Southwest Region University Transportation Center

Feasibility of Solar Powered Traffic Signs in Houston - A Step toward Sustainable Control Devices

SWUTC/12/476660-00053-1

Center for Transportation Training and Research
Texas Southern University
3100 Cleburne Avenue
Houston, Texas 77004

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/12/476660-00053-1		

4. Title and Subtitle Feasibility of Solar Powered Traffic Signs in Houston – A Step toward Sustainable Control Devices	5. Report Date August 2012 6. Performing Organization Code
7. Author(s) Khosro Godazi, Alexandra Miller, Ronald E. Goodwin	8. Performing Organization Report No. 476660-00053-1
9. Performing Organization Name and Address Center for Transportation Training and Research Texas Southern University 3100 Cleburne Houston, Texas 77004	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTRT07-G-0006
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas A&M Transportation Institute Texas A&M University System College Station, Texas 77843-3135	13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

Supported by a grant from the U.S. Department of Transportation, University Transportation Centers Program.

16. Abstract

With the economy fluctuating all the time, the federal and some city governments at times spend more money than they take in from taxes. It is important for these governments to find ways to reduce spending while still providing sufficient operations for their constituency. As the national focus turns to finding alternative energy rather than the reliance of fossil fuels, it is not hard to find ways in which the city can save money. One of these ways is taking advantage of the sun's energy to power our traffic signals as well as switching the traditional incandescent bulbs to LED. Since the city's origin, Houston, Texas has been a continuous success in population growth, land expansion, job opportunities, and a leader of industry. The city did not get to be where it is by not staying ahead of the curve. With its 2,450 signalized traffic intersections and a wide range in the number of signals at each one, the city has an opportunity to be a leader in large scale retrofitting in the United States. By retrofitting the signals to solar energy and switching to LED the city will see major energy and cost savings, as well as a significant decrease in maintenance cost and time due to the longer lifespan of the LEDs and solar panels.

17. Key Words	18. Distribution Statement
Solar Energy, Light Emitting Diodes (LED), Intersections, Incandescent Bulbs	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	37	

Form DOT F 1700.7 **(8-72)** **Reproduction of completed page authorized**

FEASIBILITY OF SOLAR POWERED TRAFFIC SIGNS IN HOUSTON – A STEP TOWARD SUSTAINABLE CONTROL DEVICES

Khosro Godazi

Alexandra Miller

Ronald E. Goodwin

SWUTC/12/476660-00053-1

Southwest Region University Transportation Center
Center for Transportation Training and Research
Texas Southern University
3100 Cleburne
Houston, Texas 77004

August 2012

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the information presented. This document is disseminated under the sponsorship of the Department of Transportation, University Transportation Centers program, in the interest of information exchange. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ACKNOWLEDGEMENTS

The authors recognize that support was provided by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the Southwest Region University Transportation Center

ABSTRACT

With the economy fluctuating all the time, the federal and some city governments at times spend more money than they take in from taxes. It is important for these governments to find ways to reduce spending while still providing sufficient operations for their constituency. As the national focus turns to finding alternative energy rather than the reliance of fossil fuels, it is not hard to find ways in which the city can save money. One of these ways is taking advantage of the sun's energy to power our traffic signals as well as switching the traditional incandescent bulbs to LED. Since the city's origin, Houston, Texas, has been a continuous success in population growth, land expansion, job opportunities, and a leader of industry. The city did not get to be where it is by not staying ahead of the curve. With its 2,450 signalized traffic intersections and a wide range in the number of signals at each one, the city has an opportunity to be a leader in large scale retrofitting in the United States. By retrofitting the signals to solar energy and switching to LED the city will see major energy and cost savings, as well as a significant decrease in maintenance cost and time due to the longer lifespan of the LEDs and solar panels.

EXECUTIVE SUMMARY

In an effort to reduce the dependence on fossil fuels, societies across the globe continue developing alternate sources of energy. Solar energy has increasingly become a popular option and communities have begun evaluating solar energy's municipal uses compared to other traditional forms of energy. The City of Houston has made a concerted effort to transition to a "green" economy by using renewable forms of energy where it is feasible and cost-effective. As part of that transition to renewable energies, the City of Houston installed solar powered light emitting diodes (LEDs) in traffic control devices as part of an overall cost saving strategy.

This study presents an evaluation of installation costs of both solar panels and LED retrofits versus the traditional incandescent light bulbs of traffic control devices. The principle objective is the determination of energy and cost savings, if any exists, and to what degree such savings could be transferable to other municipalities considering similar "green" strategies.

Even though the total conversion of solar panels and LEDs requires a significant financial commitment, it is anticipated that the costs would be recouped in five years or less. Furthermore, the installation of solar panels illustrates the commitment to not only reduce energy consumption, but also reduce the reliance on fossil fuels.

TABLE OF CONTENTS

LISTS OF FIGURES

INTRODUCTION

Houston with its vast and illustrious history has continued to be a leader in business and industry around the world. As the fourth largest city in the United States and the largest city in Texas, Houston has shown its economic dominance through its prestigious Medical Center, continually booming oil industry, and the Port of Houston which ranks number one in the United States in international waterborne tonnage. Houston is also the home of the National Aeronautics and Space Administration (NASA) Mission Control, which manages all manned space flights and continues to be a symbol of American ingenuity and reminds the world that mankind can achieve great things.

The city's highway system is something to be marveled with not one but, soon to be, three loops Houston's public transportation system, through the Houston METRO, continues to expand with its buses, light rail, and lift vans services to get people all around the city. Houston comes in the number two slot for housing the most Fortune 500 headquarters behind New York, and has a population of 2.1 million people recorded by the 2010 census, and growing due to warmer weather, low cost of living, and copious job opportunities. With so much going for the city, it has all the more reason to expand into technological ventures and stay ahead of the curve.

In this economic situation, it is advantageous for Houston to try to reduce costs, if feasible and beneficial, to the city. Urban and suburban areas are continually growing. An emphasis on the impact of global warming on the environment and the national mantra to go "green" has influenced many researchers to find alternative energy sources. Research in solar energy is one option. The use of Light Emitting Diode (LED) Traffic Signals provides an opportunity for the City of Houston to save both money and energy. With other advantages such as reduced need for maintenance, a longer life span, and exceeding illumination, LED's have become building blocks in making solar traffic signals a reality and making more "green" decisions for city governments.

