Implementation – Pre-Trip Plan

Community:	Nyadire
Country:	Zimbabwe
Chapter:	Carnegie Mellon University
Submittal Date:	2/4/2017
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Draft or Final:	Final
Scope of Implementation (100 words):	To oversee the construction of decentralized solar street lights across the community

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1.0 Facility Design

1.1 Description of the Proposed Facility

General Community Information:

The Nyadire Community is a rural community in Northeastern Zimbabwe approximately 1 square kilometer in size and is home to 200 family units, 300 elementary school students, 500 high school students and 900 college students, approximating to 3000 residents. In addition to lodgings and educational facilities, the community also has a hospital, orphanage and a farm.

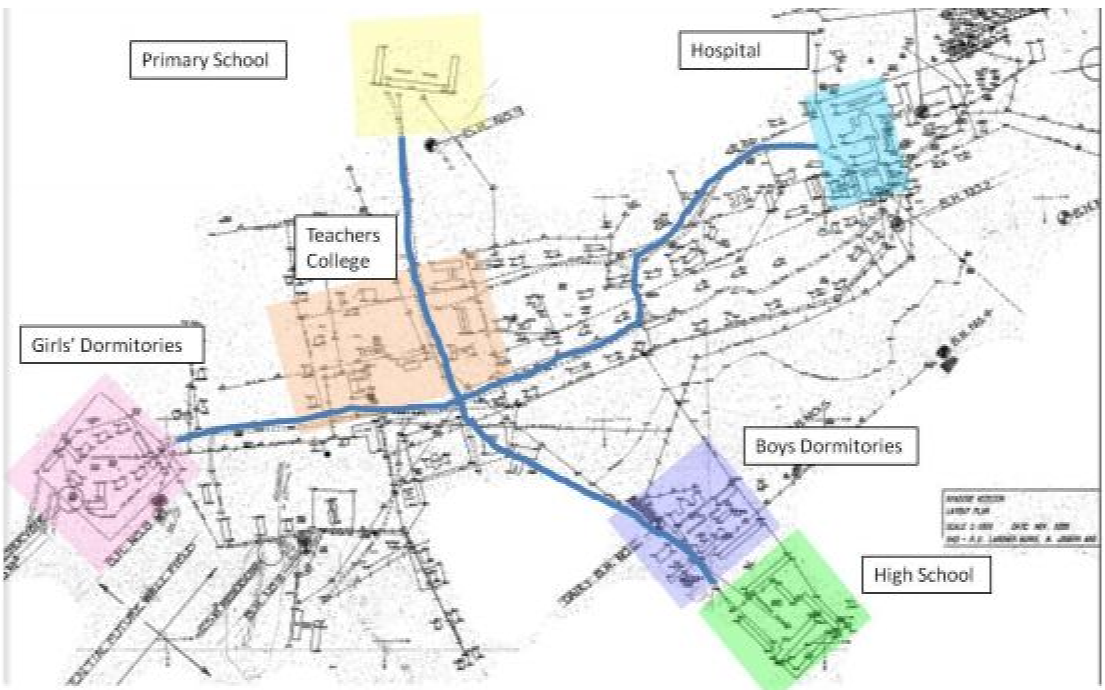


Figure 1: Highlighted map of the Nyadire community, detailing the most travelled pathways

The Community, currently reliant on ZESA's (Zimbabwe Electricity Supply Authority) inconsistent and expensive power, struggles to travel at night in a safe manner throughout the community. This is due to a lack of lighting because street lighting is unaffordable and would be too inconsistent on the grid. As a result, the design implementation we are proposing to be made in this community is street lighting along the immediate path between lodgings and the hospital (main path highlighted in blue above) in order to accommodate safe travel for ill residents as well as expectant mothers during non-daylight hours. The means of street lighting will be by decentralized solar energy, discussed in detail in the 523 document.

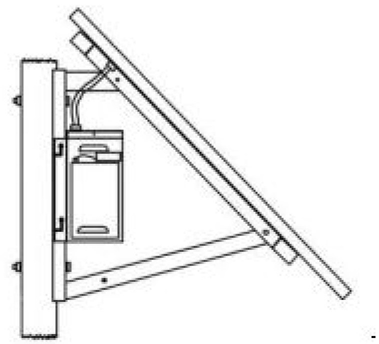
Lighting System:

Example of the Desired Final Product

Based on our current budget and funding abilities, 20 street lights will be initially installed during this assessment trip. If our budget increases due to incoming grants, we plan to install additional street lights. Section 2.3 includes a map of proposed street light locations on the community map. The number of poles is adjustable to accomodate incoming funds; after the course of the implementation trip our contractor can continue to install poles with this arrival of new funds. For subsequent pole installation, a contractor will be trained with our exact specifications so that a travel team will not need to be present. Each light pole will placed at a distance of approximately 20 meters apart from one another along the main path and consist of a pole, a solar panel, a battery box with charge controller, a light fixture, brackets, and other assembly pieces (e.g. nuts and screws) needed to secure the structure.

The poles will be 7.5 m long and truncated in diameter from 168 mm at the bottom to 80mm at the top. The pole will have a thickness of 3.5 mm. The round pole will be made from Q235 galvanized steel and will have all electricity wiring pre-filled on the inside of the pole prior to installation. It is important to note that none of the grounds are paved; all light installations will be into dirt.

The solar panel, made of polycrystalline and Grade A cells, will be 1480mm by 673 mm by 35 mm'. The 80W module has a lifetime expectancy of approximately 25 years. With an adjustable bracket, the solar panel can be tilted between 5 and 45 degrees from horizontal position in order to maintain maximum sun exposure based upon solar readouts taken during the assessment trip at each potential area of pole installation. Additionally, a lead-acid battery unit with capacity of 100 Ampere-hours will come with each pole. The battery will be encased and will have an approximate weight of 30kg. Ideal operation would be conducted at a maximum of 25% of battery discharge per day. Also needed as part of the electrical assembly is the controller for the system. The intelligent digital controller is encased in waterproof sealing and is rated 12V/10A. The controller is programmable to alter power load based on internal temperature sensor, as well alteration in the LED light output as seen fit. The assembly of the controller can be seen in the drawing section below.



Solar Panel to Controller and to Pole Assembly

The light fixture itself is the final major attachment in the system. The LED fixture is 494 x 326 x 109 mm. This particular unit has specification of 90 lumens per Watt and could last well past 50,000 hours. Aluminum casing material provides sturdy protection to the lighting unit again weathering. The energy efficiency associated with LED bulbs will maintain lower power costs, necessary for the sustainability of the structure in a cost limited environment such as Nyadire and will limit the maintenance needed in upkeep of each individual pole.

System Installation:

A 0.6m x 0.6m hole will be dug approximately 2m into the ground by our contractor prior to installation. Concurrently, a concrete mix, specified in 4.0.B.1.4, will be prepared. The poles will be held at the desired vertical position and set in concrete using a truck with a crane extension. For 20 poles, this process will take approximately 6 days. The concrete will need to come up to strength before the lighting fixtures are installed. This will take at least 7 days; 7-day concrete strength should be tested by the concrete provider. Using a crane truck the lighting fixtures and components can be installed in approximately two days. Detailed instructions can be viewed below in the construction section.

1.2 Description of Design and Calculations

Pole:

The pole for each street light forms the basis of its foundation. Page 4 of the technical specification sheet shows a diagram of the street light pole and the interconnected components. For our design, we have selected poles that are 7.5 m in length. Specific locations have been marked on a map of the community for priority and proposed locations for the lights (refer to page 1 of the technical specification sheet). These locations were determined when taking our assessment trip in August of 2015. They are agreed upon by us and the community to be places of considerable need for the street lights.

Poles will be provided to us by Sinet and will fit the specifications of our final design. The installation of each pole happens in phases and this is done to ensure the stability of each unit. At least five to six days before the travel team arrives in Zimbabwe, holes will be dug at the final locations and concrete will be poured in to create the footers. Once these footers have been put in, the poles will be installed. For more information on this process, please refer to the Construction Plan and Calculation sections of the document.

We considered the need for poles and reusability of existing poles. We determined that new poles would be needed because of the nature of the project, despite the high estimate quotes on prices. As our design was adjusted and we were given specific feedback from the contractors, we determined that the best logical option was to plan in our budget and our design to use pre-manufactured poles for the streetlights. When we considered the possibility of using existing poles we discovered that many of these poles were degrading in quality and we could not find an approach for amending them. With this in mind we decided to request information from the contractors on streetlight poles to help us create technical specifications.

Solar Module:

The functionality of the solar modules is to collect energy from the sun and generate a flow of electricity that will charge the battery. Solar modules are in abundance within Africa which makes our main considerations for them it’s rating and the size. Our design will use solar modules of 80W with dimensions of 780mm by 670 mm by 30mm. Within the Calculations section are details on the power generation of the solar module and how different ratings affect other components.

The size of the solar module will have an affect on the poles we can use and the armature that we install to mount the module. The solar module will be tilted for maximal exposure to the sun’s rays. We’ll fine tune the degree of tilt for each solar module based on solar pathfinding information that was taken at different sites during the assessment trip in August 2015. The PV array is installed at 6m from the ground to guard against vandalism and theft.

Solar modules excel in lifetime and require minimal maintenance. As part of our operation and maintenance plan, assigned members of the community will clean the modules routinely for dirt and also take readings (please see the Operations and Maintenance manual for more details). The solar modules come with a warranty of 25 years which reflects the highly sustainable nature of this project.

In Nyadire we expect about 5 to 6 solar hours, assuming a worst case scenario. The hot climate of Zimbabwe makes this streetlight project feasible and our approach of modularization makes it possible to update the project in a lot of cases.

Battery Box:

The battery box contains the battery unit and the terminals for connecting the battery to the rest of the components. The batteries we will be using are 12V DC. They will be connected to the charge controller which will control the charge rate and the discharge rate of the battery. The lights will be able to function for five consecutive days without recharge. This means that when the battery is discharged overnight, assuming that it was fully charged at the beginning of the night, it will reach a capacity of 80% at the end of the night. It will then be charged to maximum capacity each day and continue this cycle. We have calculated that a battery with a capacity within 100Ah-200Ah will be suitable for our project needs. We do not want a battery with too small a capacity that will overshoot the depth of discharge and thus harm the lifetime of the battery. We also want to avoid a battery of too large a capacity because those will be heavier in size and more expensive.

The batteries will use a NEMA 3R battery box with a thick gauge to protect the batteries from the elements and to ensure it is waterproof. The batteries will be enclosed above ground next to each streetlight in a lockable enclosure. This process removes the cost of buying more expensive, durable poles to hold the up.

Our plan expects the terminals of the battery to be routinely cleaned and the voltage levels to be checked. The maintenance overall ensures that the battery meets its life expectancy of 6-7 years. In the case of insufficient readings from the battery, members of the community assigned to maintenance will be able to use the charge controller to configure the lighting settings.

Charge Controller:

The charge controller is responsible for controlling the flow of charge from the solar module, to and from the battery, and to the light fixture. It is powered through interconnect from the battery. The charge controller in our design will be able to configure the battery to charge and discharge based on sunlight or time. It comes in a it's own small enclosure and only exposes necessary wires and terminals for connecting to other components. It also comes with LED indicators that show when the battery is charging or discharging which makes it easy for the maintainers of the streetlights to tell the mode of operation. The calculations also show that the current through the LED will be well within the maximum load current allowable by the charge controller.

Light Fixture:

The light fixture is a 14W, 12V bulb that is attached to the head of the light pole. The charge controller regulates when the light fixture will be powered. We'll be using LED type light bulbs for efficiency and brightness. LEDs are the also the standard kind of bulbs found in most solar street lighting implementations. The light fixture will be enclosed within a bracket that can be mounted onto the pole. The bracket will be there for protecting the bulb from the elements and also make renewal of the bulb possible. We have variability in exactly which light bulb we can use because of the standardization of the technology. There is also little maintenance needed with this aspect of the design besides for replacement.

Conductors:

1, **Application**

The PVC insulated wires are suitable for laying at the fixed places. They are widely used as connectors of driving, lighting, electric equipment, instrument and telecommunication equipment with rated voltage up to 450/750V(U0/U). Part of the plastic insulated wires are used at the equipment with AC rated voltage up to 300V

Type	**Name**	**Application**	**Working Temp.**
RVV	**Copper** conductor, PVC insulated and PVC sheathed round flexible wire	Mainly used at middle and light type movable equipment, instrument, and lighting, as well as in places where flexibility is required	70℃

Nominal Section (mm^2)	Core Structure No./Dia.(mm)	Max Dia.(mm)	Reference Weight(kg/km)
2.5	49/0.25	4.2	24.5

Our contractor who is located in Harare, Zimbabwe, uses the local Standard Association of Zimbabwe's SAZS 764:2001 Cables and Conductors – Dimensions of the components of electric Cables, flexible Cables and flexible Cords. They use this cable because of the ease of running the cable and the low current of the system for short distance of 5-7m (for wiring panels to battery and LED light) (average 1A DC).

