 lb seed/gallon of oil was taken as an overestimate (based on canola vs. carinata oil content) of oil production [10].

Solar Power

Solar power provides an alternative solution to zero net carbon emissions by producing electricity that would offset the electricity produced through carbon emitting sources, such as coal power plants. An important consideration is the difference between an offset and removal. While biomass can absorb carbon dioxide, reducing the amount in the atmosphere, solar can only provide energy that would have otherwise been produced through a carbon dioxide emitting method. It does not reduce the amount of carbon dioxide in the atmosphere, but reduces the amount being added. That being said, Georgia has great solar potential and is considered to be a leader for solar power in the region. Furthermore, the Clean Power Plan specifically calls for 500 MW of solar power in the state of Georgia [18]. This results in unanimous support for solar initiatives from the Georgia Public Service Commission, Georgia Department of Natural Resources, and utilities.

However, solar does include several limitations of its own. For large scale electricity production, infrastructure must be installed, such as converters, and high voltage transmission lines. The panels would also need to be cleaned and maintained. There are also risks associated with placing solar panels close to the highway. USDOT requires a three meter shoulder on any interstate highway for emergency vehicles [22]. While biomass may be grown in this shoulder, solar panels can not be installed in this region. This also limits the space that can be used along the median, due to it being limited by three meters on each side. Lastly, solar panels may cause significant glare, which can blind drivers and cause accidents. To avoid this, all solar panels must be cleared by the Federal Aviation Administration (FAA) to cause no glare to any part of the highway during all parts of the day, all year long. Because the highway turns along several points, this could eliminate certain regions next to the highway.

Topics Not Considered

Bioethanol production and biodiesel production from fats, oils, and greases (FOG) were disregarded. From initial calculations, it became obvious that bioethanol production along the highway would be unprofitable because of the low production rate from the land available. The option of producing biodiesel from FOG was not considered because of time restrictions during this project, the amount of restaurants available on the highway, and the lack of technology for handling trap grease (the only true ‘waste’ product from FOG from restaurants). However, some calculations were done to look deeper into this option. Based on the restaurants and companies listed on Google Maps, it was averaged that there are approximately 28 restaruant-sized establishments along the highway. Using data from the National Renewable Energy Laboratory (NREL) waste grease assessment [11] for Macon, GA. it is averaged that the corridor produces about 225,000 lbs/year of yellow grease and 474,000 lbs/year of brown grease. Brown grease is unusable because of the high pretreatment cost required; however, yellow grease is usable to produce biodiesel. Yellow grease should have a minimum of 80% conversion rate (accounting for unusable materials). Even with this amount, overall it will be offsetting only a small amount of carbon dioxide emissions per year.

Another technology not considered was concentrated solar power. Concentrated solar power works by using a parabolic trough, or similar geometry, to focus sunlight on a central pipe filled with a working fluid. Typically molten salt, this working fluid would then be pumped to a heat exchanger and used to produce steam to power a turbine. However, due to the losses associated with every step, the final efficiency is approximately 10% [20]. The levelized cost of electricity for solar thermal is also significantly higher than that of solar photovoltaic [21]. Based on these obstacles, it seems unlikely that solar thermal will be able to outproduce solar panels, either per dollar or per acre, the two limitations focused on in this report.

Potential Solutions

All Biomass Solution

The first potential solution that was eventually disregarded was an all biomass scenario. Considering how much carbon dioxide that will be needed to offset from the corridor in the year 2030, by producing only Carinata, 185 square miles of land will be required. In comparison, growing only switchgrass requires about 39.9 square miles of land. This shows how inefficient the land use is for using only biomass as the source of carbon dioxide offset. Calculations are shown in more depth in the appendix. For a scenario where carinata was grown along the sides of the highway and where switchgrass (for biogas production) is grown along the median of the highway, about 0.54% CO2 offset per year. Even though switchgrass requires significantly less area than Carinata, we still took Carinata into consideration because biodiesel production directly offsets a source of carbon emissions. Switchgrass only indirectly offsets carbon emissions by producing a renewable source of methane gas.