Research Objective

The goal of this research is to show how much money and energy the city of Houston can save, long term, by switching to LED and solar energy traffic lights by:

- Creating a cost and wattage analysis of the amount of projected savings using five sample intersections in the Houston area and looking at 10 intersections that have already been retrofitted.
- Showing the positive outcomes and best practices of other cities and countries that have already converted, and why they are successful.

LITERATURE REVIEW

The profound need to find alternative energy sources, stemming from the realization that fossil fuels will not last forever, has stimulated researchers and engineers to find solutions before it's too late. As we move towards a more "green" economy, the idea of using energy from the sun as a surrogate solution has become a popularized study that has impacted many fields of industry with copious advantages. Apart from the wonderful things solar energy has done for reducing energy in residential and commercial buildings, it has also made its way as a booming energy reducer in the transportation industry. Countries all around the world have started to take advantage of the impacts solar energy and light emitting diodes (LED) can have on the economy. The following represents previous literature about the benefits of using solar energy and LED, the environmental impact, as well as how it has and can be used worldwide.

The Benefits of Conversion

A study sponsored by the Arkansas Department of Economic Development in 2003, tested the advantages in wattage and cost savings of using LED's in traffic signals on three intersections, in comparison with three traditional incandescent lights of similar design and number of signal lights. Researchers found a 90 percent energy saving in LED signals compared with their traditional incandescent counterpart with averages of 111kWh versus 1203 kWh. With the success of the project, the city of Little Rock decided to retrofit all 263 signalized intersections in the city. A reduction in energy cost resulted in savings of $111,000 annually. ("Arkansas")

In Texas, the City of Houston has been designated as a solar city and has begun the conversion of 300 traffic lights to LED, finding that 85 percent less energy is being used. Houston acknowledges the benefits of using LEDs including reduced maintenance costs, a decrease in the amount of emissions produced, cost savings in replacing the bulbs, and also the long life span of the light source lasting around 100,000 hours, which equates to about 11 years. The city plans to continue to expand the retrofitting to all other signals in the city and requires all future signal installations to be LED. ("Green Houston")

The Journal of Chemical Education in 2001 published an article detailing the benefits of LEDs compared to the pitfalls of traditional signal lights and their utilization in the transportation industry. The authors compare the life spans of both light sources, 1000 hours for the incandescent bulb and 100,000 hours for LEDs, and emphasize the reduced maintenance and replacement costs by switching. The energy consumption of the light sources is also mentioned heeding the significant differences in typical wattages, 150W for incandescent and 20W for LEDs, which produce the most energy and cost savings. The article does not neglect to mention that LEDs have a brighter illumination creating safer road conditions (Condren, Lisensky, Ellis, and et al 1033-1040).

Benefits and Utilization of Solar Energy

Researchers in Greece convey the fact that when it comes to energy, the environment will always be impacted whether good or bad. Solar Energy is on the good spectrum when it comes to the environment producing less CO_2 emissions than fossil fuels, and little to no air emissions. During operation solar panels using Photovoltaic's release no discharges of pollutants. "Solar Energy can be considered as an almost clean and safe energy source" (Tsoutsos, Frantzeskaki, and Gekas 289-296).

Lewis and Nocera explain the breakdown of chemical properties needed to use solar energy in a way society can fully benefit and the role the sun's energy plays in a global perspective. The sun is the largest source of renewable energy we have; making it an obvious choice to use as we move away from the reliance of fossil fuels. The amount of energy the sun provides on Earth in one hour is more than all energy consumed by its inhabitants in one year. Photovoltaics are used in order to capture, convert, and store the sun's energy so that it can be produced into energy usable for human consumption (Lewis and Nocera 15729-15735). From the review of literature, it is clear that solar energy and the use of light emitting diodes have made life easier in some respects and saved both money and energy.

METHODOLOGY

In this simulation study, various data methods including literature reviews, talking to consultants in the industry, and a meeting with a City of Houston representative were used. Literature reviews provided valuable information on the advantages of solar energy and the use of LEDs, as well as comparison data between them and traditional incandescent light bulbs. Two consultants were used to provide information on detached ideas. One explained what the city has worked in the past when it comes to traffic signals and the structure of the city itself. This helped to better understand the types of operations put in place and how retrofitting would tie in and the benefits. The other consultant, a Solar Energy expert, discussed materials needed to set up the LED signals and how solar energy is connected to the system as well as some proposed cost options for materials and labor. This was beneficial in making mathematical representations of the investment the city would partake and its long term benefits. It also helped create the cost analysis to show the city about how much it can save in energy costs per year. Talking to the City of Houston representative helped to identify what is currently being done with traffic signals in the city and to identify 10 intersections that have already been converted to LED to see the successfulness in power consumption savings they have already seen. Five intersections were identified in major industry areas of Houston where there is daily heavy traffic flow to show the install costs of LEDs and solar panels as well as the power consumption savings.

DATA

General Information Summary

- The city will see the largest amount of cost and energy savings coming from the conversion of traditional incandescent bulbs to LED.
- A $0.12 electric rate per kWh (Blended Rate) per kWh is the average energy cost the city of Houston is charged for powering traffic lights.
- Installing Solar Panels at traffic intersections has the ability to reduce energy consumption to zero and, in some cases, creates negative energy allowing the city to sell back excess energy to power companies
- There are 2,450 signalized intersections in Houston, most averaging between 10 to 12 signals at each one

Installation Cost Analysis of LED vs. Incandescent Bulbs

The results below in Fig. 1 are based off of a study conducted in Little Rock, Arkansas concerning the retrofitting of incandescent lights to LED. The data reflects an example of the average costs for each signal light installation. The data is an initial installation cost comparison, per signal installation by each color light. Although there are high installation costs for converting to LED, the long term savings make it well worth the investment. This is not an estimate of what Houston will spend, but it does provide an idea of what Little Rock spent that can be a starting point for the city.

