

Electric Little Free Library: Solar Kiosks for Energy Access

Brittany Bondi

*Nelson Institute for Environmental Studies
University of Wisconsin-Madison
Madison, WI*

Stephanie Bradshaw

*Department of Atmospheric and Oceanic Sciences
University of Wisconsin-Madison
Madison, WI*

William Keenan

*La Follette School of Public Affairs
University of Wisconsin-Madison
Madison, WI*

Maitreyee Marathe

*Department of Electrical and Computer Engineering
University of Wisconsin-Madison
Madison, WI*

May 2022

Abstract

Socioeconomic and housing status should not be barriers to electricity access in the United States. However, under-served communities, especially those experiencing homelessness, often have little access to outlets, phone chargers, and electricity at-large. Our project sought to utilize and electrify little free libraries (LFLs). Our electric little free library (eLFL) provides a stable connection to electricity, a safe space for individuals to charge their electronic devices, and resources for those currently experiencing homelessness. Through our prototype deployment at Lisa Link Peace Park, located on State Street in Madison, WI, our group collected data and sought to provide a road map for future implementation of electric/solar-powered charging stations. During deployment the charging portion of the eLFL was used an average of 1.6 times per day, 17.3 minutes average time per charge per day, and the library was used an average of 3.7 times per day with the maximum use days in both cases - charging and library, occurring around weekends.

Acknowledgement

Our capstone group would like to thank EAP Professor Scott Williams, our client Megan Levy, and our faculty advisor Professor Giri Venkataramanan. We would also like to thank undergraduate students Savannah Ahnen and Tricia Nazareth for their efforts in developing and deploying the prototype, and graduate student Rebecca Alcock, the Director of UW Makerspace - Lennon Rodgers, the Wisconsin Electric Machines and Power Electronics Consortium, and the Team Lab for their help and support. We are grateful to all our interviewees for their time, Mark Kiesow of the Madison Parks Department for his support, Alder Patrick Heck and Alder Juliana Bennett for their inputs, and Chris Hubbuch of the Wisconsin State Journal for covering our story.

There have been numerous entities and individuals who have supported and/or continue to support this project. They are listed as follows in no particular order: Great Lakes Community Conservation Corps, Wisconsin Office of Energy Innovation, UW Makerspace, Department of Electrical and Computer Engineering UW-Madison, Wisconsin Electric Machines and Power Electronics Consortium, Little Free Library, Milwaukee Tool, Sustainable Microgrids Partnership.

Contents

1	Executive Summary	1
2	Background	1
2.1	The Intersection of Energy Justice and Homelessness	1
2.2	Homelessness in the United States, the State of Wisconsin, and the City of Madison	2
2.3	Project History and Goals	4
3	Methodology	5
3.1	Prototype Development	5
3.2	Prototype Deployment	5
3.3	Conducting Interviews	6
4	Results	7
4.1	Interviews	7
4.2	Policy	9
4.3	Costs	10
4.4	Deployment	10
4.5	eLFL Usage	11
5	Discussion	13
5.1	Benefits	13
5.2	Obstacles	14
5.3	Future Work	15
5.3.1	Replicability	16
6	Conclusion	17
A	Engineering Documentation	17
A.1	Electronics	17
A.2	Structure and Mounting	19
B	Interview Guides and Informational Poster	20

1 Executive Summary

As the United States and cities across the country move to a more renewable energy future, the energy transition must be equitable and just for all, regardless of race, gender, and socio-economic status. In the context of energy access and infrastructure, a particularly vulnerable population is the homeless population, especially those in Madison, WI. Those currently experiencing homelessness rely on their electronic devices such as cell phones and laptops to find resources, connect with others, and remain safe. However, this population does not typically have stable access to electricity to charge their devices, which this project seeks to address.

Megan Levy and Dr. Giri Venkataramanan asked this capstone group to evaluate the need, feasibility, cost, and benefits of deploying energy kiosks (electric little free libraries; eLFLs) particularly in the context of individuals experiencing homelessness in Madison to address their lack of stable electricity. The final report will act as a roadmap or implementation model for other states wanting to deploy such kiosks.

Site visits to city parks across Madison, interviews with staff at homeless shelters and resource centers, meetings with local alderpersons, and interviews with those on State Street have led us to conclude that eLFLs will have a positive impact on the homeless population and community in Madison. The eLFL prototype was deployed at Lisa Link Peace Park on State Street, an area that encompasses a large amount of the homeless population. Through interviews on State St, our group learned that many (self-identified) homeless people (a) had cell phones and electronic devices and (b) did not have very stable access to electricity to charge those devices. Our prototype was deployed at Lisa Link Peace Park on State Street from April 6, 2022 to May 6, 2022. Our prototype was generally well received and there were an average of 1.6 phone charges per day, as well as 3.7 library door openings per day — showing that our prototype successfully supplied electricity and resources to those who used it.

2 Background

2.1 The Intersection of Energy Justice and Homelessness

Energy justice seeks to address inequities related to the impacts of, decisions surrounding, and access to energy infrastructure. This project delves particularly into energy justice as energy access, with a focus on vulnerable populations. As a community with especially low access to energy infrastructure, the homeless population is of particular interest.

Energy access for homeless populations is very understudied. Still, findings of tangential academic research highlights a potential need for improved electricity access- particularly charging areas, for housing populations ((Moczygemba et al., 2021)(Raven et al., 2018)(Woelfer and Hendry, 2011)). Although focusing on a global scale, some experts have even suggested the idea of electricity access as a legally-recognized human right (Tully, 2006). Indeed, a 2005 United Nations Millennium project report United Nations (2005) highlighted electricity access- particularly in the Global South- as a noted area of improvement for global

development. Today, the UN’s Sustainable Development Goal (SDG) 7 builds on that, seeking to achieve universally *affordable* and *clean* energy.

Access to energy and electricity overlaps considerably with access to housing. For example, Article 25.1 of the Universal Declaration of Human Rights states: “Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, **housing** and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control.” United Nations (1948)

Other international frameworks that position access to adequate housing as an area of global improvement include: the International Covenant on Economic Social and Cultural Right, Human Rights Council Resolution 43/14, General Assembly resolution 76/133, and others. Several SDGs further outline the necessity to expand housing access. For example, SDG 11.1 states: “By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums. (United Nations, 2015) You can learn more about the intersection of homelessness and SDGs here: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2019/07/SALCEDO_Jesus_Presentation_2-1.pdf

While the ultimate global goal is clearly to improve access to housing, such an objective will take significant time. In the meantime, unhoused folks face other immediate needs in their day-to-day lives. People experiencing homelessness often rely on smartphones and other energy-dependent appliances to meet personal, social, and health needs (Raven et al., 2018); (Thurman et al., 2021). These needs, particularly access to health providers, can magnify with age (Raven et al., 2018). Indeed, one small study conducted in San Diego noted that even those who temporarily reside in shelters can have difficulties accessing charging infrastructure (Kim, 2014). However, before we can begin to explore energy access for those experiencing homelessness, we must first understand the state of homelessness on both a national and local level.

