AGC
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University of New Mexico

AGC 2015 Sustainable Building & LEED Competition

Problem Statement 1: LEED 2009 vs. LEED v4 Assessment

Part 1: Overall Project Review

Utilizing the LEED 2009 Rating System, the Exposition Light Rail Transit Station at Colorado and 4th Street received a total of 58 of 110 credits.

Utilizing the LEED v4 Rating System, the Exposition Light Rail Transit Station at Colorado and 4th Street received a total of 65 of 110 credits. The project evaluated by the LEED v4 Rating System received more credits than the LEED 2009 Rating System partly because of the addition of the new category, Location and Transportation. The fact that the project itself is a public transportation system increased LEED v4 credits.

Due to the fact that some necessary information was not provided regarding the construction and maintenance of this transit system, many assumptions were made while assessing this project under both rating systems.

Part 2: Materials Category

The following are the main changes in the Materials and Resources Category:

Major Difference	**Credit/Documentation**	**Pros/Cons**
LEED v4 focuses more on extracting and using environmentally friendly materials.	The introduction of all Building Product Disclosure and Optimization Credits shows that LEED v4 has focused on using green materials (Material Ingredients), green manufacturers (Environmental Product Declaration), and Sourcing of Raw Materials in a sustainable manner.	Pros: Increases occupant health, encourages manufacturers to go green, prevents resource depletion (mining, deforestation etc.), prevents habitat loss, and reduces raw material usage. Cons: LEED v4 loses focus on recycling, wood, and regional materials.
LEED v4 is more flexible and gives more rewards for all material reuse.	Because building and material reuse is the most effective strategy in avoiding environmental burden, LEED v4 has decided to reward all material re-usage now.	Pros: Helps create new products through recycling, less resource depletion. Cons: Includes mechanical, plumbing, and electrical equipment (may get confusing).

LEED v4 introduces and emphasizes the idea of a Lifecycle Assessment.	The introduction of the Building Life Cycle Impact Reduction Credit shows that LEED v4 analyzes all stages of a building's life, from material extraction to demolition.	Pros: Increases occupant and environment health (stops ozone depletion), improves product selection, spurs market transformation, cost-effective (reduces materials). Cons: More in-depth and lengthy process

Part 3: Recommendation of Rating System

The Exposition Light Rail Transit Station at Colorado and 4th Street should ultimately use the LEED v4 Rating System. With this rating system, the transit line can receive more credits then the LEED 2009 Rating System. Therefore, the Light Rail Transit can receive a LEED Gold level of certification, compared to the LEED Silver certification the transit system would receive if it would use the LEED 2009 Rating System.

The rationale and assumptions I made below are the reasons Exposition Light Rail Transit Station should use LEED v4 Rating System.

For Sustainable Sites:

CREDIT	REASONING/ASSUMPTIONS
Site Selection	Project is not located on farmland/floodplain.
Protect Habitat	Project is not disturbing animal/plant life.
Open Space	Project does not have enough vegetation.
Stormwater Design	Project must have SD Plan because it is required by law.
Heat Island Effect	Project has trees, shade structures, and solar panels to minimize heat given off.
Light Pollution	Project shows nothing that will stop light pollution.

For Location and Transportation:

CREDIT	REASONING/ASSUMPTIONS
Neighborhood Development Location	Project has not been LEED certified ever so it is not considered for this credit.
Public Transportation	Project itself is public transportation. There are numerous bus services that stop at this station.
Density/Community	Project located by huge shopping mall and dozens of services.
Public Transportation	Project itself is public transportation. There are numerous bus services that stop at this station.

Bicycle Facilities	Project has a long bike path along the whole transit system.
Protect Habitat	Project is not disturbing animal/plant life.
Parking/Fuel-Efficient Cars	Project does not parking incentives for green or carpool vehicles.

For Water Efficiency:

CREDIT	**REASONING/ASSUMPTIONS**
Outdoor Water Reuse	No indication of any sort of water recapture. Given 1 credit assuming they reuse water for landscaping.
Indoor Water Reuse	Again, no indication of any indoor water reuse. Given 3 of 6 because maybe they use water-efficient toilets.

For Energy and Atmosphere:

CREDIT	**REASONING/ASSUMPTIONS**
Optimize Energy Performance/Renewable Energy Production	Project uses solar panels on the majority of the roof.
Demand Response/Advanced Energy Metering	Project information is not known, so no credits were given.
Green Power/Carbon Offsets	Some of the project's carbon footprint is offset through solar panels, but that is the only green power on site.
Refrigerant Management	Assumes project will not use harmful refrigerants in the air.

For Materials and Resources:

CREDIT	**REASONING/ASSUMPTIONS**
All BPD&O	No information is given on where materials come from, so I assumed most of them were green and responsibly extracted since the project is in California.
Construction Waste	Assumed that waste from construction was taken care of because of location in the middle of Santa Monica, California.

