



**Cook Engineering
Design Center**
at Dartmouth

Proposal

Electric Bicycle Charging Infrastructure in Lebanon, NH

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Sponsored by

The City of Lebanon

Project Team #20

Grace Connolly, Gannon Forsberg, Nathan McAllister, Avery Moorhead

Faculty Adviser

Professor Vicki May



Executive Summary

Significance: The Upper Valley has seen a major increase in e-bike usage as they have become both cheaper and more accessible. The City of Lebanon hopes both to address the needs of current riders and encourage the use of these environmentally friendly vehicles in the future by installing e-bike charging stations in the city green, Colburn Park, and near the Kilton Library. Research has shown a growing preference for e-bikes as a short-distance transportation method, and our team hopes to capitalize on this by working to bring a charging station to fruition in Lebanon, NH.

Objectives: There are multiple objectives which our team had to work to meet throughout this project. These include both final deliverables and necessary intermediate decisions which had to be made. Objectives included (1) determining whether designing our own electric bike charger or recommending the purchase of an off the shelf charger made more sense, (2) selecting an e-bike charger once we determined we should recommend purchasing one, (3) designing a solar array to power the charging station and (4) analyzing a survey sent out through the City of Lebanon to gauge interest in the project.

Approach: We worked step by step to iterate through and complete each of the objectives listed above. First, we met multiple times with both the City of Lebanon and other stakeholders in the project (including Vital Communities, the Ped-Bike Committee, and Omer and Bob's) to gain insight on how we could best serve potential future users of the project. In addition, these organizations helped us to assess interest in the project through survey distribution and e-bike purchase data in Lebanon.

Next, we conducted our own research to determine which product should be recommended to the City. While our group initially decided to design and build our own e-bike charger, after consultations with stakeholders and deeper research into the risks of e-bikes, we determined that this was not a safe or financially viable option. In part, this was due to the \$5,000 certification required by UL for any charging station.

In addition, we worked throughout the term on creating and distributing a survey, which currently has over 120 responses, and will remain open through November 30. Finally, our team worked on the design of a solar array and battery for the charging station, as this would mean the City would not have to pay for electricity to power the station, and bolster the charging stations' messaging around environmental impact.

Impact: These charging stations have the potential to do a great service to e-bike riders who live and work in the City of Lebanon by giving riders convenient access to outdoor charging. They also support the City's mission of encouraging a move away from gas-powered, climate-harming vehicles by working in conjunction with the City's installation of electric vehicle charging stations.

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Project Definition and Value

Problem Statement and Significance

This report project proposes a design for the construction of electric bike charging stations for the City of Lebanon (Figure 1). The City hopes to build two electric bike charging stations in high-use areas to both meet the needs of current e-bike users and encourage residents to buy e-bikes to lower their carbon footprints. Colburn Park and Kilton Library are currently being explored as potential sites. While public e-bike charging stations are relatively new in the United States, they can provide a great service to surrounding communities. A pilot study conducted by the National Renewable Energy Laboratory (NREL) found e-bikes were the preferred method of transportation for distances of one to four miles. More than half of all daily car trips in the United States were under three miles, meaning that electric bikes would serve well as a substitute for these daily trips.¹

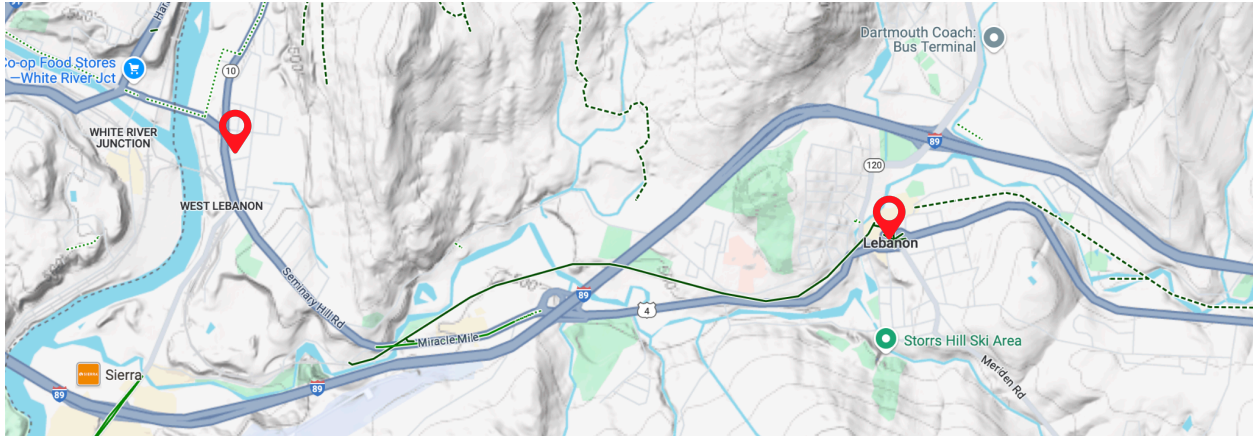


Figure 1: Map of potential locations

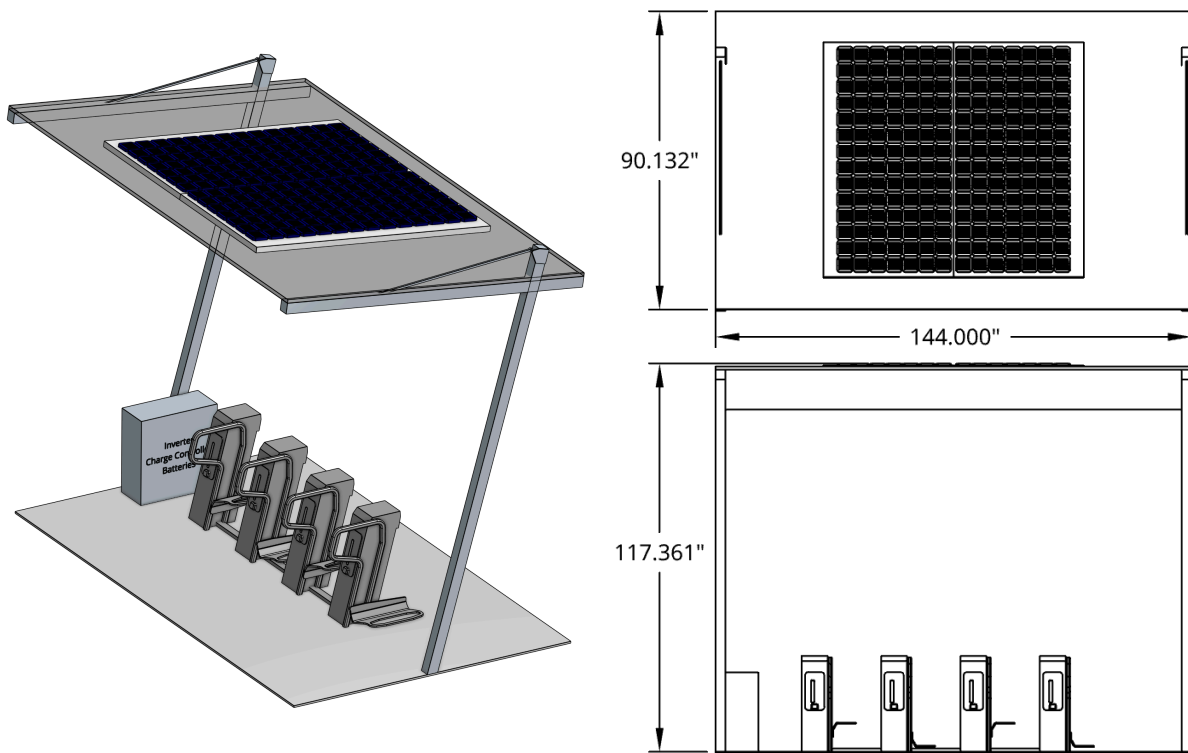


Figure 2: Design mockup of station, with racks, shelter, solar panels, and electrical box (containing batteries, charge controller, & inverter) displayed

