Ithaca Carbon Neutrality
Final Report
Spring 2022

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1. Introduction

The 'Ithaca Carbon Neutrality 2030' (ICN) project is a joint project of the Cornell Systems Engineering Program's MEng degree program and two of the undergraduate-based Cornell University Sustainable design (CUSD) teams: ICN Policy and ICN Modeling. The ICN project began in Fall 2019 shortly after the City of Ithaca passed its Green New Deal (IGND) and set goals to be carbon neutral by 2030. The ICN project teams, under the direction of Professor Al George, are student-led and aim to support the City on its path to decarbonization. As the team names suggest, ICN Policy supports the City of Ithaca with developing policy recommendations and strategies while ICN Modeling supports the City with modeling information. Masters of Systems Engineering (Systems MEng) students are also involved with the team, and their process is summarized in the following section.

Initially, the ICN team focused on building decarbonization/electrification and mainly worked to support the Ithaca Energy Code Supplement for the construction of new buildings in the City. Then in March 2021, the City of Ithaca hired a Director of Sustainability, Dr. Luis Aguirre-Torres, to advance the goals of the IGND. Under the guidance of Aguirre-Torres and Rebecca Evans (Sustainability Planner for the City of Ithaca), the ICN team has broadened its spectrum to work on transportation and renewables in addition to building electrification in the Fall of 2021.

The ICN team largely works similarly to a consultant firm for the City of Ithaca and other local organizations. The projects we work on are determined by what the City and additional stakeholders need assistance on. This report will show the progress of the ICN project teams for the Spring 2022 semester, where members have been split into four research subteams: building electrification, renewable energy, transportation, and (currently in a pilot stage) waste management.

2. Systems Engineering Process and Results

Since the inception of the Ithaca Carbon Neutrality 2030 project, the team has utilized a systems engineering approach in developing report deliverables and organizing project resources. Systems Engineering is a field focused on synthesizing stakeholder needs, environmental impacts, and other diverse inputs into requirements for a system and then to possible systems solutions and analyses of these for effectiveness, cost, etc. In the case of this project, our system is the whole City of Ithaca, as well as some surrounding areas. This report presents our findings as deliverables to the City of Ithaca and other stakeholders. Utilizing systems engineering tools, the team was able to narrow down their scope while considering the multitude of stakeholders contained within Ithaca and then based on their goals and requirements, analyze many different possible mitigations for greenhouse gas emissions including considerations of effectiveness, costs, financing, and acceptability to the City's residents and other stakeholders.

During the Spring 2022 semester, the team continued to focus in three primary areas: electrification, renewables and transportation. After the Fall 2021 semester, the team's stakeholders expressed interest in exploring sustainability in waste management and few other possible mitigations and practicality measures. In order to tackle these new areas, a small team of the systems engineering masters students were deployed. One group's team's primary focus is to research potential avenues for estimation and reduction of GHG emissions associated with waste management in Tompkins County. This area within the project is in its infancy, but the systems engineering team intends to continue working on it in future semesters.

The project team has seen some significant growth over the 2021-2022 academic year. The team currently consists of 40 graduate and undergraduate students, with a leadership team of 12 students. This growth is a testament to the momentum the team is gaining which will help ensure strong future contributions to meeting Ithaca's Carbon Neutrality objectives. However, this growth has brought organizational challenges. This semester, the Systems Engineering team put an emphasis on revamping meeting structures, team structures and the project's Work Breakdown Structure (WBS). These improvements have helped the team communicate effectively and ensure results are delivered, despite the size of the team.

Another major focus area of the Systems Engineering team was in developing an Ithaca Readiness Level (IRL) model that will assist the City of Ithaca in determining which programs and technologies are the most feasible to implement. This is the beginning of the project team's plan to build a Roadmap for Deployment for the City to use as a cheat sheet for pursuing various technologies. In the future, this roadmap will include technical feasibility, market feasibility, carbon impact, cost and timeline.

If you would like to learn more about the team's systems engineering process, please reach out to Professor Al George al.george@cornell.edu for a copy of the separate, more detailed Systems Engineering sub-team report.

3. Electrification

3.1 Residential Retrofitting Model

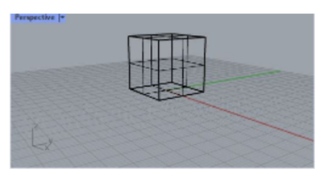
3.1.1 Website Structure

Since the ultimate goal of the residential retrofit modeling project is to provide information to homeowners in Ithaca, we need a method of communication that properly outlines our recommendations, expected energy savings in terms of carbon footprint and reduced costs, and evidence for our beliefs. We want as little friction as possible in the process of pursuing the information on the part of Ithaca residents, and we want them to be able to quickly understand, using graphics and text, how to get a recommendation and its implications. We want users to be interested in learning more about the retrofit we recommend, so that they can make a personalized and informed investment.