Calculations:

The calculations are broken into three sections:

1.0.P.6.A: Electrical System Power Calculations
1.0.P.6.B: Volume of Concrete at Each Caisson
1.0.P.6.C: Moment Force of 100 MPH Wind Force Extreme

1.0.P.6.A. Electrical System Power Calculations:

This section illustrates the balance that must be achieved between the power output (LED Lamp Fixture), the storage capacity (Battery) and the power input (Solar Module. Each Section will carry forward the results of the previous Section's resulting calculation. We will compute the following system type:

14 W 12v DC LED Lamp Fixture, 100 Ah 12v DC Battery and 80 Watt Solar Module.

Section 1: LED Lamp Fixture:

The LED Lamp Fixture will have a power consumption between 15-90 actual watts (not for calculation: but it would compared to 70-175 nominal output watts of a Metal Halide/High Pressure Sodium).

14 watt LED Lamp Fixture: converted to amps (Volts=Watts/Amps).
14W / 12V (system voltage 12 V DC) = 1.1667 amps
1.1667 amps x 12hrs (avg, daily running time of lamp)= 14Ah (Amp Hours) consumption

Section 2: Battery Capacity:

Single 100 Ah Battery:

To serve a 14 Watt LED Light Fixture utilizing 14Ah and to only dip 1/5 of total battery capacity daily we will have to have a battery capacity that is 5 x 14 Ah= 70Ah. To account for any variability in our system design and inconsistent daily lighting, we will want to buffer that capacity by 40%. 1.40 x 70 Ah = 98.8 actual Ah or a nominal battery usage of 100 Ah.

A 14 Watt LED Fixture will work with a 100 Ah battery that is being recharged daily to its full capacity of 100 Ah.

Section 3: Solar Module Production:

Below are specifications of the solar module from the manufacturer, Eco Green Energy.

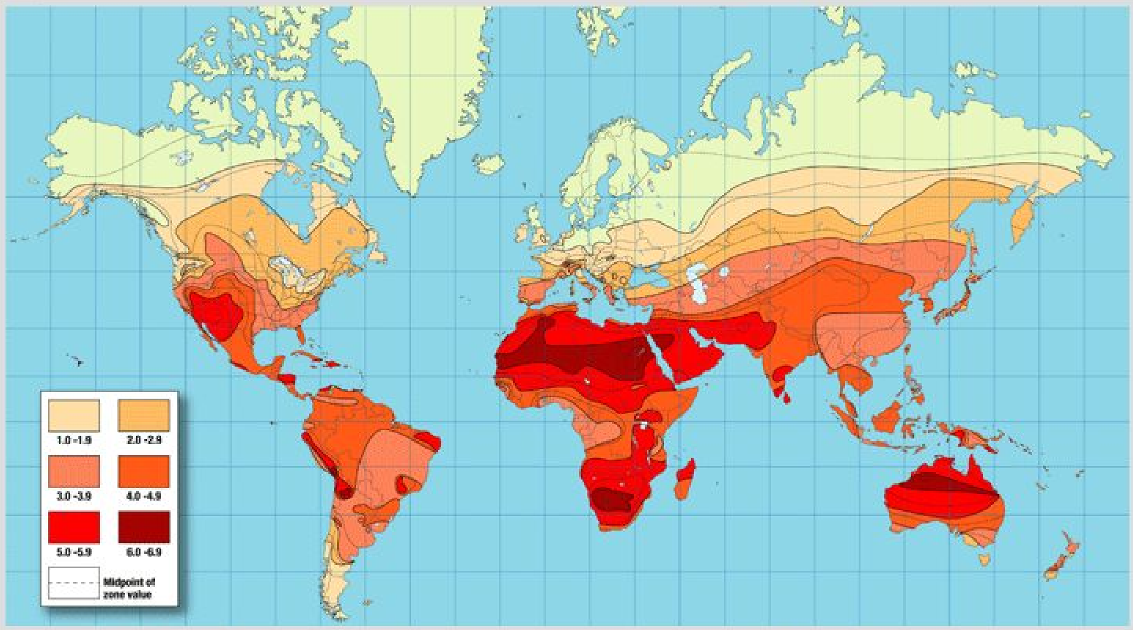
Temperature Coefficient

Nominal Operating Cell Temperature	(NOCT)	47℃+/-2℃
Temperature Coefficient of Pmax		-0.47%/K
Temperature Coefficient of VOC		-0.346/K
Temperature Coefficient of ISC		+0.036/K

Electrical Characteristics

Model		EGE-80P-36
Maximum Power at STC	(Pamx)	80W
Optimum Operating Voltage (Vmp)		17.8V
Optimum Operating Current (Imp)		4.50A
Open-Circuit Voltage	(Voc)	23.4V
Short-Circuit Current	(Isc)	4.59A
Solar Cell Efficiency	(%)	17.1
Solar Module Efficiency	(%)	14.4
Operating Temperature		-40to85℃
Maximum System Voltage		DC1000
Maximum Series Fuse Rating		15A
Power Tolerance		+/-3%
STC:Irradiance 1000W/㎡,Modules Temperature 25℃,AM=1.5		

The Solar Module must input at least enough Amp Hours per day to recharge the battery to full capacity. In this case we will look at our 80 Watt Solar Module. For this purpose we will need to reference solar sun hours that are particularly high in ZI at a range of 5.0-5.9 (we will use the lower end of the range in our calculations as a worst-case scenario, 5.0 sun hours):



This map shows the amount of solar energy in hours, received each day on an optimally tilted surface during the worst month of the year.
(Based on accumulated worldwide solar insolation data.)

To serve a 14 Watt LED Fixture, working with a 100 Ah battery capacity that is being recharged daily to its full capacity of 100 Ah with a 80W Module we must consider: A 80W Module will produce daily: 5.0 (Sun hours) x 80W = 400Wh. In a 12V DC system that is: 400 / 12V = 33.33 Ah/day. Since our LED Lamp Fixture pulls 14 Ah/day and the Solar Module produces 33.33 Ah/day this will effectively offset the daily usage with some room for variability and allow the battery to recharge to full capacity daily. This accounts for three levels of variability/ degrees of error:

1. Battery utilizing 14% of total capacity daily, 6% lower than our optimal 20% daily discharge from battery. This allows for two days of absolutely no sunlight.
2. Considering Solar Sun Hours at the lower end of the scale at 5.0.
3. Allowing the daily production input out-pace the daily discharge.

The following information has been calculated by our contractor.

<u>Cold Temperature Max Voltage and Hot Temperature Max Voltage:</u>

This means that the temperature coefficient for the module open circuit voltage $\mathbf{V_{oc} = -0.346\%/K = 0.346\%/{}^0C}$ since a rise in temperature by 1K is the same as a rise in temperature by 1^0C from T in K = T^0C + 273.

The open circuit voltage temperature response variation of a solar PV cell is given by:

$\mathbf{V_{trans} = V_{ref} + [V_{ref} \times C_v \times (T_{cell} - T_{ref})]}$
where, $\mathbf{V_{trans}}$ is the open-circuit voltage at the temperature under consideration,
$\mathbf{V_{ref}}$ is the temperature at STC (25^0C) given in the datasheet as V_{oc} = 23.4V
$\mathbf{C_v}$ **i**s the voltage-temperature coefficient given
T_{cell} is the temperature under consideration which relates to the maximum and minimum operating temperatures for the module, which in this case is **-40^{0}C to 85^{0}C** (as specified in the datasheet).

1. $\mathbf{V_{trans} = V_{oc}}$ **at -40^{0}C** **-** Cold temperature maximum voltage for PV array
2. $\mathbf{V_{trans} = V_{oc}}$ **at 85^{0}C** **-** Hot temperature minimum voltage for PV array

1. At -40^{0}C , $V_{trans} = V_{ref} + [V_{ref} \times C_v \times (T_{cell} - T_{ref})\ ]$

$V_{ref} = V_{oc}$ at 25^{0}C = 23.4V (given in the datasheet)
C_v = -0.346%/^{0}C = 0.00346/^{0}C (given in the datasheet)
T_{cell} = -40^{0}C (minimum operating temperature given in the datasheet)
T_{ref} = 25^{0}C = STC temperature given in the datasheet

Ø V_{trans} = 23.4 + [23.4 x -0.00346 x (-40 -25)]
Ø V_{trans} = 28.66V

This means the **Cold temperature maximum voltage for PV Module is <u>28.66V</u>**

2. At 85^{0}C, $V_{trans} = V_{ref} + [V_{ref} \times C_v \times (T_{cell} - T_{ref})\ ]$

$V_{ref} = V_{oc}$ at 25^{0}C = 23.4V (given in the datasheet)
C_v = -0.346%/^{0}C = 0.00346/^{0}C (given in the datasheet)
T_{cell} = 85^{0}C (maximum operating temperature given in the datasheet)
T_{ref} = 25^{0}C = STC temperature given in the datasheet

Ø V_{trans} = 23.4 + [23.4 x -0.00346 x (85 -25)]
Ø V_{trans} = 18.54V
This means the **Hot temperature minimum voltage for PV Module is <u>18.54V</u>**

<u>Ampacity for Conductor and Fuse Sizing</u>

The maximum power output from the module W_p is 80W and the system operating voltage is 12V

Ø <u>Maximum Current = 80/12 = 6.66A</u>
Assuming allowable voltage drop ΔV of 3% maximum, with conductor size given by,

S (mm^2) =[length (m) x current (A)] / (56 x ΔV)

- where length is the conductor length which is about 6m maximum considering a pole of 5m
- ΔV is 0.36 V which is 3% of 12V

This gives, s = 6 X 6.66 / (56 x 0.36) = 1.98mm^2

Ø **We will use a 2.5mm^2 cable from solar module to Solar Charge controller**
For portion from controller to LED light,

Current = 14W/12V = 1.17A

Ø **s = 6 x 1.17 / (56 x 0.36) = 0.34mm^2**

Ø **we will use 1.5mm^2 cable from controller to LED light (we can use a smaller cable but 1.5mm^2 is the smallest sizing commercially available with certified quality)**

Fuse and Disconnect Sizing

1. From SOLAR panel module to Controller we will put a Ground Fault Protector (OCPD) with a rating of **10A** and from Charge Controller to LED light we will put a fuse with a rating of **2A**.
2. As the solar light is a simple Direct Coupled PV system, we propose not to put any Disconnects (MCBs).

1.0.P.6.B. Volume of Concrete at Each Caisson:

The volume of the concrete caissons on site will have to be computed based on the final number of Solar Street Lights. For this exercise we will compute the volume of a single footer. The footer is a rectangular prism, so the volume is expressed as:

$$V = L \times W \times H.$$

The length and width are 0.6 m each and the depth of the footer is 1 m, as .per Sinet's specifications. Thus, the expected volume of concrete pour for each footer is:

$$V = 0.6 \text{ m} \times 0.6 \text{ m} \times 1.0 \text{ m}$$
$$V = 0.36 \text{ m}^3.$$

1.0.P.6.C. Moment Force of 100 MPH Wind Force Extreme:

In the climate data spanning from 1996 to 2016 we discover a max wind speed of 98 MPH. For our purposes we should make our design calculations based on the climate extreme of (100 MPH). This approximately equals a distributed load of 10 lb/ft.

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ENGINEERS WITHOUT BORDERS,
CARNEGIE MELLON UNIVERSITY

CALC BY: KDS DATE: 11/17/16
CHK'D BY: DATE:
APP'D BY: DATE:

IN ORDER TO DETERMINE WHETHER OR NOT THE POLE SPECIFIED BY THE MANUFACTURER IS STRUCTURALLY SOUND, WE WILL FOLLOW THE LOAD PATH FROM THE TOP OF THE POLE, TO THE BASE PLATE WITH ANCHOR BOLTS EMBEDED IN CONCRETE.

VERTICAL LIGHT POLE

RESULTANT FORCE ON POLE

WIND FORCES APPLY A DISTRIBUTED LOAD ON THE VERTICAL LIGHT POLE.