Value Proposition

Identified by the City of Lebanon’s 2023 Walk, Bike, Ride report as a ‘Platinum Need,’ e-bike charging stations would to serve existing e-bike owners, incentivise prospective e-bike customers to purchase and use e-bikes as a form of clean transportation, and display the City’s commitment to green technologies. An e-bike charging survey, designed and administered in partnership with the City of Lebanon, further proves demand, with 61.8% of e-bike owners indicating that they would use a charging station in Colburn

Park if built. Additionally, 54% of non e-bike owners answered “yes” or “maybe” in response to whether they see themselves purchasing an e-bike in the near future.

Technical Plan

Technical Objectives

Broad objectives for this project, as posed by the City of Lebanon, have to do with both function and optics. Of course, the City wants to serve existing e-bike owners with modern public infrastructure to encourage the use of electric bikes as a mode of transportation. However, the City is also looking to signal to the community that they are prioritizing green technologies and are climate-conscious.

Requirement	Specification	Justification
Number of charging slots	Charging station must include 4 slots for e-bikes	If a charger is built that doesn't have enough charging slots, not enough users will be able to use it. If it is too big then it will not be cost effective
Charging Versatility	The product must be able to charge a variety of different e-bike batteries that use different voltages and connectors. Specifically, the charger should work for >90% of e-bike models	If the charger is not versatile only a limited number of e-bike users will be able to charge their bikes
Cost Effectiveness	Product must be cost-effective, as it will have to rely on grant or TIF funding: <\$25,000 in material costs	Budget is unclear, but operating with the goal of remaining inexpensive
Security	Will include a way for users to securely lock their bikes: negligible chance of theft	E-bikes could be stolen from the chargers if they are not locked
Environmental Impact	Charging station will derive >50% of its electricity from renewable sources	One purpose of this project is to promote and encourage electric bike usage as an alternative to cars, and should in practice support the goal of lowering negative human impact on the environment
Community Impact	The design will have minimal or positive impact on the surrounding community	This project aims to promote usage of electric bikes, which has the potential to result in the positive human impact seen in non-car reliant societies. We hope to foster this potential for connection in our project design

Table 1: Project requirements defined by the City and preliminary research

Innovation, Approach, and Methodology

In approaching this project initially, it had been assumed to be more focussed on the lower-level design of a charging station (i.e. the design of mechanical and electrical systems that constitute a charging station). There are three components that make up a charging station: bike rack, shelter, and power solution (i.e. grid power vs. solar power). In researching existing solutions for each of these three components, it became clear that the market is quite saturated with good solutions already, and that innovation in any of the three would be prohibitively difficult given the timeframe. Therefore, the project soon became more high level, focussed around recommending existing products, purchased off the shelf, to build up a suitable system for an e-bike charging station.

Bike Rack

While there are a broad range of e-bike charging racks and posts available on the market, many did not match with Lebanon's desired application. Options from two companies were ultimately considered: Dero and Saris. All models can be viewed in the [appendix](#). Ultimately, two offerings from Saris, who makes cost-effective, weather-resistant bike racks, were selected: the Saris Power Post Locking (\$350 per charger), and the Saris eBike Charging Station (\$1500 per charger). The Power Post Locking, with one outlet on either side, is the budget-friendly option, coming out to \$700 total to accommodate four bikes. Each eBike Charging Station, on the other hand, is meant for one e-bike, thus totaling to \$6000 to accommodate four e-bikes. If budget allows, the Saris eBike Charging Stations are preferable, as they offer a cooled chamber for charger storage, the option for users to bring their own padlock to ensure that their chargers are protected, and a more visible aesthetic with the words "eBike charging station" along the side panels. However, the Power Post Locking offers the same charging functionality, and while it does not have the extra security feature to allow users to secure their chargers in a locker, it is much less expensive.

Shelter

Both of the recommendations for bike racks above necessitate a shelter to protect the electrical components from any weather. Two popular options were considered: the Dero Vazor (\$13,552.00), and the Duo-Gard Razor (\$19,817.93). Both serve very similar functions, but in speaking with Carolyn Misch, the Director of Planning and Sustainability in Northampton, MA, she mentioned that they had just purchased a Dero Vazor shelter for a similar project. For this reason, along with the lower price tag, the Dero Vazor shelter is also recommended for this project in Lebanon.

Power Solution

While many options were considered, there are a handful of power solutions that make the most sense for an e-bike charging station like the one that Lebanon may look to install. Keeping in mind the objectives for this project, three options emerge:

1. *Routing an existing grid line to the location.* This is the most straightforward, proven solution for supplying power to the charging station. Per the National Electrical Code, PVC conduit lines are

required to be buried at least 18 inches underground and other lines are required to be buried at least 24 inches underground.^{2,3} Depending on the location, this could be either quite painless and inexpensive (i.e. Colburn Park, routed underneath the soil) or conversely, quite high-effort and costly (i.e. Kilton Library, underneath concrete).

2. *Installing an off-grid solar system.* An off-grid system would be most directly in line with the City of Lebanon's green agenda, signaling a forward-thinking, environmentally conscious government. Additional hardware is necessary for this system: solar panels, a charge controller, batteries, and an inverter. This additional hardware would need to be sheltered from the elements, and the solar panels would need to be mounted somewhere. For these reasons, this system must also include a shelter to cover the charging station and associated equipment, as well as to provide surface area for the solar panels.
3. *Installing a grid-tie solar system.* Lastly, a grid-tie solar system offers the best of both worlds: green signaling and renewable energy production, all while ensuring consistent flow of energy to the charging station. However, this is likely the most expensive option, requiring both a grid line to the station as well as the hardware for a solar system, in addition to a meter to tie the two together.

Out of these three options, option 2 (off-grid solar) best fulfills the requirements of the town. With this project there is a grand opportunity to inspire change. Not only can a charging station be a functional location for community members to park their e-bikes, but it can also be a beacon of hope for those who grow increasingly concerned about climate change and its associated threats. However, additional analysis is required to verify that this solution is viable and cost-effective. Local survey results revealed that e-bike users in and around Lebanon mostly ride their bikes in the spring, summer, and fall, with a sharp decline in the winter. Conveniently, these usage patterns line up with solar generation, which peaks in the summer and decreases during the winter, meaning the system can safely be designed around the warmer months.