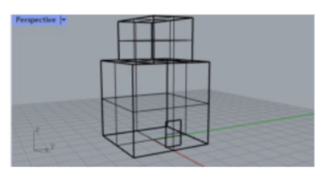
To get all of this across, we needed to design an ergonomic website, and we started this during this semester. The site's current features include a landing page, an about us page as well as a page to utilize the retrofit model. Currently the tutorialization and TensorFlow library are not on the retrofit model page, but those will be promptly added once the model's implementation is complete. This site's construction will directly contribute to ICN 2030's overall goal of reducing carbon emissions, done in a way that lets households reduce their carbon footprint on their own terms, and become more educated about energy and their home in the process. Our planned implementation will follow a flowchart made by us which can be accessed here (https://tinyurl.com/2p8c3nza). The development of the website will continue into next semester, during which we will release a rudimentary but still informative write-up of general recommendations and trends we have seen from work in the past.

3.1.2 Model Generation Architecture

The previous method of generating data for the machine learning model to learn from did not bear fruit as it did not produce useful boundary representations for the Rhino models we created. As a result, we pivoted to utilizing Rhinocommon instead of Rhinoscript because the codebase has better documentation and is easier to use. We made a program to build different rhino models of houses with varying floors, windows, and doors. Going forward, the data generated by the program will be fed into an application that will turn the boundary representations of the houses into data that the machine learning model can train on. This is to say, we hope that our five defined geometry variables are enough that with a computer's efficient analysis of patterns, it will be able to detect correlations between certain features and energy usage so as to give personalized advice to Ithacan's with their own houses. The future of this project depends on being able to run through a lot of data, and due to the importance of this component to the project we are hoping to finish next semester, as we are about half-way done.



Above: A Rhino model with just one floor
Below: A Rhino model with multiple floors and a window.



3.2 Mixed Use Buildings

3.2.1 Informational Interviews

This semester, ICN Policy spoke to two mixed-use building owners through brief, informational interviews to gain their insight into the City of Ithaca's electrification programs. While we were unable to conduct more interviews, the two interviews we conducted still provided a clearer understanding of what concerns property owners held about retrofitting and the City of Ithaca's efforts.

We first spoke to an employee from HH Ithaca, a property management company that has four properties across Ithaca, including Cayuga Place, a newer apartment complex built with a green construction loan. The employee expressed little familiarity with the City of Ithaca's electrification program: "This is the first time that I've heard that the City wanted all buildings to be completely electrified by 2030." But they had also stated that their company has had some initial conversations about retrofits but had no concrete plans for the future. They expressed concerns surrounding the affordability of retrofits and expressed doubt about the availability of funding from the City to help support them if they were to retrofit their building stock. The biggest takeaway from this conversation was that the employee expressed that they believed the City could do a better job at developing relationships with local landlords instead of "just putting policies in place".

We then spoke to someone from Lambrou Real Estate, a student housing company that owns several apartment buildings in the Collegetown neighborhood. This person expressed more interest and excitement in the City's efforts to electrify all of its building stock and had mentioned that they have done minor energy and water efficiency upgrades in the past. They also expressed concerns about their lack of knowledge about the City's electrification program and affordability. Another concern worth noting is the economic impact of taking student housing off the market for long periods of time. The high renter population saturated by Cornell and Ithaca College students would be impacted if multiple apartment buildings were taken offline due to retrofit upgrades. Ultimately, this person seemed willing to work with the City to help achieve its goals of decarbonization, but wanted more information on how the program would make "financial sense."

In future semesters, ICN Policy hopes to improve outreach efforts by creating a larger list of owners to speak to. It may be that the larger property management companies are less likely to cooperate, so finding small landlords to talk to may be a more effective approach to soliciting informational interviews. The more interviews the team conducts, the greater understanding we will gain of how our stakeholders think about the City's efforts to achieve decarbonization.

3.2.2 Building Retrofitting Models

Building modeling was to reintroduce building energy use modeling into the project with a particular focus on mixed-use buildings. This included our educating new members on the modeling process. The basic workflow of building modeling is to obtain floor plans and energy use or meter data from building owners. Modelers on the team create models based on the received floor plans in Rhinoceros 3D (Rhino). In the model space of Rhino, buildings are understood as thermal zones and fenestration. The buildings modeled in Rhino are run through the Grasshopper plug-in ClimateStudio that will run an energy use simulation through the modeled building. The modeled building is then calibrated to the energy use data obtained from building owners to ensure accuracy of the model and its settings input in ClimateStudio. The last step is to run use cases of potential retrofits that improve building energy efficiency.

