

THE SEED LIBRARY: TRANSPORTABLE ARCHITECTURE, STUDENT COLLABORATION, AND LOW ENERGY APPROACHES

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ABSTRACT

Students for Environmentally-Enlightened Design (SEED), a student organization at The Pennsylvania State University, is designing and building a book library that can be shipped to any destination using standard shipping methods. The Library utilizes a recycled shipping container that is outfitted with shelves and seating, stocked with donated books, and equipped with photovoltaic panels to generate all of its energy needs without connection to an energy grid. SEED's first prototype is being constructed in University Park, PA and will be sent to a refugee camp in Sub-Saharan

Africa in late 2013. See Fig. 1, below.

The design includes both passive and active energy reduction strategies, including solar orientation, stack ventilation and an external shade canopy to limit heat gain, provide mounting space for photovoltaic panels, and create an outdoor reading space. The photovoltaic panels will provide DC power for LED lighting and mechanical fan ventilation.



Fig. 1 SEED Library Rendering.

1. CONCEPTION AND DEFINITION

1.1 The Background

Books are rare to non-existent in many villages and refugee camps in Africa and libraries are rarer still. SEED collaborator Dr. Andrew Sicree, adjunct professor and former director of Penn State's Earth and Mineral Sciences Museum, first became aware of this problem when he spent one year volunteering to teach computer data processing at Strathmore College in Nairobi, Kenya, 1986-1987. While in Kenya he saw how many schools and towns were without a library, how few rural Kenyans owned their own books, and how rampant illiteracy was. Upon his return to the United States, Sicree began sending small packages of about 100 collected books to Strathmore College and with thousands of books sent, he succeeded to fulfill his initial goal of helping people to learn. In 2005 Strathmore College strived to earn university status from the Kenyan Commission on Higher Education and therefore was required to grow its library by 80,000 volumes. Sicree again led the way by delivering large quantities of books and established The African Book Project to support the larger effort. To store the books, Sicree rented a twenty-foot shipping container and stocked it with 17,000 books before sending the container to Strathmore College. Combined with Strathmore College purchases, other donations, and another 33,000 hand selected books from Sicree, Strathmore College elevated to Strathmore University.

Dr. Andrew Sicree also collaborated with Bernadette and Philip Thiuri who had the goal to establish rural reading centers in Kenya. Their books were shipped to Nairobi along with Sicree's, and Strathmore students helped distribute the books to rural reading centers in Kenya. Not every book Sicree finds is suitable for a university library, so he has contributed many volumes to Bernadette Thiuri's rural reading program.

In 2009 Dr. Andrew Sicree approached SEED, a then newly established student organization, with the proposition to transform one of his rented shipping containers into a transportable library. He had aided university libraries and rural reading centers, but had not yet been able to help refugee camps where infrastructure is limited or nonexistent. SEED ambitiously accepted the challenge and the SEED Library was born.

1.2 Instant Library

The idea of using a shipping container to create a ready-to-go "instant library" was a natural outgrowth of this need for library buildings. The instant library is a turnkey design requiring minimal tools, ensuring that virtually any aid organization and community members could manage its

preparation, assembly, and use in the future. The strategy is to install shelving, solar-powered lighting, a card catalog and a checkout desk inside of a purchased (rather than rented) shipping container along with all of the books necessary for a small village or refugee camp library. Such an instant library could be moved to a remote, rural village, and serve readers who are many miles from any other library resources. Refugees often stay in such camps for many years—and their children grow up in the camps often without access to reading materials. By utilizing this type of 'instant architecture,' educational materials can be distributed to those who would otherwise not receive them.

1.3 Design Considerations

The SEED library design utilizes a forty-foot purchased shipping container to be outfitted and stocked in the United States and shipped to Sub-Saharan Africa. To guarantee shipping insurance, the container's steel structure and shell cannot be compromised or penetrated. The fact that no holes may be cut poses some difficult structural, lighting and mechanical challenges. All of the library's building components must ship within the container and be easily assembled upon arrival at a specific site, which is initially unknown to the design team.