A solar system such as the one necessary for powering an e-bike charging station must include the components in Figure 2. Solar panels generate DC power, which a charge controller pushes into battery storage before an inverter converts the stored energy into 120 V AC wall power for users to plug their e-bike chargers into.



Figure 3: Block diagram of off-grid solar system

It is imperative that the solar system is sized correctly so that the charging station always has enough power, but is not wasting too much unused energy from the solar panels. However, even experts with ample experience in the process can miss the mark sometimes, and system sizing is considered more of an art than an exact science.⁴ In predicting how much energy may be drawn from the charging station, the worst case is taken to be two full charges at each of the four ports in one day. Assuming that each e-bike

battery is 700 Wh (on the larger side of the spectrum among e-bike batteries), the worst-case energy usage would be 5600 Wh per day.⁵ Using the National Renewable Energy Laboratory’s PVWatts tool, a full year of solar generation was simulated for a 1 kW solar system in Lebanon, NH (Figure 3)⁶

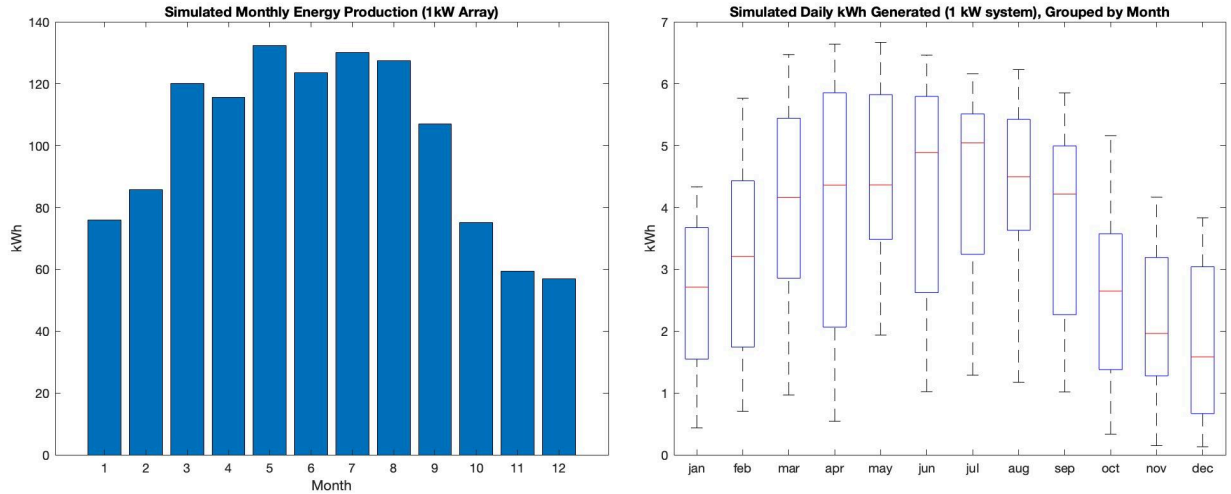


Figure 4: Simulated energy production for a 1 kW solar system in Lebanon, NH

At peak energy production (during the summer months) a 1 kW solar system in Lebanon, NH can be observed to produce in the realm of 4 or 5 kWh per day on average, which is just below the calculated worst-case load.⁷ For this reason, a 1 kW solar system should be the ballpark size for a charging station with room for four e-bikes.

For a 1 kW solar system, estimating a minimum of 15 W per square foot of solar, panels will take up at most 67 ft². The Dero Vizor shelter’s 90 ft² of rooftop area easily accommodates a solar system of the required size; the panels modelled in Figure 2 are approximately to scale.

With the panel array sized to accommodate prediction charging volume, battery size must also be decided. While 4 to 5 kWh per day is the expected average during peak solar generation, energy production volume is subject to fluctuations due to weather conditions. Additionally, solar panels only generate energy during daytime hours, mostly from noon to five in the afternoon, as they are conditional on the presence of sunlight. Therefore, an energy storage solution is required in the case that one may desire to charge an e-bike during a cloudy day or overnight.

Battery sizing, similarly to solar array sizing, constitutes an educated guess of supply and demand of the power generation and usage at the station. Price is an additional consideration; in the current market, lithium batteries cost around \$100 per kWh of capacity.⁸ Significantly oversizing the battery should be avoided due to cost, even though doing so would ensure a constant excess of energy. Again, knowing that demand is much lower during the winter months, the battery sizing can safely be informed by higher usage periods. Additionally, given that the solar system was sized based on the maximum predicted daily usage, and that charging volume can be assumed to be directly correlated to weather (people are more likely to ride their bikes in sunny conditions), more than two days of capacity would be excessive. A 5

kWh battery (around one day’s-worth of predicted maximum load) strikes a healthy balance between ample storage capacity in the case that users still want to charge during cloudy days, and cost. Given also the size of the system, a 12 or 24 volt battery is sufficient to power the charging station, as opposed to 48 volts.⁹

Additional components include a charge controller and an inverter. Maximum Power Point Tracking (MPPT) charge controllers are becoming increasingly popular due to their ability to handle a wide range of input and output voltage. They are also significantly more efficient when compared to legacy Pulse Width Modulation (PWM) controllers, and while MPPT used to be much more expensive, prices have now dropped considerably.¹⁰ Operating functionally as a buck converter (which trades voltage for current), MPPT controllers are rated for maximum current draw. For example, using equation 1, a 1 kW solar system charging a 24 V battery would require a controller rated for at least 41.67 A.

$$\frac{\text{Solar System Size (W)}}{\text{Battery Voltage (V)}} = \text{Minimum Controller Current Rating (A)} \quad (\text{Equation 1})$$

Finally, an inverter is necessary to convert the DC battery voltage to an AC 110-120V line that can be sent to the station for users to plug their chargers into. Electric bike chargers range from around 30 W to as high as 250 W, so with four electric bikes charging at once, a worst-case load of 1000 W can be expected. Thus, an inverter rated for around at least 1000 W is necessary for this system.¹¹

Taking this technical research as background, a comprehensive market analysis followed, viewable in the [Appendix](#). In searching for a suitable panel, only monocrystalline (higher efficiency than polycrystalline) monofacial (photovoltaic cells on only one side, as opposed to bifacial) panels were considered. Of the reputable solar panel manufacturers and models surveyed, Canadian Solar’s TOPHiKu6 was the most cost effective and among the most efficient. Rated for 455 W, two panels is enough for a 910 W system, which is within reasonable margin of 1 kW. The only driving question that remained regarding the sizing of components was whether to use a 12 V or 24 V battery: the battery voltage also dictates the specifications of charge controller (which must be able to supply the chosen battery voltage out) and the inverter (which must be able to take the chosen battery voltage). As it turns out, using a 24 V battery is more cost-effective than using a 12 V: the 24 V batteries themselves are less expensive, and while 24 V inverters cost slightly more than 12 V inverters, the charge controller can be downsized (rated for less amperage) and is therefore less expensive. Thus, from the options considered, an optimal combination of components emerged. Despite historically being more expensive, “newer” technologies are now somewhat in line with, and becoming cheaper than, legacy technologies. The list below reflects this: 24 V systems are gaining popularity due to their efficiency, and now also happen to be more cost effective.