This semester we were able to obtain data for 4 buildings and have modeled 3 buildings. Communication was slow while we attempted to get comprehensive information on the buildings from the owners. Additionally, a big task this semester was reworking and optimizing our use case system. In previous years, we have focused on behavioral retrofits as they were more accessible solutions for building owners, but moving forward we want to look at physical solutions like infiltration reduction and renewable energy sources such as heat pumps.

Building 1 is a mixed-use building located on the Ithaca Commons pedestrian mall. The basement and first floor are retail spaces with an almost fully glazed storefront on the first floor and apartments on the second and third floors. Building 1 was modeled as four zones, one for each floor. Due to the building's location, fenestration is only located on the north side of the building where the storefront is located. The building is also directly adjacent to its neighboring buildings which work as shading masses to the building.

Building 2 is a mixed-use building located on Green Street at the Ithaca Commons. It is a new retail development that is an example of adaptive reuse. The first floor was modeled as 10 thermal zones, each of which will be used as retail space for different upcoming businesses. This means that several doors are placed on the sides of the building, while the front of the building is also lined with glass doors, which lead to thermal complications. The second floor was modeled as 12 thermal spaces. As these spaces are residential, there are 3-sided bay view windows to allow in maximum light, which add to the thermal gains and losses. These are addressed by running thermal simulations on Rhino and Grasshopper.

Building 3 is also a mixed-use building, located in Ithaca Commons. The first floor is a retail shop while the other top three floors are residential spaces. Similar to Building 1, the first floor has an almost fully glazed storefront, however, it is facing south. Fenestration is also only located towards the front side of the building because it is directly adjacent to other mixed-use buildings around Ithaca Commons. The building was initially modeled as four thermal zones to indicate each floor level, however, once detailed floor plans were collected, the thermal zones became more specific to the arrangement of the building and its programs. We used this model to run a grasshopper analysis on the thermal zones. The end goal is to ultimately use the data generated by the analysis and calibrate it to create a use-case spreadsheet. This will better give us an estimate of the best retrofit options to make energy use more efficient.

For the future, we will run use cases on the buildings modeled this semester with our new use case system. We also currently plan on modeling a building located in the collegetown area of the Cornell University campus. Following that, we will collect data on and model more of the mixed use buildings in the Ithaca area. Our work will be in collaboration with our machine learning team to help them in their model generation process for multiple and more complex building structures and programs.

3.3 Retrofit Brochures Outreach and Distribution

The brochures are focused on advice for commercial, historical and residential property owners to retrofit their buildings. The Historical and Residential brochures offer information on rectifying issues that can lead to a loss of energy efficiency such as air sealing/insulation, heating and cooling systems, lighting and hot water. The Commercial brochures also highlight financial incentives and local resources while also offering images on the same variables to help increase the efficiency of local buildings.

The outreach process began by researching suitable organizations whose values aligned with those of the project. This included multiple environmental awareness and governance-based organizations around the Ithaca and Tompkins County region. To begin, we collected as many emails and phone numbers as possible and drafted a blanket email to send to them. After a mixed-bag of responses, we saved the emails of contact-people from those organizations and sent the brochures to ascertain if they were interested in distributing our brochures through their networks. Organizations that showed willingness to this initiative included Get Your GreenBack Tompkins, Thrive Ithaca, Ithaca Farmers Market, Tompkins County Climate Protection Initiative and Tompkins County Environmental Management Council.

From these conversations with stakeholders, we received feedback for the brochures highlighting the best resources to refer people to, as well as updates on the latest laws and incentive programmes. We used this feedback to update our brochures to make sure that they had the most impact. Through these conversations, we also gained the opportunity to potentially combine efforts with other organizations, increasing stakeholder relationships and setting the foundation for more collaboration in the future. At this point, stakeholders have received the brochures via email, where some have included them in distribution materials, but they have not been distributed officially. Retrofit brochures can be found in Appendix V.

3.4 Building Energy Performance Standards

3.4.1 Case Studies: Cities and Rating Systems

The City of Ithaca should seriously consider implementing a building performance standard for existing building stock. The City's current building electrification program does not require building owners and homeowners to retrofit their properties, so the City needs a policy mechanism to encourage and influence building owners to comply with electrification efforts.

Building performance standards for existing building stock are present in several municipalities across the country. Several cities, including Boulder, CO, Burlington, VT, and Gainesville, FL, have implemented efficiency standards for rental properties in particular. The implementation of these standards aims to catalyze the process of electrification in areas with high renter populations, as well as to address concerns surrounding the split incentive problem and tenants' safety and equity. This section will focus primarily on rental energy efficiency policies due to the fact that Ithaca has a high renter population and there are significant hurdles in incentivizing property owners to retrofit their rental properties.