2.2 Homelessness in the United States, the State of Wisconsin, and the City of Madison

It is difficult, if not impossible, to keep a continuously accurate count of the number of the houseless population. Not only does the actual number change everyday, but there are also clear outreach obstacles in finding the resources to keep a consistent count. Still, the U.S. Department of Housing & Urban Development (HUD) organizes the Point-in-Time (PIT) count to try and keep an annual estimation of those experiencing homelessness. For this, Consortium of Cares (CoCs) around the country organize and conduct a careful count of those experiencing homelessness in their designated region once a year in late January. In charge of conducting PIT surveys as well as securing funding for support programs and to aid individuals, CoCs are HUD-funded programs. Outside of the PIT counts and often specifically covering regional or city locations, CoCs aim to help those experiencing homelessness navigate housing systems.

The COVID-19 pandemic brought undue health risks associated with in-person contact,

thus making PIT counts logistically difficult. With this, the HUD’s 2021 Annual Homeless Assessment Report (AHAR) to Congress focuses specifically on those experiencing homelessness, i.e. those who utilize shelters or stay in temporary assisted housing. Still, as AHAR discloses, the national PIT counted over 326,000 people experiencing sheltered homelessness on a single 2021 night. In fact, signs show that housing insecurity is a growing nationwide problem, as “the number of sheltered individuals identified as chronically homeless increased by 20 percent between 2020 and 2021”. (U.S. Department of Housing and Urban Development, 2022)

In the past few years, Wisconsin has boosted its efforts to improve, understand, and end homelessness in the state. In 2017, with unanimous legislative support, then-Governor Walker created the Wisconsin Interagency Council on Homelessness (WICH). This Council is an amalgamation of eight member agencies: Department of Administration, Department of Children and Families, Department of Health Service, Department of Veteran’s Affairs, Wisconsin Housing and Economic Development Authority, Department of Corrections, Department of Workforce Development, and the Department of Public Instruction. The state’s four CoC representatives [Dane County, Milwaukee County, Racine County, and Balance of State] are also part of the Council. WICH’s ultimate goal is to prevent and end homelessness.

Earlier this year, WICH published “Welcoming Wisconsin Home: A Statewide Action Plan for Homelessness” (hereto referred to as the WWH report). Significantly, the report writes as its first guiding principle that “housing is a human right. The Council affirms the idea that everybody who wants and needs a safe, stable, and affordable home should have access to one. Included in this is the need to address the criminalization of homelessness where it emerges in Wisconsin.” (State of Wisconsin Interagency Council on Homelessness, 2021). The report further recognizes the compounding roles that race, gender & sexual orientation, mental health, substance use disorders, and other sociodemographic characteristics can play in perpetuating homelessness. The WWH report ultimately outlines several goals for improving the state of homelessness in Wisconsin, with large focuses on increasing access to stable affordable housing and ensuring equity throughout these processes.

Wisconsin’s 2021 PIT count was lower than previous years. However, the WWH report provides the disclaimer that the 2021 figure was most likely significantly undercounted, again due to logistic restraints created by the pandemic. Despite these counting obstacles, the 2021 PIT account still revealed a more-than 10% increase in those experiencing chronic homelessness (State of Wisconsin Interagency Council on Homelessness, 2021). HUD defines chronic homelessness as “people experiencing homelessness for at least one year, or who have at least four experiences of Category 1 homelessness in the last three years for a total of at least one year and who have a verified disability diagnosis” (State of Wisconsin Interagency Council on Homelessness, 2021).

Home to the state capitol Madison, Dane county is one of the few counties in Wisconsin (alongside Milwaukee and Racine counties) with a major urban center. As such, it is also home to many people experiencing housing insecurities. In 2021, PIT counts for the county numbered 855 (Homeless Services Consortium of Dane County, 2022b). While African Americans only comprise 5.5 % of the county’s total general population, this group represented 46 % of those experiencing homelessness (Homeless Services Consortium of Dane

County, 2022b). With these stark numbers, it is clear that homelessness in the state is as much a racial justice problem as much as it is an economic issue. As the number of people experiencing homelessness rose 36% between 2020 and 2021 (City of Madison: Community Development Division, 2021), there is a clear and growing need to address the problem of homelessness in the county.

To systemically tackle the problem, Dane county has its own CoC, which aims to achieve the following four goals to ensure reliable and affordable housing: 1. Prevent Homelessness; 2. Support People Experiencing Homelessness; 3. End Homelessness; and 4. Collaborate with Local, State, and National Partners. Additionally, the Homeless Services Consortium of Dane County- recognizing housing as a human right- also focuses its efforts on achieving "safe, stable and affordable housing" for all (Homeless Services Consortium of Dane County, 2022a).

For individuals seeking resources, Madison hosts a large variety of infrastructure to support those experiencing homelessness. Shelters and/or Transitional Housing Centers include but are not limited to: Porchlight, Port St. Vincent, and Beacon. However, many of the city's shelters only operate during part of the day (either in the day or night), leaving people often in a state of daily transition. Additionally, for various personal reasons, some people may refuse to utilize these shelters, instead opting to reside completely on the streets. With such a transitory lifestyle, folks may struggle to access important secondary resources, such as stable electricity and energy.

2.3 Project History and Goals

While currently focused on Madison, this project's roots began with an initiative originating in Racine. The Great Lakes Community Conservation Corps (GLCCC) is an organization based in Wisconsin which works with veterans experiencing homelessness and disadvantaged youth by providing them job skills training. GLCCC recognized that often their trainees did not have a permanent residence and hence a safe place to charge their personal electronics. They identified a two-fold need: (1) community solar-powered charging kiosks for their trainees to charge their electronics for free; and (2) training the trainees to fabricate the kiosks to improve their job market potential and to serve as green ambassadors. GLCCC received a grant from the Wisconsin Office of Energy Innovation in 2021 to build these kiosks and they partnered with UW-Madison to get technical assistance on the prototypes. To kick off this project, a makeathon ("Solympics") was organized in Summer 2021 during which UW students made kiosk prototypes. A unique feature of this makeathon was that the GLCCC veterans participated as advisors to provide immediate feedback to the students, helping them devise contextually relevant designs. The winning team designed a Little Free Library (LFL) retrofitted with a small solar charging system called the electric LFL or eLFL. The design was developed into a field-ready prototype and was installed at the GLCCC facility in Racine, WI in March 2022. Using a similar prototype of these eLFLs, this project seeks to answer: How would publicly-available energy kiosks impact underserved communities? Specifically, we aim to:

- Understand the energy needs and accessibility of specific Madison populations, partic-