Component	Mnfr	Model	Qty
Solar Panels	Canadian Solar	TOPHiKu6	2
Charge Controller	LiTime	60A MPPT 12V/24V/36V/48V	1
Battery	LiTime	24V 100Ah	2
Inverter	Mean Well USA	NTS-1200-124UN	1

Table 2: Solar system selected components

Please note that equivalent options are available from various manufacturers, and while these models are what were selected as of November 2024, prices, availability, and technology is subject to rapid change. A full outline of the costs, adding up the selected components for bike rack, shelter, and power solution can be found in the [cost estimate](#) section.

Key Personnel, Consultants, and Supporting Staff

In addition to speaking with Dartmouth staff members, such as Vicki May and Tad Truex, we spent the term consulting and engaging with numerous figures in the local community and government. These people were invaluable in assessing the scope and feasibility of designing and building electric bike charging stations in Lebanon, as well as in determining local demand for these stations.

Tad Montgomery: As the City of Lebanon Energy and Facilities manager, Tad was our main contact within the city government. He connected us with a number of resources instrumental to our success.

Sal Cania (Omer and Bob's): Sal Cania, the owner of Omer and Bob's bike shop in downtown Lebanon, assisted us by providing sales data on e-bikes to demonstrate demand and justify the installation of EBCS in Lebanon. His experience with e-bikes helped inform our technical design choices - he advised us to create a design in which customers had to bring their own e-bike chargers to plug into the station, as the sheer volume of different charger connectors made any design infeasible.

Anna Guenther (Vital Communities): We consulted with Anna Guenther of Vital Communities, a local nonprofit that works to build a thriving Upper Valley by focusing on the biggest issues facing our region including housing, transportation, climate disruption, and access to nourishing food and a resilient local economy. Vital Communities runs an e-bike lending program, and advised us on their experiences working with individuals in the local community. They also helped distribute our survey.

Bob Bender (Solaflect): Through his work at Solaflect, Bob Bender has extensive experience implementing solar systems. He helped us find resources to design and size a solar system for the charger stations.

Tony Puntin (UNH, DOT): In the process of designing the survey to determine demand for e-bike charging in Lebanon, we needed to fill large gaps in civil engineering knowledge. Emily connected us with Tony, who was able to advise us on not only important ideas to consider when working with transportation and civil engineering projects, but also on how to deal with municipalities and approach our project from his perspective as an engineering professor at UNH.

Carolyn Misch (Northampton): Carolyn Misch, Director of Planning & Sustainability in Northampton, MA spoke with us about the ValleyBike bike share program in Northampton. She

helped us gain a better understanding of how the City implemented ValleyBike and obtained funding to support the project.

Catheryn Hembree (Ped + Bike Committee): Catheryn Hembree of the Lebanon Pedestrian and Bicycle Committee was able to advise us on how e-bikes are used in the Upper Valley, emphasizing their popularity among high schoolers to get to school and older residents for leisure, as well as changes in their seasonal usage. This gave us a better understanding of our target customer and helped us design survey questions. Additionally, Catheryn helped to distribute our finalized survey.

Project Management

Our team implemented the following management plan to coordinate our efforts in ENGS 89:

Team Member	Title(s)
Avery Moorhead	Project Manager, Electrical Lead
Nathan McAllister	Mechanical Lead, Policy Lead
Grace Connolly	Treasurer
Gannon Forsberg	Sponsor Liaison

Table 3: Project Roles

As the term progressed, we remained flexible and supported each other in our assigned tasks. Grace helped Avery significantly with electrical research, Gannon and Nathan assisted Grace in economic analysis, and everyone began working together to communicate with our sponsor and other supporters, including others in the conversation with open email chains. As the team pivoted towards a secondary proposal for a fire prevention device that required significant electrical viability research, Nathan took ownership over the specification work required for Lebanon with support from the rest of the team.

Cost Estimate

Cost, based on analysis in the [Innovation, Approach, and Methodology](#) section, is estimated here. The two options for charging racks are reflected below as two total cost estimates (Tables 4 and 5). The solar system and shelter remain the same for the two. The estimations also include the maximum estimated cost of design drawings from LaValley Building Supply. Please note that the estimations below are for the materials alone, and do not include the costs of labor and assembly, as the work will be carried out by city contractors.

CONFIGURATION 1					
Component	Mnfr	Model	Price	Qty	Total Price
Bike Rack	Saris	Power Post (Locking)	\$350.00	2	\$700.00
Shelter	Dero	Vizor	\$13,552.00	1	\$13,552.00
Solar Panels	Canadian Solar	TOPHiKu6	\$179.99	2	\$359.98
Charge Controller	LiTime	60A MPPT 12V/24V/36V/48V	\$149.99	1	\$149.99
Battery	LiTime	24V 100Ah	\$399.99	2	\$799.98
Inverter	Mean Well USA	NTS-1200-124UN	\$259.45	1	\$259.45
Design Plans	LaValley Building Supply	N/A	\$5,000.00	1	\$5,000.00
Total Material Cost					\$20,821.40

Table 4: Configuration 1 Cost Estimate

CONFIGURATION 2					
Component	Mnfr	Model	Price	Qty	Total Price
Bike Rack	Saris	eBike Charging Station	\$1,500.00	4	\$6,000.00
Shelter	Dero	Vizor	\$13,552.00	1	\$13,552.00
Solar Panels	Canadian Solar	TOPHiKu6	\$179.99	2	\$359.98
Charge Controller	LiTime	60A MPPT 12V/24V/36V/48V	\$149.99	1	\$149.99
Battery	LiTime	24V 100Ah	\$399.99	2	\$799.98
Inverter	Mean Well USA	NTS-1200-124UN	\$259.45	1	\$259.45
Design Plans	LaValley Building Supply	N/A	\$5,000.00	1	\$5,000.00
Total Material Cost					\$26,121.40

Table 5: Configuration 2 Cost Estimate

Desirability Plan and Consideration of the Broader Context

Stakeholder Engagement Process

Our stakeholder engagement has taken place nearly entirely within the context of our ENGS 89 Project. In addition to regular meetings with Tad Montgomery, the City of Lebanon Energy and Facilities Manager,

we have met with numerous other stakeholders in potential public e-bike charging stations in Lebanon, NH. These parties include the Lebanon Energy Advisory Committee (LEAC), the Lebanon Ped Bike Committee, and Vital Communities.