Rental buildings use upwards of 20% more energy than owner-owned properties, which results from the split incentive issue in which property owners are not incentivized to make retrofit upgrades because they would not reap the benefits of reduced energy costs and tenants are not incentivized to make the upgrades themselves because they may not remain in their rental units for long.[1] If there are building performance standards in place, property owners would be required to make these upgrades; and while these retrofit costs may get passed down to their tenants, an effective program would allow the cost of energy savings to cover any rent increase. Furthermore, implementing these types of standards will improve the quality of rental units. Tenants, especially from marginalized backgrounds, are more likely to live in poorer quality and less energy-efficient homes, which often usually result in higher energy bills.[2] Thus, implementing building energy efficiency standards will not only reduce energy consumption and costs but will also promote higher standards of living for all tenants. Ultimately, the City of Ithaca would benefit from adopting a building performance standard specifically targeted at rental properties. Boulder, CO, Burlington, VT, and Gainesville, FL provide excellent frameworks for the City of Ithaca to draw on if it were to establish its own standards. A description of each of these case studies can be found in Appendix VI.

Aside from the financing and incentive policies that Ithaca can implement, its actual energy code must be determined as well. We propose to base the new energy code for existing buildings to be based off of an existing building rating system. The standards chosen to focus on this semester included LEED, PassivHaus, and Green Globes. LEED and PassivHaus are known as the leading certification standards whereas Green Globes is a newer adaptable and feasible alternative for cities that is gaining more prominence across the United States. A detailed description of each of these rating systems can be found in Appendix VI.

3.4.2 Recommendations for the City of Ithaca: Cities

It would be advisable for the City of Ithaca to implement a building performance standard aimed specifically at rental properties since the City is home to a high renter population. A program targeted at rental properties will address the split incentive issue, as well as improve the quality of housing stock in the city, especially for low and moderate income renters and student renters.

Depending on how expansive the City wants these energy efficiency standards to be, the City may benefit most from looking to Burlington, VT for the specific type of standards to adopt. Weatherization standards are common sense, and would greatly benefit Ithaca's housing stock —

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[1] Jake Glassman and Sneha Ayyagari, "Rental Efficiency Standards: A Win for Equity and Climate," RMI, May 25, 2021, https://rmi.org/rental-efficiency-standards-a-win-for-equity-and-climate/.

[2] Ibid.

many of which are older buildings with inefficient heating and cooling systems, insulation, and infiltration.

Furthermore, the development of such a program should absolutely involve stakeholders from across the City. Gainesville, FL provides an illustrative example of coalition building to the benefit of renters and landlords. Active engagement in policy making will only help to increase city residents' approval and acceptance of Ithaca's Green New Deal program.

3.4.3 Recommendations for the City of Ithaca: Building Standards

When analyzing the costs, Green Globes is the most affordable certification system for homeowners. For buildings with gross floor areas 400<25,000 square feet pay certification costs of $4,750, in addition to registration fees of $1500 and assessor travel of $1500, leading to a total of $7,750. [3] LEED certification costs can range from $2,250 to $22,500 only for certification registration fees,[4] making it more costly for homeowners than Green Globes. PassivHaus certified buildings tend to be around 5-10% more expensive upfront on average in the US compared to conventional buildings.[5] This creates a greater obstacle for homeowners to certify their buildings as PassivHaus requires a fundamental shift in building construction perspective.

Green Globes has risen as a challenger to LEED, aiming to gain significant market share in the US, after becoming the predominant rating system in Canada. It has been endorsed by the federal government in the US and Canada as well as many federal organizations such as the EPA, Department of the Interior, General Services Administration and numerous states and provinces.[6] Even though LEED is seen as the more rigorous system, it is significantly more expensive which was seen through a study done at Drexel University where LEED was $1 more expensive per square foot.[7]

Overall, Green Globes provides a faster streamlined approach through their online platform. After the questionnaire is completed by homeowners, the report is automatically generated providing ratings, achievements and recommendations. Green Globes has been used on a variety of building projects including, large university buildings such as the 150,000 square-foot Papadakis Integrated Sciences Building at Drexel University [8], 9 MGM resorts in