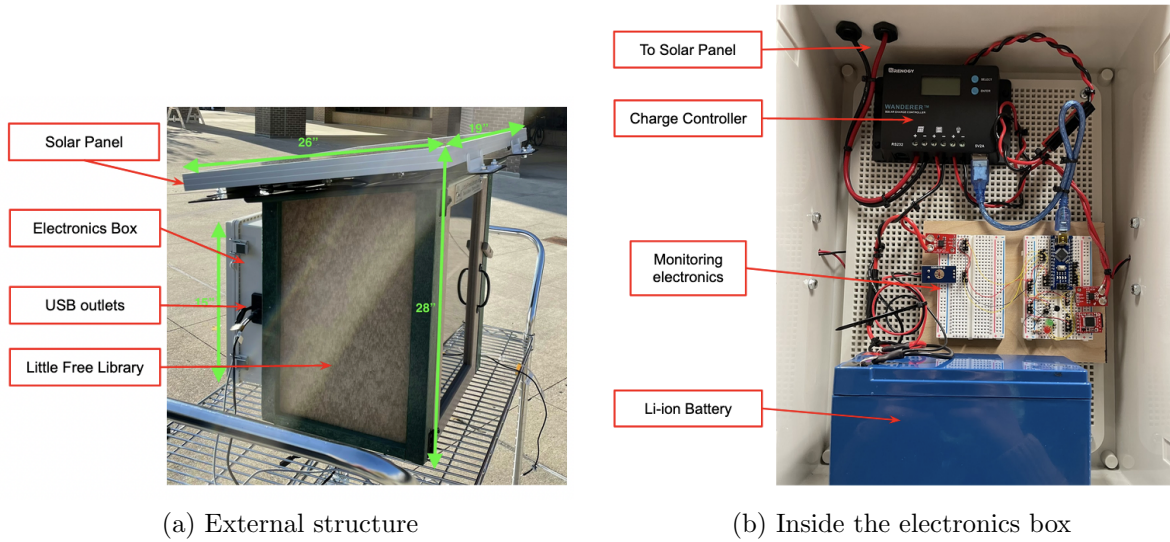


Figure 1: Prototype

ularly for those experiencing homelessness;

- Test the feasibility and usefulness of a solar-powered eLFL;
- Highlight the general costs associated with implementing such energy infrastructure;
- Synthesize our findings to highlight the replicability for other cities.

3 Methodology

3.1 Prototype Development

The eLFL prototype is shown in Figure 1. The team used commonly available off-the-shelf components for the power circuit and control circuits. The power circuit includes a 50W 12V solar panel, 20Ah 12V Li-ion battery, 10A 12V charge controller, and two 12V/USB converters with 2 USB outlets each. The control circuit includes a microcontroller which reads data from sensors and writes it to a data logger. A majority of the electronics is placed inside the electronics box which is mounted to the back of the LFL and the solar panel is mounted on the top. Further details about the electronics, including bill of materials and circuit schematics can be found in Appendix A.1. For pole mounting the eLFL, a universal pole mounting bracket and shelf bracket with hose clamps was used. More details about the pole mounting structure and bill of materials can be found in Appendix A.2.

3.2 Prototype Deployment

In order to test the prototype eLFL and obtain data regarding eLFL usage, permission was obtained from the City of Madison Parks Department for a temporary deployment at Peace (Elizabeth Link) Park. Peace Park (shown in Figure 2) was selected for deployment due to

its central location in Madison (in downtown) and the ease of access for all persons, including the homeless population. Though there are electrical existing outlets in Peace Park, Mark Kiesow, the Mall Foreperson in the City of Madison and this project’s point of contact at the Parks Department, indicated the outlets are not typically electrified to discourage folks from using the outlets for disruptive activities like loud speakers. Therefore, the eLFL would be the only working outlet in the park for the duration of the deployment. Since the eLFL has only USB outlets, it limits the scope of devices to basic personal electronics and reduces chances of engagement in disruptive activities.



Figure 2: A photograph of Peace Park in Madison, WI CODAworx (2009)

Per specifications from the parks department as communicated by Mark Kiesow, the eLFL was attached with the pole mounting gear discussed in Section 3.1 to a pole, as shown in Figure 3, from April 6, 2022 to May 6, 2022, a period of four weeks. For the duration of deployment, data was logged into the SD card every 10 seconds and the team would copy that data every three days or so for post processing. The following information is logged: load current (mA), battery current (mA), temperature (degrees Celsius), battery voltage (V), and door status (binary signal of closed or open).

3.3 Conducting Interviews

To specifically probe the need of eLFLs and energy access, we interviewed people representing various organizations and agencies working with and on homelessness or energy. We contacted a total of 53 people and interviewed the 31 who responded and agreed to speak with us. All of our interviewees worked specifically with Wisconsin homelessness or energy, and a majority specifically worked within Madison. Asking questions relating to energy access and/or houselessness, we used these interviews to also determine if any changes should



Figure 3: A photograph of the eLFL during deployment in April 2022 Eichstadt (2022).

be made to future eLFLs to better meet community needs. See Appendix B for our general interview guide.

4 Results

4.1 Interviews

Interviewees by Sector

<u>Sector</u>	<u>Number of Individuals/Organiza tions Contacted</u>	<u>Number of Interviewees</u>
Utilities	1	1
Elected Officials	3	2
Non-Profit/Community Experts	12	3
City/County Officials/Agencies	14	6
Media	5	1
End-Users	18	18
Total	53	31

Figure 4: A listing of interviewees by sector and frequency.

In order to explicitly probe the need for increased energy access, we interviewed a variety of representatives involved with the issue of homelessness. Perhaps as expected, representatives

unanimously agreed that access to affordable housing was the number one area of need for those experiencing homelessness. Yet, when asked specifically about whether and how electricity access was a need, some interviewees said they were not quite sure. This, however, does not mean that energy access is not an issue. Rather, it may just be often overlooked or simply drowned out by the larger structural issues. A representative of the Milwaukee CoC summarizes this well, explaining: "I don't think it gets talked about a lot, but I think it's something that people assume everyone has access to. But they don't necessarily have access to it."

Still, some of our interviewees expressed clear excitement at the prospect of an energy kiosk. Representatives from Catalyst for Change, an organization serving individuals and families experiencing homelessness in Dane County, were so enthusiastic about the concept of an eLFL for charging phones and tablets that they offered to sponsor two eLFLs in the future with some added features like having a secure place to store their device during charging (Catalyst for Change, 2022). Also, a representative of Port St. Vincent de Paul, was particularly excited about the scalability as well as the renewable energy aspect of the kiosk. He mentioned that Philadelphia has electric kiosks with lock boxes to help shoppers, tourists, and locals charge their phones. However, he noted that these other kiosks are not powered by renewable energy.

Just speaking and inciting thought energy access sparked new ideas within our interviewees' own work. For example, after being asked about the accessibility of outlets at their facilities, one interviewee pondered: "It's funny- I had never thought about it before, but I'm wondering if we should put some kind of charging station into [our] waiting room when we end up having people back in the building again". While they do have many outlets that their clients use, he notes that many of them are inconveniently placed.

At the same time, resource providers are considering energy access when designing resource facilities. One Dane County CoC representative mentioned that they made sure to consider how many outlets would be needed when designing the Beacon resource center. Additionally, as the city just found a new location for a permanent men's shelter, one design consideration is how to set up bunks to try and allow everyone access to an secure outlet as they sleep.

In terms of who would most benefit from eLFLs, one interviewee highlighted that the kiosks would most benefit those experiencing unsheltered homelessness, i.e. those on the street. A WICH member noted that the number of unsheltered folks is increasing, this suggests that eLFLs may especially support this growing group of people. However, while our interviews with organizations helped us to understand, many noted that the best way to understand the needs of those experiencing housing insecurity would be to speak with them directly.

During interviews conducted on and near State Street in Madison, WI (the location for our project's deployment of the eLFL as discussed in Section 3.2) a few individuals self-identified as being homeless and provided their thoughts regarding the need for places to charge their devices for free. Though one person indicated they would not use a charging station as they did not have a phone at the time and had no desire to obtain one in the future,

the majority of others expressed they would benefit greatly from a free, easily accessible charging stations. They were informed of this project’s plans to deploy such a station in the form of an eLFL and expressed they would use it.