ASSUME: WIND FORCE IS 10 lb/ft

R = RESULTANT FORCE
H = POLE HEIGHT
F_d = DISTRIBUTED FORCE
x = DISTANCE FROM A TO RESULTANT FORCE

$H := 15 \cdot ft$ $F_d := 10 \frac{lb}{ft}$ $x := 7.5\ ft$

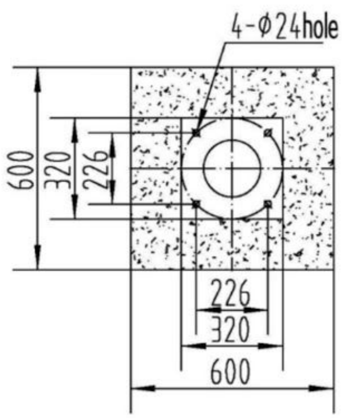
$R := H \cdot F_d$
$R = 150\ lb$

MOMENT ABOUT POINT A (OVERTURNING POINT)

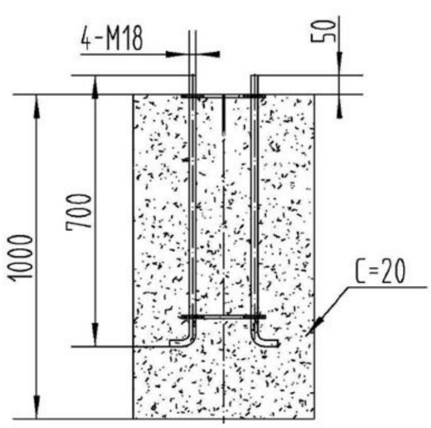
$M_A := R \cdot x$
$M_A = (1.125 \cdot 10^3)\ lb \cdot ft$

CONNECTION FROM POLE TO FOOTER

- THERE ARE 4 ANCHOR BOLTS. AT ANY GIVEN POINT, TWO WILL ACT IN TENSION AND TWO WILL ACT IN COMPRESSION
- ONE SIDE IS IN TENSION (2T)
- ONE SIDE IS IN COMPRESSION (2C)
- |T| = |C|



ANCHOR BOLT DETAIL: TOP VIEW



ANCHOR BOLT DETAIL: SIDE VIEW

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FORCES ACTING ON ANCHOR BOLTS:

d = DISTANCE BETWEEN ANCHOR BOLTS

T = TENSILE FORCE ON ONE BOLT

$d := 226\ mm$

$$T := \frac{M_A}{2\ d}$$

$T = 759\ lb$

EACH BOLT MUST WITHSTAND AT LEAST A FORCE OF 759lb IN COMPRESSION OR TENSION

ANCHOR BOLT DETAIL:

M18 ANCHOR BOLTS (MADE FROM CARBON STEEL)

d_b = BOLT DIAMETER

l_b = BOLT LENGTH

F_y = YIELD STRESS

F_t = ULTIMATE STRESS

GIVEN:

$l_b := 700\ mm$

$d_b := 18\ mm$

ASSUME:

$$F_y := 36000\ \frac{lb}{in^2}$$

FROM ACI 318-11, THE FOLLOWING FAILURE METHODS ARE TESTED FOR

ALLOWABLE STRESS ON ANCHOR BOLT

$F_t := 0.6 \cdot F_y$

$$F_t = \left(2.16 \cdot 10^4\right)\ \frac{lb}{in^2}$$

SRESS ON ANCHOR BOLT

σ = STRESS ON BOLT

$T = 759\ lb$

A = BOLT AREA

$$A := \pi \cdot \left(\frac{d_b}{2}\right)^2$$

$A = 0.394\ in^2$

$$\sigma := \frac{T}{A}$$

$$\sigma = \left(1.92 \cdot 10^3\right)\ \frac{lb}{in^2} \qquad F_t = \left(2.16 \cdot 10^4\right)\ \frac{lb}{in^2}$$

$$F_t > \sigma$$

THE MAXIMUM EXPECTED COMPRESSIVE OR TENSILE STRESS ON THE BOLT IS LESS THAN THE ALLOWABLE STRESS. THE ANCHOR BOLT SHOULD BE ABLE TO WITHSTAND EXPECTED LOADS IN TENSION OR COMPRESSION.

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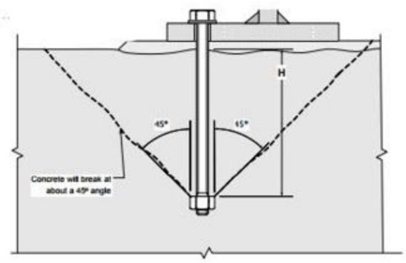
ACI 318-11 D.5.3: PULLOUT STRENGTH CAST-IN, POST-INSTALLED EXPANSION OR UNDERCUT ANCHOR IN TENSION

THE NOMINAL PULLOUT STRENGTH OF A SINGLE CAST-IN, POST-INSTALLED EPANSION, AND POST-INSTALLED UNDERCUT ANCHOR IN TENSION SHALL NOT EXCEED THE STRENGTH OF CONCRETE

ASSUME THE CONCRETE WILL BREAK AT A 45* ANGLE IN A CONE SHAPED SECTION



SA_{cone}= SURFACE AREA OF CONICAL CONCRETE FRACTURE
H = BOLT HEIGHT EMBEDMENT
$H := 700\ mm$

$SA_{cone} := \pi \cdot 1.4142 \cdot H^2$
$SA_{cone} = 2.177\ m^2$

F = FORCE REQUIRED TO PULL THE CONCRETE APART IN SHEAR

$F := 800\ \frac{lb}{in^2} \cdot SA_{cone}$

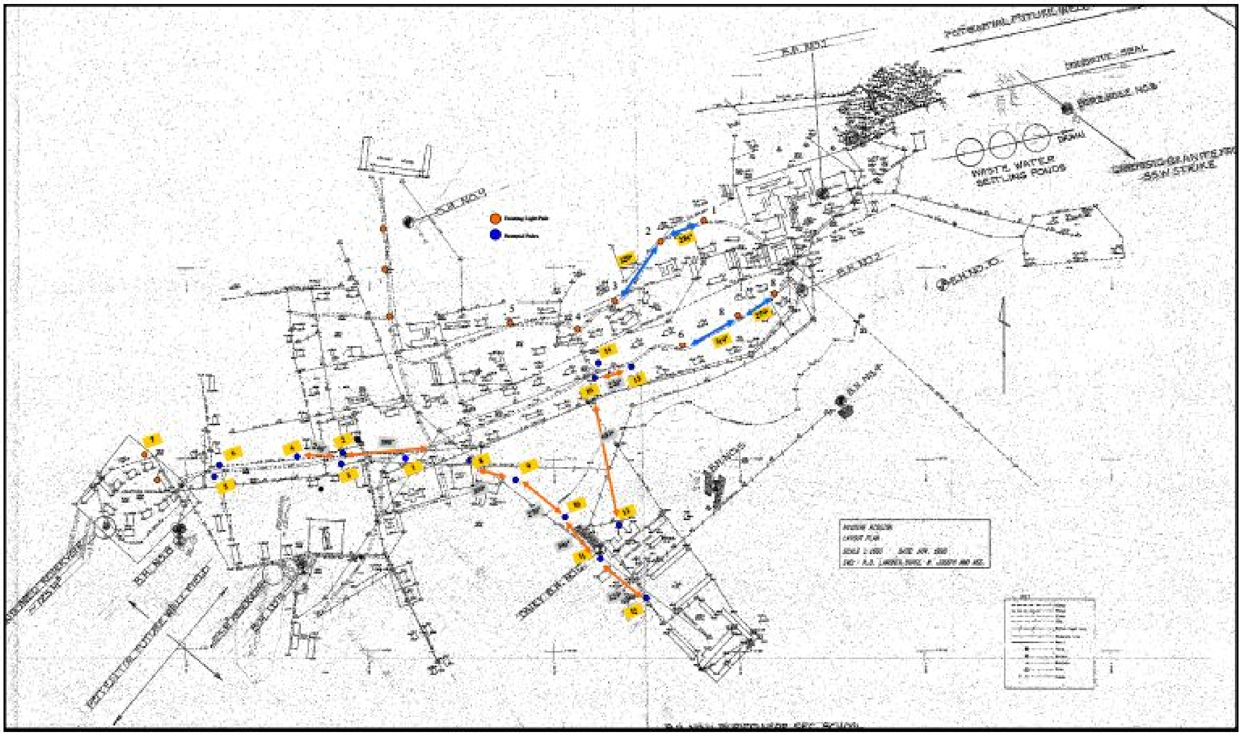
$F = \left(2.699 \cdot 10^6\right)\ lb$

T = TENSILE OR COMPRESSIVE FORCE ON ANCHOR BOLT
$T = 758.628\ lb$

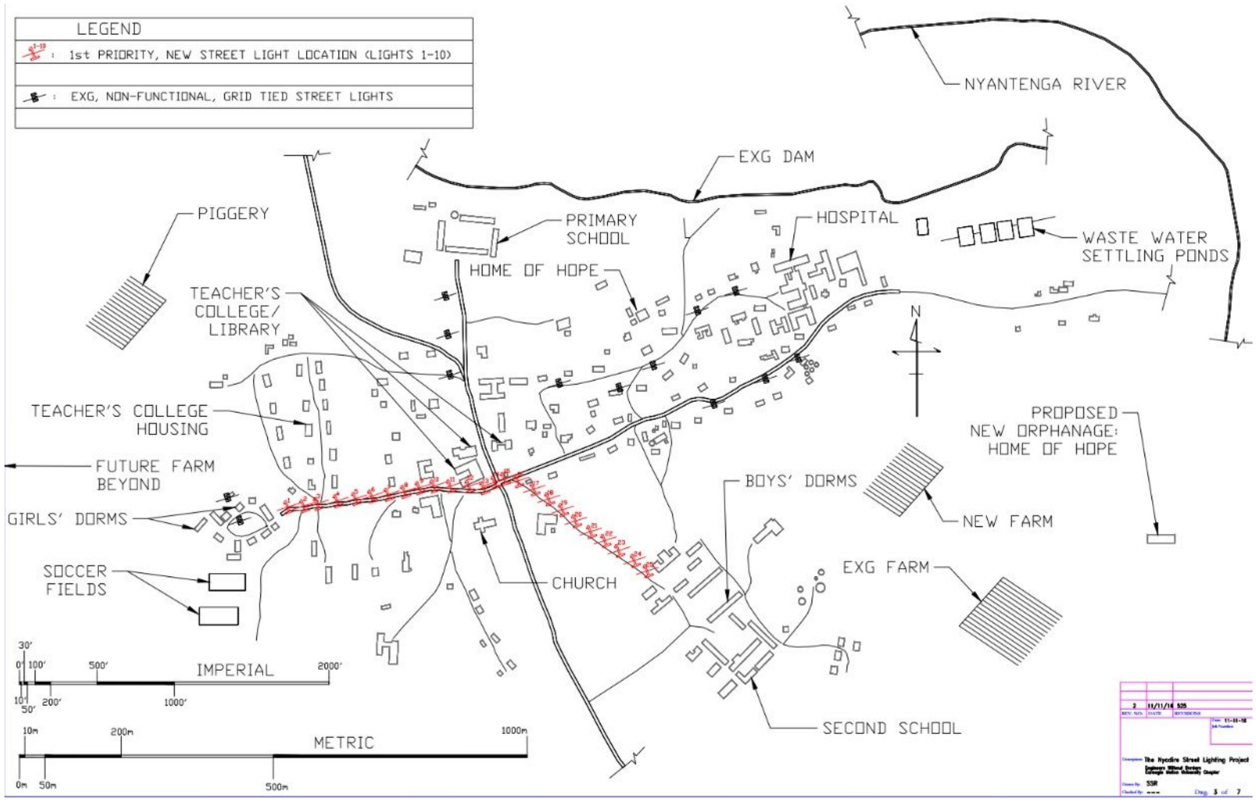
F > T,
SO WE DO NOT EXPECT THE CONCRETE TO PULL OUT WHEN LOADED BY WIND FORCES

1.3 Description of Construction Drawings

Additionally see appendices below for more detailed map specifications and engineering drawings for field use.



All possible light locations based upon solar pathfinder readings with assumption of unlimited funding opportunity



For this first implementation phase, we will put the lights on the community's pathways as shown above, from the girls' dormitories to the school.

2.0 Construction Plan

First and foremost, this project is designed for reliability of the final product and then thereafter, flexibility, to accommodate a larger scope of work as our fundraising campaign allows. This first project in the Nyadire Community is not a one off, it is the beginning of establishing trust with the community and part of the project will be to ascertain the projected priority needs of the community and develop future projects beyond the mandatory expectation of project maintenance.