[3] Green Building Initiative. 2021. "Existing Buildings." Green Building Initiative. https://thegbi.org/green-globes-certification/how-to-certify/existing-buildings/.
[4] Facilities Net. 2008. "Measuring The Cost To Become LEED Certified - Facilities Management Insights." FacilitiesNet. https://www.facilitiesnet.com/green/article/Measuring-The-Cost-To-Become-LEED-Certified--10057.
[5] Loviglio, Joann. 2013. "Highly efficient 'passive homes' gain ground in US." Yahoo News. https://news.yahoo.com/highly-efficient-passive-homes-gain-ground-us-174019914.html.
[6]North American Coalition on Green Building. 2009. "Department of Energy Notice of Determination Green Building Certification System." Obama White House Archives. https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/oira_meetings/1904_meeting_051309-3.pdf.
[7] Green Building Initiative. 2014. "Drexel University case study report: Green Globes cheaper, faster than LEED." Building Design + Construction. https://www.bdcnetwork.com/drexel-university-case-study-report-green-globes-cheaper-faster-leed.
[8] Drexel University. n.d. "Buildings and Landscapes | Real Estate and Facilities." Drexel University. Accessed May 5, 2022. https://drexel.edu/facilities/sustainable-operations/buildings-landscapes/.

Las Vegas including The Bellagio and MGM Grand hotel[9], offices, one family homes, multi-family homes and offices, representing a large scope of possibilities similar to Ithaca. Additionally, Green Globes awards partial credit for varying levels of achievement which can incentivize homeowners to undertake any renovations to begin to become more efficient. This allows for a groundwork of action and awards any strides towards improvement, which LEED and other certification systems do not.

Additionally, through building interviews, we found that many homeowners owned multiple properties and Green Globes portfolio management system allows owners with multiple properties to assess and compare buildings in their portfolio, providing an added benefit for owners. Furthermore, updates to account for the latest requirements and transitions in the industry are easy to implement as the questionnaire is updated frequently and homeowners can change inputs as often as needed prior to verification. Finally, the greatest advantage for Green Globes is the reduced time and costs. The assessment and certification process usually takes around 3-5 months, with a total of between 39-77 working hours. This is considerably lower than other certification processes.

However, Green Globes, as any other certification system, has its drawbacks. Building Green, an independent publishing company, found Green Globes to be technically less rigorous than LEED.[10] Additionally, in the past, they had a somewhat negative perception as their board of directors were made up of corporations that had a track record of opposing environmental regulations but they have cut ties with them and announced a new board of directors in 2022. Due to their more accessible rating methods, Green Globes has been accused of greenwashing by institutions such as the Sierra Club. However, the federal and state level endorsements as well as the importance of having a rating system that is accessible makes it a valid and respected certification system.

Overall, the implementation of Green Globes seems feasible for the City of Ithaca due to the advantages mentioned throughout. Cities such as Charlotte have included Green Globes in their Sustainable Facilities Policy. Under the policy, all City-owned or City-managed new construction and renovations must achieve either LEED or Green Globe certification. [11] Similar to Ithaca, Charlotte implemented the Strategic Energy Action Plan in 2018 with the aim to reduce the carbon footprint, use 100% zero carbon fuels by 2030 and become a low carbon city by 2050[12]. Therefore, it can be used as an example for the implementation of Green Globes in an energy policy. Similar projects were also seen in Baltimore, Chicago, New Smyrna Beach, Pinecrest and more.

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[9] MGM Resorts. n.d. "Our Approach to Sustainable Design & Development." MGM Resorts. Accessed May 5, 2022. https://www.mgmresorts.com/en/company/esg/protecting-the-planet/design-and-development.html.
[10] Roberts, Tristan. 2014. "Drexel Study: Green Globes Cheaper, Less Rigorous Than LEED." BuildingGreen. https://www.buildinggreen.com/news-analysis/drexel-study-green-globes-cheaper-less-rigorous-leed.
[11] City of Charlotte. 2021. "Sustainable Facilities Policy Revision Date Effective: The City of Charlotte is committed to operating its buildings and facilit." City of Charlotte. https://charlottenc.gov/sustainability/seap/SEAP/Revised_Sustainable_Facilities_Policy_2021.pdf.
[12] City of Charlotte. 2022. "Strategic Energy Action Plan > Home." City of Charlotte. https://charlottenc.gov/sustainability/seap/Pages/default.aspx.

In the Ithaca Energy Code Supplement, two possible implementations could be considered. Through the prescriptive path, an amendment can be made to include Green Globe certification which aligns with many of the prescriptive path elements. There will be minimal extra work required for homeowners and they will be able to receive a credible and reliable certification system. This will also allow for LEED and PassivHaus construction methods to remain under the performance path to allow for a step-up for homeowners who choose that path. This will result in more buildings in Ithaca to become certified and act as a blueprint for other cities to follow. The tiered system between Green Globes/LEED and the prescriptive and performance path allows for the greatest impact to be made. The second possibility will alter the performance path. Under C402.2 and C403.3.1 of the performance path, LEED certification is not required, so homeowners still need to build towards LEEDS standards, but there's no enforcement and will need to undergo the process of certification without receiving official certification. Therefore, we suggest replacing this with a mandatory Green Globes certification. Homeowners will undergo the same processes and collect the same documents, but will be able to have their buildings certified. The alterations in 2023 and 2026 can increase these methods to more ‘rigorous’ certification methods.