For Indoor Environmental Quality:

CREDIT	**REASONING/ASSUMPTIONS**
Low-Emitting Materials	Project must use low-emitting materials to increase commuter health.
Indoor Air Quality	Project must have breathable air for commuters.
Thermal Comfort	Project does not have 90% individual lighting controls so it does not meet this requirement.
Daylight	Project received 1 out 3 credits because it is not fully exposed to sunlight at all times. There are not enough windows.
Quality Views	Project received credit because it is overlooking the beautiful city

	of Santa Monica.
Acoustic Performance	Project received credit because it would have to be built in order for the quiet the loud sound of the rail system.

For Innovation:

CREDIT	REASONING/ASSUMPTIONS
Innovation Idea	The bike path with pretty landscaping along the entire transit system is pleasing and attracts more commuters.

For Regional Priority (Santa Monica):

CREDIT	REASONING/ASSUMPTIONS
Access to Quality Transit	Project is located near many bus services.
Surrounding Density	Project is surrounded by shopping malls, restaurants, and schools.

Problem Statement 2: Life Cycle Sustainability Analysis – Lighting

Part 1: Annual Energy Use

For each of the lighting options, the annual energy usage for one fixture was calculated using **Equation 1.** The values of the annual energy usage in kilowatt-hours for each of the lamps can be found in **Table 1** below. These values were calculated based on the provided rating of power (in watts) on the lighting specification sheets. Based on the contract documents, specifically the electrical reference drawings, the annual energy usage was determined for all of the internal fixtures to the rain canopy for the ticketing area, the singlewide platform and the doublewide platform. These values can be seen in **Table 2**.

Equation 1- Annual Energy Usage = Power (watts) x (8760 hours/year)

Table 1: Annual Energy Usage for A Single Fixture

	Power (watts)	Power (kilowatts)	Hours (in one year)	Annual Energy Usage (kWh)
XWLED 3' Slim LED Wet Light	17.7	0.0177	8760	155.052
XWLED 4' Slim LED Wet Light	23.63	0.02363	8760	206.9988
XWLED 5' Slim LED Wet Light	29.6	0.0296	8760	259.296
ALX2-RLR-WL (WET) Series T8				
X-6A 3'	25	0.025	8760	219
X-6B 4'	32	0.032	8760	280.32
X-6C 5'	40	0.04	8760	350.4

Table 2: Annual Energy Usage for all fixtures specified in Contract Documents

ALX2-RLR-WL T8 (WET) Fluorescent Light	**Power (watts)**	**Power (kilowatts)**	**Hours (in one year)**	**Annual Energy Usage (kWh) for one fixture**	**Number of Fixtures**	**Annual Energy Usage (kWh) for all fixtures**
Ticketing Area Rain Canopy X-6A	25	0.025	8760	219	32	**7008**
Platform Rain Canopy Single Wide X-6B	32	0.032	8760	280.32	36	**10091.52**
Platform Rain Canopy Double Wide X-6C	40	0.04	8760	350.4	36	**12614.4**
XWLED Slim LED Wet Light	Power (watts)	**Power (kilowatts)**	**Hours (in one year)**	**Annual Energy Usage (kWh) for one fixture**	**Number of Fixtures**	**Annual Energy Usage (kWh) for all fixtures**
Ticketing Area Rain Canopy 3'	17.7	0.0177	8760	155.052	32	**4961.664**
Platform Rain Canopy Single Wide 4'	23.63	0.02363	8760	206.9988	36	**7451.9568**
Platform Rain Canopy Double Wide 5'	29.6	0.0296	8760	259.296	36	**9334.656**

Part 2: Life Cycle Analysis

The Life Cycle Cost for each of the fixtures from each of the subcontractor's bids was determined utilizing **Equation 2 below**. There were some assumptions made when calculating the Life Cycle Cost. First, it was assumed that the lights had no salvage value. Referenced from the U.S. Energy Information Administration, it was assumed that the current electric cost per kilowatt-hour was $0.022. The specification sheet for the XWLED Slim LED Wet Lights provided a life span of 50,000 hours and a manufacturer's warranty of 5 years. The ALX2-RLR-WL T8 (WET) Fluorescent Light specification sheet did not provide a life span so it was assumed that it may have a lifespan of half of the LED light (25,000 hours). There was no specified manufacturer's warranty for these fluorescent lights.