The cost of building an anaerobic digester system at the Lagrange landfill was calculated by scaling down a conceptual 5000 ton per year digester [16]. In order to accommodate 795 tonnes of switchgrass produced along the median in a year, the total capital cost for an anaerobic digester would be about $430,000. Assuming the annual operating and repairing expenses are 4% of the initial capital, the total annual operating costs for the digester would be about $17,200 [16]. We also need to include the cost of growing the switchgrass and transporting to the Lagrange landfill [17]. Using the production costs per acre, only the transportation costs to the plant and a total of four harvests per year, the total costs of producing switchgrass itself was $36,600 per year. This results in a total annual cost of $53,800. Even though the cost of producing biogas from switchgrass is relatively low, the amount of carbon dioxide offset that is achieved is also really low. There is a low offset because biogas is about 60% methane with the remaining 40% being carbon dioxide. This result is problematic for two reasons. Not all of the organic carbon of the switchgrass is going toward offsetting the carbon dioxide but rather produces carbon dioxide itself. The other reason is conventional natural gas is usually above 90% methane. With this large discrepancy in methane quality, businesses will be more reluctant to accept biogas produced from anaerobic digestion.

In order to calculate the processing cost of carinata, values were taken from Canola processing costs because of the similarities in harvesting costs and seed type. As much in depth cost analysis has not been done for carinata yet because it is such a new crop to the United States. The processing costs are a combination of the harvesting, crushing, and conversion (processing) costs of the seeds to biodiesel. These values does not include the cost of building the plants.

Feedstock Processing Costs:

(3500 lb seed/acre * Acres)*(0.15 $/lb seed)

Crushing Costs:

(gallons of oil)*(0.81 $/gal)

Processing/Conversion Costs:

(gallons of oil)*(1.25 $/gal)

For the scenario of total carbon dioxide offset per year, the biodiesel plant processing costs are

$96,348,468.81 (Table 1 in Appendix). For the scenario of only growing carinata along the sides of the highway (30 meters on each side), the total processing cost is $106,506.11 per year (Table 2 in Appendix).

A way to make a small dent in the carbon footprint with little effort is to look at the grass clippings on the median of the highway. Currently, a contractor is paid by the Georgia Department of Transportation (GDOT) to mow the median four times a year, and the grass clippings are just left behind. We recommend having the contractors voluntarily take the clippings to the Lagrange landfill, where the methane produced from decomposition could be collected instead of escaping to the atmosphere. To calculate the potential carbon offset, we assumed an average annual yield of 5.94 tonnes per acre of grass clippings along the median of the Ray [15]. Assuming a methane production of 200 m^3 per tonne of grass, the total carbon footprint offset from this small change would be 0.16% [14]. To ensure the contractor would participate in this implementation, we suggest the DOT mowing contract should be rewritten to include the collection and transportation of the grass clippings to the Lagrange landfill as an obligation for the contractor.

Combined Biomass and Solar

The combination of biomass and solar along the highway offers a balance between the two main alternative energy technologies considered. Using 30 feet on either side of the highway to grow carinata for biodiesel production and the 50-foot median to grow switchgrass for biogas production, we would achieve a total carbon offset of 0.54%. The remaining 99.46% would be offset by solar power generation. As a resource along the Ray, land area is more scarce than money. Because solar panels use a unit of area more effectively to offset carbon dioxide emissions compared to biomass, we believe an all solar scenario is the most feasible.