4.2 Policy

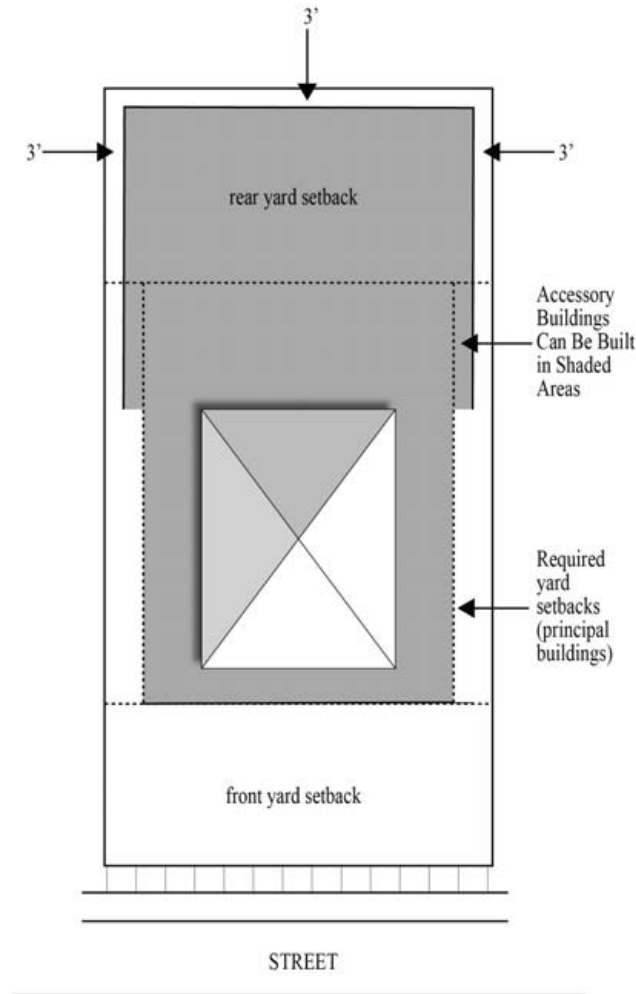


Figure 5: A diagram of the areas considered a setback for structures in Madison, Wisconsin according to the City Ordinances City of Madison (2021). The white areas do not allow accessory structures like Little Free Libraries.

When determining a suitable location for the eLFL and obtaining permission to deploy, the project team had a virtual discussion with the City of Madison Common Council Alders of District 2 and District 8, Patrick Heck and Juliana Bennett respectively. Alder Heck indicated Little Free Libraries violate existing zoning ordinances. For example, in Sections 28.131 and 28.132 of Madison, Wisconsin’s Code of Ordinances, Little Free Libraries are considered accessory buildings for mixed-use purposes and are not allowed in front yard setback areas as shown in Figure 5 City of Madison (2021). Though they are not allowed,

there are still many Little Free Libraries existing through Madison already because they are considered “beneath the notice” of city staff.

Additionally, if Little Free Libraries are desired in the public right of way in the City of Madison, a Street Encroachment Application would need to be submitted and approved by city staff at the Development Services Center, which can take up to two months to complete (Development Services Center, 2022). Luckily, due to the temporary nature of this deployment, the prototype was able to be deployed with emailed written consent from the City of Madison’s Parks Department without going through this application structure. However, future permanent eLFLs will need to obtain the necessary permissions prior to installation.

The policies around where Little Free Libraries are allowed to be in Madison, WI may be changing in the future. As a result of this project, Alder Heck has been working to amend the existing zoning laws to allow for “Mission Boxes” in zoning districts and Special Districts (like Parks). This change is not official yet, but Alder Heck estimates it could go into effect around June of this year pending approval by the City Council.

4.3 Costs

The costs for the prototype can be divided into electronics and mounting. The cost of the electronics was slightly above \$300. At scale, this could be brought down to the range of \$200-\$250. A detailed bill of materials is available in Appendix A.1. The mounting structure costed about \$100. This does not include the cost of the LFL since it was donated by the parent organization. This cost may not be significant if a wooden structure is used instead. This can be relatively simple to manufacture with simple tools available in a machine shop. The bill of materials for the mounting can be found in Appendix A.2.

4.4 Deployment

Since the eLFL was a prototype that was put together in a laboratory setting and not in a production quality manufacturing facility, the team had concerns around its robustness to the elements - natural as well as man-made. The prototype held strong through changing April weather - wind, snow, and rain.

We did experience some problems with the USB-A to multi-port charging cable. Initially, the charging cable was not secured and it went missing within the first week of the deployment. We placed a new charging cable and secured it to the electronics box using a zip-tie. After about ten days, the part of the charging cable secured using the zip-tie was found to be broken and the charging cable appeared damaged. We replaced this cable and secured the new cable in the same fashion. Securing the charging cable using metallic rings or making in-built charging ports could be a necessary feature for future versions.

4.5 eLFL Usage

To determine how many times the eLFL was used for charging devices during deployment in April and May of 2022, the load current records from the SD card were analyzed. As shown in the Figure 6, times when the load current is positive and large (i.e. greater than approximately 150 mA) are instances when a device is plugged in (circuit is complete and current flows to the device). These cases were counted each day and summarized in Figure 7. The average number of phone charges per day was 1.6 charges with the maximum charging days occurring over weekends. The daily average amount of time per phone charge is shown in Figure 8. The average charge time over the course of the deployment was 17.3 minutes.

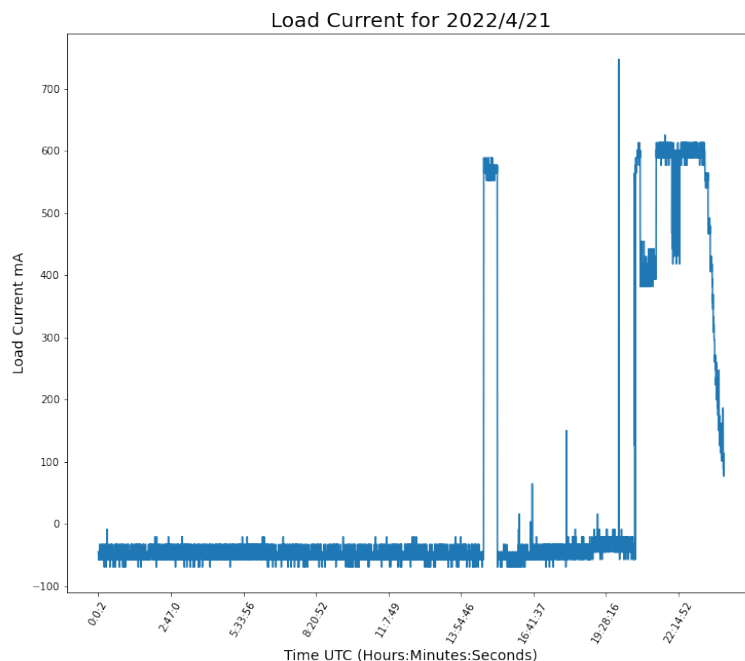


Figure 6: The load current for April 21, 2022 (UTC).

The library part of the eLFL was monitored with a sensor on the inside of the library by the door. When the library door was closed the sensor would record a “0” on the SD card and a “1” when the door was open. Figure 9 shows the number of library uses per day for the duration of the prototype’s deployment. On average the library part of the eLFL was used more often than the device charger portion with an average of 3.7 uses per day. The library was used most often on Fridays and weekends as shown in Figure 9.