It was determined that the alternative, the XWLED Slim LED Wet Lights, had a lower life cycle cost for each of the subcontractor's bids. The life cycle cost for each subcontractor's bid can be seen for both the fluorescent and the LED alternative in **Table 3.**

Equation 2-Life Cycle Cost

$$LCC = FC + \sum_{t=0}^{t=n} pwf\,[MC+IC+FRC+UC] + pwf\,[S]$$

LCC- Life Cycle Cost
FC-Initial Cost
pwf-Present Worth Factor
MC-Maintenance Costs
IC-Inspection Costs (not applicable for this calculation)
FRC-Replacement Costs
UC-User Cost
S-Salvage Value (not applicable for this calculation)

Table 3: Life Cycle Cost Analysis

FOV Group	Initial Cost	Maintenance Cost (after warranty)	Replacement Cost after Life Span	User Electricity Cost	LCC for One Fixture	LCC for All Fixtures Specified in Contract Documents
X-6A Fluorescent	188	1677.903236	582.0473438	63.6303624	2511.580942	80370.59015
X-6B Fluorescent	213	1677.903236	582.0473438	81.44686387	2554.397444	91958.30797
X-6C Fluorescent	234	1677.903236	582.0473438	101.8085798	2595.75916	93447.32975
		*Assuming No Manufacturer Warranty and 1-Year Subcontractor Warranty; 25,000 hours of life or approximately 3 Year lifespan				
3' LED	298	998.8353693	219.5204288	45.05029658	1561.406095	49964.99503
4' LED	315	1234.762798	212.8199505	60.14341854	1822.726167	58327.23735
5' LED	388	1234.762798	212.8199505	75.33610015	1910.918849	61149.40316
		*Assuming 5-Year Manufacturer Warranty and 1-Year Subcontractor Warranty; 50,000 hours of life or approximately 5 Year lifespan				

McKinstry	Initial Cost	Maintenance Cost (after warranty)	Replacement Cost after Life Span	User Electricity Cost	LCC for One Fixture	LCC for All Fixtures Specified in Contract Documents
X-6A Fluorescent	194	1198.416861	457.539825	63.6303624	1913.587048	61234.78555
X-6B Fluorescent	220	1198.416861	457.539825	81.44686387	1957.40355	70466.5278
X-6C Fluorescent	241	1198.416861	457.539825	101.8085798	1998.765266	71955.54957
		*Assuming No Manufacturer Warranty and 3-Year Subcontractor Warranty; 25,000 hours of life or approximately 3 Year lifespan				
3' LED	307	526.3176464	144.2198166	45.05029658	977.5374629	31281.19881
4' LED	325	526.3176464	144.2198166	60.14341854	1055.680882	38004.51173
5' LED	400	526.3176464	144.2198166	75.33610015	1145.873563	41251.44827
		*Assuming 5-Year Manufacturer Warranty and 3-Year Subcontractor Warranty; 50,000 hours of life or approximately 5 Year lifespan				

Cochran	Initial Cost	Maintenance Cost (after warranty)	Replacement Cost after Life Span	User Electricity Cost	LCC for One Fixture	LCC for All Fixtures Specified in Contract Documents
X-6A Fluorescent	213	1756.502693	538.520325	63.6303624	2358.65338	75476.90817
X-6B Fluorescent	242	1756.502693	538.520325	81.44686387	2376.469882	85552.91575
X-6C Fluorescent	252	1756.502693	538.520325	101.8085798	2396.831598	86285.93752
		*Assuming No Manufacturer Warranty and No Subcontractor Warranty; 25,000 hours of life or approximately 3 year lifespan				
3' LED	338	1218.355798	219.5204288	45.05029658	1820.926523	58269.64875
4' LED	357.52	1219.355798	219.5204288	60.14341854	1856.539645	66835.42723
5' LED	388	1219.355798	219.5204288	75.33610015	1902.212327	68479.64377
		*Assuming 5-Year Manufacturer Warranty and No Subcontractor Warranty; 50,000 hours of life or approximately 5 Year lifespan				

Part 3: Subcontractor Selection

The subcontractor that the team has selected is McKinstry. Although this contractor has a higher construction fee, a three-year warranty is offered on substantial completion of workmanship in addition to any manufacturer's warranty that applies to McKinstry supplied material. Within the calculation of the Life Cycle Analysis, this three-year warranty lowered the Life Cycle Cost proving that McKinstry would be both the lowest subcontractor bid as well as the overall best value for the ten-year cycle. The maintenance and replacement fee for the XWLED Slim LED Wet Lights was the same as the ALX2-RLR-WL T8 (WET) Fluorescent Light maintenance and replacement fee. McKinstry also appears to be a responsible bidder that advocates collaborative and sustainable solutions to ensure occupant comfort, improve systems efficiency, reduce facility operational costs, and ultimately optimize client profitability for the life of their building.

Part 4: Incentives & Rebates

There are available incentives and rebates for business rate plans through Southern California Edison (SEC), a local electricity provider for the Santa Monica area. The maximum customer incentive per energy solution is 100% of the energy upgrades cost. The installed cost includes material cost only. Labor costs may be eligible when a vendor-installed project is involved. As provided in Southern California Edison's Solutions Directory, the LED lights as well as linear fluorescent lights are also eligible for incentives. For exterior induction fixtures with LED bulbs up to 70 watts, the incentive is $25.00 per fixture. For exterior linear fluorescent light, the incentive is $0.03 per kilowatt-hour.