All Solar Solution

For this solution, several assumptions were made to provide accurate estimations. For the purpose of this report, only silicon-based photovoltaic panels were considered. While thin film photovoltaic panels can reach slightly higher efficiencies, they experience a much higher degradation rate [23] and have a significantly shorter lifespan. This degradation also lowers the efficiencies to lower than that of silicon panels after 6-8 years. In addition, using silicon photovoltaic panels can lower the balance of system costs in terms of the mounting and equipment needed to complete the photovoltaic panel setup. It was assumed that any photovoltaic panels installed would offset an equal amount of production from all sources in Georgia rather than purely offsetting a single source, such as coal. Georgia is estimated to produce 1200 lbs/MWh, or 544.3 kg/MWh, by 2020 [18]. Another key assumption was panels would have approximately 15% efficiency and a lifetime of 30 years, based on industry standards. Solar insolation in Lagrange, GA was estimated at 4.43 kwh/m^2/day [19]. The calculations also used a conversion rate from the estimated Watts peak (Wp) at the Kia Motors Manufacturing plant that was given to us by Finn Findley, the CEO of Quest Renewables. He said that just by covering the existing parking lots, a solar power capacity of 85 MWp/day can achieved by using 15% efficient utility-scale photovoltaic panels. Typically throughout the day, a conservative 20% of the 85 MWp is generated across 8 hours of sunlight a day, which results in 136 MWh/day. This number is then converted to $kWh/m^2/day$ by taking into consideration that the typical ratio of solar panel land use to total land use needed is 72.73% according to a 2013 NREL technical report on the Land-Use Requirements for Solar Power Plants in the United States:

$$(136\ MWh/day)(1000\ kWh/1\ MWh)(0.7273)(881900\ m^2 \text{ of parking lot land at Kia}) = 0.21309\ kWh/m^2/day$$

The total land at the chosen locations is determined from the information from the ARCGIS estimations.

Based on 2030 emission estimates, solar would have to produce approximately 814 MWh/day to reach 100% offset. To produce this power, 6.26 million m^2 of land would be required. This size would not be feasible to install along the sides of the highway. Therefore, alternative land opportunities were pursued since our original solution to utilize the right-of-ways and interchanges along the highway was limited. By examining the land area occupied by local establishments through ARCGIS which is explained in the next section, several options seemed feasible.

The most easily usable land would be from parking lots in the area. The land is accessible and unlikely to be redeveloped. Parking lots contain a large amount of land and would benefit the local business who owns the parking lot by providing shade to vehicles parked under the panels. The Kia Motors Manufacturing plant operates a large factory along the corridor, which contains a large parking lot that holds inventory before it can be shipped out. This, along with other parking lots in the area, would account for 22.25% of the land need to offset the entire carbon footprint. The calculations are placed in the appendix in Tables 6 and 7.

The next most accessible land would be rooftops. Most rooftops are flat, and already contain a supporting structure that can be used high above the ground. This also provides a demand for the electricity, reducing the need for infrastructure. This land accounts for 8.23% of the needed land.

After considering all developed land, the next option would be open areas of land. This would be land that has already been clear, but not developed. Large sections of land appear along the highway, although it is unclear who owns them, if anyone, or for what they might want to use the land. However, considering solar panels can be implemented in most structures, it is likely this land will be available for use. These areas account for another 13.77% of land.

The remaining land must come from repurposed lands. These are lands that currently contain vegetation or minor structures that would have to be cleared prior to use. This land is the most readily available, but less accessible and desirable than previous options. The final 55.75% would come from this land.

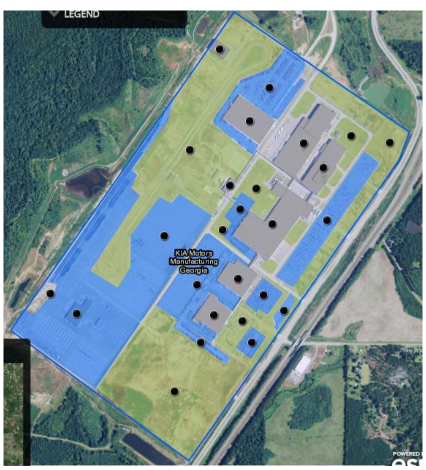
Based on a LCOE of $122/MWh [23], the cost of such a system would be approximately $1.32 billion according to Tables 6 and 8.. This includes installation and infrastructure, as well as solar subsidies offered. Over 15 years, $88 million would have to be paid each year. However, based on the wholesale price of electricity in Georgia [23], the payback period would be approximately 22 years. The remaining 8 years would return a profit. It is also possible to use the solar panels after the expected 30 years, although the efficiencies typically seen after such lengths is expected to be lower than 70% of that of a new panel.