The construction team will consist of the local contractor Sinet, the Nyadire Community (who have expressed sincere interest, but would not be implicitly burdened or tasked with participation) and the EWB-CMU implementation team.

Planning and coordination of material acquisition will be the responsibility of the local contractor.

As an introductory comment to this project, "The Nyadire Street Lighting Project," is a project that is meant to ramp according to the funding that will be ongoing up until roughly mid July when we have about a month until departure. This said, we have already crossed a threshold in our funding to assure 20 solar street lights at a minimum (referred to as the 1st Priority Lights in the drawings) (the assurance of ten lights is based on our highest cost quote per solar street light kit). However, as time goes on and fund raising continues the number of street lights will grow. Illustrated in our plan drawing, is the location for additional lights, referred to as second Priority (21 or more and up to 30) based on our final fundraising amount before departing for Nyadire, ZI.

In addition, there is also contingencies for multiple construction styles and variety of variants (ie. pole height, caisson diameter, lamp fixture, solar module, battery, etc...) This is to ensure that we can weigh the contractor prices against each other and provide the most to our end user, the community of Nyadire.

The construction plan is broken into two parts:

4.0.A: Construction Schedule
4.0.B: Construction Plan

Phases in each of the Construction Schedule and the Construction Plan are related respectively. The Construction Plan can be understood as a detailed elaboration on the Construction Schedule.

4.0.A. Construction Schedule: (August 4 2017- August 21 2017):

General Note: The contractor will be engaged in completing the project between August 4 and August 21. EWB will be present during August 11 to August 25 to ensure the system meets acceptance criteria. The below date ranges are an estimation.

4.0.A.Phase 1. FOOTER & POLE August 4 - August 11:

*Location of Solar Street Lights is detailed in the Construction Plan (4.0B) below and should be considered the necessary precursor to A.Phase i.

4.0.A.Phase 2. ELECTRICAL August 11 - August 21:

Arrival of EWB-CMU chapter to ZI and subsequently Nyadire on March 11th. Between the 11th and the 13th is for electrical implementation. This includes full installation of all armatures, electrical equipment and connections including grounding of all electrical devices outlined in detail below. At onset of all equipment operating as intended, the project will be handed over to the community with a ceremony thanking the community for allowing us to learn from them and for their allowance of our project to take place.

4.0.A.Phase 3. ANALYSIS August 15-21:

Record (Audio & Written) of the community's response/satisfaction/criticisms to the current project and a census on what priorities/needs the community determines for future EWB-CMU projects (again this is beyond current project maintenance outlined in Part II, Section 6.0). Recording (Video & Photo) of equipment operating in fashion intended. Handing over, and thorough explanation of, operations and maintenance manual, operation and contact information to the community point person, Christopher Kuwana.

4.0.B. Construction Plan:

4.0.B.Phase 1. FOOTER & POLE

4.0.B.Phase 1.Section 1: *Locations of Solar Street Lights:

Our campus plan, found on page 3 of the drawing set, will show prescribed locations for each of the 20 Solar Street Lights (known as SSLs from here on in). These locations were chosen in collaboration with the community, solar data collected on the first site trip, and optimization of the product. These locations are considered to be a thoughtful and measured placement of the SSLs, but with this said, there will have to be further consideration and responsibility imparted on the local SSL Contractor/Installer. The following considerations must be made:

1. If the SSL is shaded at any given time during solar production hours it should be moved to a reasonable location nearby to the prescribed location found on page 3 of the drawing set.

2. Please consider the community to which this serves and furthermore the proximity to the surrounding buildings that will be subject to nighttime light pollution. Placing a SSL near an otherwise unused structure in the evening (ie. a schoolhouse) is not an issue so much as placing a light where the vantage point from a window will light and otherwise dark bedroom (ie. the dormitories). There is delicate work of placing the SSLs both in a manner that lights a

student returning home in the evening and does not disturb their sleep (night time is noticeably and by our records, typically extremely dark). So the SSLs must be placed with mindfulness to not disrupt the communities healthy norms.

3. If, while digging for a footer/caisson and rock or unfavorable digging conditions are encountered it is perfectly reasonable to restart and furthermore if the time spent digging at a hole is inordinately long, it is good practice to relocate before too much investment is made.

4. If a community member or a group of community members has a reasonable request for a revised location, that still remains close to adhering to the plan agreed upon by the community it should be considered with good judgment by the installers to favor the community's will.

5. Locations of lights should not overlap, or encroach on each other, as to optimize the amount of gross lit area coverage of the entire campus. Remembering that the campus is a beacon for healthcare for distant neighbors of Nyadire and miles of surrounding countryside in Zimbabwe.

4.0.B.Phase 1.Section 2: Installing Caisson/Footer:

The rectangular holes should be at least of 0.6 m width x 1.0 m length at a depth of 1.0 m. Sinet, the local contractor, will dig the holes using their own equipment. The caisson will have anchor-bolts embedded in the concrete.

After excavations a plastic and reflective barricade is erected around the excavated base to protect people and animals from getting trapped by the excavated holes and also prevent the disturbance to the newly poured concrete or any incidental collapsing of the sides of the excavated hole.

4.0.B.Phase 1.Section 3: Anchor-Bolt Caisson:

Hardware at the footer/caisson shall be hot dip galvanized for corrosion protection. Hole for concrete caisson is to have a concrete forming tube allowing top of poured concrete to be 2" minimum above grade (seen in detail 2&3, page 5 of the drawing set). Concrete is to be composed of 1 part Portland Cement, 3 parts aggregate (2B or similar) and 3 parts sand (with the addition of fiber reinforcement if available). The concrete shall exhibit a minimum compressive strength of 2500 P.S.I. (24 Mpa) at time stress is transferred from the steel to the concrete, and 5,000 P.S.I. (34.5 Mpa) at 28 days determined by (2) concrete core samples that the contractor shall furnish to the head of maintenance (6" x 12" cylinder)(152 x 305 mm). The first core sample is made of the first batch of concrete and the second core sample is made of the last remaining concrete after the last footer/caisson is poured.

There will be (4) 18mm diameter or larger Anchor Bolts directly inserted/embedded into the poured concrete. The bolts will be drilled in the correct bolt pattern to allow the pole base plate to seat with precision.

4.0.B.Phase 1.Section 4: Pole:

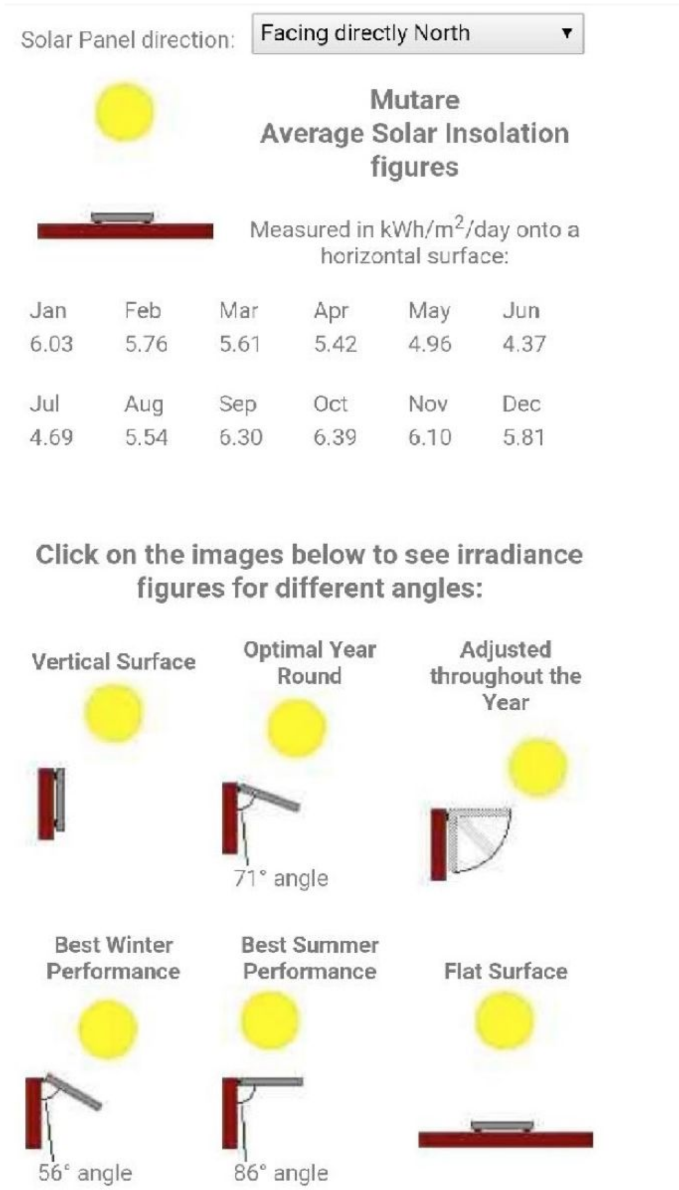
Concrete must cure for a minimum of one week before adding pole or any weight (such as electrical equipment). After one week, (4) hex nuts (and washers) are threaded on the exposed Anchor-Bolts with a minimum of 1: between top of nut and top of concrete. Hex nuts and washers are then made level to each other.

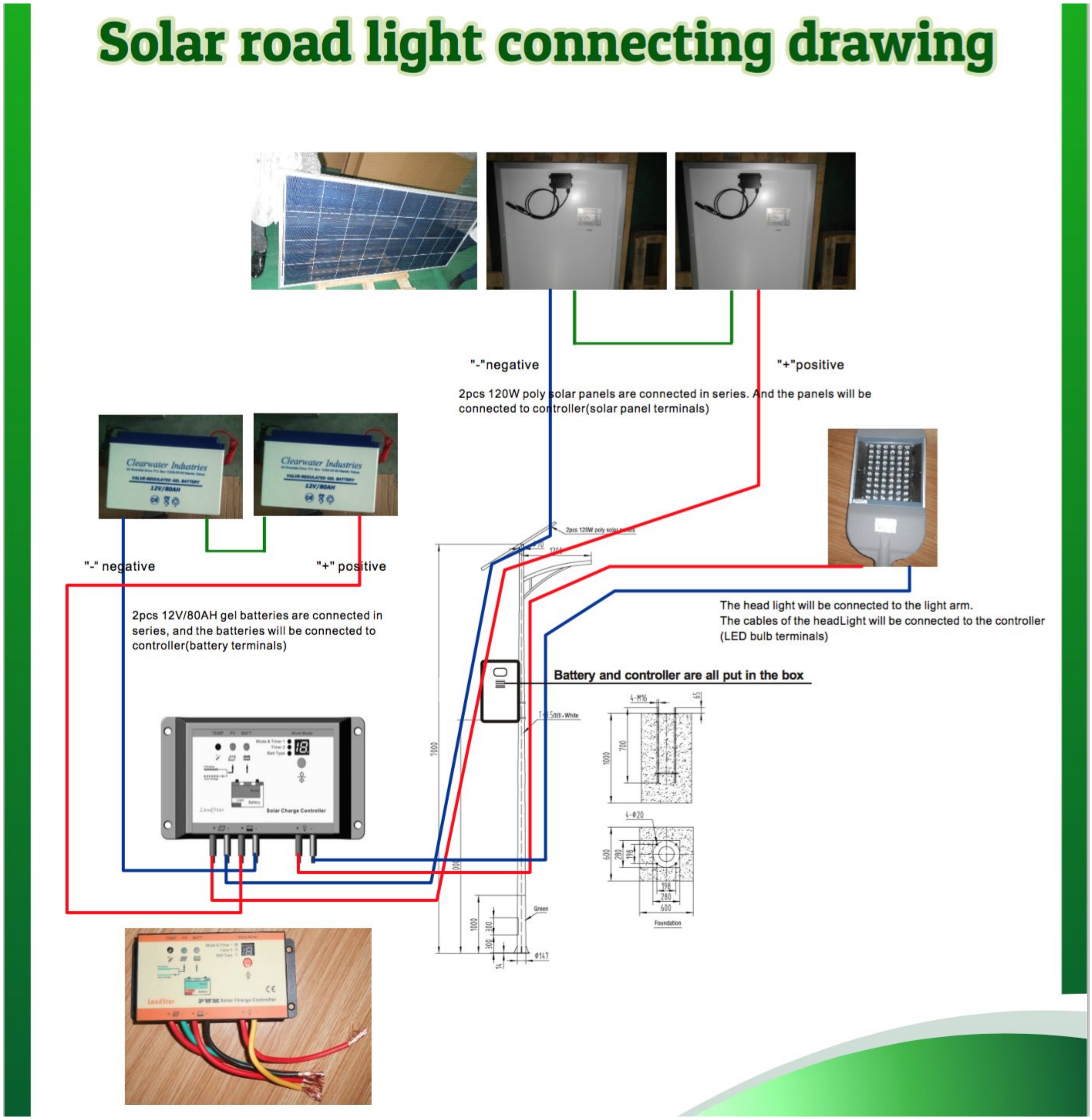
The pole will be hot dip galvanized, and has an outer diameter of 168mm at the base, and 80 mm at the top. The pole's wall thickness is 3.5 mm. The pole will be pre-drilled on the ground for attachment points of electrical equipment and wire chase locations. All holes to be sprayed with galvanizing spray paint to deter rust and corrosion. The pole will be raised by crane truck utilizing proper rated slings and or choking straps. During erection of lights using a truck crane, a total of six people will be required namely (a) Overall supervisor. This is a qualified artisan either an electrician or a Civil Engineer . He is in charge of all works on site and supervision of all the workers. (b) Crane operator. He is also a qualified tradesman who is responsible for the operation of the crane in lifting the assembled light and placing it in place. (c) 2 Mechanical artisans. They are responsible for the actual fixing of the pole onto the holding down bolts with the assistance of the electrician (d) One electrical artisan and his assistant. These are responsible for the actual assembly of the solar street light onto the pole and arm and then the battery connections. These are the people who will be allowed on to the site. The Supervisor will also double up as the safety officer and is responsible for safety induction at the start of the works. The pole base plate will be lowered onto Anchor bolts and its weight will be placed on the level nuts and washers. Check pole for plumb and adjust base nuts as needed, maintain a safety supervisor through this entire process. Check pole for plumb and tighten top nuts to a torque of 70-90 ft-lbs. After top hex nuts have been tightened and pole is plumb, the tops of exposed Anchor-Bolts are the be marred to discourage tampering.