As part of our work for the City of Lebanon, a survey was designed and administered to determine demand for e-bike charging stations in the area in collaboration with stakeholders such as Vital Communities, the City of Lebanon, and Omer and Bob's Bike Shop. In addition, Vital Communities was instrumental in the distribution of our survey across several listservs. A detailed exploration of the results of the survey can be found in the Appendix. These groups each represent the interest of numerous members of the Upper Valley community, particularly those with an interest in bikes and e-bikes. Thus, outside of the survey most of our contact has been with groups that represent stakeholders. Meeting with these groups has influenced our design solution in numerous ways. For example, prior to meeting with Omer and Bob's a charger with multiple cords for different e-bikes was being considered before discovering during the meeting that this would not be possible due to the high number of different charging cords. In addition, solar was recommended due to concerns from both City Council members and residents about the electricity costs of the project. With solar, there would be only a one-time cost, and it would mesh well with the City's aim to promote environmentally friendly practices through this project.

These interactions and engagement with various stakeholders and interest groups had a substantial impact on this project, and aided greatly in allowing our team to make a recommendation to best suit the needs of the City of Lebanon and its residents.

Societal Context Considerations

This project exists within the context of numerous political, environmental, and socio-cultural systems, which each have a large impact on our project beyond the scope of just the engineering and design portions of the project. Each of these three contexts had to be considered as we worked on the final recommendation.

Electric vehicles in general often become topics of political discourse, with electric bikes being seen as representing a more green, eco-friendly alternative to cars and other gas-powered transportation. This can, as is the case with many other new technologies, artificially turn e-bikes into a politicized topic instead of allowing them to be recognized as a new tool to allow for lower-impact transportation. In addition, governments have the opportunity, as in this project, to shape opinions about e-bikes via tools such as subsidies and public charging stations. The actions of governments in this area can thus impact both the environmental and socio-cultural systems around e-bikes.

On a similar note, e-bikes are a large part of the environmental system. E-bikes have the potential to greatly benefit the environment through both far lower emissions produced in their use and manufacturing compared to conventional motor vehicles, and because they reduce the need for car-centric infrastructure. Both conventional and electric vehicles produce a staggering amount of emissions in just their manufacturing, while e-bikes produce far less due to their far smaller size.¹² In addition, e-bikes do not emit toxic tire particles in the same manner as cars, which can enter and poison local bodies of water.

Finally, the relatively small size of e-bikes also means that they are far more efficient in terms of energy consumption per mile than all cars or similar vehicles.

Car-centric infrastructure has a negative impact on both the natural environment and on the people living nearby. It leads to massive increases in air pollution and emissions, and motor vehicles are responsible for tens of thousands of deaths in the United States alone every year. In addition, car-centric infrastructure makes it far more difficult for residents to exercise and socialize, and presents a massive financial burden, in that cars are very expensive to buy and maintain, and rapidly depreciate. E-bikes allow for users to commute, complete errands, and exercise, all with a far smaller footprint and cost compared to cars. Their potential to reduce many regions in the United States's reliance on car-centric infrastructure alone can prove to be a great boon for the environment.¹³

However, there are environmental drawbacks to e-bikes. For one, in areas where electricity is provided by fossil fuels, all of the electricity used by the battery will contribute to emissions. In addition, lithium-ion batteries must be safely disposed of at industrial waste centers, as their "ignitability and reactivity characteristics" cause them to be classified as hazardous waste by the Environmental Protection Agency (EPA).¹⁴ E-bike fires, additionally can be a great hazard to the environment, as lithium-ion battery fires are notoriously dangerous and difficult to extinguish.

Finally, e-bikes are part of a socio-cultural system. There is a wide gap between the cost of safe, UL-certified e-bikes and unregulated e-bikes. Often, bike shops will not even service the unregulated bikes due to their safety concerns, meaning that these bikes can easily end up in the landfill. Even though e-bikes can act as an equalizer in providing transportation for those who cannot afford cars, a socio-economic gap persists. As discussed in greater detail in part 3, as a result of socio-cultural systems e-bikes remain out of reach for many who would benefit most from their use. In addition, as we have found working on this project, charging stations can receive pushback if placed in certain pedestrian areas where people do not want visible new infrastructure projects.

While e-bikes may present issues in some of these fields, they ultimately present an overwhelming positive in many ways, as a relatively inexpensive way for governments to support eco-friendly transportation, a means of mitigating human impact on the environment, and an equalizer of opportunity when it comes to transportation.

Design for Inclusion

According to a study by the United States Department of Transportation, 8.5% of Americans aged five and older have a travel-limiting disability, making foot or bike travel substantially more difficult.¹⁵ E-bikes have the potential to counteract these limitations for people with disabilities and those of advanced age, as pedal assist will allow them to travel farther and with less exertion. However, e-bike usage among these groups has remained low, which may be due to persistent social stigmas about the use of both bikes and electric bikes as mobility aids. These stigmas have cropped up even in preliminary survey results from the City of Lebanon, with some respondents dismissing e-bikes as transportation for those who are "out of shape" compared to regular bike riders. In addition, both the high cost of UL-certified e-bikes as well as a lack of safe infrastructure in many regions act as barriers for these

groups who could stand to benefit the most. Similarly, those from low-income groups for whom e-bikes could replace more expensive vehicles are frequently met with similar barriers, and are forced to face the sometimes deadly consequences of dangerous lithium-ion batteries and poor bike construction.

Electric bikes, and public charging for them, stand to improve activity and mobility for numerous marginalized groups, but adoption has been severely curtailed by social and financial barriers. It is our group's aim to help mitigate these barriers by designing public e-bike charging stations which show the public good from e-bike subsidization and remove some social barriers to riding.

Financial Viability Plan

One of the main funding options currently being considered by the City of Lebanon for this project is Tax Increment Financing (TIF). TIF protocol constitutes a small incremental increase in taxes for those who reside within the designated TIF district benefiting from the new infrastructure being built. Below is a map showing the borders of the Downtown Lebanon TIF District, which would be used to fund the project.



Figure 4: Map of Downtown Lebanon TIF District

However, there are also grants which the City of Lebanon could take advantage of for this project. For example, the New Hampshire Department of Environmental Services (NHDES) offers Climate Pollution Reduction Grants, which have been pre-funded by the EPA. These grants target community-based solutions which will decrease emissions by 2030, which makes the fund an good fit for this project.¹⁶ An available private grant is The Adelard A. and Valeda Lea Roy Foundation, which targets projects that will

have a positive impact on the environment in Vermont, Maine and New Hampshire.¹⁷ Another private grant option is through the Hypertherm Associates Hope Foundation; they specifically provide grants for projects in the Upper Valley related to the “Outdoors & Climate”.¹⁸ An additional option is a grant through the Jack and Dorothy Byrne Foundation. Applications can be submitted to The Jack and Dorothy Byrne Foundation, Box 599, Etna, NH, 03750. The foundation asks that applicants send a letter outlining their particular need to Dorothy Byrne.¹⁹

Appendix

E-Bike Charging Survey Results

As a part of the Lebanon E-bike charging station project, a survey was designed and distributed to gauge demand for the installation of e-bike charging stations in Lebanon. The survey was specifically designed to be answered by Upper Valley residents regardless of whether they owned an e-bike. Most survey questions depended on whether the respondent regularly used an e-bike or not. If they stated that they owned an e-bike then they were asked questions about their experiences using an e-bike and whether they would be interested in a public e-bike charger. If they stated that they did not own an e-bike, respondents were asked whether they were planning to purchase one in the future, and why they didn't currently own one.