ARCGIS

ARCGIS was used to help identify possible locations at which Solar Energy would be developed. By researching using ARCGIS, a set of seven locations were identified for the 6.26 million m^2 needed. The total area of various locations:

1. Kia Motors Manufacturing Plant
2. WALMART Distribution Center
3. Caterpillar Dealership
4. Local Business in West Point, GA
5. Hyundai Dynamos
6. Open Areas Near Kia Plant
7. Lanes Along the Highway

Option 1: Kia Motors Manufacturing Plant



The best option to use for the solar panels is the Kia Motors Manufacturing Plant. This is because there is a large amount of land, approximately 2.26 million m^2 of 6.26 million m^2 available in a single location. Of the 2.26 Million m^2, the area breakdown is as follows:

- Total Rooftop Area (Grey) - 283,234 m^2
- Total Open Area (Green) - 1,101,690 m^2
- Total Parking Lot Area (Blue) - 881,900 m^2

Option 2: WALMART Distribution Center in Lagrange, GA

The second option for placing the solar panels is a WALMART Distribution Center in Lagrange, GA where there is a total of 633,370 Sq. M. of the needed 6.26 million m^2. The area breakdown is as follows:

- Rooftop (Blue) - 93,570.7 m^2
- Parking Lot (Grey) - 268,707.6 m^2
- Open Area (Green) - 271,092.2 m^2

Smaller areas can be used in case the above two are unavailable or as pilot projects.

Option 3: Caterpillar Dealership

Near the WALMART Distribution Center, there is another possible location; the Caterpillar Dealership with a total 78,871.6 m^2 available.

The area breakdown is as follows:

- Rooftop (Blue) - 25,003.6 m^2
- Parking Lot (Grey) - 53,868 m^2

Option 4: Local Businesses in West Point, GA

There are a group of local businesses (bank, carpet store, auto parts store, call center, holding company) in West Point, GA which can be used as locations for placing solar panels.

The area breakdown is as follows:

- Total Rooftop Area (Grey) - 61,999.2 m^2
- Total Parking Lot Area (Blue) - 128,810 m^2

Option 5: Hyundai Dynamos

There is a small Hyundai Dynamos factory along the highway with a total area of 22,370 m^2. The area breakdown is as follows:

- Rooftop (Grey) - 1283.8 m^2
- Parking Lot (Blue) - 2069.6 m^2
- Open Area (Green) - 15,130.4 m^2

Option 6: Open Areas Near Kia Plant

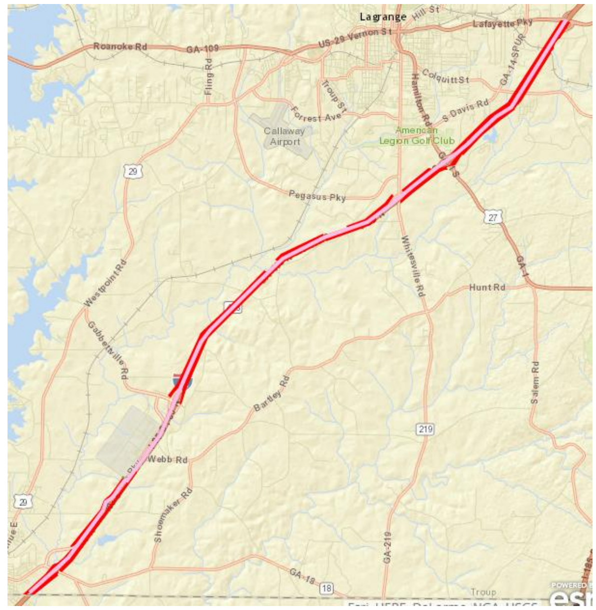
There are a few large pieces of land near the Kia Motors Manufacturing Plant that seem to be open. The total area is 713,610 m^2.