Fig. 1: Average Costs Comparison of LED and Incandescent Bulbs

Material (per bulb)	LED	Incandescent
Red	$57.00	$2.75
Yellow	$66.00	$2.75
Green	$119.00	$2.75
Labor (per retrofit installation)	$55.00	$55.00

Having such high installation costs is the only major disadvantage with LEDs. Some of the more advantageous qualities of LEDs are that they provide more visible light than the incandescent bulbs and require little to no maintenance over its lifespan. If one of the mini diodes on an LED dissolves out, the entire light source will still be able to function with ample brightness; whereas, if the filament of an incandescent bulb goes out, that's the end of the bulbs life and it will need immediate replacing. Most LEDs last about 100,000 hours creating a lifespan of about 11 years. Its traditional counterpart has a lifespan, if lucky, of about 6,000 to 10,000 hours, making the bulbs need to get replaced every year. The maintenance cost of replacing the incandescent bulbs every year, compared to the low maintenance cost of 11 year lifespan of the LED's, provides good incentive for the conversion.

Typical Power Consumption

The bulk of the saving the City of Houston will see stems from the lower power consumption between the two types of lights. Typical power consumption of an Incandescent bulb goes upwards of 150 Watts. LEDs, however, range from five to 25 watts. It is worth mentioning that 90 percent of energy given off by incandescent lights is through heat energy rather than visible light; LEDs do not have this problem. Using the same Arkansas source as before, the typical power consumption seen in their retrofitting project is as follows:

Fig. 2: Typical Power Wattage Comparison of LED and Incandescent Bulbs

Display Type	Typical Power (Watts)
Incandescent Bulb	135
Red LED	10
Yellow LED	22
Green LED	12

It is clear that there is a significant disparity of consumption by the two types of light sources. In a four way intersection with two signals (8 signals total), according to Arkansas' wattage data, an incandescent light intersection consumes 1080 watts. The same type of intersection running on LEDs would only consume 352 watts.

Proposed Cost Options for Installation of Solar

It has been tested and proven that running the traditional incandescent light with solar energy is impractical and incredibly expensive; making LED a most feasible option. The retrofitting and installation of solar lighting and LEDs still comes with a small fortune needed to be paid in order to get significant savings in the long run. Cost estimates are proportionate to the options chosen, such as whether or not the city wants to connect a battery back-up or not, and the complications that may arise during installation. Cost options for installation include using a battery back-up or not, and if the existing pole is able to be used in the installation process. Labor charges depend on the options the city decides to put in place. The LEDs reduce the power consumption tremendously; and the inclusion of solar panels allows for the goal of having zero energy consumption.

For a four- way intersection with two signals per direction, eight signals total, and two pedestrian signals that consumes 120kWH per month materials needed include:

- Quantity of four 260 watt solar PV modules for a total cost of $1600, each panel costing $400.
- Pole Mounting hardware (top of pole adapter and rail hardware) for $800. This assumes that the current pole can be used for mounting. If a new pole needs to be installed it will cost around$3500 for the pole and concrete.

If the city decides to offset power consumption completely, without installing back-up power source, grid-tie inverters need to be installed on each panel for $200 each or $800 total because the system will need to be grid–tied in case of consecutive cloudy days or times the system does not have enough energy to run itself. Additional hardware and wiring also need to be included for around $500. This will offset essentially 100 percent of the annual energy consumption of a typical converted LED intersection. If the decision is to include a battery powered back-up, additional materials are necessary:

- Quantity of six 200A-H 12 V lead acid batteries costing $600 per battery or $3600 total
- Industrial Battery Box for $2000
- Solar Charge Controller for $500
- Inverter to power 120VAC LED-converted traffic signal system for $750

The battery size lasts for about three days of autonomy from concentrated sunlight. Because the system can be both battery-backup powered and grid-tied, it creates the opportunity to sell excess power back to the utility company. To do so, a more expensive inverter is required for around $2,000. Charge for labor ranges from $2000 to $4800 based upon the decisions made by the city.

The solar panels size (1kw) was chosen for this example because it will produce approximately equal the annual consumption of a typical converted LED intersection. The lifespan of a typical crystalline silicone solar panel is 35-40 years with a 25 year manufacturer's warranty and maintenance for them is negligible.

Figures 1-4 show the four scenarios of materials and installation cost of solar.

Fig. 3: Scenario 1: Using Existing Pole without Battery Back Up

Material Cost			
Materials Needed	Price	Quantity	Total
Solar Modules	$ 400.00	4	$ 1,600.00
Mount Hardware	$ 200.00	4	$ 800.00
		Subtotal	$ 2,400.00

Cost with no Back-up			
Materials Needed	Price	Quantity	Total
Grid-Tie Inverters	$ 200.00	4	$ 800.00
Hardware and Wiring			$ 500.00
		Subtotal	$ 1,300.00

Labor Charge	
High Labor Charge	$ 4,800.00
Low Labor Charge	$ 2,000.00

Solution			
	Low Labor Charge		High Labor Charge
Cost Per Intersection Range	$ 5,700.00	~	$ 8,500.00
Cost for All Intersections in Houston Range	$ 13,965,000.00	~	$ 20,825,000.00

If conditions are good with the existing pole, installers can mount the solar panels without installing a new pole, and then the city can save money by not having to pay for the material and labor for the additional installation. The materials needed to install the solar panel are the solar module itself and the mounting hardware. There needs to be four modules and four sets of mount hardware with ends for a total cost of $2,400. By not installing a battery back-up, the system would need to be grid-tied. There would need to be four inverters, one for each panel, for $800; and the hardware and wiring would run about $500 for a total of $1,300. A general labor range for the installation of the intersection could run from around $2,000 to $4,800. The total cost per intersection could cost around $5,700 to $8,500. If this is implemented at all 2,450 intersections around the city, it would run the city approximately $13,965,000 to $20,825,000.