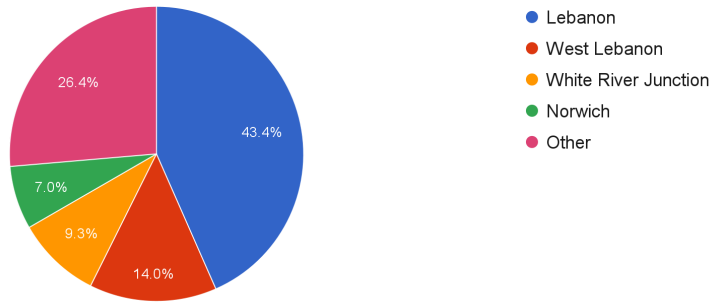
The survey was live from November 12th to November 30th and there were 129 responses. The survey was distributed at a number of different locations. These were:

- City of Lebanon public listserv
- Upper Valley Climate listserv
- Town of Hartford listserv
- UV Digest listserv
- Directly to the Vital Communities E-bike Lending Program Recipients
- Directly to the Vital Communities E-bike Subsidy Program Recipients
- QR codes at Colburn Park and at Omer and Bob's

The raw survey data is linked [here](#). Below, key survey results will be discussed.

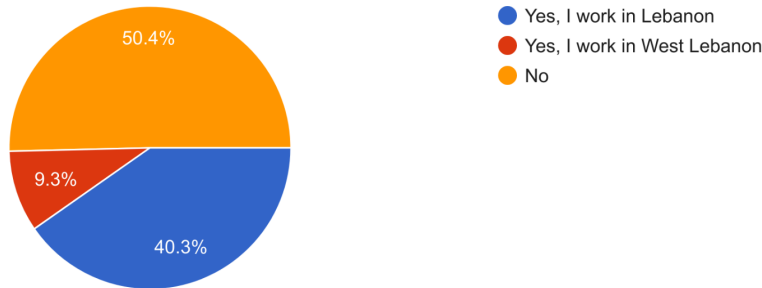
42.6% percent of respondents (n = 55) stated that they owned or regularly used an e-bike while 57.4% of respondents (n = 74) stated they did not use one.

What city/town do you live in?



Do you work in Lebanon or West Lebanon?

129 responses



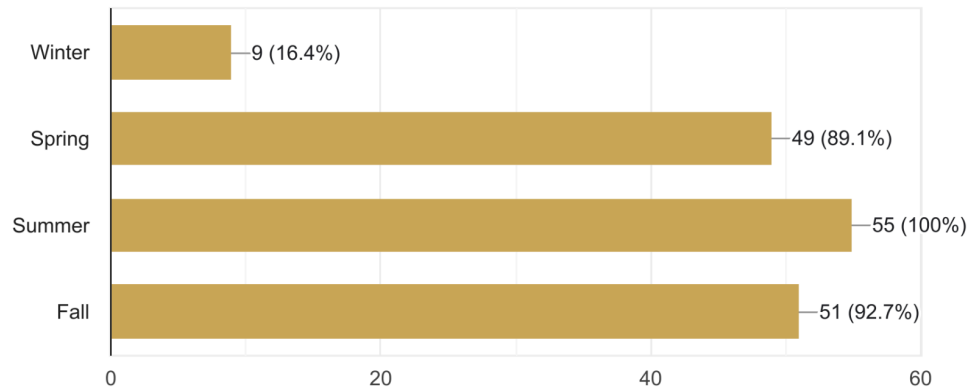
43.4% of respondents live in Lebanon, 14.0% live in West Lebanon, and the remaining respondents live in other Upper Valley communities. 40.3% of respondents work in Lebanon and 9.3% work in West Lebanon.

Questions For Current E-bike Users

E-bike owners were asked questions related to their experiences using e-bikes, their experiences charging their bikes and whether they would be interested in an e-bike charging station in Lebanon or West Lebanon.

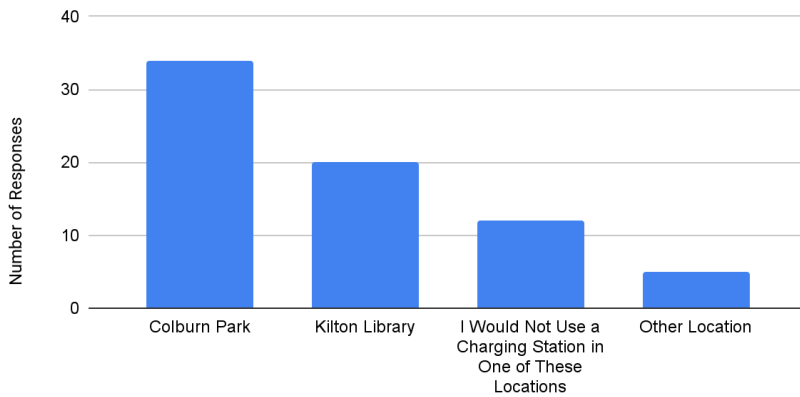
During what seasons do you ride your electric bike?

55 responses



When asked about seasonal usage, users reported that they mostly ride during the spring, summer, and fall, with only 16.4% reporting riding through the winter months.

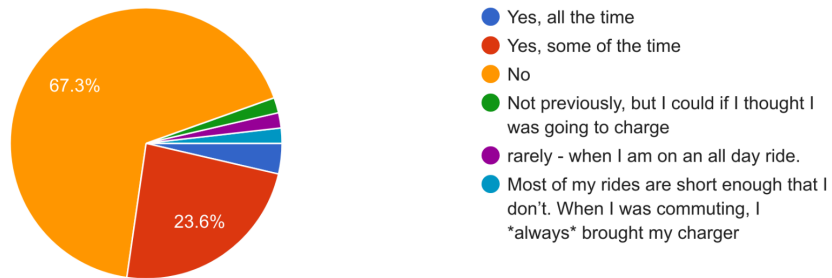
Would you use a charging station at one of the following locations?



When asked about location, 61.8% of respondents said that they would use a charging station in Colburn Park, and 36.4% said they would use one in Kilton Library. 21.8% of respondents said that they would not use a charging station in one of these locations and 9.1% suggested a different location.

Do you bring your e-bike charger with you on rides?

55 responses



Respondents were asked if they typically bring their charger with them on rides. Among them, 67.3% reported that they never bring their charger, 23.6% said they bring it occasionally, and 3.6% stated they always bring their charger on rides.