2. SIGNIFICANCE OF THE PROJECT

2.1 Education

While considerable charitable work has been done to provide books and educational materials to underprivileged African communities, these resources have rarely found their way to areas lacking permanent lending infrastructure. Too often this type of infrastructure investment is not made in refugee camps because they are seen as temporary and therefore do not receive assistance beyond basic sustenance. All of the books shipped are hand-sorted by Dr. Andrew Sicree for appropriateness and recipient libraries receive a wide variety of books.

2.2 Humanitarian Design

Every human should have access to education, yet many refugees who stay in camps for extended periods of time are not provided this basic human right. Also, architects have generally avoided these types of problems in favor of more monumental buildings and wealthy clients. More recently, as part of a paradigm shift, members of the architecture profession are placing value on every level of design and every human's right to good design. Humanitarian Design address issues such as disaster reconstruction, shelter, education, and the basic needs of communities, and demands the same emphasis on aesthetics as in traditional

architecture. By constructing the Library, our group is creating a place to gather and learn, where camp refugees' pride in their community can be restored through good design.

2.3 Sustainability

Another shift in design philosophy represented by the Library is that of sustainable design. Sustainable Design is not a fad to produce "green buildings," but a growing movement of individuals and organizations that seeks to redefine how buildings are designed, built and operated to be more responsible to the environment and more responsive to people.¹ Over the past two centuries the building and construction industry has negatively impacted the environment and significantly contributed to climate change. According to US Energy Information Administration (2011), the building sector consumes 48.7% of the total US energy, surpassing both the transportation and industry sectors. Now more than ever, it is time to take a stand against energy consuming buildings and design with future generations in mind. The Library's construction seeks to reuse materials like the shipping container and upcycled pallet wood, as well as generate its own renewable energy. It uses passive strategies including orientation, shading, and day-lighting to limit the need for mechanical systems.

3. RESEARCH PLAN AND METHODOLOGY

The SEED Library is an in-progress prototype project. We arrived at our first design model through careful investigation with help from professionals and subsequently are constructing a full-scale shipping container library. Our team will monitor this initial prototype in terms of the health of its book supply, its built structure, and its overall use and success. Experience gained in this effort will be incorporated into a second-generation library.

4. TECHNICAL SYSTEMS INTEGRATION

The power for the library will be generated using photovoltaic panels that are mounted on a canopy structure, which also shades the container from the intense African sun (Fig. 1). The interior systems are broken into two parts: lighting and ventilation.

Apart from the initial investment, little money will be required to maintain the system throughout the course of its deployment, which is approximately 10-15 years. The library requires a ventilation and lighting system, along with a battery backup system for after-hours operations. The size of the photovoltaic system is dependent on the energy demand from these components.

4.1 System Loads

Ventilation and lighting systems loads are based a run time assumption of 12 hour/day. Table 1. on following page shows the estimated loads for both the fan and lighting systems. Equation 1., seen below, shows how the system loads were calculated.

Equation 1.

$$(Watts/unit) \times (\# \text{ of units}) \times (\text{hours/day}) = Wh/day$$

Having the estimated loads from each system, the total potential load was assessed. Equation 2. shows the expected load doubled and half a day without sun added to calculate a maximum design load into the total potential load.

Equation 2.

$$(Wh/day) \times (\text{doubling factor}) = \text{Total Potential Load} (Wh/day)$$

The potential load is less than the design load, which makes evident the purpose of this number. The photovoltaic system is designed to supply this design load. Table 2. shows how much energy will potentially be produced from the PV system design. With the use of solar radiation mapping, the estimated Wh/m²/day for a given location in Africa was used to calculate how much energy the panels for that specific location would produce. See Fig. 2., below.