Fig. 4: Scenario 2: Using Existing Pole with Battery -Back Up

Material Cost			
Materials Needed	Price	Quantity	Total
Solar Modules	$ 400.00	4	$ 1,600.00
Mount Hardware	$ 200.00	4	$ 800.00
		Subtotal	$ 2,400.00

Cost with Back-up			
Materials Needed	Price	Quantity	Total
Batteries	$ 600.00	6	$ 3,600.00
Industrial Battery Box			$ 2,000.00
Solar Charge Controller			$ 500.00
Inverter to Power			$ 750.00
		Subtotal	$ 6,850.00

Labor Charge	
High Labor Charge	$ 4,800.00
Low Labor Charge	$ 2,000.00

Solution			
	Low Labor Charge		High Labor Charge
Cost Per Intersection Range	$ 11,250.00	~	$ 14,050.00
Cost for All Intersections in Houston	$ 27,562,500.00	~	$ 34,422,500.00

This scenario can be projected if the existing pole can be used and a battery back- up is installed as a way to have a direct energy source in case there is not enough energy stored or many consecutive rainy days where the panel cannot get enough rays from the sun to run the system. The materials needed to install the solar module and hardware is the same as in Scenario 1 at $2,400. By installing a battery back-up, the system has additional costs connected but are provided as a useful investment if this option is chosen. Six batteries would be required as well as the battery box, solar charge converter, and inverter to power totaling $6,850. A general labor range for the installation of the intersection could still run from around $2,000 to $4,800. The total cost per intersection could cost around $11,250 to $14,050. If this is implemented at all 2,450 intersections around the city, it would run the city around $27,562,500 to $34,422,500.

Fig. 5: Scenario 3: Installing New Pole without Battery Back Up

Material Cost					
Materials Needed	Price		Quantity	Total	
Solar Modules	$	400.00	4	$	1,600.00
Mount Hardware	$	200.00	4	$	800.00
Pole & Concrete	$	3,500.00	1	$	3,500.00
			Subtotal	$	5,900.00

Cost with no Back-up					
Materials Needed	Price		Quantity	Total	
Grid-Tie Inverters	$	200.00	4	$	800.00
Hardware and Wiring				$	500.00
			Subtotal	$	1,300.00

Labor Charge		
High Labor Charge	$	4,800.00
Low labor Charge	$	2,000.00

Solution					
	Low Labor Charge			High Labor Charge	
Cost Per Intersection Range	$	9,200.00	~	$	12,000.00
Cost for All Intersections in Houston Range	$	22,540,000.00	~	$	29,400,000.00

There may be a problem with the pole if installers cannot use the current pole to mount the hardware. In this case, a new pole would have to be installed. The materials need to install the solar module and hardware is the same as in Scenarios 1 and 2, but would require an additional charge for the pole and cement for $3,500 making the material cost a total of $5,900. Without the back- up, the material cost would be the same as Scenario 1 at $1,300. A general labor range for the installation of the intersection is again about $2,000 to $4,800. The total cost per intersection could cost around $9,200 to $12,000. If this is implemented at all 2,450 intersections around the city, it would run the city around $22,540,000 to $29,400,000.

Fig. 6: Scenario 4: Installing New Pole with Battery Back Up

Material Cost			
Materials Needed	Price	Quantity	Total
Solar Modules	$ 400.00	4	$ 1,600.00
Mount Hardware	$ 200.00	4	$ 800.00
Pole & Concrete	$ 3,500.00	1	$ 3,500.00
		Subtotal	$ 5,900.00

Cost with Back-up			
Materials Needed	Price	Quantity	Total
Batteries	$ 600.00	6	$ 3,600.00
Industrial Battery Box			$ 2,000.00
Solar Charge Controller			$ 500.00
Inverter to Power			$ 750.00
		Subtotal	$ 6,850.00

Labor Charge	
High Labor Charge	$ 4,800.00
Low Labor Charge	$ 2,000.00

Solution			
	Low Labor Charge		High Labor Charge
Cost Per Intersection Range	$ 14,750.00	~	$ 17,550.00
Cost for all Intersections in Houston Range	$ 36,137,500.00	~	$ 42,997,500.00

Much like Scenario 3, if a new pole needs to be installed, it will create an additional charge. Adding a battery back-up as in Scenario 2 makes this the most expensive scenario. The materials needed to install the solar module and hardware is the same as in Scenario 3 at $5,900. The materials needed for battery back-up is the same as in Scenario 2 totaling $6,850. The general labor range for the installation of the intersection is the same as the other options at about $2,000 to $4,800. The total cost per intersection could cost around $14,750 to $17,550. If this is implemented at all 2,450 intersections around the city, it would run the city around $36,137,500 to $42,997,500.

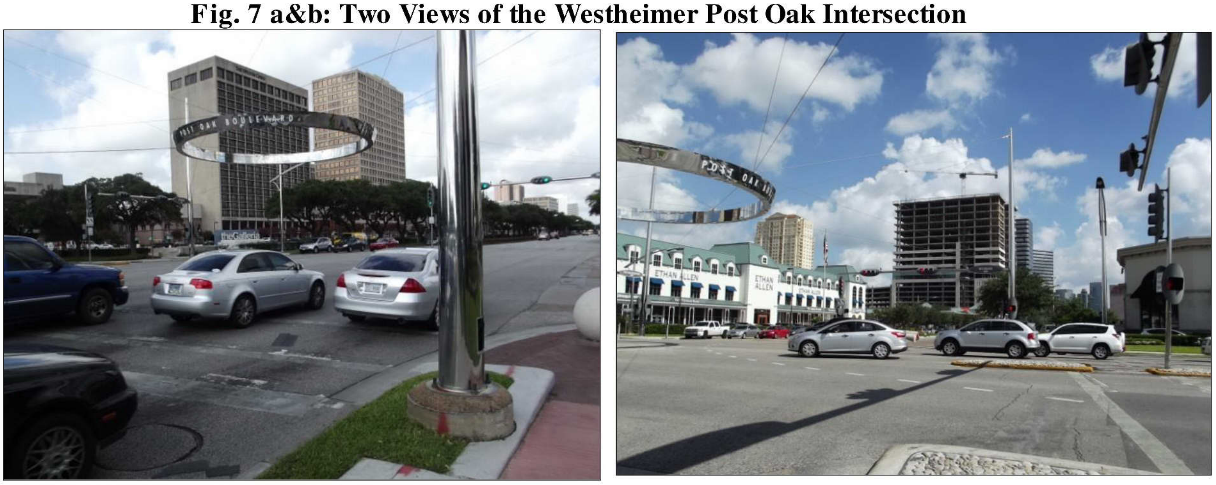
Sample Intersections Installation

The City of Houston has four major industry corridors: Galleria, Greenway Plaza, Downtown, and The Medical Center all which have high traffic volumes on a daily basis along with many other areas that have steady traffic flow throughout each day. Many of Houston's intersections are wide requiring on average 10 to 12 traffic signal lights at each one. Surveying some of these intersections, and examining the amount of traffic signals at each one as well as how the lights control the different traffic directions , it is not hard to see how the conversion to LED can get the city savings. The explanation below represents a simulated reflection of the amount of energy the city can save by converting the incandescent light bulbs to LED at five intersections in Houston. This is done based on the idea that all incandescent bulbs use 100 watt bulbs, and all LED light sources use 20 watt bulbs. It will also show an installation simulation of LED lights based on the cost Arkansas incurred, as well as choose one of the solar panel installation scenarios from above and apply it to make a complete installation proposal for each intersection.