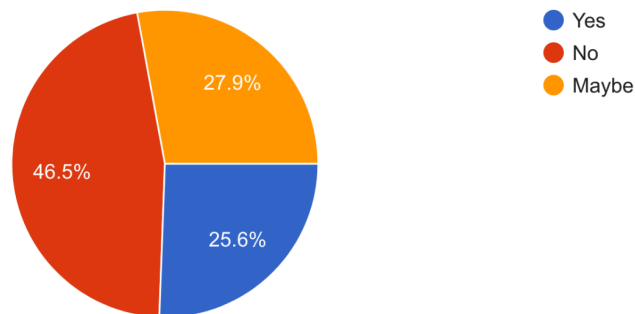
In summary, a charging station in Colburn Park is the most desired location for respondents; approximately 61.8% of respondents said that they would use an e-bike charging station in Colburn Park, indicating that there is likely sufficient demand for the station. However, given the low sample size, it is difficult to determine a precise number of potential charging station users. Additionally, while 61.8% of respondents expressed interest in a charging station at Colburn Park, the majority do not typically bring their charger on rides. Consequently, the actual number of respondents who would utilize a charging station requiring them to bring their own charger may be lower than indicated in this survey.

Payment System

All respondents were asked for their opinions on paying for the use of an e-bike charging station. Respondents who did not use an e-bike were asked to answer as a prospective owner or user.

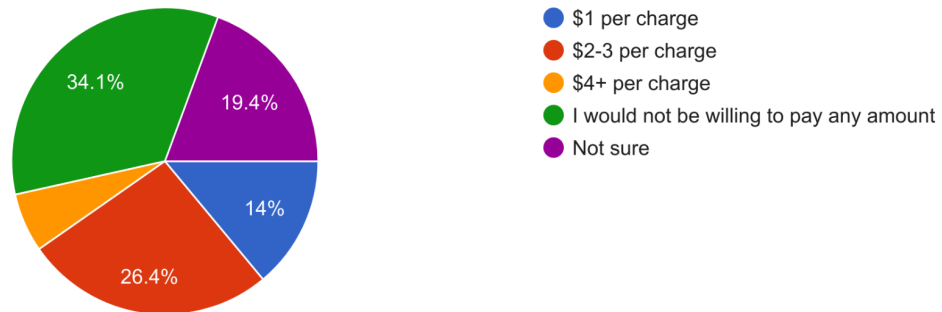
Would you pay for usage of a public e-bike charging station in downtown Lebanon?

129 responses



How much would you be willing to pay for e-bike charging per charge

129 responses



Respondents were asked whether they would be willing to pay for an e-bike charging station; 25.6% said yes, 27.9% said maybe and 46.5% said they would not. When asked about how much they would be willing to pay 34.1% said they would not be willing to pay any amount, 19.4% said they were not sure, and the rest of respondents were willing to pay some amount.

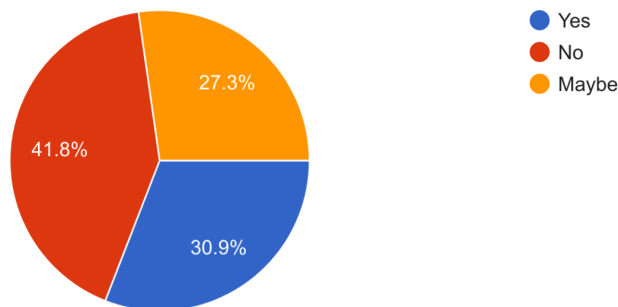
Therefore, a significant number of respondents are not willing to pay any amount; as a result, requiring payment would likely substantially decrease the use of the charging station.

Tunnel Storage

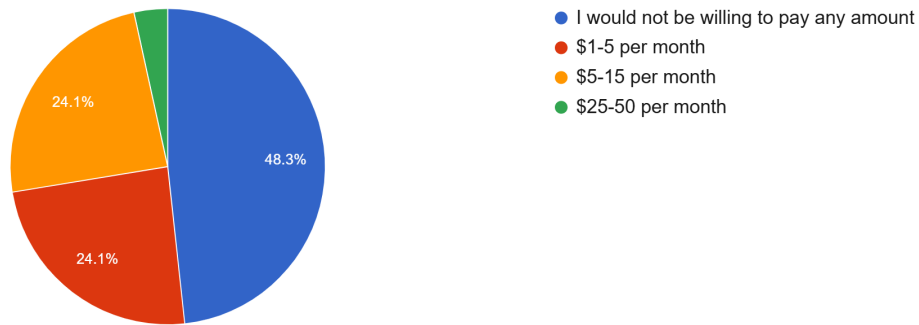
Respondents who regularly use e-bikes were asked whether they were interested in public secured bike storage near the Lebanon Mall and how much they would be willing to pay.

Would you be interested in public, secured bike storage in a location near the Lebanon mall?

55 responses



If so, how much would you be willing to pay?



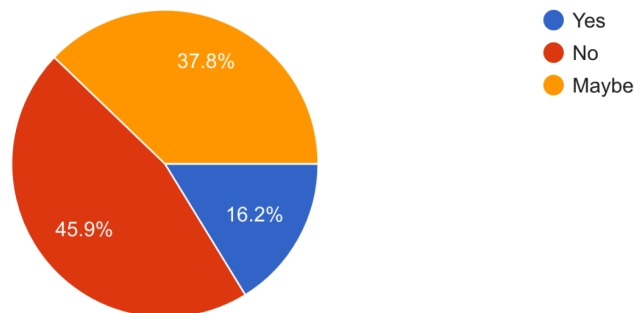
When asked about their interest in public storage, 30.9% of respondents expressed interest, 27.3% were undecided, while 41.8% stated they were not interested. When asked about payment, 48.3% were not willing to pay any amount, 24.1% would pay \$1-5 per month and 24.1% would pay \$5-15 per month. Therefore, there is some demand for the public storage, but only about half of those interested in the storage would be willing to pay.

Non E-bike Users

Respondents who did not own an e-bike were asked several questions about whether they were considering purchasing one and what factors would need to change for them to make that decision.

Do you see yourself purchasing and using an e-bike in the near future?

74 responses



When asked whether they were considering purchasing an e-bike in the future, 16.2% of respondents said they were planning to do so, 37.8% said they would maybe do so, and 45.9% stated they had no plans to purchase an e-bike. Given that there are a significant number of users who are planning to purchase, or considering to purchase an e-bike, there will likely be an increase of e-bike usage in the Upper Valley as well as potentially increased demand for the e-bike charging stations.

Respondents were also asked about the factors that would influence their decision to purchase an e-bike. Improved safety was mentioned by 44.4% of respondents, 34.7% cited a lower price, and 22.2% highlighted the need for more convenient charging and storage options. A number of respondents also stated that they would only purchase one when they were physically unable to use a regular bike.

Conclusions

The survey results indicate that the e-bike user respondents most prefer a charging station in Colburn Park. While about 60% of e-bike users stated that they were interested in the Colburn Park charging station, only about 33% of respondents brought their chargers with them on rides. Therefore while there is likely demand for the charging station, there may be less demand than is indicated on the survey as the charging station would require that users bring their chargers with them. That being said, many respondents who did not currently own e-bikes stated that they were considering purchasing one in the future and many stated that they thought that e-bike usage was growing in the Upper Valley; therefore, there is likely to be increased demand for the charging stations in the coming years. The majority of respondents are not interested in paying for the use of the charging station and as a result, requiring payment is likely to significantly decrease the use of the station. Lastly, there is some interest in bike storage in the tunnel amongst the e-bike user respondents; more data should be collected amongst all residents to see if residents with regular bikes would also be interested in the storage.