Part 5: Incentives & Rebates

Based on the above Life Cycle Cost Analysis, the team would recommend the alternative Lithonia XWLED Slim LED Wet Light. For all of the subcontractor bids provided, the Lifc Cycle Cost was found to be the lowest for the LED lights. While the upfront cost may be higher, the LED lights typically have a longer life span of 50,000 hours or more as seen in the analysis. Fluorescent lighting is often loud and requires time to reach optimum lumens. Using a simple Life Cycle Cost Analysis calculator, it was determined that for example the annual savings per year for one bulb utilizing the Lithonia XWLED 4' Slim LED Wet Light (based on McKinstry's subcontractor bid and a rate of $0.022 per kilowatt-hour) would be $41.56. The payback analysis reveals that it would only take approximately seven years to earn back the initial investment for the LED lights.

	Lamp 1	Lamp 2
Lamp name:	Fluorescent	LED
Cost over lamp life:	$350.60	$463.99
Cost per 1,000 hours:	$14.02	$9.28
Cost per year:	$122.85	$81.29
Savings:		+$41.56

Problem Statement 3: Concrete Carbon Footprint

Part 1:

1) How many cubic yards of concrete will be required for the 4st street station?

Station Takeoffs		Stations Summary	
Platform Footings	185.84	Platform Footings	186
Platform Walls	141.56	Platform Slabs & Mat Footing	7.3
Sidewalk Footings	10.88	Platform Walls	142
Sidewalk Slab	18.82	TC & C Flooring	20

Sidewalk Walls	20.16	TC & C Walls	27
Slabs & Mat Footing	7.16	Sidewalk Footing	12
TC & C Footing	20.15	Sidewalk Walls	66
TC & C Walls	27	TOS Footing	92
TOS Buildings	91.34		
Total	**522.91**	**Total**	**552.3**
Add 7% Waste	559.5137		
Total Concrete (cy)	**559.51**		

2) What is the total price for each supplier? Which is the least expensive?

White Castle Concrete

Assume 1" aggregate @ 4000 psi	$64
Total Concrete (cy) for 4th St Station	559.51
Total:	$35,808.64
Extra Costs - Fuel Charge per load @ $20	
Total Concrete (cy)	559.51
Assume each Ready Mix Truck Capacity (cy)	10
Total # of trips (concrete / capacity)	55.95 or 56
Fuel Charge ($20 * 56)	$1,120
Overall Total:	$36,928.64

Slip Diamond Ready Mix

Assume 1" aggregate @4000psi		$73.50
Total Concrete (cy) for 4th St Station		559.51
	Total:	$41,123.99
Extra Costs - Fuel Charge per load @ $20		
Total Concrete (cy)		559.51
Assume each Ready Mix Truck Capacity (cy)		10
Total # of trips (concrete/capacity)		55.95 or 56
Fuel Charge ($20 * 56)		$1,120

Extra Costs - Environmental Fee

Charge (per load)		$20
Total # of trips (concrete/capacity)		56
Environmental Fee ($20 * 56)		$1,120
	Overall Total:	$43,363.99

City Park Concrete

Assume 1" aggregate @ 4000 psi		$63
Total Concrete (cy) for 4th St Station		559.51
	Total:	$35,249.13

Extra Costs - Environmental Fee

Charge (per load)		$25
Total # of trips (concrete/capacity)		56
Environmental Fee ($25 * 56)		$1,400
	Overall Total:	$36,649.13

The overall total price for each supplier is :	White Castle	$36,928.64
	Slip Diamond	$43,363.99
	City Park Concrete	$36,649.13

The least expensive supplier is City Park Concrete just barely edging out White Castle Concrete.

3) What is the carbon footprint of each supplier? Which Supplier has the smallest footprint?

White Castle Concrete

From source to batch plant:

Cement (on site)		0 tons of CO_2
Fly Ash (San Antonio, TX)		
	Type of fuel used:	diesel
	Avg fuel efficieny:	3.05 mpg
	Total qty of Flyash (cy) *	48.07 cy

*Made a ratio from our total cy of concrete to the amount of cy of fly ash

*(559.51 cy of total concrete * 2.32 cy of flyash) / 27cy

Truck Capacity: 81cy

# of trips (total flyash/truck capacity) 0.59 or 1 (rounded)

Distance from source: 1,362

Equation used to convert equipment and fuel of trucks to tons of CO2

Fuel Consumption per Trip = (1 * distance from source) / Avg Fuel Efficienty

446.6

Fuel Consumption per # of trips = # of trips * fuel consumption per trip

446.6

Carbon emissions per gallon of diesel

22.23

Carbon emissions per trip = fuel consumption per # of trips * carbon emissions

9,927.92 lbs of CO2

Convert lbs of CO2 to tons 4.96

Aggregates (Orca Quarry, Vancouver, BC)