To gauge feedback from those using the eLFL, a survey was created using Google Forms. A QR code linked to the form was then supplied on the outside of the eLFL. Unfortunately, we did not receive any responses during the prototype’s deployment.

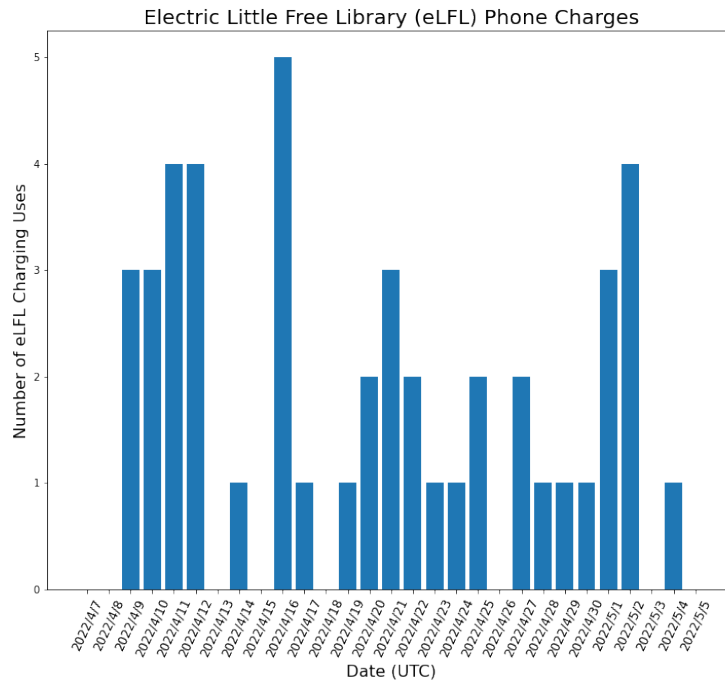


Figure 7: A bar graph depicting how many times the charging mechanism was used each day of deployment based on the load current (mA).

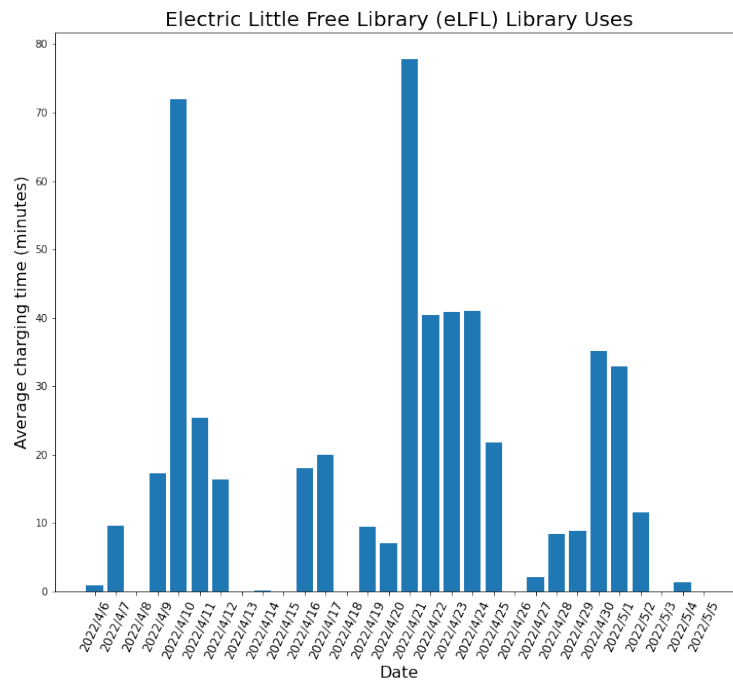


Figure 8: A bar graph depicting the daily average time per phone charge.

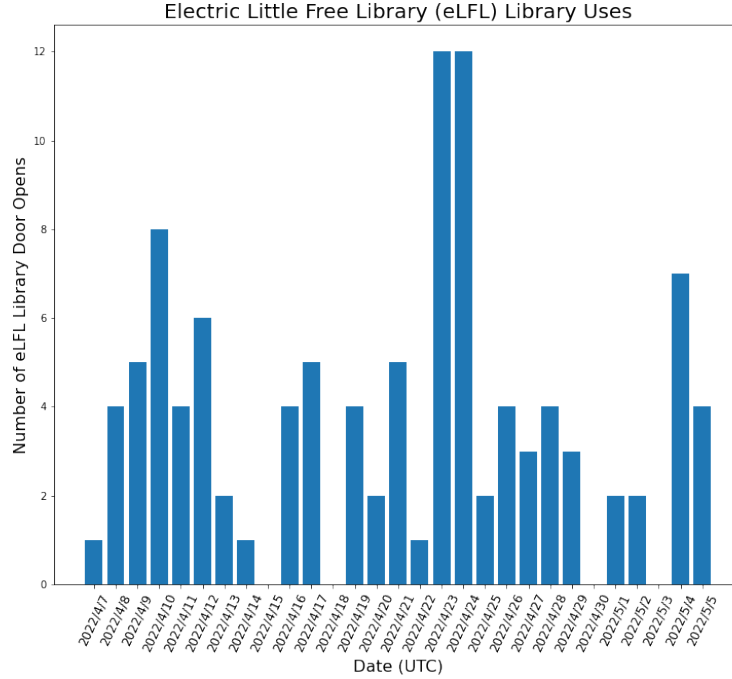


Figure 9: A bar graph depicting how many times the library part of the eLFL was used each day of deployment from the door sensor.

5 Discussion

5.1 Benefits

There are a multitude of benefits that our prototype deployment and this project provide. First, our eLFL was able to provide free, clean electricity for under-served communities, and individuals on State Street. Individuals currently experiencing homelessness are often either without USB cables for charging, lack access to outlets, or rely on light poles and city-provided outlets which are typically either broken or not working. Access to electricity ensures that individuals have a lifeline — a charged phone — which provides safety, a means of communication, and connection to others. Our eLFL provided a stable, and safe, place for electricity access in an area where they otherwise would not have one. The solar energy harnessed was also free and clean.

In addition to the tangible benefits described above, our group was able to provide knowledge in the form of books and resource lists to those who used our eLFL. The books themselves were very popular, even needing to be replenished every so often. In addition to the books inside the LFL, we provided lists of resources available for those experiencing housing insecurity, domestic violence, power shutoffs, and other associated materials. While we of course wanted to provide access to electricity, our goal was to also spread knowledge about available local resources. We included phone numbers, addresses, points of contact, and web addresses for local shelters, domestic violence centers, local government agencies,

and so on to ensure that information about local resources spread. Thus, the little free library served more purposes than one, with the access to knowledge being a popular resource per the data presented in Section 4.5.

We also placed graphics explaining how solar energy and solar panels worked in the eLFL. We discovered during our interviews on State Street that many individuals did not have much knowledge about how solar energy worked, or how the energy could be converted and used to charge devices. Explaining the benefits of solar, how it works, and why it is effective lent our project credibility and gave information about our eLFL to those experiencing homelessness and those using the eLFL.