- **<u>The Galleria/ Uptown Area</u>**:

  Home to what some would call Houston's second downtown; the Galleria Uptown District is a bustling shopping and commercial center located six miles west of downtown and is larger than the downtown areas of most big cities around the country. The Galleria mall, one of the largest malls in the nation, is the main entertainment attraction. Top-notch restaurants, hotels, and nightlife surround the area with plenty of things for residents and visitors alike to take part. The Uptown Business District houses about 2,000 companies and a good percent of the city's occupied office space, increasing the traffic flow on a daily basis.

Fig. 7 a&b: Two Views of the Westheimer Post Oak Intersection



(a) **(b)**

The intersection of Post Oak and Westheimer serves as a main entrance to the city. This intersection has 12 signal heads housing a total of 40 bulbs. If the intersection is running on 100 watt incandescent bulbs, which equates to 4000 watts for the intersection, it will consume four kilowatts. By comparison, if the intersection was run on 20 watt LED's it would only consume 800 watts, or 0.8 kilowatts. Since signal lights run all day and all night the intersection will consume 96 kilowatt hours per day on the incandescent bulbs versus 19.2 kilowatt hours on the LED's. If the energy company charges $0.12 per kilowatt hour, then the cost of energy per day would be $11.52 on incandescent lighting and $2.30 running on LEDs. In a year's time, taking for granted that there are no power outages or anything else to cause the lights to go out, running a full 365 days the incandescent intersection would cost the city $4204.80 compared to $840.96. Converting the signals to LEDs results in a savings of $3,363.84 per year. This can be seen in Figure 9 below.

Fig. 8: Simulation of Cost of Energy for a 40 Bulb Intersection

Incandescent Bulbs		
1.Total Wattage for Intersection		
Wattage of 1 bulb	# of bulbs at intersection	Wattage for intersection
100	40	4000
2. Kilowatts Used by Entire Intersection		
Intersection in watts	1 watt=0.001 kilowatts	kilowatts
4000	0.001	4
3. Amount of Kilowatt-hrs/day		
kilowatts	hrs per day	kilowatt-hrs/day
4	24	96
4. Power Costs $0.08 Per Kilowatt for 1 Signal		
kilowatt-hrs/day	Energy Cost per kilowatt	cost of energy per day ($)
96	0.12	11.52
5. Cost Per Year		
cost of energy per day	days per year	cost of energy per year ($)
11.52	365	4,204.8

Light Emitting Diode Bulbs		
1.Total Wattage for Intersection		
Wattage of 1 bulb	# of bulbs at intersection	Wattage for intersection
20	40	800
2. Kilowatts Used by Entire Intersection		
Intersection in watts	1 watt=0.001 kilowatts	kilowatts
800	0.001	0.8
3. Amount of Kilowatt-hrs/day		
kilowatts	hrs per day	kilowatt-hrs/day
0.8	24	19.2
4. Power Costs $0.08 Per Kilowatt for 1 Signal		
kilowatt-hrs/day	Cost per kilowatt	cost of energy per day ($)
19.2	0.12	2.304
5. Cost Per Year		
cost of energy per day	days per year	cost of energy per year ($)
2.304	365	840.96

This intersection has 16 red lights, 12 yellow lights, and 12 green lights. If $57 is used for the cost of red lights, $66 for yellow, and $119 for green lights, the costs for installation of LEDs at the intersection would result as follows.

Fig. 9: Installation Cost for LEDs at 40 Bulb Intersections

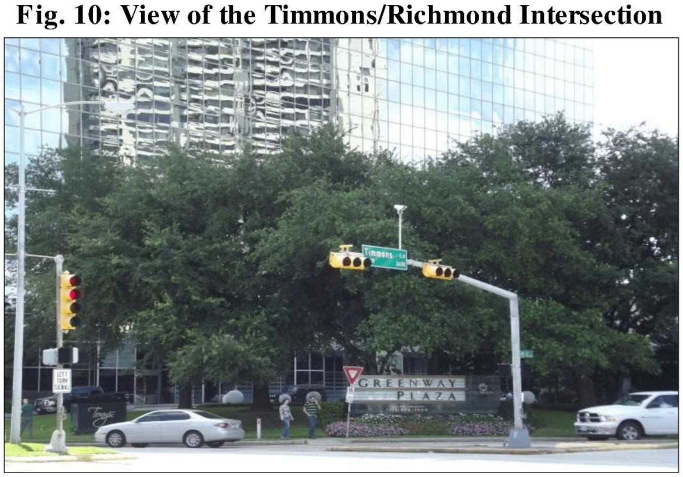
Color of Light	# of Lights at Intersection	Cost for LED light	Total
Red	16	$ 57.00	$ 912.00
Yellow	12	$ 66.00	$ 792.00
Green	12	$ 119.00	$ 1,428.00
		Subtotal	$ 3,132.00
Labor Cost	$ 55.00	Total	$ 3,187.00

If the $5700-$8500 cost range per intersection from Scenario 1 is used for the installation of solar panels at this intersection, the total installation cost range for both solar and LED install would be $8,887 to $11,687. Many of the intersections in Houston are built in this configuration, especially those in the main industry corridors of the city. This example can be used for other intersections that look exactly like Westheimer at Post Oak.

- **Greenway Plaza**:

  Greenway Plaza lies five miles west of downtown Houston and serves as a premier business center in the city. With ten thoughtfully developed buildings, Greenway Plaza, featuring 4,250,641 square feet of top notch office space this area, serves as a beautiful work and entertains professionals of all kind. The main entrance at the intersection of Richmond and Timmons separates this area from the many entertainment spots that surround the area.