Type of fuel used: diesel

Avg fuel efficieny: 3.05 mpg

Total qty of aggregate * 117.3 cy

*Made a ratio from our total cy of concrete to the amount of cy of fly ash

*(559.51 cy of total concrete * 5.66 cy of flyash) / 27cy

Truck Capacity: 104cy

# of trips (total aggregates/truck capacity) 1.13 or 1 (rounded)

Distance from source: 1,275

Equation used to convert equipment and fuel of trucks to tons of CO2

Fuel Consumption per Trip = (1 * distance from source) / Avg Fuel Efficienty

418.03

Fuel Consumption per # of trips = # of trips * fuel consumption per trip

418.03

Carbon emissions per gallon of diesel 22.23

Carbon emissions per trip = fuel consumption per # of trips * carbon emissions

9292.8 lbs of CO2

Convert lbs of CO2 to tons 4.65

From Batch Site to Project Site

Type of fuel used: diesel
Avg fuel efficieny: 3.05 mpg
Total qty of concrete 559.51 cy
Truck Capacity: 10cy
Distance from Source 10.76 mi

Fuel Consumption per Trip = (2 * distance from source) / Avg Fuel Efficienty
7.06 gallons

Fuel Consumption per # of trips = # of trips * fuel consumption per trip
395.36 gallons

Carbon emissions per gallon of diesel 22.23 lb of CO2

Carbon emissions per trip = fuel consumption per # of trips * carbon emissions
8,788.85 lbs of CO2

Convert lbs of CO2 to tons 4.39

Total tons of CO2: **14**

City Park Concrete

From source to batch plant:

Flyash (none stated) 0 tons of CO2

Cement (Ontario, CA)

Type of fuel used: diesel
Avg fuel efficieny: 3.05 mpg
Total qty of Cement (cy) * 84.13

*Made a ratio from our total cy of concrete to the amount of cy of fly ash
*(559.51 cy of total concrete * 4.06 cy of flyash) / 27cy

Truck Capacity: 10cy
# of trips (total cement/truck capacity) 6.79 or 7
Distance from source: 18.9 mi

Equation used to convert equipment and fuel of trucks to tons of CO2

Fuel Consumption per Trip = (2 * distance from source) / Avg Fuel Efficienty
12.39

Fuel Consumption per # of trips = # of trips * fuel consumption per trip
86.73

Carbon emissions per gallon of diesel 22.23

Carbon emissions per trip = fuel consumption per # of trips * carbon emissions

1,928 lbs of CO_2

Convert lbs of CO_2 to tons 0.96

Aggregates (Irwindale, CA)

Type of fuel used: diesel

Avg fuel efficieny: 3.05 mpg

Total qty of aggregate * 369.07

*Made a ratio from our total cy of concrete to the amount of cy of fly ash

*(559.51 cy of total concrete * 17.81 cy of flyash) / 27cy

Truck Capacity: 104

# of trips (total aggregate/truck capacity) 3.55

Distance from source: 37

Equation used to convert equipment and fuel of trucks to tons of CO_2

Fuel Consumption per Trip = (2 * distance from source) / Avg Fuel Efficienty

24

Fuel Consumption per # of trips = # of trips * fuel consumption per trip

85.2

Carbon emissions per gallon of diesel 22.23

Carbon emissions per trip = fuel consumption per # of trips * carbon emissions

1,893.99 lbs of CO_2

Convert lbs of CO_2 to tons 0.95

From Batch Site to Project Site

Type of fuel used: diesel

Avg fuel efficieny: 3.05 mpg

Total qty of concrete 559.51 cy

Truck Capacity: 10cy

Distance from Source 12.5 mi

Fuel Consumption per Trip = (2 * distance from source) / Avg Fuel Efficienty

8.2

Fuel Consumption per # of trips = # of trips * fuel consumption per trip

459.2

Carbon emissions per gallon of diesel 22.23 lb of CO_2

Carbon emissions per trip = fuel consumption per # of trips * carbon emissions	
	10,208.02
Convert lbs of CO2 to tons	5.1
Total tons of CO2:	**7.01**

4) Due to the sustainability goals of the client, each ton of CO2 produced has a cost to the project of
$40/ton.

City Park Concrete came up with the total lowest CO2 produced with 7.01 tons. If we multiply 7.01 *
$40 a ton, the total cost will be $280. If we add that to their overall total price of $36,649 and add the $280, we will get a new total price of 36,929. Thus, we still recommend City Park Concrete for the job.