4. Renewable Energy

4.1 TCAT Microgrid

4.1.1 Preliminary Roof Analysis

The roof installation would be a 30,000 sq ft area of monofacial panels. The roof is not facing south so the panels will have to be diagonally placed. PVWatts from NREL shows that according to the roof size of the TCAT facility, about 500 kW are available if fully covered with about 1300 hours of usable sunlight per year which delivers about 650 MWh in a year. This charges about 4 buses from 0-100% for an entire year, daily. Cost is about $1,000,000 capital with inverter, it saves about 300 metric tons of CO_2, and eliminates about 70 cars worth of CO_2. These solar panels have a 20 year lifespan and the batteries have about 10-15 years. An informational interview regarding a project of this size was conducted with Nicole and Dave Tedeyan from Sungineer Solar. A detailed report of this interview can be found in Appendix IX.

4.1.2 Preliminary Canopy Analysis

The roof installation would be a 15,000 sq ft area of monofacial panels. According to the bus parking space of the TCAT facility, about 200 kW are available if fully covered with about 1300 hours of usable sunlight per year which is about 260 MWh in a year. This charges about 2 buses from 0-100% for an entire year, daily. Cost is about $400,000 capital with inverter, saves about 150 metric tons of CO_2, and takes about 30 cars worth of CO_2. The battery would be housed in the current bus parking spaces and should be able to handle around 700 kW. This would cost about another $500,000 which would bring the whole project with other expenses up to $2,000,000.

4.1.3 Current Modeling on Rhino

TCAT provided the solar team with a blueprint to assess their solar energy demand. On the analysis of the blueprint, a 3D model of the garage was recreated using Rhino 3D.

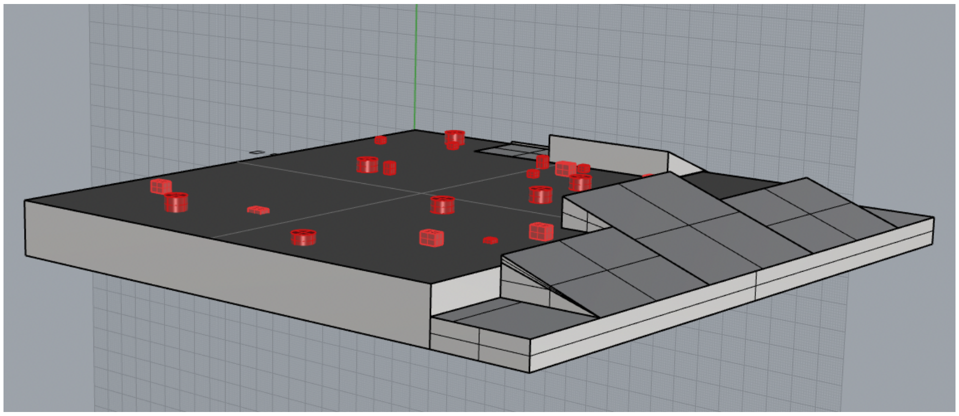

Figure 4.1: Rhino 3D Model of TCAT Garage

The solar modeling team also went to the TCAT Garage to assess their energy usage and to understand the blueprint. Upon receiving roof access, the size of roof top units (RTU) was assessed to be 0.7 m. This hinders the number of panels and the pattern of panels to be installed on the roof.

The recommendation for the solar panel is for a mono-facial panel with high efficiency. While a bifacial panel is ideally more efficient, the gravel on the roof is not going to enable the bifacial nature of panels. The total area of the roof is 30,840 sq. ft. for the flat area and the area of the slant surface is 12,302.24 sq. ft. The size of the panel is 7 ft by 3.5 ft and in this study a LG450N2W-E6 solar panel has been considered. This panel has an efficiency of 20% and a power output of 1,830 Watts per day. It is suitable for commercial use due to a robust build of 1.5 Safety Factor. Based on creating a module of 32 solar panels, we should be able to fit about 600 panels (cost of around $206,720) on the roof of the garage as shown in Figure 4.2.