As part of our outreach efforts, we wanted to gain media coverage of our project for a few reasons. We wanted to gain community support and spread information about our project: What is it? How does it work? Who are we? And so on. We contacted Chris Hubbuch, a reporter for the Wisconsin State Journal, who joined us at our deployment at Peace Park. Chris wrote a story for the State Journal, which made the front page of the newspaper — spreading information about our project and answering the above questions. In addition to the story, we also wanted to share our project in a more academic setting. Our team submitted an abstract to the Global Health Symposium and presented a poster at the event as well. Experts in public health, climate change, and energy were able to learn more about our project and team, and spread the word of the eLFL, expanding access to the eLFL.

In sum, our group and our project was able to provide **free, clean** energy to those experiencing homelessness (and the general public), provide resources to those experiencing housing insecurity, socio-economic hardships, and violence, supply knowledge about solar energy, and gain key media coverage.

5.2 Obstacles

While our group did have a successful deployment of our prototype, we did face challenges and obstacles along the way. During the early stages of our project, our team ran into difficulties getting into contact with Madison Metro, local alders, the city Parks Department, and community representatives. We sought information about zoning ordinances, feasibility, and need. At times, our calls and emails went unanswered. However, our persistence paid off as we eventually were able to speak with alders Bennett and Heck, Parks Department official Mark Kiesow, and community experts from Saint Vincent de Paul, Catalyst for Change, Madison Consortium of Care, the Interagency Council on Homelessness, and other experts which led to us gaining valuable insight on homelessness in Madison and the needs of this community.

Additionally, our team did face obstacles during the initial design of our mounting and security structures. Our team wanted to ensure that the eLFL could not be tampered with, that the box on the back of the eLFL (that contained our electronics) could not be stolen. We went through a few sketches of security features and finally found pole mounting gear to ensure the safety of our prototype. We found that commercially available pole mounting structures are either for light loads like security cameras or TVs or very heavy loads like

overhead speakers in sports stadiums. The latter were found to be more expensive than the cost of all the electronics put together. The team decided to use a pole-mounting bracket made for security cameras along with additional support with a shelf bracket as discussed in Appendix A.2.

As previously mentioned, LFLs (and eLFLs) do violate existing zoning ordinances, which led to some pushback from the city Parks Department when we first approached them about deployment. However, Alder Heck noted that local businesses and enforcers of the ordinance typically ignore the ordinance against LFLs, due to their popularity, usage, and support. Additionally, since our prototype deployment was not going to be a permanent installation, the Parks Department allowed us to temporarily deploy for a period of four weeks for initial data collection.

There was, at some stages, resistance to our project due to community attitudes towards a charging station. In particular, there is a negative connotation associated with homelessness and a fear that encouraging individuals to use an area for free charging of their devices would encourage loitering and unsafe conditions. For example, Madison Metro immediately turned us down when we pitched our eLFL project to them, citing “safety” and “loitering” concerns. We are hopeful that community attitudes will change, but this is something that must be kept in mind for further implementation.

Lastly, in preparation for our State Street interview session on March 16, 2022, multiple community experts and our client warned us about making assumptions and “deciding” about who we approached. While the goal of our interview session was to interview individuals currently experiencing homelessness, we could not make value judgements on who we believed to be “homeless”. Therefore, rather than targeting individuals, our team approached individuals equally — individuals sitting on benches, at Peace Park, walking down State Street and so on. We also learned that unless our interviewees self-identify as someone experiencing homelessness, we must not make any assumptions. The insights we gained were invaluable and we did not make value judgements on who to approach.

5.3 Future Work

Through conversations with community members, organizations, and the experiences of the team while designing the prototype, recommendations for future work and implementation of similar projects along with features for future versions of the eLFL are summarized below.

- Funding - The eLFLs or solar charging kiosks in general, fulfill a basic need - *free* access to *clean* electricity. Kiosks can be funded through multiple entities such as utilities, corporate social responsibility funds, homeless shelters, or even municipalities. Another idea could be to reach out to LFL stewards in the area i.e those with an LFL in their front yard and ask them to sponsor an eLFL in a public place.
- Locations - Kiosks can be installed in public places like parks and bus stops as also near resource centers such as outside homeless shelters and food banks.
- Signage - Homelessness is a loaded term and using this terminology in signage around the kiosks can hinder people from approaching them. These kiosks can be useful for

not just people experiencing homelessness but also underserved communities and the general public.

- Features

- WiFi - This feature was a common recommendation in multiple conversations. Access to open WiFi may be limited and can be a useful add-on to the eLFL. This can be achieved through cellular communication and the router can be powered using the solar power system.
- LFL light - A small LED light inside the LFL can be useful for access in the dark and can be powered using the solar power system.
- Secured charging cables - To prevent charging cables from being taken, they need to be secured using metallic rings or locks to the prototype. The prototype can also have the charging cable integrated inside the electronics box with only the multi-port end sticking outside to prevent the cable from being unplugged and taken.
- Timer-based secure phone storage - A common theme among conversations was around security of the cellphone while it is being charged. Small boxes with the charging port inside and locked through a key code can be a possible solution. To avoid this being used as a facility to store other personal belongings or illegal substances, the lock can be timer-based i.e it will open automatically after a certain number of minutes/hours after being locked or if the key code is input into the system. A timer-based lock would also allow individuals to retrieve their devices if they forgot what code they set initially.
- Juice Jacking - Juice jacking (stealing data from or installing malware into phones connected in public charging points) can be a major concern for end-users. A note assuring users that this is not being done through the eLFL may be useful.

5.3.1 Replicability

Based on the results of this project, eLFLs may be useful for other locations in the United States besides Madison, WI. Before producing eLFLs en masse, it is important to keep in mind the findings from this report. When reproducing eLFLs in other places this project recommends the policies for small structure placement be fully evaluated to ensure they do not violate any existing ordinances and to ensure proper permission is obtained for deploying the eLFLs to their respected locations. City Council Alders may be particularly useful to talk to in order to understand the existing policies. Additionally, it can be useful to promote positive public opinion for the project by reaching out to local businesses near deployment locations, reaching out to media outlets, and surveying the community. For the eLFLs themselves, this project recommends expanding the eLFL capabilities per the recommendations in Section 5.3 while using the eLFL prototype presented here as an initial guide.

6 Conclusion

Through meetings with local non-profits, elected officials, community experts, and end-users, our group was able to determine there is a **need** for electricity and access to electricity for under-served individuals and communities. Our prototype deployment led to daily uses of the eLFL (both for charging and books), meaning it is **feasible** to deploy energy kiosks in areas of high need. The benefits of the eLFL (electricity access, resource sharing, information sharing) far outweigh the costs of the eLFL deployment and our project (time to seek permission, cost of the materials).

Clean, renewable technology and energy and electricity should be widely available, regardless of socio-economic or housing status, for everyone. Our group hopes that our report, interviews, and eLFL prototype deployment serve as a roadmap for future projects and eLFL deployments in Madison, and the state at-large. We encourage folks to reach out with questions if applying similar projects in new locations.

Our group has thoroughly enjoyed working with Megan, Professor Giri, Scott and all of the individuals that we have interviewed. It was especially rewarding to see a community come together to address energy access in Madison, WI and experience the enthusiasm from all for this project.

A Engineering Documentation

A.1 Electronics

Bill of Materials

The bill of materials for the electronics is given in Table 1. The total cost comes out to be about \$323.