Part 2

1.

$$1. CO_2 = \frac{((16\times2\times5\times)(2))}{20}\times19.4\times1.053 = 326.74\times2\ Veh\ = 653.47\ lbs$$

$$2. CO_2 = \frac{((70\times2\times5)(2))}{20}\times19.4\times1.053 = 1429.47\times3\ Veh = 4{,}288.42\ lbs$$

$$3. CO_2 = \frac{((93\times2\times5)(2))}{20}\times19.4\times1.053 = 1899.16\times2\ Veh = 3798.32\ lbs$$

$$(653.47) + (4{,}288.42) + (3798.32) = 8740.21 lbs \div 2000\ lbs = 4.37\ Tons\ CO_2$$

2.

$$CO_2 = \frac{((15\times2\times5)(2)}{20}\times19.4\times1.053 = 306.32\times7\ Veh = 2144.24\ lbs$$

$$\frac{2144.24 lbs}{2000\ lbs} = 1.072\ Tons\ CO_2$$

3.

$$CO_2 = \frac{(70\times2\times5)(2)}{20}\times19.4\times1.053 = 1429.47\ lbs\ CO_2$$

To Carpool from Riverside

$$CO_2 = \frac{(93\times2\times5)(2)}{20}\times19.4\times1.053 = 1899.16\ lbs\ CO_2$$

To Carpool from Oceanside

$$1429.47 + 1899.16 = \frac{3328.63\ lbs}{2000\ lbs} = 1.664\ Tons\ CO_2$$

Problem Statement 4: Water Collection and usage

Part 1. Monthly Water Usage

To calculate the total monthly water used to irrigate landscaping we used the following Equations:

$K_L = k_s \times k_d \times k_{mc}$

Where K_L is the Landscape Coefficient

k_s is the Plant Coefficient

k_d is the Plant Density

K_{mc} is the Microclimate Factor

The landscape coefficient equation is used to calculate the amount of water loss from landscape plants. Plant coefficient was given in the problem to be .5, the density was calculated to be 1.0 due to the placement and quantity of mixed plants, the microclimate was calculated to be 1.1 due to the close proximity of concrete and asphalt pavement to the landscaped areas.

$ET_L\,(in) = ET_0 \times K_L$

Where ET_L is the Landscape Evaporation

ET_0 is the Reference Evaporation

K_L is the Landscape Coefficient

The Landscape Evaporation equation is used to obtain the amount of moisture that is evaporated form landscaping in inches. K_L was used calculated using the previous equation, ET_0 was referenced from a chart found on Atomic Irrigation's website. The chart shows the evaporation rate for each month in the Santa Monica area.

Number	Name	Region
32	Colusa	Sacramento Valley
99	Santa Monica	Los Angeles Basin

Stn	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
32	0.95	1.73	3.42	5.03	6.43	7.62	8.34	7.23	5.35	3.78	1.79	1.08	52.75
99	1.79	2.12	3.30	4.49	4.73	5.03	5.40	5.38	3.94	3.40	2.42	2.22	44.22

Table taken form atomicirrigation.com

$$TWA\ (gal) = (\frac{Area(sf)xETL(in)}{IE})\times 0.6233(\frac{\frac{gal}{sf}}{in})$$

Where TWA is the total water applied in gallons
IE is the sprinkler efficiency factor

The Total Water Applied formula calculates the amount of water needed for landscaping for the given month. The area to be landscaped was calculated to be 7,933 square feet. Drawings show three areas to be landscaped, two on drawing L-007 and one on L-008. The area is multiplied by the ET_L factor then divided by the sprinkler efficiency factor. Sprinkler efficiency (IE) was estimated to be 50% based on the overhead sprinkler design specified by the landscape areas. Once the TWA was calculated a conversion from inches of water to gallons was made by multiplying TWA by the conversion factor of .6233. This process was repeated for all months using their unique ET_0 factor.

Months	**K_L**	**ET_0**	**ET_L**	**IE**	**Gallons/sf/in**	**Gallons per Month**
January	0.550	1.79	0.98	0.50	1.97	9735.99
February	0.550	2.12	1.17	0.50	2.33	11530.90
March	0.550	3.30	1.82	0.50	3.63	17949.04
April	0.550	4.49	2.47	0.50	4.94	24421.57
May	0.550	4.73	2.60	0.50	5.20	25726.96
June	0.550	5.03	2.77	0.50	5.53	27358.69
July	0.550	5.40	2.97	0.50	5.94	**29371.16**
August	0.550	5.38	2.96	0.50	5.92	29262.37
September	0.550	3.94	2.17	0.50	4.33	21430.06
October	0.550	3.40	1.87	0.50	3.74	18492.95
November	0.550	2.42	1.33	0.50	2.66	13162.63
December	0.550	2.22	1.22	0.50	2.44	12074.81
					Total Gallons per Year	**240,517.13**

The month of July will require the most Gallons at 26,701.

<u>Part 2: Rain Water Collection</u>

In order for the irrigation needs to be met, it will be necessary to store more than 29,371.16 gallons. A cistern would need to be larger than 29,371.16 gallons to hold enough water for the month with the highest evaporation rate.

Los Angeles has an annual rainfall of 14 inches, the months from December to March make up 83% of annual accumulation. With May through August requiring the most irrigation a cistern much larger will be required to store seasonal rainfall to sustain the arid summer months. The excess rainfall from December to March will keep the Cistern full to meet the demand of the summer months.