Fig. 10: View of the Timmons/Richmond Intersection



This intersection is an exact replica to the Galleria Area intersection of Westheimer at Post Oak with the identical number of traffic signals and individual bulbs. By taking the same $3,187.00 total cost for the LED installation and energy power savings of $3,363.84, but using Scenario 4 from above with a cost per intersection estimate at $14,750 to 17,550, the total installation cost range for both solar panels and LED would be around $17,937 to $20,737.

- **<u>Texas Medical Center:</u>**

  The Texas Medical center is the largest medical center in the world encompassing 14 hospitals, six nursing schools, three medical schools, as well as schools for dentistry, public health, pharmacy, and all other forms of heath care related fields. Being over 1,000 acres land-wise, the Texas Medical Center is larger than the downtowns of most cities including Dallas and Denver. Located in a prime location just outside of the museum district and Hermann Park, the TMC's traffic flow is non-stop. The intersection of Braeswood and Holcombe lies on the outside of the Medical Center. It is a fairly wide intersection with 12 signals lights much like the intersections in the Galleria and Greenway plaza areas. Although this intersection is not the exact replica in terms of the set up as the previous two, it does have the same amount of signals and light sources needed to move traffic smoothly. By taking the same $3187.00 total cost for the LED installation and energy power savings of $3,363.84, but using Scenario 2 from above with a cost per intersection estimate at $11,250 to 14,050, the total installation cost range for both solar panels and LED would be around $14,437 to $17,237.

- **<u>Museum District:</u>**

  The Houston Museum District is composed of 19 museums, galleries, and cultural centers allowing residents and visitors alike to emphasize a wide range of art, science, history, and other educational learning experiences. Situated one and half miles from the Mecom Fountain, this area lies in between The Medical Center, Downtown Houston, and Hermann Park, making it a heavy traffic flow area. Many intersections flow three ways due to the METRO Rail running through it and retain typical four-way intersections.

The intersection at Main where Binz St. turns into Bissonnet St. is a premier heavy traffic flow four-way intersection in this area. It has 10 signals with 12 red lights, 10 yellow lights, and 10 green lights, a 32 lights total. Using the same format as the Table in the Galleria example, the table below shows the comparison of incandescent lights to the LED light sources for the 32 bulbs.

Fig. 11: View of the Main/ Binz-Bissonnet Intersection

Again, using 100 watts as an average power consumption unit for incandescent bulbs, this intersection would consume 3200 watts or 3.2 kilowatts. If the intersection was retrofitted at 20 watt LEDs it would consume only 0.64 kilowatts. Running on LEDs would have the intersection consuming 15.36 kWh per day whereas the incandescent intersection consumes 76.8 kWh per day. At $0.12 per kWh the cost of energy per day would be 9.216 kilowatt hours using incandescent bulbs and 1.8432 using LEDs. The cost of energy per year is $3,363.84 using incandescent bulbs and $672.768 with LEDs, resulting in a savings of $2,691.07. This intersection has 12 red lights, 10 yellow lights, and 10 green lights. If $57 is used for the cost of red lights, $66 for yellow, and $119 for green lights, for the installation of LEDs at the intersection, the cost would result as follows.

Fig. 12: Simulation of Cost of Energy for a 32 Bulb Intersection.

Incandescent Bulbs		
1.Total Wattage for Intersection		
Wattage of 1 bulb	# of bulbs at intersection	wattage for intersection
100	32	3200
2. Kilowatts Used by Entire Intersection		
Intersection in watts	1 watt=0.001 kilowatts	kilowatts
3200	0.001	3.2
3. Amount of Kilowatt-hrs/day		
kilowatts	hrs per day	kilowatt-hrs/day
3.2	24	76.8
3. Power Costs $0.08 Per Kilowatt for 1 Signal		
kilowatt-hrs/day	Energy Cost per kilowatt	cost of energy per day
76.8	0.12	9.216
4. Cost Per Year		
cost of energy per day	days per year	cost of energy per year
9.216	365	3,363.84

Light Emitting Diode Bulbs		
1.Total Wattage for Intersection		
Wattage of 1 bulb	# of bulbs at intersection	wattage for intersection
20	32	640
2. Kilowatts Used by Entire Intersection		
Intersection in watts	1 watt=0.001 kilowatts	kilowatts
640	0.001	0.64
3. Amount of Kilowatt-hrs/day		
kilowatts	hrs per day	kilowatt-hrs/day
0.64	24	15.36
3. Power Costs $0.08 Per Kilowatt for 1 Signal		
kilowatt-hrs/day	Cost per kilowatt	cost of energy per day
15.36	0.12	1.8432
4. Cost Per Year		
cost of energy per day	days per year	cost of energy per year
1.8432	365	672.768

Fig. 13: Installation Cost for LEDs at 32 Bulb Intersections

Color of Light	# of Lights at Intersection	Cost for LED light	Total
Red	12	$57.00	$684.00
Yellow	10	$66.00	$660.00
Green	10	$119.00	$1,190.00
		Subtotal	$2,534.00
Labor Cost	$55.00	Total	$2,589.00

If the $9,200-$12,000 cost range per intersection from Scenario 3 is used for the installation of solar panels at this intersection, the total installation cost range for both solar and LED install would be $11,789 to $14,589.

LED in Practice in Houston

The City Of Houston installed solar powered LEDs in ten traffic control devices as a pilot project. The city has already converted 300 signals to LED. The Figure below shows 10 intersections in a Southwest Houston Area that have already been converted to LED. Results from the "City of Houston Signal Light LED Project Annual Consumption Comparison," shown in Figure 14, show that there has been 48-60 percent savings in energy consumption by switching to LED based on a $0.12 electric rate per kWh (Blended Rate) per kWh of how much the city has saved in 2011. The data also indicates an average cost savings in excess of $700.00 and an average energy savings of 5,888 kWh by using solar powered LEDs versus traditional incandescent light bulbs.