4.0.B.Phase 2. ELECTRICAL

After caissons have cured for at least one week, place cap on pole with stainless steel fastener. Assembling electronics can begin on the poles(all poles should have pre-drilled locations for attaching the solar module armature, the battery enclosure and the lamp mounting bracket. Next, all grounding between the previously assembled items should be made. The pole serves as a grounding conductor so all grounding terminations can be made to the pole.

Following this, all electronics can be mounted and immediately wired to ground. This includes the solar module (mounted at optimal angle of 71 degrees from the pole and facing north), the lamp fixture (with LONG-LIFE PHOTOCELL attached), the solar charge controller, the battery's in-line fuse and lastly, the battery.





Make all remaining connections (chase all wires through pole wherever possible and provide drip loops where applicable) except the final connection at the negative terminal of the battery. All wire that is visible to sunlight must be rated for the elements and outdoor sun exposure. All wires that are not provided by the manufacturer(s) shall adhere to the EIC 60228, or the International Electrotechnical Commission's International Standard. Test all electronics with DC setting on meter for normal operation. Based on the site wiring diagram above, the test points are battery terminals, controller terminals and LED light terminals and in all cases we are tracing battery voltage which should be between 12-13.8V when light is switched ON at the LED light and output controller terminals and always at the battery terminals and input controller terminals. Sinet, our contractor, will be testing for these values and monitoring while on-site and completing the installation. Our proposed data logging method is as below for the light installation. We will also take battery readings 3-4 times a day for each of the poles while we are there. Follow up with making sure equipment operates normally at dusk (on) and dawn(off). Clean site and return it to original condition as possible.

Expected voltage is 12-13.8V when light is switched ON at the LED light.

Pole #	Battery Voltage	Output Controller Terminal Voltage	Input controller Terminal Voltage	Battery Terminals Voltage	Light On

4.0.B.Phase 3. ANALYSIS

Record (Audio & Written) of the community's response/satisfaction/criticisms to the current project and a census on what priorities/needs the community determines for future EWB-CMU projects (again this is beyond current project maintenance outlined in Part II, Section 6.0). Recording (Video & Photo) of equipment operating in fashion intended. Handing over and thorough explanation of operations and maintenance manual and contact information to the community point person, Christopher Kuwana.

3.0 Materials List and Cost Estimate

The estimates of the project cost are shown in the table below. The estimates shows the cost of each component that is used in a streetlight. Later in the project timeline the materials list and cost estimate will be updated to be more consistent with the any budget changes which are dependent on available funds. Labor costs are more varied so they aren't included. For more details on the materials, please see the technical submission document.

Material	# Units	Unit Cost	Total Cost
Solar Module 80 W	20	$108	$2,160
Solar Module PWM Charge Controller	20	$70	$1,400

10A 12V DC			
Sealed GEL Battery 100Ah 12V DC	20	$285	$5,700
LED Fixture 14W	20	$161	$3,220
Hot Dip Galvanized Pole 5m	20	$600	$18,000
Cables	20	$42	$840
Civil Works	20	$200	$4000
Electrical Works	20	$200	$4000
		Price per unit:	**$1,666.00**
		VAT (15%):	**$249.90**
		Total price per unit:	**$1915.90**
		Grand Total (including labor):	**$38,318.00**

4.0 Draft Design Report Comments (Only Completed for Final Plan)

The feedback received for the draft has been responded to and affected this version of the plan. To see how the feedback was addressed, please see Appendix C.

5.0 Project Ownership

The Nyadire United Methodist Mission (the CBO) in Zimbabwe is a large complex including a hospital, a school system including boarders, a teaching college, a school of nursing, an orphanage, churches, and a large farm. They are the owner of the project and are responsible for the operation and maintenance of the Nyadire Street Lighting system. Our partnering organization is the “Mother Church”, specifically the Zimbabwe West Annual Conference of the United Methodist Church. The Zimbabwe United Methodist Church owns the land on which the Nyadire Street Lighting system will be built. The CMU Chapter of EWB has gained the formal support of both entities and has the commitment of both for the implementation of this project.

6.0 Operation and Maintenance

Creator: Scott Rhodehamel
The maintenance plan is broken into three parts:

6.0.A: Maintenance Fund
6.0.B: Anticipated Maintenance
6.0.C: Maintenance Manual - attached separately

6.0.A. Maintenance Fund:

To reiterate, this project is designed for reliability of the final product and then thereafter, flexibility, to accommodate a larger scope of work as our fundraising campaign allows. This first project in the Nyadire Community is not a one off, it is the beginning of establishing trust with the community and part of the project will be to ascertain the projected priority needs of the community and develop future projects beyond the mandatory expectation of project maintenance. Christopher Kuwana is the manager for campus operation and maintenance.

Beginning at 3 years and one day (approx. January 3, 2020), any battery failures will first be brought to the attention of the original contractor/company in Harare. We are establishing a relationship with this solar street lighting company and so they may be able to extend the warranty of the batteries to a degree if there is an expressed understanding that we intend to work with the company in the near future for additional street lighting and centralized solar plant options. If the battery has failed in a way that is expressively the manufactures fault due to negligence (battery seals are not absolute, etc...), we would then approach the manufacturer directly. It is not in EWB policy for student chapters to help with the maintenance funding of a given project. Thus after all options are exhausted, the Nyadire will need to fund the maintenance of any battery or solar equipment. It is in the best interest of the community to start a maintenance fund and routinely contribute to said fund. We required in our Community Agreement that the community save $83 a month for this project's maintenance funds, so as to cover the cost of replacing batteries if they fail within the projected 6 year life. Christopher Kuwana will be in charge of this fund. If during the course of the EWB CMU-Nyadire Community project agreement, the CMU Chapter decides to add further light poles, the funding of this will follow project funding protocol with only a need for 5% contribution from the community. However, all other maintenance needs must be addressed by the community per the project agreement.

Maintenance, for safety and expediency, should be done from a man-lift, bucket truck, or like vehicle. If one is not available on campus contact the installer to have them lend you one. Proper voltage safety equipment including rated gloves, rated tools, eye protection and insulated boots should be worn/utilized.

6.0.B. Anticipated Maintenance:

6.0.B.Section 1: BATTERIES:

All other project components have a longer lifespan than the battery, which is the point of weakness of the project. All other considerations allow the project long term success projected to 30 years and beyond. With a warranty for 5 years the battery becomes a high stakes target for bi-annual maintenance. This is especially true approaching the warranty expiration (approx. March 18, 2022). As a variant to the bi-annual test readings, all campus solar street light batteries should be tested approx. 3 months prior to the expiration of the battery warranty (approx. December 18, 2021). This is to avoid claims that will become contentious closer to the warranty expiration date. All warranty claims should be made by email first and followed up with a phone call to the installing contractor and after the warranty period expires (approx. March 18, 2022) then claims should be made by email followed by a phone call to the battery manufacturer directly. Batteries cost $285 and the warranty replacement cost is 75% of the original price.

<u>6.0.B.Section 2:</u> <u>SOLAR MODULE:</u>

Bi-annually take readings of all Solar Modules (Solar Panels) to test against each other. In order to test the solar module it must be disconnected, but please note: (Never disconnect (unplug) a solar module under load (daytime), disconnect solar module the night before testing and take readings the next day within a 3 hour window in the morning after 10 am. After nightfall (approx. 9pm) reconnect the solar module leads. In this testing phase the battery will dip below 1/5 discharge, but this is acceptable on a 6 month interval. **Be sure not to leave solar module disconnected for more than one day as to strain the battery, this will reduce battery life. If reconnecting the battery was forgotten for two days, do not simply reconnect them, you must wait again until night fall when the solar module is not under load. This is to prevent arcing in the connectors which can damage all products and be dangerous.** It is the most productive way to maintain that the panels are operating normally under their 25 year warranty to compare output one to the other. Small variations in DC Voltage Output is normal, but variations up to 100 Volts would have other implications on the product operating normally. Finally, verify that the angle between the pole and the solar module is still the optimum 71 degrees. Solar Modules cost $108.

<u>6.0.B.Section 3:</u> <u>SOLAR CHARGE CONTROLLER:</u>

The solar charge controller, by the specification, will have LED status indicators that will illustrate normal operation and diagnostic information per the manufacturer's manual. The solar charge controller's LED status indicators are to be recorded and reviewed bi-annually. Solar Charge Controllers cost $70.

<u>6.0.B.Section 4:</u> <u>LED LAMP FIXTURE & PHOTOCELL:</u>

Unless a lamp is out, which requires immediate action. There will again be a bi-annual review. If a lamp is out, it could mean failure of any other electrical component beyond the LED fixture, it does not mean that the light fixture has failed, although that could be the case. First, follow instructions, 6.0.B.Section 3, to diagnose the issue. If then it is determined that it is the lamp follow-up with the installer by email and then by phone or if outside warranty window, follow-up with the manufacturer by email and then by phone. Finally, test photocell by cupping hand and essentially covering to allow light fixture to turn on. LED Lamp Fixtures cost $161.

6.0.B.Section 5: GROUNDING & WIRING:

Bi-annually, verify that all wires have no exposed conductors (with the exception of grounding conductors). Check for fraying, splitting of any jackets or cracking of any conduit or like wire chases. Wiring that is faulty in this manner is dangerous and should be notified to the original installer for proper safety precautions and tools in repair.

6.0.B.Section 6: BRACKETING & ARMATURES:

Check all hardware associated with the battery enclosure, solar modular armature (ensure that solar module armature allows for the optimal angle of 71 degrees between pole and solar module) and the lamp fixture bracket. Take appropriate wrenches to touch each bolt and nut, do not tightened bolts/nuts that are not loose, only tighten bolts/nuts that obviously loose.

6.0.B.Section 7: POLES:

At a bi-annual interval inspect poles and alert installer of any hairline fractures in pole by email and then by phone. Also look for visible signs of rust and if identified use fine sandpaper for 1 minute. Spray any of these previously sanded areas with galvanizing spray paint. Verify pole cap is securely attached to top of pole. Take note especially of the base of the pole for rust, corrosion and/or flaking of metal. Poles cost $795.

6.0.B.Section 8: FOOTER:

At a bi-annual interval visually inspect footer for major cracks and crumbling. Minor cracks at the periphery of the concrete caisson are normal, but even a hairline fracture that transverses the caisson is dangerous and should immediately be brought to the attention of the installer by email and then by phone.

6.0.B.Section 9: COMMUNITY:

Gather any notes from the community here as they are presented to your attention, with a date and name of commentator. (ie. "I have noticed that this light is flickering at night...") Bring to the attention of the original installers, any safety matters otherwise, and if applicable, address the issue personally.