Part 3: Cistern

Accounting for the 1 foot cistern walls on all sides, the dimensions were calculated to be 10 feet deep by 31 feet long and 24 feet wide. The volume of the cistern was calculated to be 7,440 square feet. Taking the conversion rate of 7.48 gallons of water per cubic foot, the capacity of the cistern in gallons is 55,655.
The size of the Cistern will be large enough to handle the maximum demand of the highest month of the year. However with an average annual rainfall of just 14 inches the catchment area will have to exceed 13,781 square feet to supply enough water for the irrigation demand. To account for dry seasons a catchment area of 150% or 20,671 square feet is recommended. The set aside area of the platform, track and plaza will be large enough to supply the annual demand for irrigation.

Part 1:Solar Panel Design

1)

Amount of panels needed to provide			
sufficient power to buildings	166	1148	202
# of panels in lot	148	1123	184
# of panels on roofs	18	25	18
% total energy provided by roof panels	8.1	1.6	6.7
Cost (panel materials and installation)	$77,190	$172,200	$90,900

Evaluation: The two buildings will require a total of 18 Sunpower panels installed on the roofs to provide at least 8% of their energy use. The other two models do not have the capability to provide that amount of energy in the limited spacing on the roof. The C/S building will only be able to hold 2 panels due to their size and the extremely limited space on that roof from the ductwork and gate with fencing. The TOS roof is assumed to be free from any interfering objects and can fit the rest of the solar panels on top. See layout of panels below. The remainder of the solar panels will be located in the 4 acre lot to the side of the property.
Calculations:

$$\boldsymbol{Total\ Energy\ from\ both\ buildings}$$
$$= [(380.19 + 240) * .293 * 1139m^2]365day/year$$
$$= 567kWh/day$$
$$\boldsymbol{Energy\ per\ panel(Sunpower) = .345(6.1)(1.63) = 3.4kWh/day}$$
$$\boldsymbol{Number\ of\ Panels\ Required = \frac{567}{3.4} = 166\ panels}$$

$$\mathbf{18}\boldsymbol{panels} * \mathbf{3.4} * \frac{(\mathbf{0.75})}{\mathbf{567}} = \mathbf{8.1}\%\ \boldsymbol{use\ on\ roof}$$

Repeat for the other models of solar panels

2)

	Sunpower X21-345	Grape Solar GS-Start-100W	Sunmodule SW275 Mono
Installation Cost (per panel)	$465	$150	$450
Size (mm x mm)	1559x1046	1020x670	1675x1001
Lifetime	25 years	25 years	25 years
Efficiency	21.50%	16.80%	16.40%
Maximum Power (W)	345	100	275
Area (m^2)	1.63	0.682	1.677
Guaranteed Output over 10y	93%	90%	90%
Cost Estimate ($/W)	1.35 $/W	1.50 $/W	1.64 $/W

Evaluation: After comparing and contrasting the 3 solar panel alternatives, we have determined the best brand to use in this instance is the Sunpower X21-345. There are several reasons why this model was selected over the others.
First the cost per Watt produced is the cheapest. Given the higher efficiency of the Sunpower solar panels, fewer of them are required to supply enough energy to keep the C/S building and TOS building running on net zero energy, and for a much cheaper cost.
Calculations:

$$\frac{\mathbf{465\$}}{\mathbf{345}\boldsymbol{W}} = \mathbf{1.35\$}/\boldsymbol{W}$$

3)

-a) For optimal energy returns from your solar panels in the Los Angeles area, all the panels should face directly south. This was determined to be the optimal direction using the Solar Electricity Handbook.

-b) In order to have the most benefits in energy returns from the solar panels without changing their orientation throughout the year, the panels should be oriented at 56d from the vertical. This was also determined using the Solar Electricity Handbook.

-c) If the intent is to adjust the angle of the panels twice during the year, different angles should be used. For the summer months, starting April 1, the solar panels should be inclined at an angle of 71d from the vertical. For the next 6 months, beginning October 1, the panels should be adjusted to an angle of 41d from the vertical in order to take full advantage of the sun's lower orbit in the sky. These orientations and dates were determined using the Solar Electricity Handbook.

Part 2: Additional Renewable Energy – Options to Net Zero

Cost-Benefit Analysis: 4th Street Station					
			Total	Discount	Present

Years	Costs	Savings	Savings	Factor	Value
2015	$113,784.00	4553.01	-$109,230.99	0.133454702	-$14,577.39
2016	$400.00	$4,553.01	$4,153.01	0.13332138	$553.69
2017	$400.00	4553.01	$4,153.01	0.133188192	$553.13
2018	$400.00	$4,553.01	$4,153.01	0.133055137	$552.58
2019	$400.00	4553.01	$4,153.01	0.132922215	$552.03
2020	$400.00	$4,553.01	$4,153.01	0.132789425	$551.48
2021	$400.00	4553.01	$4,153.01	0.132656769	$550.92
2022	$400.00	$4,553.01	$4,153.01	0.132524244	$550.37
2023	$400.00	4553.01	$4,153.01	0.132391853	$549.82
2024	$400.00	$4,553.01	$4,153.01	0.132259593	$549.28
				NPV=	-$9,614.09
Discount					
Rate=	0.10%				
Shortcut:					
NRV=	-$72,040.10				
IRR=	-17%				

The cost for 2015 was the initial cost of panels, slab on grade, inverters, gravel, and fencing. The savings are the costs not used paying utilities annually. The net present value is negative because the pay back period for return on investment is 16 years.