The area breakdown is as follows (from top) :

- Area 1 - 123,848.9 m^2.
- Area 2 - 231,884.6 m^2.
- Area 3 - 357,876.4 m^2.

Option 7: Lanes Alongside the Highway

A final option is to repurpose the land within a 100 ft. of the highway for placing solar panels. The land around the highway which can be repurposed is colored in red. A total of 4.8 million m^2 is available for use.



The highway is about 16 mi long, about 15 mi of which is open for use.

Length = 15 mi = 24,140 m

Width = 100 m on both sides = 200 m

Area = (Length)(Width) = (24,140 m)(200 m) = 4.8 million m^2.

Conclusion

Carbon neutrality is attainable with primarily photovoltaic panels in the form of solar power. Even though solar power is preferred over biomass options that require a large amount of land to offset the entire carbon footprint of The Ray, the monetary cost of solar panels is large in the billions of dollars. In addition to the cost, the land needed by the solar panels is contingent on key business partnerships with companies, such as the Kia Motors Manufacturing plant, the Walmart distribution center, and the Caterpillar dealership, along this stretch of highway. Strong support from policymakers, especially the Georgia DOT, is crucial to the overall of offsetting the carbon footprint of The Ray. Apart from the impact from the technologies, the societal impact on the highway will be evident. It is important that renewable energy solutions can be implemented with collaboration from engineers, investors, and politicians on many more miles of the highway across Georgia and other states. Georgia will be a leader in sustainable highway development.

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Appendix

Table 1

Amount of Land required to offset all the CO2 per Year	
Total amount of biodiesel to produce per year [gallons]	16,096,429.10
Total amount of oil to produce per year [gallons]	16,579,321.97
[lbs seed] required	414,483,049.23
Acres required	**118,423.73**
mi^2 required	**185.0370755**
Total Processing Cost ($)	**96,348,468.81**

Table 2

Biodiesel Production From 30 ft on each side and not median	60ft = 0.0113636 miles
Total Amount of Space [mi^2]	0.2045448
Total Amount of Space [acres]	130.908672
Total oil that can be produced in the medians per year [gallons of oil --not biodiesel]	18,327.21
Total amount of Biodiesel gal/year	**17,777.40**
Total Processing Cost per year [$]	106,506.11
Total CO2 offset	**0.11%**
Cap Ex and Op Ex Cost	138,845.48

Table 3

Amount of Land required to offset all CO_2 on corridor per year with biogas	
projected CO_2 footprint on highway (kg/day)	444085
projected 2030 CO_2 footprint total (kg/year)	162091025
C output by highway (kg/year)	44206643.18
amount of CH_4 needed to offset (kg/year)	58942190.91
amount of CH_4 needed to offset (m^3/year)	82519067.27
switchgrass needed to offset (tonne/year)	183375.7051
Area required (ha)	**10187.54**
Area required (mi^2)	**39.33**

Table 4

Biogas production from 50 ft Median switchgrass	
total area of median (acres)	109.090944
switchgrass yield (tonnes/ha/year)	18
switchgrass production (tonnes/year)	794.6730036
CH_4 production (m^3/year)	**357602.85**
CH_4 production (kg/year)	255430.6083
amount of C from CH_4 (kg/year)	191572.9562
C offset (%)	**0.43**
Production cost of switchgrass ($/acre/year)	328.91
Total production costs ($/year)	35881.10
Transportation cost to landfill ($/harvest)	173.06
Total transportation costs ($/year)	692.24
Total switchgrass production costs ($/year)	**36573.34**