Fig. 14: City of Houston Signal Light LED Project Annual Consumption Comparison

Intersection	Pre-Install Annual Consumption (kWh)	Post-Install Annual Consumption (kWh)	Annual Savings (kWh)	Percent Difference (%)	Energy Cost Savings
Telephone / West Over	17,232	8,979	8,253	47.89%	$ 990.41
Fondren / Willowbend	17,614	8,638	8,976	50.96%	$ 1,077.12
Bellfort W / Gessner	18,414	8,589	9,825	53.36%	$ 1,179.02
Bellfort / Jutland	6,539	2,957	3,582	54.79%	$ 429.88
Bellfort W / Braesridge	7,460	3,320	4,140	55.49%	$ 496.82
Chimney Rock / Gulfton	17,896	7,820	10,076	56.30%	$ 1,209.17
Glenmont / Renwick	5,998	2,530	3,468	57.82%	$ 416.21
Fondren / Ludington	9,557	3,990	5,567	58.25%	$ 668.04
Academy / Bissonnet	3,325	1,354	1,971	59.28%	$ 236.53
Reveille / Thurow	5,074	2,053	3,021	59.54%	$ 362.54

CONCLUSION

Unlike other cities in the northern states of America where walking and bicycling are more heavily used, Houston residents are heavily dependent on the use of roadways and cars to get around the city. As Houston continues to grow larger in usable space and population every year, the city has to ensure that it is able to meet the needs of its land expansion and new constituents to serve them in a safe and orderly way especially when it comes to transportation. Houston Mayor Annise Parker says that Houston strives to be the “alternative energy capital of the world”. Incorporating solar energy in traffic signals allows the city to move one step closer in reaching this goal.

By looking at the data presented, retrofitting the traditional incandescent bulbs to LED is a viable option to save the city money and reduce energy consumption. Although this is a costly venture, the pay off can be seen in less than five years. The addition of installing solar panels aids in support of reducing energy consumption down to nothing. With the panel’s 35-40 year lifespan, the benefit outweighs the initial cost.

It was important to sample intersections in the areas chosen because they are major industry areas in the city and support a heavy traffic flow on a daily basis. By using the average wattages for the incandescent light bulbs and LEDs shows that that energy costs are five times less using the LED light source. Combining the installation cost, of the solar panels and LEDs, gives the city an idea of the costs incurred so that they can decide whether they want to put up the upfront costs in order to reap the long term savings. The literature shows the benefits of using solar energy and LEDs as well as the successes that have been seen in both the United States and abroad. The city has already seen significant savings in energy costs and consumption demonstrated by the 10 intersection analysis. Therefore, because the city has already been successful in seeing energy costs and consumption savings in the intersections it has already converted, it would behoove the city to continue this retrofitting to all the intersections in Houston.