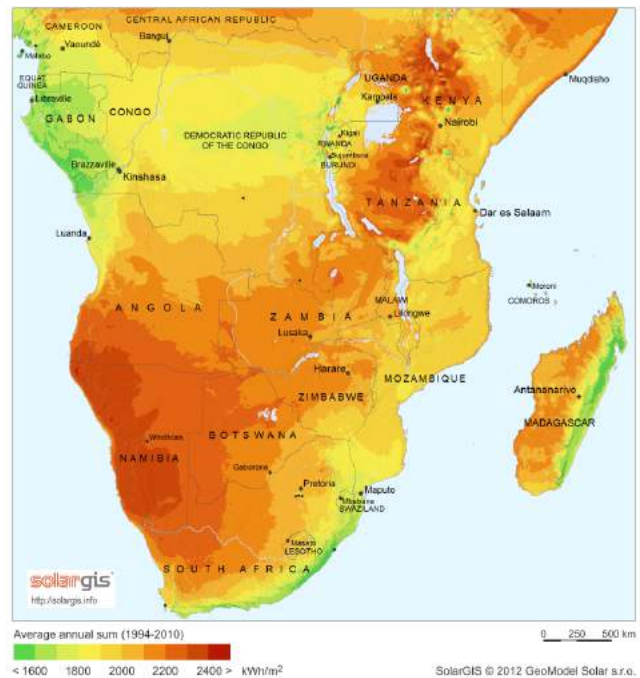


Fig. 2: Solar Radiation, Southern Africa. ²

TABLE 1: FAN AND LIGHTING ESTIMATED LOADS

<u>Fans</u>		<u>LED Lights</u>		<u>Total Potential Load</u>	
12	Volts	12	Volts	1548	
1	Amp	0.58333333	Amps	2	doubling factor
12	Watts	7	Watts	0.5	days no sun
2	Fans	15	lights	1548	Wh/day
12	hours/day	12	hours/day		
288	Wh/day	105	Watts		
		1260	Wh/day		

TABLE 2: SOLAR PANEL AND BATTERY CALCULATIONS

<u>Solar Panels</u>		<u>Batteries</u>	
245	W/panel	1548	Wh/day
2	panels	0.73	Battery Efficiency
490	Watt system	0.5	Battery Discharge
1.65	m ² panel area Suntech 245	4241	Wh/day
6130	Wh/m ² /day in Lodwar Kenya from PVWatts	12	V
10115	Wh/day	108	Ah
		1296	Wh/Battery
		3	Batteries

TABLE 3: LIGHTING MATRIX

	<u>Light</u>	<u>Rating</u>	<u>Socket</u>	<u>Output</u>	<u>Lifetime</u>	<u>Efficiency</u>
1	Globe LED Bulb E26/E27	12VDC 3W	edison	240-260 lm	>50,000 hr	Very High
2	Compact Fluorescent Lamp 2U	12VDC 13W	edison/bayonet	720 lm	10,000 hr	Moderate
3	LED Spotlight Lamp L-A7W-12V	12VDC 7W	edison	600lm	>50,000 hr	Very High

Equation 3.

$$\text{Panel Area (m}^2\text{)} \times (\text{Wh/m}^2\text{/day)} = \text{Estimated Energy Production (Wh/day)}$$

With the estimated energy production (Equation 3., above) larger than the potential load, the PV system will be sufficient for the library's energy demand. Using the total potential load, the number of batteries required to operate the system after the sun sets can be referenced in Table 2.

Equation 4.

$$\begin{aligned} \text{Total potential load (Wh/day)} \times \text{Day of no sun} \\ = \text{Battery Load (Wh/day)} \\ (\text{Battery Efficiency} \times \text{Battery Discharge}) \end{aligned}$$

The battery load necessary to run the fan and lighting systems was then divided by the Wh/battery to determine the number of batteries necessary for the back up system. See Equation 4. above.

4.2 Lighting

Table 3. outlines a decision matrix to decide what type of lighting to use. LED lighting was chosen because LEDs can directly use the DC power produced by solar panels. LED lights were also chosen because of their 90% efficiency and longer lifetime compared to fluorescent bulbs of similar lumen output.