Circuit Schematics

The power circuit is shown in Figure 10. The PV panel feeds in to the charge controller. The battery is connected to the charge controller through a fuse. A current sensor and voltage sensor monitor its current and terminal voltage respectively. The two 12V/USB converters are connected to the charge controller through separate fuses. A current sensor monitors the total current drawn by the two converters. The control circuit is shown in Figure 11. The voltage and current sensors give analog outputs. A magnetic switch sensor is placed near the door of the LFL and acts as a door sensor i.e to check if the door is open or closed. The real-time clock module interfaces the microcontroller via I2C and runs on a coin cell to keep time even if the microcontroller switches off. The microcontroller sends data to the data logger using serial communication. The two indicator LEDs (green and red respectively) indicate the state of the battery voltage. If it is greater than 12V, the green LED is ON indicating that the battery is operating at safe voltage levels with enough charge. If it is less than 11.5V, the red LED switches ON indicating the battery is at deep discharge levels.

Table 1: Electronics - Bill of Materials

Component	Description/Part no.	Quantity	Total Cost
Power			
PV (solar) panel	Renogy 50W, 12V, flexible	1	\$120
Charge controller	Renogy 10A, 12V	1	\$19
Li-ion battery	Miady 12V, 20Ah LiFePO4	1	\$82
12V/USB converter	Output 5V, 2.1A	2	\$18
Control			
Microcontroller	Arduino Nano Every	1	\$13
Current sensor	ACS723, 5A	2	\$20
Voltage sensor	25V to 5V	1	\$7
Temperature sensor	TMP36GT9Z	1	\$2
Door sensor	magnetic door switch	1	\$4
Data logger	OpenLog	1	\$16
SD Card		1	\$8
Indicator LEDs		2	\$2
Real-time clock	DS1307 RTC board	1	\$8
Door sensor	COM-13247	1	\$4
Total			\$323

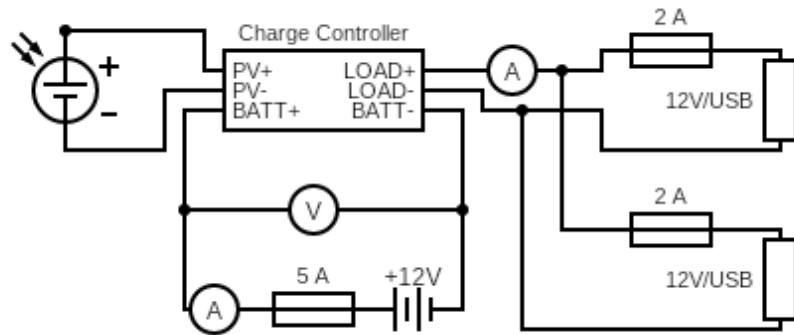


Figure 10: Power Circuit

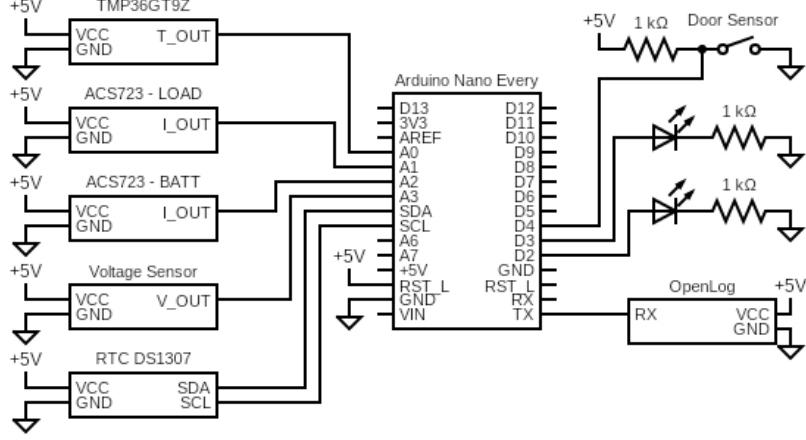


Figure 11: Control Circuit

Embedded Firmware

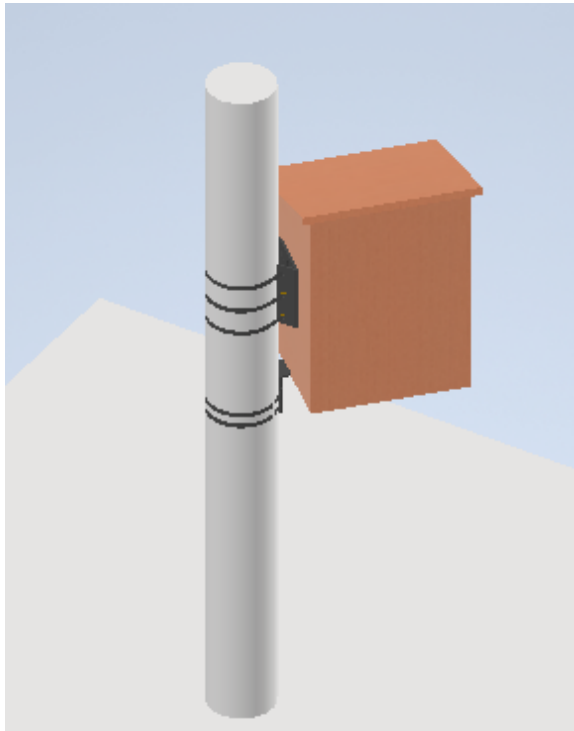
The data from sensors is read into the microcontroller and logged into the SD card. The repository for the code can be found at gitlab.com/msmarathe/elf1.

A.2 Structure and Mounting

The bill of materials for the mounting structure is given in Table 2. The LFL was donated by the parent LFL organization. It is made of HDPE (High Density Polyethylene) and costs about \$390 on their online store. A similar structure using wood as the raw material can be manufactured with access to a machine shop. In addition to the universal pole mount bracket, a shelf bracket was attached to the base of the LFL and secured to the pole with two additional hose clamps. This arrangement is shown in the 3D rendering of the prototype (Figure 12a) and a photograph of the actual prototype (Figure 12b).

Table 2: Mounting - Bill of Materials

Component	Vendor	Quantity	Total Cost
Electronics box	QILIPSU, Amazon	1	\$60
Composite Two Story Forest LFL	LFL org	1	-
Universal Vertical Pole Mount	WiTi, Amazon	1	\$21
1/4" Shelf Bracket	Claimed Corner, Amazon	1	\$8
Hose Clamp	Amazon	1	\$15
Total			\$104



(a) 3D rendering of pole-mounted eLFL



(b) Prototype showing the Universal Pole Mount and the Shelf Bracket

Figure 12: Pole Mounting

B Interview Guides and Informational Poster

Interview Guide - Organizations

The following questions informed our semi-structured interview process with organizations. Actual questions asked varied from interviewee to interviewee.

- 1.
2. Can you tell me about your work and how you work with/on homelessness?
3. What are some of the biggest areas of need (infrastructure or otherwise) for the communities you work with?
4. How would you describe the energy/electricity access for these communities?
5. Is clean energy something you consider in your work? Is it something of interest for the population you work with?
6. Where do you think our kiosks would be most helpful?
7. How do you think these kiosks may (or may not) be helpful?

8. What other supporting infrastructure or features might be useful with these kiosks? For example, wifi, benches, pamphlets?
9. What other factors or data do you think we should consider in this project?
10. Is there anything you'd like to mention that we haven't talked about or anything you think I should have asked?
11. Do you have any contacts that you think would be helpful for us to speak with and who may be interested in speaking with us?