Product chosen is the Sunpower X21-345 panel for the adjoining parcel of (~4 acre site). Based on the cost analysis we concluded that the cost for Grape Solar was $285948 and Sunmodule plus was $158280.

	Sunpower X21-345	Sunmodule Plus	Grape Solar GS-
Cost	$465.00	$450.00	$150.00
Watt	345 W	275 W	100 W
kwh/m^2/day	1.16	0.9	0.81

Sunpower				
Items	Cost ($)	Quantity	Units	Totals ($)
Panels	465	148	(materials &	68820

			install)	
Slab on Grade (6in) total cost	4.5	3256	sqft	14652
Inverters	2,159	14	units	30226
Gravel	1.5	2500	Sqft	3750
Fencing	20	3256	Sqft	65120

Overall Cost	33976

Grape Solar

Items	Cost ($)	Quantity	Units	Totals ($)
Panels	150	1148	(materials & install)	172200
Slab on Grade (6in) total cost	4.5	17220	sqft	14652
Inverters	2,159	14	units	30226
Gravel	1.5	2500	Sqft	3750
Fencing	20	17220	Sqft	65120

Overall Cost	285948

Sunmodule

Items	Cost ($)	Quantity	Units	Totals ($)
Panels	275	202	(materials & install)	55550
Slab on Grade (6in) total cost	4.5	4040	sqft	18180
Inverters	2,159	14	units	30226
Gravel	1.5	2500	Sqft	3750
Fencing	20	4040	Sqft	80800

Overall Cost	158280

Area per panel (additional space for maintenance)	22	sqft
Area needed for mounting and panels	3256	sqft

kwh electric costs in L.A.	0.022		
days	365	8.03	
kwh/day used by TOS , C&S	567	4553.01	annual electric cost
16yr payback period	25.6725	Future Value Factor on Annul Series	
	$116887.1492		

Project maintenance cost is washing the panels, which require 1 gallon of distilled water per panel at one dollar per gallon totaling $148. Plus labor costs of $9.00 per hour and assumption of 5 hours for washing, totaling $45.00 every six months for a grand total of maintenance of ~$400.00 annually.

Part 3: Alternative Renewable Energy Sources

a. Biofuel-based electrical systems
   Biofuel-based electrical production incorporates the use of untreated wood waste. For this option to be sustainable there needs to be a supply of biofuel in a close proximity to the location it will be burned. Storage considerations are also a drawback to this technology, on this site there will not be adequate storage locations to store the biofuel before it is burnt.

b. Geothermal energy systems
   Geothermal energy systems provide energy by absorbing the energy that is stored in the earth from geologic processes. Through the use of heat pumps heat is transferred from a fluid traveling through wells drilled into the earth. To install geothermal energy systems, they require enough land to drill the appreciate amount of wells to supply the heat pumps with enough heat to power steam generators and heating systems. Due to the limited space available geothermal systems will not be possible on this site.

c. Hydroelectric power systems

Hydroelectric power is produced using the energy stored in water as it is released from a dam or ocean via tidal power stations. The potential energy is turned into electricity either by turbines or mechanical energy from waves and tides in the ocean. Due to the proximity to the ocean this option is possible for the site. Due to regulatory regulations however the bay may not be permitted for the installation of tidal power stations.

d. Micro wind turbines

Micro wind turbines are smaller than standard turbines with rotor span of up to 12 feet. Their size allows them to be able to be mounted to roofs of buildings and homes. A single micro turbine can provide enough power to power a small house. Through strategic locating these turbines provide the best alternative to PV panels. Cost is under 10,000 dollars. On the bay there is ample wind energy available to provide power. The drawback to wind turbines is the noise pollution they produce and the potentially undesirable aesthetic appeal.

Bonus Questions

1. The estimated ridership of the Expo 1 and 2 project in 2030 is 64,000 daily riders.

2. 2030-2015= 15 year span

   Assumptions

   - All 64,000 people drive a 2005 Toyota Camry.
   - They all have a 18.5 gallon fuel tank capacity and get 25 MPG.
   - Each person commutes 5 miles round-trip each day.

   5 miles/day x 64,000 people= 320,000 total miles every day

   320,000 total miles every day x 5475 days (15 years) = 1,752,000,000 miles

   1,752,000,000 miles / 25 MPG = 70,080,000 gallons saved

3. To increase ridership, we propose a frequent rider program based off of a points rewards system. A rider earns a point every time he/she steps on the Light Rail. Once a rider earns 30 points, he/she will earn a full day free on the Light Rail. Additionally, we propose a 25% off discount for all college students on weekdays.

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