The proper amount of lighting is required to enable safe and easy access, retrieval, and reading of books and other media. The necessary lighting amount for a library is 6 foot-candles on the face of the bookshelves³. A foot-candle is a measure of light that indicates the illuminance of a point on a surface perpendicular to the source. The software AGI, was used to calculate and design the lighting schematic of the library. The information (watts, lumens, etc.) of the LED light bulbs that will be used in the design was entered into the AGI database to produce a design. See Fig: 3 above, right.

4.3 Ventilation

Ventilation is needed in the library to keep the space cool and keep humidity low. The geographical region where the first prototype library will be deployed has average humidity levels between 13%-42%⁴. Library standards state that the air should be at humidity between 30%-50% to achieve the maximum lifetime from the books³. Our design load does not include provisions for a humidifier to keep the humidity above 30%. The library will be able to keep the humidity below 50% by exchanging the air within the container at 4 times an hour.



Fig. 3: AGI interior rendering of the library with lighting.

Equation 5.

$$40' \times 8' \times 8' \times (4 \text{ air exchanges/hr.}) \times (1 \text{ hr./}60 \text{ min.}) = 171 \text{ CFM}$$

From Equation 5. above, the design requires two fans of at least 171 CFM each to achieve the desired air exchanges in the library.

4.4 Photovoltaic System

The libraries photovoltaic (PV) system design will incorporate the use of two 245 watt panels, which will harness the sun's solar radiation (kW/m²) for energy production. The photovoltaic system is designed to be located in Africa at a latitude + 15° from the equator. The system is designed to supply power for ventilation, lighting, and a battery backup system for the library. The energy created from the panels during the day will be passed through a charge controller, which will supply power to the internal components of the system and charge the batteries at the same time. Once the sun has set, the battery system will power the library. The array will consist of three marine deep-cycle batteries. The deep-cycle allows them to dissipate up to 70% of their charge, which is a much higher efficiency than standard car batteries. These batteries should power the library for a maximum of 6 hours after sunset.

A rendering of the string of 15 lights (Fig. 3 above) spaced three feet apart along the centerline of the ceiling produced 6 foot-candles along the face of the bookshelves. To maximize the lighting for the space, one-foot sections of electrical metallic tubing (EMT) will be used to hang the

fixtures. The EMT will be connected to a round electrical box that will house the Edison socket and screw in LED bulb.

The PV system will require a combiner box located underneath the panels on top of the container. The combiner box contains a fuse block between the photovoltaic panels and the container to prevent electrical hazards. At the combiner box location, there will be a disconnect switch in case of any safety issues occurring at the photovoltaic panels.

To bring the power from the panels into the container, a watertight bulkhead connection will be made on the side of the container above the librarian’s desk. The bulkhead will be a five-wire connector that will be flush with the container wall in order to pass shipping inspection. The wire feeding the bulkhead connection from the outside will be a 12/3 SJ

cord. The cord boasts a thick rubber jacket that makes it waterproof to withstand the elements. The bulkhead connection will feed another disconnect inside the container. This disconnect will add yet another safety feature if the bulkhead connection ever had to be detached.

The inside disconnect will be fed into the charge controller which will electronically determine the share of the load being sent to the battery system and to the load center. At the load center, there will be eight circuit spaces. DC breakers (15 amp) for circuit protection will occupy the first two spaces. The purpose of using two separate breakers fulfills the client’s request of being able to switch the lights at different locations (Fig. 4).