Interview Guide - End-users

The following questions informed our semi-structured interview process with potential end-users i.e the interviews conducted on and near State Street in Madison, WI. Actual questions asked varied from interviewee to interviewee.

Open-ended questions

1. What devices do you own that require charging or access to an outlet? What do you currently use electricity for? (Purpose: Aims to see if larger-powered energy infrastructure (100W and 200W are needed, and if so, how/why))
2. How often do you use them? (Do they ever die when you use them?)
3. Do any of your friends or family also rely on your devices (e.g. your child shares the phone)?
4. Where do you currently go when you need to charge these devices? (Do you have a portable power bank? If yes, how often do you use that? How often do you charge it? If no, would you use one?) (Purpose: Determines current energy use patterns and locations)
5. How long do you stay at the (insert outlet location) and what do you do while it is charging? (Get numbers). If you did not have to worry about your phone being taken, would you prefer to do something else (like go for a walk, get your groceries, etc.)? Or do you like sitting with it?
6. How often do you access the internet, and how do you access it?
7. How often do you visit [insert site location]?
8. Has your phone ever died in a situation where you needed it?
9. It is very common to charge your electronic devices while you're sleeping since you're not actively using them. Do you have a place to reliably charge your electronics overnight?
10. Is there anything you need or want to use electricity for, but can't because you can't plug it in? (Purpose: Further probes question #1 to see if energy inaccess prevents people from using/having certain items)

11. What are some of the biggest challenges you currently face in accessing electricity? (Purpose: To identify current challenges in energy access, especially ones outside of outlet access)
12. How would one of these charging kiosks help you? (Purpose: Determines self-identified need)
13. Where would these kiosks be most helpful? (Purpose: Determines usefulness of prototype location and the relative need for other locations)
14. Are you interested in learning more about renewable energy, such as solar? What would the best way be to circulate this information for you? (Purpose: Determines educational value and need, as well as what mediums of information are most helpful)
15. Do you reside in Madison Year Long? IF YES: If you feel comfortable sharing, where else do you go and when? Do you have access to electricity in these areas? IF YES: Is there anything in (other places) that you would like to see in Madison, especially related to electricity access? (PURPOSE: To determine other locations in Madison where a solar kiosk may be useful, and to see if other cities/places have better, worse, or similar energy access for those experiencing homelessness)
16. If you feel comfortable sharing, when you are in Madison, where do you usually frequent?
17. What other issues are you facing outside of electricity access?
18. Is there anything you'd like to mention that we haven't talked about or anything you think I should have asked?

Quantifiable Questions

1. How would you rate your current access to charging cables? (Determines need.): (a) Outstanding (b) Very good (c) Good (d) Improvement needed (e) Non-existent
2. How would you rate your current access to outlets/power strips/areas to plug in a charger? (Determines need and access): (a) Very good (b) Good (c) Improvement needed (d) Non-existent
3. How familiar are you with solar energy? (Determines knowledge-level, could be helpful): (a) Very familiar (b) Somewhat familiar (c) Unsure/base-level understanding (d) No familiarity
4. How far away is the nearest charging area? (Determines access, gauges current level): (a) Very far (2-3 miles) (b) Far (0.5-1.9 miles) (c) Near (0-0.5 miles)
5. If a solar kiosk were to be deployed here, how likely would you be to use it?: (a) Very likely (b) Likely (c) Occasionally (d) Very rarely (e) Never



Electric Little Free Library



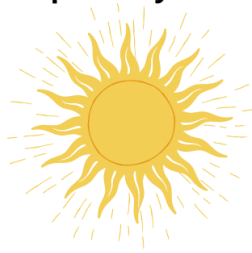
What is an Electric Little Free Library (eLFL)?

This is a little free library with an attached solar-powered phone charging kiosk and small battery storage. It was designed by electrical and computer engineering students on the winning team of the Summer 2021 "Sollympics" hosted by UW-Madison in partnership with the Great Lakes Community Conservation Corps. Currently, a group of capstone students in the Graduate Energy Analysis and Policy Program at UW-Madison are testing the need and feasibility of these eLFLs in Madison.

The eLFL is designed to allow you to charge your small devices for free using clean energy. Everyone can use it! **The USB outlets are on the sides of the white box, covered with a black rubber lid.** It will only be on State Street for a few weeks, but we hope to implement permanent solar kiosks throughout Madison in the future.

Your Feedback is Appreciated!

This is a prototype eLFL, and we are looking for ways to improve. If you use the kiosk, please let us know about your experience by scanning the QR code or by going to <https://tinyurl.com/SolarLFL>



UW-Madison and its affiliates are not responsible for any lost or damaged devices. We do not recommend leaving your device unattended while charging.



Sustainable Microgrids Partnership & Energy Analysis and Policy
NELSON INSTITUTE FOR ENVIRONMENTAL STUDIES
WISCONSIN ENERGY INSTITUTE
UNIVERSITY OF WISCONSIN-MADISON



References

- Catalyst for Change (2022). What we do. Accessed: 2022-05-06.
- City of Madison (2021). Accessory buildings and structures on lots used exclusively for residential and mixed-use purposes.
- City of Madison: Community Development Division (2021). Request for proposals: Rfp #10055-2021, homeless services & housing resources.
- CODAworx (2009). Lisa link peace park. Accessed: 2022-04-28.
- Development Services Center (2022). Street encroachment.
- Eichstadt, S. (2022). Uw-madison students expand services of little free library by going solar. *The Daily Cardinal*.
- Homeless Services Consortium of Dane County (2022a). About us. Accessed: 2022-05-08.
- Homeless Services Consortium of Dane County (2022b). Point in time count. Accessed: 2022-05-08.
- Kim, M. (2014). Designs on mobility: Perceptions of mobile phones among the homeless.
- Moczygemba, L. R., Thurman, W., Tormey, K., Hudzik, A., Welton-Arndt, L., and Kim, E. (2021). Gps mobile health intervention among people experiencing homelessness: Pre-post study. *JMIR Mhealth and Uhealth*.
- Raven, M. C., Kaplan, L. M., Rosenberg, M., Tieu, L., Guzman, D., and Kushel, M. (2018). Mobile phone, computer, and internet use among older homeless adults: Results from the hope home cohort study. *JMIR Mhealth and Uhealth*.
- State of Wisconsin Interagency Council on Homelessness (2021). Welcoming wisconsin home: A statewide action plan for homelessness (2021-2023). Accessed 2022-03-15.
- Thurman, W., Semwal, M., Moczygemba, L., and Hilbelink, M. (2021). Smartphone technology to empower people experiencing homelessness: Secondary analysis. *J Med Internet Res*.
- Tully, S. (2006). Access to electricity as a human right. *Netherlands Quarterly of Human Rights*.
- United Nations (1948). Universal declaration of human rights. Accessed 2022-05-01.
- United Nations (2005). The energy challenge for achieving the millennium development goals. Accessed 2022-05-01.
- United Nations (2015). Transforming our world: the 2030 agenda for sustainable development.
- U.S. Department of Housing and Urban Development (2022). The 2021 annual homeless assessment report (ahar) to congress: Part 1: Point-in-time estimates of sheltered homelessness. Accessed 2022-03-01.

Woelfer, J. P. and Hendry, D. G. (2011). Homeless young people and living with personal digital artifacts. *CHI '11: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.