6.0.C. Maintenance Manual:

The Operation and Maintenance Manual is attached separately to the submission and includes all the information for Anticipated Maintenance

7.0 Sustainability

7.1 Background

The primary sustainability issue for this project will be changing the batteries every 5 years. Battery replacements will cost approximately $280 each, leading to a total cost of $5600 for the anticipated 20 street lights after 5 years. The community is willing to contribute to funding the maintenance, as previously illustrated in section 6.1. One additional task to sustain the operation of the street lights, though optional, is to annually dusting the solar panels. Using a rented bucket truck, a skilled laborer in the community could perform this maintenance. With this periodic battery replacement and general monitoring of the system, as well as no unpredictable weather changes, this project can be sustained for decades, with additional poles can be added with similar parameters.

7.2 Organizational Capacity of the Community

Nyadire is led by two positions - the “pastor in charge", Reverend Forbes Matonga, and the “station chairperson”, or administration leader, recently appointed Lancelot Mukundu. These individuals report to the Zimbabwe Methodist Church Bishop and/or his organization which resides in Harare. Any strategic direction and decision is made at the Bishop level.

The mission is grouped into several departments that operate independently. For example, a doctor leads the hospital, an educator leads the Teacher’s College, a headmaster leads the high school, etc. The heads of each department are recognized by the community as decision makers and leaders. The church is also very influential and powerful in the community.

During our assessment trip, we spoke to community members to better understand the difficulties which arise when the electricity turns unexpectedly off. On our first full day, we met with the department heads of the mission where then station chairperson Julius Tsiga, who also served as our liaison, introduced us and EWB. We explained the department heads and leadership the purpose of the project and general nature of EWB, stressing that we are working in collaboration with community and value their input.

We then set up individual meetings with the department heads to tour their domains and understand how each part of the mission is affected by intermittent electricity. After touring the facilities and talking with members of the community, the shared desire for lit pathways became apparent. We working with the community to identify the pathways most frequently traveled and most in need of light, and from that potential locations of light posts based on distance and existing structures.

7.3 Financial Capacity of the Community

The Nyadire United Methodist Mission has agreed to provide the 5% of funding required, as well as fund O&M costs. Each department (the hospital, school, college, etc.) will be asked to contribute a portion of the funds to maintain the streetlights, aided by individuals and families who live on the mission. Families will be visited individually and encouraged to donate after an explanation of the project and benefits. The community has proved capable of maintaining past major projects, such as a recently constructed rural health clinic with a $300,000 budget.

The mission also has relationships with several church affiliated groups and NGO's from around the world, which could provide support services if need be.

7.4 Technical Capacity of the Community

The Nyadire community (Nyadire United Methodist Mission) has agreed to identify a formal system of responsibility for the operations and maintenance of Nyadire Street Lighting. This includes identifying a single person accountable for addressing system maintenance. With the implementation, we will use a solar lighting contractor for the materials (Samansco). The CMU chapter of EWB-USA will carry out the implementation of the system with the aid of in-kind contributions from the community such as skilled and unskilled labor as well as borrowed equipment and local materials. To help make the community more familiar with the solar technologies we are implementing, we will provide the technical specification as well as project-specific education and training, as described more below.

7.5 Education

The CMU Chapter of EWB wants to ensure that the Nyadire United Methodist Mission and the United Methodist Church of Zimbabwe have the appropriate technical knowledge and education in order to operate and maintain their solar lighting system. We will provide to them the technical specification through a manual, which will include descriptions, definitions, a materials list, illustrations, maintenance instructions and procedures, and troubleshooting. After implementation, we want to provide the as-built drawings of the components utilized and installed.

For our project education and training, the CMU Chapter of EWB in conjunction with the contractor will provide training sessions both to the residents of Nyadire United Methodist Mission as well as the United Methodist Church of Zimbabwe. We will have a smaller training seminar with the United Methodist Church organization, and they in part will also help provide project-specific training for the residents of the Nyadire United Methodist Mission as needed beyond our time in Nyadire. For our community-wide information and education session, we will inform the residents about the newly installed system. We will include information on the function of decentralized solar lighting and its sustainability for the community. Our outline of the lesson plan can be found in Appendix B.

List of Attachments

Appendix A - Implementation Agreement

Appendix B - Project Related Education

Appendix C - Feedback Response

Appendix D - Mentor Qualifications and Resumes

Technical Submission - Includes title sheet and drawing set (attached separately)

Operation and Maintenance Manual (attached separately)

Alternatives Analysis (attached separately)

Post Assessment Report (attached separately)

Project Partnership Agreement (attached separately)

Appendix A - Implementation Agreement

Community Agreement – Implementation

EWB-USA projects are most successful when there is a three-way partnership between each of the entities listed below. Each partner has specific skills and expertise, which together, contribute to a more sustainable project over the long-term.

- **Community** - Nyadire United Methodist Mission
- **Local Partner Organization(s)** - United Methodist Church of Zimbabwe
- **EWB-USA Chapter -** Carnegie Mellon University

This contract is between the Carnegie Mellon University Chapter of Engineers Without Borders, USA, the Nyadire United Methodist Mission, and the United Methodist Church of Zimbabwe for the purpose of setting guidelines for the Nyadire Street Lighting Project. **The specific conditions listed below must be included in the standard EWB-USA Community Agreement – Implementation.** Additional roles and responsibilities identified by any party to the agreement may be added at the discretion of all parties to the agreement. This document must be signed by all parties in order to begin construction of the Nyadire Street Lighting Project. The roles and responsibilities agreed to in the previously-signed Project Agreement remain in effect in addition to the commitments outlined below.

EWB-USA is a volunteer-based organization without a pre-approved budget. Implementation of all projects is contingent upon all parties meeting the commitments outlined below, funds being raised and a stable security situation which allows travel to the site by our members. This agreement is not legally binding, but is intended to clarify expectations, roles and responsibilities of all parties to the subject project.

PROJECT SCOPE

Indicate Project Type: Energy

Indicate expected number of beneficiaries: 3000

Indicate project capital budget in US$ and local currency: $45,000 (lighting system) ($55,000 light and team travel cost)

PRE-CONSTRUCTION PHASE

Nyadire United Methodist Mission responsibilities:

- Provide 5% of the capital construction cost in cash ($2250) before construction begins.

- Provide written confirmation that the land required for the project implementation is owned by the community before construction begins. Alternatively, in lieu of ownership, the community can provide written confirmation that it has a permanent easement to use the property.
- Commit 0 workers for 0 hours per day for 0 days to the construction site.
- Provide the name of the community representative responsible for organizing the in-kind labor
    - o Christopher Kuwana
- Provide the names of community members who will be responsible for operation and maintenance
    - o Christopher Kuwana

United Methodist Church of Zimbabwe responsibilities:

- Provide 0% of the capital construction cost in cash before construction begins.

Carnegie Mellon University chapter of EWB-USA responsibilities:

- Provide 95% of the capital construction cost in cash before construction begins.
- Provide qualified representatives of the design team during construction for observation or oversight.
- Communicate the requirements of site preparation prior to the chapter arriving for construction. This will be communicated to the community and the local partner two months prior to construction, or earlier as determined by the project needs.
- The contractor will provide the all of the equipment and tools required for construction:

POST-CONSTRUCTION/OPERATIONS AND MAINTENANCE PHASE

Nyadire United Methodist Mission responsibilities:

- Pay for 100% of the costs to operate and maintain the project, Nyadire Street Lighting. This cost is estimated to be $1,000 USD per year, local currency (Zimbabwe uses USD).
- Monetary resources will be collected from the community for operations and repairs monthly.
- The amount collected per the schedule above will be: $83 a month
- The position responsible for identifying maintenance needs is: Maintenance Department Head - Christopher Kuwana
- This position/committee will be Appointed by Maintenance Department Head
- This position/committee will serve in this role for term of position.
- The position/committee responsible for performing maintenance is: Contractor for warranty, or Christopher Kuwana for normal maintenance
- This position/committee will be hired by maintenance department head.
- This position/committee will serve in this role for lifetime of project.

United Methodist Church of Zimbabwe responsibilities:

- Provide ongoing support to Nyadire United Methodist Mission for a minimum of 5 years after construction is complete, as needed.
- Assist with additional monitoring activities as identified by Carnegie Mellon University chapter of EWB-USA as long as the program is active for the EWB-USA chapter.

Carnegie Mellon University Chapter of EWB-USA responsibilities:

- Develop a detailed operation and maintenance manual for the community (including applicable photos as appropriate). The manual will include a maintenance schedule and anticipated costs. The manual will be in English.
- Provide monitoring and evaluation of the project, Nyadire Street Lighting, for a period of not less than one-year post-construction and as long as the program is active.
- Perform repairs to the project that are the result of errors in the design until they are corrected.

In addition to the responsibilities listed above, indicate the responsible party for each of the following:

- Coordination of transportation for travel team members of Carnegie Mellon University chapter of EWB-USA within Zimbabwe will be provided by the Station Chairperson of the Nyadire United Methodist Mission.
- Coordination of translation services are not needed.
- Scheduling of community-provided labor will be provided by Maintenance Department Head. This includes 0 community workers for 0 hours per day for 0 days at the construction site.
- Procurement of construction materials before Carnegie Mellon University chapter of EWB-USA arrives for construction will be arranged by the Carnegie Mellon University chapter.
- Transportation of materials will be coordinated by the Station Chairperson of Nyadire United Methodist Mission.

On behalf of, and acting with the authority of the residents of the Nyadire United Methodist Mission, the NGO/local municipal partner United Methodist Church of Zimbabwe, and the Carnegie Mellon University chapter of EWB-USA, the under-signed agree to abide by the above conditions.

On behalf of, and acting with the authority of the residents of the Nyadire United Methodist Mission, the NGO/local municipal partner United Methodist Church of Zimbabwe, and the Carnegie Mellon University chapter of EWB-USA, the under-signed agree to abide by the above conditions.

Signature Date 21/11/16

Printed Name Rev Alan M.Gurupira +263 773 227 102/753615

Contact Telephone Number (including country code)

Position in Local Partner Organization - Administrative Assistant to the Bishop

Signature Date 12/1/12

Printed Name Kavin Sanghavi

Contact Telephone Number (including country code)

Position in Carnegie Mellon University chapter of EWB-USA — Project Lead

Signature Date 25/11/16

Printed Name Rev. LANCELOT MUKUNDU +263772607993

Contact Telephone Number (including country code)