The light fixtures will be split in half between the front and back of the unit (Fig. 5). The next two spaces will house a breaker for each of the two fans for the ventilation. This

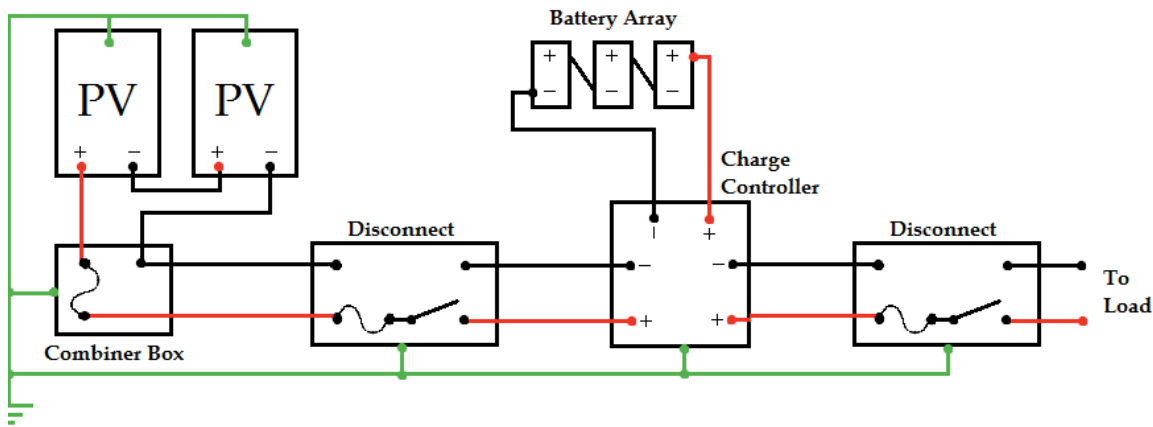


Fig. 4: Power System Schematic

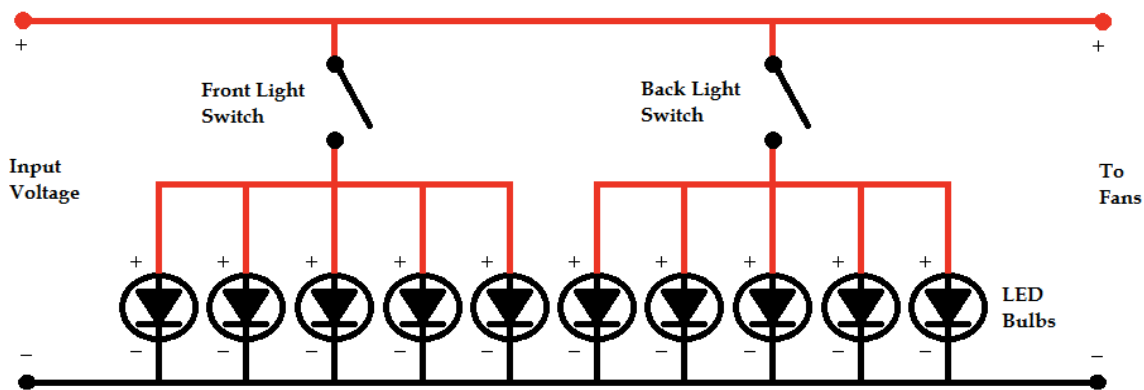


Fig. 5: Lighting Schematic

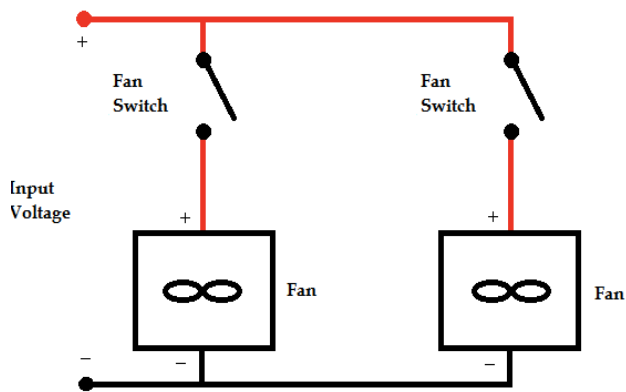


Fig. 6: Fan Schematic

control will allow for the ventilation to be run on half power, only one fan, if the climate allows (Fig. 6). The final used space will be a breaker for the photovoltaic panels. The remaining spaces will be unused.