Component Specifications

BIKE RACK				
Mnfr	Model	Style	Price	Notes
Dero	Bikeep Charging	5-station rack	\$17,970.00	Additional monthly service fee of \$79.00; most expensive option
Dero	E-swerve	Double-sided post	\$425.00	Not weather resistant
Saris	Power Post (Locking)	Double-sided post	\$350.00	Weather resistant
Saris	Power Post	Double-sided post	\$250.00	No locking ability
Saris	eBike Charging Station	Single Rack/Locker	\$1,500.00	Users must carry a padlock to use charger locker (not required)

SOLAR PANELS							
Mnfr	Model	Voltage (V)	Power (W)	Efficiency	Price	Notes	Link
QCells	Q.PEAK DUO BLK G10+	34.58	365	20.30%	\$140.00	They manufacture in the state of Georgia and Malaysia	Link

Sunpower	MAXEON 3 430 WC	70.4	430	22.70%	\$390.99	Highly rated, high-efficiency panels. Cell fabrication in Malaysia, operates only certified zero-to-waste-landfill solar panel factory in Mexicali	Link
Jinko	54HL4R-B	32.73	425	21.76%	\$194.99	Jinko owns more than 10 globalized manufacturing bases in China, the United States, Southeast Asia, and the Middle East	Link
Panasonic	EVPV360K	36.7	360	20.60%	\$410.00	Panasonic does not manufacture its own panels, and is generally more expensive	Link
Canadian Solar	TOPHiKu6	33.2	455	22.30%	\$179.99	Manufactured in Canada, China, Indonesia, Vietnam, and Brazil. Building a \$250 million manufacturing plant in Mesquite, Texas	Link

CHARGE CONTROLLER

Mnfr	Model	Type	Voltage	Current Limit (A)	Price	Notes	Link
Renogy	RNG-CTRL-RVR40-US	MPPT	12, 24	40	\$169.99		Link
LiTime	60A MPPT 12V/24V/36V/48V	MPPT	12, 24, 36, 48	60	\$149.99		Link
Renogy	RCC60RVRE-US	MPPT	12, 24, 36, 48	60	\$229.99		Link
Inverter.com	ATO-MPPT-100	MPPT	12, 24, 36, 48	100	\$368.97	Would need to use this one with a 12 V battery	Link

BATTERIES

Mnfr	Model	Composition	Voltage (V)	Capacity (Ah)	Price	Notes	Link
Renogy	RBT12200LFP-US	Lithium Iron Phosphate	12	200	\$699.00	Weatherproof terminal caps	Link
LiTime	12V 400Ah LiFePO4 8D Deep Cycle	LiFePO4 Prismatic	12	400	\$1,099.99	IP65 Waterproof & Dustproof	Link

		c					
LiTime	24V 200Ah Group 8D	LiFePO4	24	200	\$1,202.99	IP65 Waterproof & Dustproof	Link
LiTime	24V 100Ah	LiFePO4	24	100	\$399.99		Link
INVERTER							
Mnfr	Model	Vin (V)	Vout (V)	Rated Power (W)	Price	Notes	Link
AIMS Power	PWRIX1200 12SUL	12	120	1200	\$344.00		Link
Renogy	RNG-INVT-1000-12V-P2-US	12	120	1000	\$169.99	More budget option	Link
Mean Well USA	NTS-1200-12 4UN	24	110	1200	\$259.45		Link
Renogy	RIV2420P2-1 2S-US	24	120	2000	\$309.99	On presale right now	Link

PVWatts Data Visualization Script (MATLAB)

```

% 20-720 // Nathan McAllister
% pvwatts data vis - can be used for any monthly/hourly dataset from PVWatts

% reading in data
addpath("engs 89_90/")
monthly_data = readmatrix("pvwatts_monthly.csv", "Range", "34:45");
hourly_data = readmatrix("pvwatts_hourly.csv", "Range", "33:8792");

% monthly plot
months = monthly_data(:,1)';
kWh_monthly = monthly_data(:,4)';
figure(1)
bar(months, kWh_monthly)
title("Simulated Monthly Energy Production (1kW Array)")
ylabel("kWh")
set(gca, 'XTickLabel', {'jan', 'feb', 'mar', 'apr', 'may', 'jun', 'jul', 'aug', 'sep', 'oct', 'nov', 'dec'})

% hourly plot
figure(2)
bar(hourly_data(:, 11)/1000)
title("Simulated Hourly Energy Production (1kW Array)")
xlabel("Hour")
ylabel("kWh")

daily_data = zeros(1, 365);

```

```

% hourly --> daily
for n = 1:365
    for m = 1:24
        daily_data(n) = daily_data(n) + hourly_data((n-1)*24 + m, 11);
    end
end

daily_data;

% daily plot
figure(2)
bar(daily_data/1000)
title("Simulated Daily Energy Production (1kW Array)")
xlabel("Day")
ylabel("kWh")

% summary statistics

% full year
avg_day = mean(daily_data); % 3.48 kW
sd_day = std(daily_data); % 1.73 kW

boxplot(daily_data/1000, "Labels", "All Days in a Year")
title("Simulated Daily Energy Production (1kW Array)")
ylabel("kWh Generated Daily")

% may-october
summer_daily_data = daily_data(121:274);
avg_summer_day = mean(summer_daily_data);
sd_summer_day = std(summer_daily_data);

boxplot(summer_daily_data/1000, "Labels", "All Days in a Year")
title("Simulated Daily Summer Energy Production (1kW Array)")
ylabel("kWh Generated Daily")

% distilling into one neat visualization

% separating days by month
jan = daily_data(1:31)';
feb = daily_data(32:59)';
mar = daily_data(60:90)';
apr = daily_data(91:120)';
may = daily_data(121:151)';
jun = daily_data(152:181)';
jul = daily_data(182:212)';
aug = daily_data(213:243)';
sep = daily_data(244:273)';
oct = daily_data(274:304)';
nov = daily_data(305:334)';
dec = daily_data(335:365)';

% months have different lengths... matlab does not like that. hence this:
group = [    ones(size(jan));
          2 * ones(size(feb));
          3 * ones(size(mar));
          4 * ones(size(apr));
          5 * ones(size(may));
          6 * ones(size(jun));
          7 * ones(size(jul));
          8 * ones(size(aug))];

```

```
    9 * ones(size(sep))
    10 * ones(size(oct))
    11 * ones(size(nov))
    12 * ones(size(dec))];

boxplot([jan; feb; mar; apr; may; jun; jul; aug; sep; oct; nov;
dec]/1000,group)
set(gca,'XTickLabel',{'jan','feb','mar','apr','may','jun','jul','aug','sep','o
ct','nov','dec'})
title("Simulated Daily kWh Generated (1 kW system), Grouped by Month")
ylabel("kWh")
ylim([0 7])
```

Endnotes and Sources

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