APPENDIX

Figure 15: Pre vs. Post Energy Consumption of 10 Converted Intersections

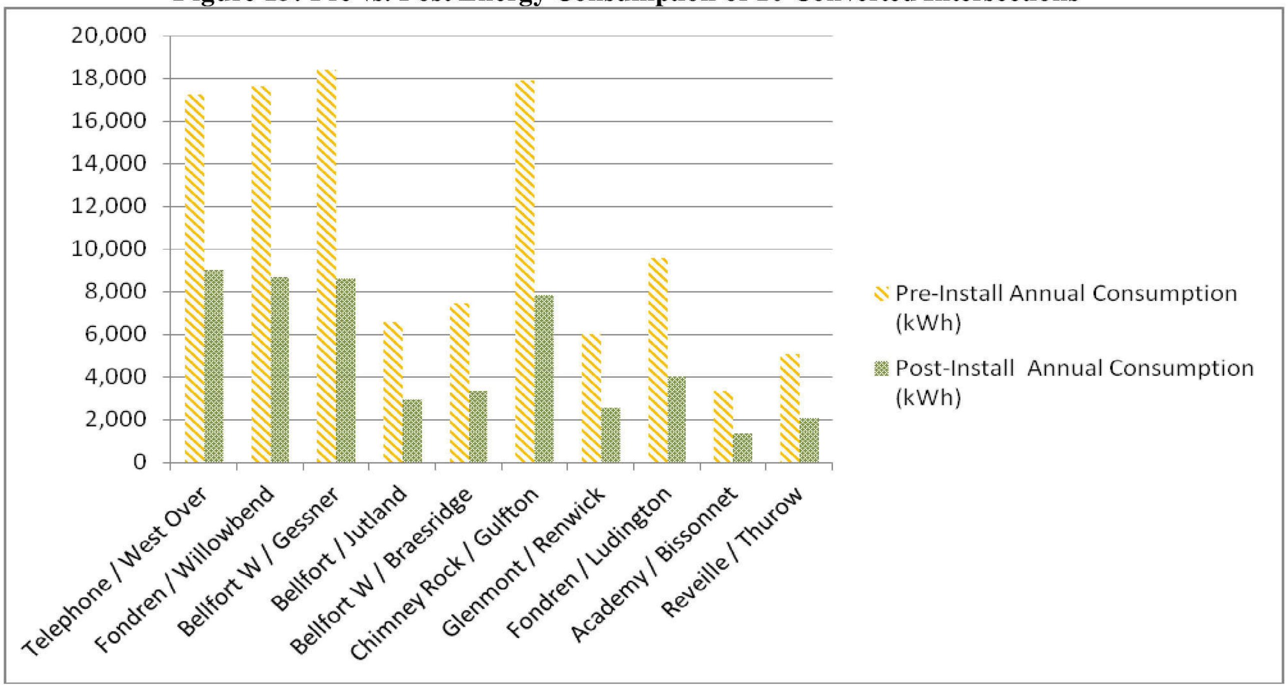


Figure 16: Energy Cost Savings of the 10 Converted Intersections

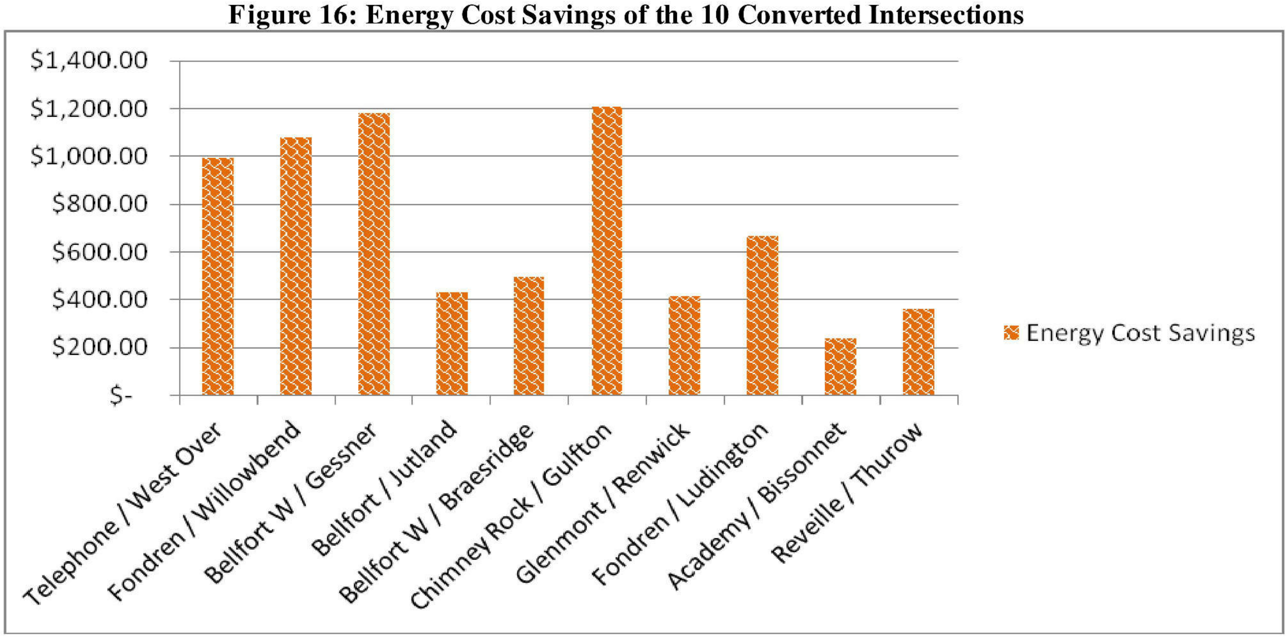
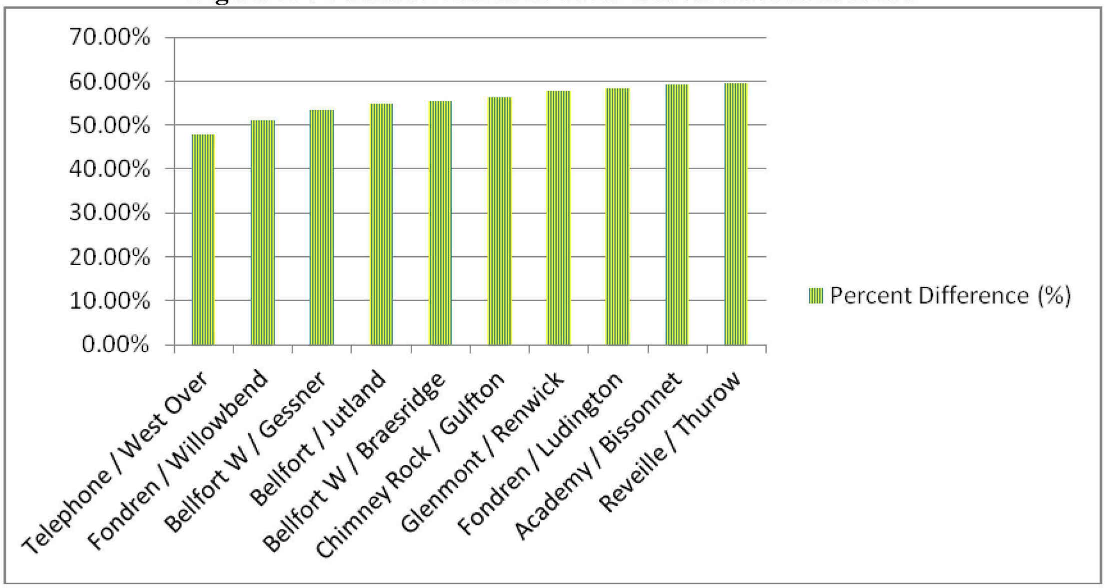


Figure 17: Percent Difference in 10 Converted Intersections



REFERENCES

"Green Power Partnership Partner Profile." United States Environmental Protection agency. EPA, July 30, 2012. Web. August 7, 2012. <http://www.epa.gov/greenpower/partners/partners/cityofhoustontx.htm>. ("United States Environmental Protection agency")

"Why Houston? " The University of Texas MD Anderson Cancer Center. MD Anderson Communications Office 9/11, n.d. Web. 7 Aug 2012. <http://www.mdanderson.org/library/files/whyhouston2.pdf>.

"Conventional Vs LED Traffic Signals; Operational Characteristics and Economic Feasibility." . Arkansas Department of Economic Development, July 1, 2003. Web. July 11, 2012. <http://www.cee1.org/gov/led/little_rock.pdf>.

Green Houston. N.p., n.d. Web. 7 July 2012. <http://www.greenhoutsontx.gov/epr-energysources.html>.

Condren, S. Michael, George Lisensky, Arthur Ellis, et al. "LEDs: New Lamps for Old and a Paradigm for Ongoing Curriculum Modernization." Journal of Chemical Education. 78.8 (2001): 1033-1040. Web. 10 Aug. 2012. <http://condrenrails.com/p1033.pdf>.

Tsoutsos, Theocharis, Niki Frantzeskaki, and Vassilis Gekas. "Environmental impacts from the solar energy technologies." Elsevier. 33.3 (2005): 289-296. Web. 10 Aug. 2012. <http://tbm.home.tudelft.nl/fileadmin/Faculteit/TBM/Over_de_Faculteit/Afdelingen/Afdeling_Multi_Actor_Systems/Sectie_Beleidsanalyse/Medewerkers/Niki_Frantzeskaki/doc/Tsoutsos_Frantzeskaki_2006_EIA_ST.pdf>.

Lewis, Nathan, and Daniel Nocera. "Powering the planet: Chemical challenges in solar energy utilization." Proceedings of the National Academy of Sciences of the USA. 103.43 (2006): 15729-15735. Web. 10 Aug. 2012. <www.pnas/cgi/doi/10.1073/pnas.0603395103>.