The majority of the system will be installed prior to shipping to ensure quality and safety. The installations that will be made on-site are the mounting of the rails to the L-brackets on the canopy and then securing of the PV panels to the rails. The combiner box will be secured to the undercarriage of the canopy with bolts; the feeds will be connected from the panels into the combiner box prior to shipping. Slack will be provided so the panels can move freely during installation. The excess wire will need to be fastened to the bottom of the rails or canopy. The last connection that will need to be made is to connect the SJ cord from the combiner box into the bulkhead.

Because the prototype of the SEED Library is still being built, testing was done for our system using computer programs and professional assessments. The lighting was shown to be sufficient by using AGI software, which produced a rendering and light outputs as shown in Fig. 3. This software indicated that the light levels inside the library were greater than 6 foot-candles, which is sufficient for our design. The solar portion of project was confirmed via the calculations seen in equations 1 through 4 above. Also, we ran the system through solar software SAM (System Advisory Model). SAM is a program accredited by the National Renewable Energy Laboratory (NREL) and used for renewable design. This program used the weather data and sun resource of Sudan to determine system output. To verify our design, a NABCEP (North American Board of Certified Energy Practitioners) solar installer reviewed and approved our design.

5. CONCLUSIONS

It is the ambition of the SEED group to complete the first iteration of the SEED “instant library” and prepare to ship the container and educational resources to a site chosen by Dr. Andrew Sicree by late 2013. The outcomes of this project will be evaluated by the success of its occupant use in the refugee camp and by its systematic performance in an African climate. By assessing the instant library prototype through maintained contact with its recipient, SEED members at Penn State plan to continue developing the project, so that it may become a standard of transportable library designs for future iterations. SEED intends to provide public access to all documentation for the instant library, so that other groups may produce a similar project.

Through this system of networking the instant library goals and designs, SEED plans to be a leader in promoting responsible, humanitarian design as well as to aid in the process of providing educational resources to those in need.

6. ACKNOWLEDGEMENTS

The SEED Library is a highly collaborative, student-initiated project and it would not be possible without our many supporters. We would like to acknowledge Dr. Andrew Sicree for imagining the project and seeking SEED’s design skills to execute his vision. He has provided first hand accounts to inform design decisions and will be responsible for determining the library’s final destination from his African contacts. Sicree’s dedication to education and collecting books inspired SEED to create an accessible architecture for suffering refugees.

SEED faculty advisors Lisa Iulo and Ute Poerschke continuously guide our process and are the constant thread connecting the past four years as student officers and members graduate and change. They oversee design and construction, and generously volunteer their time and patience to learning students. Influential past and current SEED members include, but are not limited to, Stephanie Brick, George Gard, Emily Halm, Jeff Brown, Evan Murphy, Matt Graham, Chad Garrety, Kelly Ryan, Aaron Wertman, Bethany Drab, Emily Stein, Katherine English, Gina Rossi, Sally Ostendorf, Debra Dudenhoeffer, Travis Creighton, Laurie Mendez, Josh Seiler, and Hannah Estrich. The SEED Library is an entirely extracurricular project and students have volunteered over 2, 000 hours to its design, funding, promotion, and construction.

In Spring 2012, SEED partnered with Penn State Architectural Engineering students Lee Cunningham, Stephen Dudek, David Lambert, Adam Phoebe, and James Reilly to develop the electrical and mechanical systems.

Section 4. TECHNICAL SYSTEMS was largely adapted from their capstone final report, including tables and figures. Their expertise was necessary to progress the project and extremely relevant to the ASES Solar 2013 conference.

Generous donations from the African Book Project, College Of Arts And Architecture, Committee Of Environmentally Conscious Architecture (CECA), Learning Factory, Penn State Institutes Of Energy And The Environment (PSIEE), Stuckeman School of Architecture and Landscape Architecture, and Penn State Office of the Provost allowed the SEED Library to transition from sketches and models to a built prototype. With each party involved, it is an opportunity to educate about African illiteracy, humanitarian design, and sustainable building practices. We are grateful for these opportunities and look forward to shipping the first prototype library in late 2013.

7. REFERENCES

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