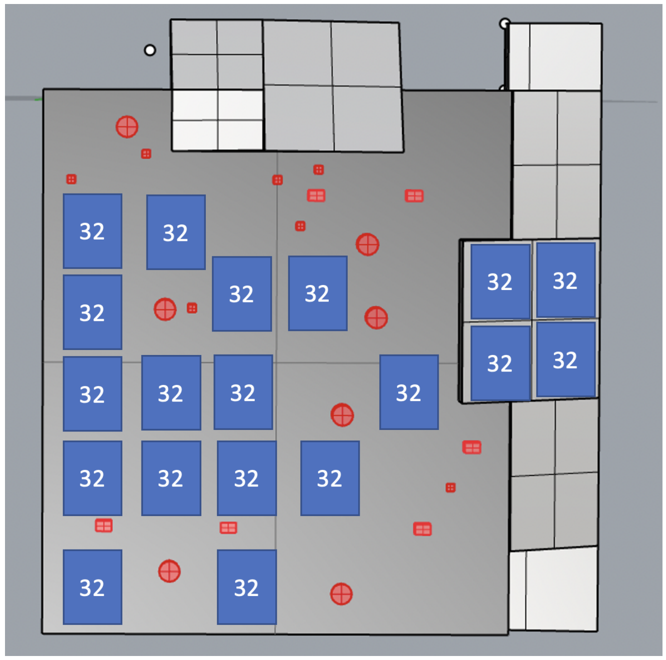

Figure 4.2: Placement of Solar Panels on TCAT Roof

The solar panels on slanted roof would require reinforcements as the structural integrity of that part of the roof is questionable. The number of panels that could be installed is greatly impacted by the vents on the roof.

Figure 4.3: Example Vent on TCAT Roof

4.1.4 NREL SAM Analysis

Using the data obtained from the Rhino roof modeling and the preliminary analysis, we were able to determine that 600 panels can fit on the roof and about 300 can fit on the canopy. The overall energy produced would be 325,000 kWh with a low cost estimate of around $800,000 for both the canopy and the roof. The lithium ion battery installed in the bus parking space would cost around $400,000. Altogether, the cost would be around $1,200,000 and would be able to charge through a peak of 120 bus charging cycles (from about 20% to 100%) in the summer on its own and about 30 in the winter.

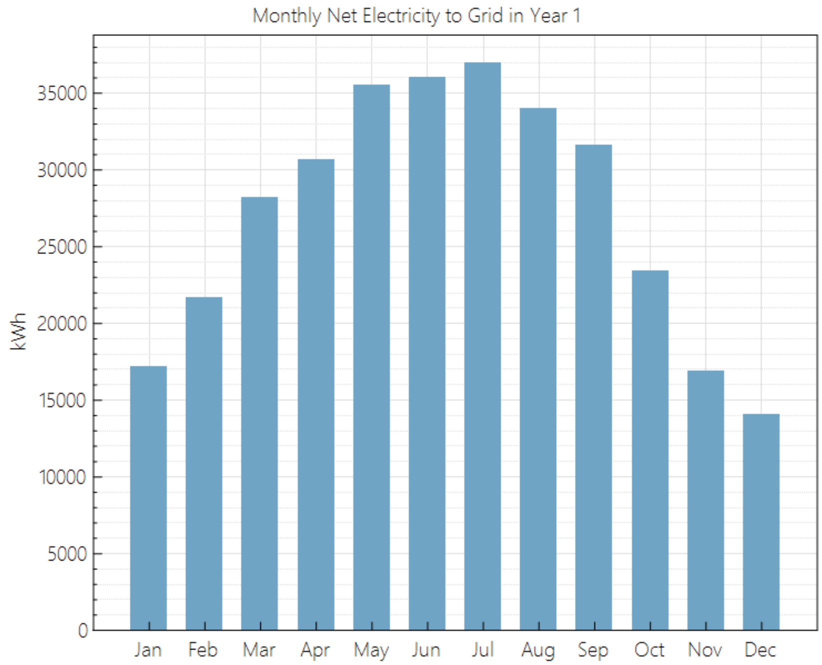

Figure 4.4: Solar Panels of Roof and Canopy Energy

4.1.5 Plans for Fall Term

For the fall term, the focus would be to set a model based on estimation through the use of GrassHopper and ClimateStudio for the thermal and solar panel analysis. Analysis on various parameters like length of the day and the various angles could also be conducted to optimize the design. Support from TCAT would be of importance. Along with that, we would like to continue working on the NREL SAM model as this will give us much more insight on the total costs of the project along with how the panels and inverters will interact with the battery. To figure out the final charging statistics possible, we would have to work more closely with the data TCAT has provided in the coming semester, along with assessing the viability of in-house pantograph charging in both the garage and the canopy.