Position in Community Based Organization - Station Chairperson

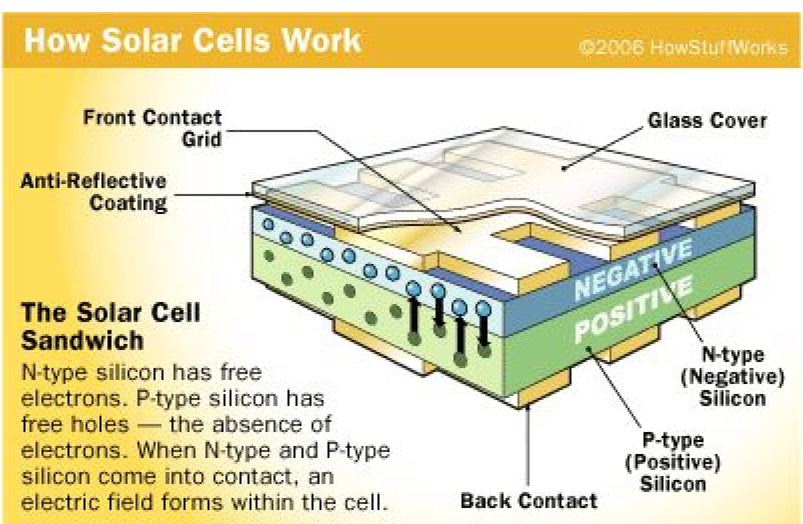
Appendix B - Project Related Education

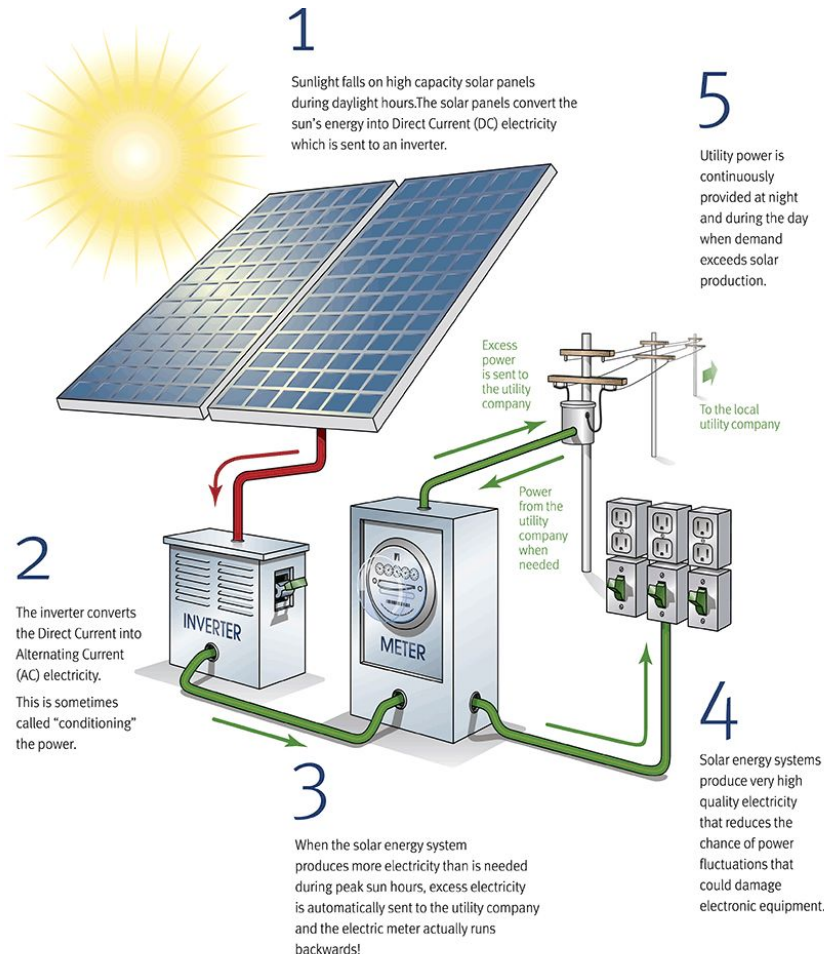
Project Education and Training

For our project education and training, the CMU Chapter of EWB will provide training sessions both to the residents of Nyadire United Methodist Mission as well as the United Methodist Church of Zimbabwe. We will pass on our lesson plan and materials to the United Methodist Church organization, and they will also help educate the community beyond our time in Nyadire. In addition we will ensure that the contractors give on-site maintenance training to key community members who will be responsible for maintenance such as Christopher Kuwana.

Lesson Plan Outline

1. Explaining the reason and importance of the Nyadire Street Lighting, why these certain streets would highly benefit from lighting
2. Review our decision process for choosing decentralized solar lighting. Teach about the different alternatives available in Nyadire (centralized solar, hydropower, battery-powered, biogas etc.) that we researched prior to deciding that decentralized solar lighting was the best solution.
3. Educate the community on how solar power and how solar panels works. Utilize a variety of visuals such as the one below.
4. Explain the mechanisms our specific system is using, detailing how the LED light, battery, solar panels, and charge controller interact with each other.
5. For the people who would help maintain the system, describe the warranties and maintenance needed for each component of the system.





Reference for Images:
http://solarcraft.com/wp-content/uploads/2013/04/how-solar-panels-work-illustration.gif
http://s.hswstatic.com/gif/solar-light-cell.gif

Appendix C - Feedback Response

	Review Comment	Chapter Response
1	I thought your team did a good job on your submittal. Thank you for your time and efforts to pull together the submittal package.	**Thank you.**
2	Most of your proposed work will occur during the holidays. Will that be an issue?	**It will not be an issue. We just have to contact the relevant people and they will be around at the time of implementation.**
3	Can you provide additional clarification regarding the $1000 allotment that your team is requesting?	**We have now omitted that from our O/M plan.**
4	I would recommend training more than a single person in this community on the O&M for the system. We have seen other programs train one person and then that person leaves for whatever reason, and the system is no longer maintained.	**We will make sure as many members of the maintenance department as possible are given on site training by the contractor. In addition we have asked the head of maintenance in the community to list backup members for maintaining this project.**
5	With your final submittal, please include a stand alone Operations and Maintenance Manual that you plan to provide to the community upon completion of the project. The O&M manual should include detailed components of the system, including cost of replacement parts and where those can be purchased. It should also include the information of the persons who will be responsible for the O&M of the system. I think it would also be helpful to include an annual calendar of maintenance activities, including the dusting of the panels (and the cost). The O&M should be the community's complete guide on how to maintain the system long into the future.	**We have added usage information that was in the report to the O/M plan. The persons responsible for O/M were also added to the O/M manual. A spreadsheet detailing which inspections should be held has also now been included.**
6	With your final report submittal, please be sure that your REIC provides the following statement in the Chatter feed in Volunteer Village. We are working on improving this aspect of the system,	**Our REIC will post the statement in the Chatter feed.**

	but for now, please have them copy and paste the following: It is the responsibility of the Responsible Engineer In Charge (REIC) to ensure that the team's preparation for this Pre-Implementation Trip meets a reasonable standard of care. I have reviewed the subject project. I am qualified by education and experience to design and provide construction phase services for this type of project. In my best engineering judgement, this report reflects a complete and comprehensive design and is ready for review by the EWB-USA and the ICP Gurus.	

Larry Bentley, ICP Guru, Review Comments:

	Review Comment	**Chapter Response**
1	Implementation PreTrip Plan Minor issue, page 5 calls for galvanized stainless pole. Seems they have two parallel designs, one to use 100W panel, 112 ampHr battery, versus second with 200W PV, 224 ampHr battery. Then 35/75 watt LED.	**Removed stainless from describing the poles. We currently are going to go with a 14W system with an 100Ah battery**
2	Plan for batteries to be buried in ground next to the pole increases risk of the battery (very valuable component) being re-purposed.	**The battery box will be in an underground brick walled enclosure with a slide in concrete top. On top will be covered by earth. So for maintenance we will have to remove the earth and slid out the concrete lid and work on the batteries. The concrete lid will be fitted with a padlock for security.**
3	Calculations on page 11 are reasonable for discharge, but batteries need about 115-120% of discharge to fully recharge. These batteries are also rated on a 20 hour discharge not the 12 hour overnight use. This will reduce rated capacity by about 25% or so.	**The contractor is providing a battery with a 5-day total discharge capacity. The contractor states that this setup is commonly used in this region, as Nyadire receives an ample amount of sunlight. We can follow up with the contractor Sinet if you have further concerns.**

4	Page 30 - They call out for 3500 psi concrete for the pole support.	**Has been changed to 2500 psi**
5	Page 32 - Solar resource minimizes in June which also will have longest hours of darkness. This is worst case for solar resource and maximum discharge load.	**The solar panel will be mounted at about 71 degrees from the pole facing north. During June the panels**
6	Page 48 - Show incorrect voltage range for the solar panels in O&M document.	**Could not locate a voltage range on page 48. If this is referring to 6.0.C.Section 2, the voltage under Module Reading has been changed to 150 V but it is only provided as an example.**
7	Overall; minor issues, it will work but battery life will not be as long as they expect.	**Thank you.**
8	Oh, all holes through side walls of metal poles, top and any exposed bottom access MUST be sealed. Ethiopia uses similar poles and bees have learned these are great beehives nearly unrobbable. A bee hive in the pole will make panel & battery maintenance much less likely to happen.	**Thank you for this consideration, and we will require the contractor to fill the holes with duct seal.**
9	I never found the text instructions for their operations and maintenance plan 6.0.B referred to in the table they provided to record readings. This needs review.	**We copied the instructions from the plan to the manual so it is now included.**

Mike Dadik, ICP Guru, Review Comments:

	Review Comment	**Chapter Response**
1	I think you might be able to purchase pre-manufactured poles. Not sure if you have looked into that but will save some $.	**We still want to move forward with component wise streetlights rather than a pre-manufactured ones. This allows us more flexibility with O/M and design.**
2	The pole in the drawings might be oversized. OK - but a refined design might save some money.	**Going with a smaller design so poles will now be smaller**
3	I think the concrete pier is probably OK. Do you have design calcs to confirm this? The reinforcing is unusual. Specific comments are in the drawings.	**We have updated these calculations.**

4	Anchorage needs to be designed, This affects pole be plate that is not detailed.	**Anchorage design is attached in the new calculations.**
5	Please submit foundation and anchorage design calculations.	**Both designs are attached in the new calculations.**
6	Please review redlined drawings for additional comments.	**Thank you and we have addressed these.**
7	I am happy to answer questions and offer design guidance - call or chatter.	**Thank you.**

Paul Scovazzo, ICP Guru, Review Comments:

	Review Comment	**Chapter Response**
1	General Comments on Constructability The plan calls for bolting aluminum components to steel pipe with stainless steel bolts. The aluminum/steel contact potentially could set up galvanized circuit that will facilitate corrosion of the components. Recommend including non-conduction washers or other elements to break the galvanic circuit.	**The contractor's materials will be of similar metals (galvanized).**
2	The wind force calculations used the maximum recorded wind speed. Recommend using a wind speed with a safety factor greater than the maximum recorded wind speed.	**We updated the wind calculations.**
3	General Comments on Health and Safety Plan Are the components of the 600 Health and Safety Plan - Part I included in the report by reference? In particular, what about the following key information items: ● Project Personnel and Emergency Contact ● Emergency Response Plan ● Location Map ● Directions and map to medical facilities ● International SOS and U.S. Dep. of State Risk assessment ● CDC inoculation and immunization recommendations	**All of these items have now been included in the 600 Health and Safety Plan-Part 1.**

	● Other site risk: animal, vegetable, and political ● Medical and First Aid Kit description ● See 600 H&S plan template for complete list	
4	Task 3 is digging holes for poles while a separate task (Task 4) fills the holes. The dug holes will be at least 4 feet deep and 16 inch wide. Such a hole is a hazard. The plan must address this tripping and falling hazard for both workers and children. Procedures for securing, marking, or covering the hole for the potential situation where Task 4 does not immediately follow Task 3.	**We will require the contractor to secure and mark the hole spots to avoid this hazard. Task 3 also requires that the holes be supervised until pole installation (Task 5).**
5	There is a potential silica hazard in this proposed work from the components of the concrete (dust from the sand, gravel etc.)	**This is up to the contractor's safety protocols. We will advise the contractor of the hazard.**
6	Page 4: Tasks 5 through 7 Emphasize hard hats for these tasks. Maintain proper standing distance from the crane load. Limit authorized personnel in the work zone.	**This is up to the contractor's safety protocols. We will advise the contractor to use hard hats.**
7	Page 6: Utility Hazard Marked for Task 1 What Utilities? These are not discussed in the text. Are there overhead lines or buried utilities?	**The contractor will work with Christopher Kuwana to avoid any overhead or buried utilities.**
8	Page 9: Item 16 Fall Protection Potential word choice issue with "Forklift;" do you mean Crane?	**Forklift has been updated to crane.**
9	Page 10: Item 22 Electrical Safety Potential word choice issue with "circuit training." Circuit training is an exercise science term.	**The contractor will be responsible for electrical install.**
10	Page 10: Item 28 Clearing, Grubbing, and Logging How are ladders related to this item?	**Ladders are not related and we have revised Item 28.**

Appendix D - Mentor Qualifications and Resumes

Name	Student or Professional	Qualifications	Work Done
Scott Rhodehamel	Professional	Refer to resume	• Created and reviewed technical design • Reviewed contractor quotes and spec sheets • Guided technical decisions • Advised on technical tradeoffs
Drew Harvey	Professional	Refer to resume	• Oversaw community considerations • Established communication with contractors
Kelvin Gregory	Professional	Refer to resume	• Monitored timeline and progress reports

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SCOTT RHODEHAMEL

employment

Solar Technician Supervisor [Pittsburgh, PA] June 2010 - Present
Energy Independent Solutions
Design and construct renewables: solar pv/hot water, charging stations + wind
Certified: OSHA 10, BLS, DOT Medical Card + Machinery Operator

Graduate Architect [Melbourne, Australia] Aug 2009 – Mar 2010
Architektonic [International Work Visa 462]
Government code compliance projects, construction set for an Australian Rules Football arena and design development for commercial housing projects.
Utilized: Revit, Rhino, AutoCAD, 3d Max, SketchUp + Photoshop.