Table 5

Biogas production from 50 ft Median of grass clippings	
total area of median (acres)	109.090944
grass clippings yield (lb/ft^2/year)	0.3
grass clippings yield (tonnes/acre/year)	5.940129364
grass clippings production (tonnes/year)	648.0143198
CH4 production (m^3/year)	**129602.86**
CH4 production (kg/year)	92573.47426
amount of C from CH4 (kg/year)	69430.1057
C offset (%)	**0.16**

Table 6

All Solar					
	kg CO2 offset equivalent	**% Offset for 2020**	**% Offset for 2025**	**% Offset for 2030**	**Cost**
Parking Lots in Kia Plant	27019588.11	19.04%	17.75%	16.67%	$181,682,400.00
Parking Lots of Warehouses	9041989.157	6.37%	5.94%	5.58%	$60,799,235.13
Rooftop Solar	13343364.91	9.40%	8.77%	8.23%	$89,722,113.84
Empty patches of land (no trees)	22327100.62	15.73%	14.67%	13.77%	$377,091,555.68
Land where we can cut down trees	90365755.36	63.67%	59.37%	55.75%	$607,628,334.07

Table 7

Breakdown of Land Needed for Solar Panels				
	Parking Lot at Walmart Distribution Center	**at Caterpillar**	**Hyundai Dynamos**	**Local Businesses around West Point**
m^2	107568.4211	11292.65789	1497.736842	93217.76316
kWh/day	22922.14915	2406.393866	319.1582338	19864.11485
MWh/day	22.92214915	2.406393866	0.3191582338	19.86411485
kg CO2/day	12476.77334	1309.82617	173.7212736	10812.25225
kg CO2/year	4554022.269	478086.5521	63408.26486	3946472.07
Total kg CO2/year: 9041989.157				
	Open Area at Kia	**Open Area near Kia**	**Open Area by Hyundai Dynamos**	
m^2	797275.6579	516428.2895	10949.63158	
kWh/day	169894.3925	110047.5972	2333.297131	
MWh/day	169.8943925	110.0475972	2.333297131	
kg CO2/day	92475.35268	59900.09569	1270.038828	
kg CO2/year	33753503.73	21863534.93	463564.1721	
Total kg CO2/year: 22327100.62				
Rooftop Solar	**Kia**	**at Walmart**	**at Caterpillar**	**Local Businesses around West Point**
m^2	204971.9737	57894.73684	6513.157895	44868.42105
kWh/day	43678.22922	12337.00169	1387.912691	9561.176313
MWh/day	43.67822922	12.33700169	1.387912691	9.561176313
kg CO2/day	23774.53189	6715.163262	755.455867	5204.251528
kg CO2/year	8677704.141	2451034.591	275741.3914	1899551.808
Total kg CO2/year: 13343364.91				

Table 8

Cost			
Parking at Kia		**Parking at Other Places**	
136	MWh/day	45.5118161	MWh/day
49640	MWh/year	16611.81288	MWh/year
1489200	MWh for 30 years	498354.3863	MWh for 30 years
$181,682,400.00	**$ (Cost)**	**$60,799,235.13**	**$ (Cost)**
Open Areas		**Rooftop Solar**	
282.2752868	MWh/day	67.16229796	MWh/day
103030.4797	MWh/year	24514.23875	MWh/year
3090914.391	MWh for 30 years	735427.1626	MWh for 30 years
$377,091,555.68	**$ (Cost)**	**89722113.84**	**$ (Cost)**
Cut down trees			
90365755.36	kg CO2/year		
247577.4119	kg CO2/day		
454.8456726	MWh/day		
166018.6705	MWh/year		
4980560.115	MWh for 30 years		
607628334.07	**$ (Cost)**		