Architectural Designer [Syracuse, NY] June 2006 – Feb 2009
King & King Architects
Healthcare construction set for a vivarium & associated offices. Education construction set for Potsdam High School renovation and pro bono design development for a community boathouse.
Utilized: Vectorworks, AutoCAD, SketchUp + Photoshop.

education

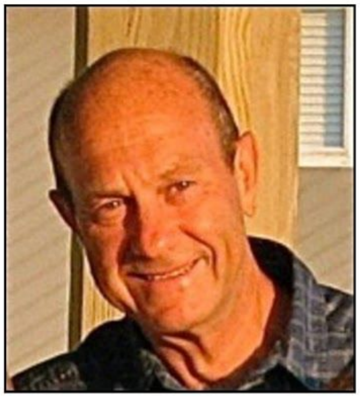
M. Arch, SUNY University at Buffalo	[Buffalo, NY]	Feb 2009
B.S. Arch, SUNY University at Buffalo	[Buffalo, NY]	June 2006
UB Dean's Scholarship		Fall 2007 + Spring 2007
UB High Academic Achievement List [>3.8 GPA]		Spring 2007 + Fall 2006
UB Academic Excellence Award [=4.0 GPA]		Fall 2006
UB Dean's Certificate [=4.0 GPA]		Fall 2006
UB Dean's List [>3.6 GPA]		Spring 2006 + Fall 2005
Architectural Design Teaching Assistantship	[SUNY, UB]	Fall 2007 + Spring 2008
Architectural History Teaching Assistantship	[SUNY, UB]	Fall 2006 + Spring 2007

volunteer

Engineers w/o Borders & CMU	[Zimbabwe]	2015 - **Present**
Children's Hospital of UPMC Volunteer	[Pittsburgh, PA]	2010 - **Present**
United Way - PITT Day of Caring	[Pittsburgh, PA]	2011 + 2012
Miracle League - Allegheny Valley Baseball	[Pittsburgh, PA]	2011
Frick Park Volunteer	[Pittsburgh, PA]	2010

software

Extensive use:	**Revit** | **AutoCAD** | **Vectorworks** | **Rhino** | Photoshop | MS Office | SketchUp
Moderate use:	Microstation | Processing | Solidworks | Viz/3DS Max | InDesign | Illustrator
Exposure:	Dreamweaver | Flash | Catia | Premiere



Drew Harvey
Resume - December 2014

The Basics

Drew was born in Texas and raised on a wheat farm, 20 miles outside of the little panhandle town of Pampa. He eventually graduated from Texas Tech University with a degree in Mechanical Engineering, and went to work for the Aluminum Company of America (Alcoa) down on the Gulf Coast of Texas. But, after only 5 months he was drafted into the army and spent the next 2 years, not in Vietnam, but at White Sands Missile Range in New Mexico. He returned to Alcoa for a 36 year career living in Texas, Tennessee, Brazil, and finally to Pittsburgh, Pa in 1982. Most of his early work was in the smelting and casting businesses working on operations support and plant expansions. After moving to Pittsburgh, he was part of a team starting a new business unit, Alcoa Automotive Structures, that hoped to convince the auto industry that car bodies should be aluminum, not steel. As the Engineering Director, Drew travelled extensively to Europe and Japan and eventually led construction of a plant in Germany that supplied aluminum "space frame" bodies to Audi for the A8, the world's first production volume aluminum car. Additional manufacturing plants followed in Hungary, Italy, England, Spain, Norway, and the USA, but the conversion pace to aluminum remains promising, but slow. As the "Director of Alcoa Business Systems", Drew led implementation of advanced manufacturing technologies throughout the business unit before retiring in 2004 at the age of 58.

His wife Paula retired the same year after many years of teaching at the elementary & pre-school levels. They have a son, Tyson, who works in medical sales and lives in Long Island, New York, and a daughter Allyson, a Veterinarian Technician living in Pittsburgh.

An avid bicyclist, Drew enjoys multi-day long distance bike tours. He also remains very connected with the Texas Panhandle and tries to return whenever possible to help on the family farm.

Work History – 36 years with Alcoa in Mech. Engr., Program Mgt., Engr. & Mfg. Leadership positions:

- Pt. Comfort, Texas – Technical support to operations and major capital expansions.
- Alcoa, Tennessee – Department Engineering Leader in Aluminum smelting and ingot production. Major project – start-up of a new Aluminum Reclamation Facility.
- Pocos de Caldas, Brazil – Mechanical Engineering & Maintenance Manager. One of two Americans in this mining, refining, smelting, ingot, & powder production facility.
- Pittsburgh, Pa. – Initially in Corporate Engineering working on introduction of new technology and major capital programs throughout the world. Joined a small new business team that initiated "Alcoa Automotive Structures" and eventually became Director of Engineering for the business unit where I was responsible for the design & construction of new auto body production plants in Germany, Italy, Norway, Hungary, England & the U.S. Also led training programs & implementation of advanced manufacturing systems based on the Toyota Production System at all locations

Interest in Africa

Drew got involved in many things immediately after retirement, one of which was a Habitat for Humanity Global Village trip together with his daughter to the village of Mpongi Puti-Puti in Uganda, Africa. As a Habitat GV team leader, he lived with the people, worked with the family receiving the house, and came back with a lot of questions around social justice, work ethic, African development, and values. More Habitat trips followed to Zambia, Ethiopia, and New Zealand.

In 2005, Drew led a team of 18 to the Nyadire United Methodist Mission Complex in Zimbabwe. Nyadire includes a large hospital, orphanage, 1200 student school system, teaching college, school of nursing, and a farm. With the ongoing collapse of Zimbabwe, it was clear this facility would not survive without outside support. Upon returning, the team created "The Nyadire Connection" (TNC) dedicated to enabling Nyadire to continue serving the people of Northeastern Zimbabwe. The guideline of "connecting people to people" has led to 13 ongoing programs which sponsor orphans, keeps a doctor & medicines in the hospital, operates a micro-loan program, etc. TNC (www.nyadire.org) strives for a true partnership, acknowledging that all involved benefit equally. Drew and others continue to take teams to Nyadire each year, the projects and programs expand, and the network of supporters grows ever more diverse. A trip in May 2013 initiated a program of renovating 6 rural health clinics that desperately need upgrades to provide the most basic of care. Funds were raised (~$300,000 needed for each clinic) and the first clinic, Chikwizo, was completed and dedicated in July 2014. The second clinic, Nyahuku, was completed in 2015 and work has now begun on the 3rd clinic, Dendera.

As part of a Jan, 2012 trip, Drew & a group of friends ascended Africa's tallest mountain, Mt Kilimanjaro in Tanzania.

Drew has been chairman of TNC since it's beginning. The success of TNC's connectional, relationship building model has led to broad involvement with the Global Methodist Church and their efforts to improve African healthcare with programs such as "Imagine No Malaria". In 2010, the Western Pa United Methodist Church Conference (900 churches) formed a partnership with the Zimbabwe church based on TNC's model of connecting locations.

After working with Brother's Brother Foundation to send containers of scavenged medical items to Zimbabwe, Drew joined the BBF board of directors in 2009. As the Chairman of the Strategic Planning Committee, he works closely with BBF's staff to greatly increase ocean container shipments to Africa. BBF's new "Africa Initiative" is now supporting over 100 Africa hospitals with the supply of medical consumables, limited drugs, medical hardware, and refurbished medical equipment. BBF has consistently been one of America's top charities as ranked by Forbes magazine and Charity Navigator.

Drew continues to be fascinated with Africa - the cultures, the history, the music, the religious mix, the high value of relationships, & the belief that tomorrow will be better. And yet, the poverty, the disease, the injustice, the wars, the hunger, and harsh realities of life call out for change. His questions - How did it all become this way? What can Africa teach us? What does effective help look like?

Other Stuff

In addition to Africa, Drew also works in numerous local and national programs. He has been on many adult mission trips to areas of disaster relief in places like New Orleans, Mississippi, North Carolina, New Jersey, and Pennsylvania.

Drew occasionally teaches classes summarizing the history and current situation of Native Americans, and joined a team building a Native American church in Illinois.

Drew's Christian faith has guided his life. He routinely has leadership roles at his local church, Christ United Methodist in Bethel Park, Pa, which is now working to increase the role of the church in effectively responding to the inequities and problems of our world.

As part of the national program "Everybody Wins", Drew reads one day each week to a 1st grade and then to a 3rd grade child attending inner city schools.

Jefferson Award

In August 2013, Drew received a "Jefferson Award" which honors volunteers performing significant community and public service in America.

Pampa High School Hall of Fame

In September 2014, Drew was inducted into the Pampa High School Hall of Fame in recognition of his professional and humanitarian contributions.

KELVIN B. GREGORY, Ph.D.

Professor, Carnegie Mellon University
Department of Civil & Environmental Engineering
5000 Forbes Avenue, 119 Porter Hall. Pittsburgh, PA 15213
Office: (412) 268-9811 E-mail: kelvin@cmu.edu

Education

2002 Ph.D. in Civil and Environmental Engineering, The University of Iowa
1999 Microbial Diversity, Woods Hole Marine Biological Laboratory
1997 M.S. in Civil and Environmental Engineering, The University of Iowa
1995 B.S. in Biological Systems and Agricultural Engineering, University of Nebraska

Positions

2016 – Curr. Professor, Carnegie Mellon University, Pittsburgh, PA.

2012 – 2016 Associate Professor, Carnegie Mellon University, Pittsburgh, PA

2006 – 2012 Assistant Professor, Carnegie Mellon University, Pittsburgh, PA

2002 – 2006 Post-doctoral Research Associate, Center for Environmental Biotechnology, University of Massachusetts, Amherst, MA. (Advisor: Derek R. Lovley)

1997 - 2002 Graduate Research Fellow, The University of Iowa, Iowa City, IA. (Advisors: Gene. F. Parkin & Michelle M. Scherer)

1995 - 1997 Graduate Research Assistant, The University of Iowa, Iowa City, IA. (Advisor: Gene F. Parkin)

1995 Water Resources and Sustainable/Appropriate Technology Engineer Non-government aid organization in Rayones, Mexico

Professional Interests

Research and teaching in environmental engineering with an emphasis in environmental microbiology and biogeochemistry. Research areas include management of produced water from oil and natural gas production, microbial interactions with nanomaterials, microbe-electrode interactions for energy and remediation, microbial ecology of natural and engineered systems and sustainable and appropriate technology for water and sanitation in developing communities.

Membership in Professional Organizations

Society of Petroleum Engineers, American Society for Microbiology, American Chemical Society, Geochemical Society, Association of Environmental Engineering and Science Professors, National Society of Professional Engineers (Registered EIT), American Academy for the Advancement of Science, Engineers without Borders

Honors and Awards

2016	U.S. Department of Energy, Oak Ridge Institute for Science and Education (ORISE), Faculty Research Participation Program.
2014	Best Feature Article (Runner-up) in *Environmental Science & Technology* for "Regional variation in water-related impacts of shale gas development and implications for emerging international plays"
2012	Best Feature Article in *Environmental Science & Technology* for "Transformations of Nanomaterials in the Environment"
2008	Ralph E. Powe Junior Faculty Award, Department of Energy, ORAU.
2003	Faculty of 1000 Recommended Paper for "Graphite electrodes as electron donors for anaerobic respiration", Gregory K.B., Bond D.R., Lovley D.R. *Environ. Microbiol.* 2004 June 6(6):596-604.
1999 - 2000	NIH Training Grant Fellowship "Biocatalysis and Bioprocessing"
1997 - 1999	NSF Training Grant Fellowship "Gene Expression and Bioremediation"
1998 - 1999	Neil B. Fisher Environmental Engineering Fellowship

Publications - Journal Articles

1. Vencalek, B.E., Laughton, S.N., Spielman-Sun, E.R., Rodrigues, S.M., Unrine, J.M., Lowry, G.V., Gregory, K.B. (2016 in Press). In situ measurement of CuO and $Cu(OH)_2$ nanoparticle dissolution rates in quiescent freshwater mesocosms. *Environmental Science & Technology Letters*.

2. Louie, S.M., Gorham, J.M., McGivney, E.A., Liu, J., Gregory, K.B., Hackley, V.A. (2016 in Press) Photochemical transformations of thiolated polyethylene glycol coatings on gold nanoparticles. *Environmental Science: Nano*.

3. Gulliver, D.M., Lowry, G.V., Gregory, K.B. (2016 in Press) Comparative study of the effects of CO2 concentration and pH on microbial communities from a saline aquifer, a depleted oil reservoir, and a freshwater aquifer. *Environmental Engineering Science*.

4. Moore, J.M., Stegemeier, J.P., Bibby, K., Marianakos, S.M., Lowry, G.V., Gregory, K.B. (2016) Impacts of Pristine and Transformed Ag and Cu Engineered Nanomaterials on Surficial Sediment Microbial Communities Appear Short-Lived. *Environmental Science & Technology* 50(5). 2641-2651.

5. Karthikeyan, K.G., Han, L., Gregory, K.B. (2015) Energy Consumption and Recovery in Capacitive Deionization Using Nanoporous Activated Carbon Electrodes. *Journal of the Electrochemical Society* 162(12), E282-E288.