4.2 District Heating

4.2.1 Outreach to Cornell Facilities

In order to learn more about Cornell's district heating system, we had a Zoom meeting with Mark Howe (Director of Utilities Distribution & Energy Management) and Josh LaPenna (Director of Utilities Production). They explained how the university uses a combined heat and power plant powered by natural gas to provide all of the school's electricity needs. Excess steam is distributed through a network of pipes to provide heat for campus buildings. They also sent data[13] of the energy plant's consumption, efficiency, emissions, and more.

While the system works well for Cornell, Josh and Mark thought the construction of a combined heat and power plant with a district heating system in downtown Ithaca would not be the best way to transition to carbon neutrality by 2030. CHP and district heating is often seen as a stepping stone towards renewable energy as nonrenewable sources (most often coal or natural gas) are used but with just much higher efficiency but still not carbon neutral. The construction of a CHP plant would require a massive upfront investment (in the tens of millions of dollars) and installing the necessary piping could prove to be difficult. If district heating were to be used, they recommended using hot water instead of steam as it would be more efficient and less expensive. They also recommended several European cities using renewables to power a district heating system that would serve as better models for a potential system in Ithaca. Those are Vienna, Helsinki, and Silkeborg in Denmark.

4.2.2 Case Studies: Citywide District Heating

Stockholm is home to one of Europe's largest heating and cooling systems. Over 90% of the homes in Stockholm are connected to the district heating network which uses several innovative energy sources: wastewater thermal energy and excess heat. The distribution network length stretches approximately 3000 km and the heat supply system is primarily based upon renewable energy resources such as biofuel and waste from households and industries. Data centers also provide 10% of the city's heating needs. The purified waste water comes from a wastewater treatment plant before it is sent to heat pumps to utilize the energy stored in the wastewater.[14]

In Okotoks, Alberta, in Canada, 52 energy-efficient detached houses are supplied with a small Low Temperature District Heating system. Heat is supplied with solar panels located on garage roofs, plus natural gas-fired peak load boilers. Both boreholes and water tanks are used to store water. District heating water is produced independently with solar collectors with back up gas-fired water heaters. This allows for a very low district heating supply temperature. Plastic, insulated, underground pipe is used to distribute heated water from the community's Energy Center back to the homes. The hot water circulating through these pipes will typically be 37 - 50°C (100-120 °F). The distribution temperature varies throughout the year based on the outside air temperature and the flow. The lower hot water distribution temperature reduces losses from the pipes and is more compatible with the solar energy source and seasonal energy storage. Keeping the system operating temperature as low as possible causes the solar collectors to operate in a more efficient manner, thus increasing the total quantity of heat available for

[13] Cornell University, Fiscal Year 2020 - Central Energy Plant (CEP) Fast Facts, (Ithaca, NY, 2020), https://fcs.cornell.edu/sites/default/files/2020-12/FY_2020_DRF_CU_Energy_Fast_Facts_FINAL%20December%2011%202020.pdf.

[14] "Stockholm Innovates District Heating with New Solutions and Renewable Sources: Best Practice," Smart City Sweden, April 17, 2020, https://smartcitysweden.com/best-practice/401/stockholm-innovates-district-heating-with-new-solutions-and-renewable-sources/.

delivery to the homes. It also increases the effective energy capacity of the borehole thermal energy system. Because of a lower water temperature used in the district heating system, each home is equipped with a specially designed air-handler unit for adequate heat distribution.[15]

4.2.3 Underground Infrastructure

District heating and cooling systems consist of a network of pipes between buildings and one or more centralized heating and/or cooling plants to supply heating or cooling efficiently. They allow the use of combined heat and power (CHP) plants, waste plants and various other industrial surplus hot or cold sources as well as several renewable energy sources to supply heat/cold to the grid. Different types of waste heat recovery methods are used based on the temperature of the source and its form of availability. The most common types are heat pumps, Organic Rankine Cycle (ORC) systems (heat and electricity), heat exchangers, shell and tube type, plate type, nonmetallic, absorption refrigeration, and heat pipe systems. In a hot water district heating system, suggested for Ithaca by the Director of Utilities Distribution & Energy Management and Utilities Production, pre-insulated pipes, insulated compact system, metering, monitoring, heat storage, heat pumps, and combined heat and power plants would be necessary for a district heating system.[16]

4.2.4 Preliminary Cost Analysis

The initial cost for a heat and power plant in the United States is around \$2500 per installed kW in the United States. Installing and supplying district heating in open areas are about 13% to 26% cheaper than pre-built areas. The investment cost required for district heating is around \$1800 per house. It is about \$175 per house to maintain district heating year round. Lifetime of consumer installation is typically 20 years and has an efficiency of about 98%. Due to the diversity of heat sources and the benefits and limitations of a centralized heat production the District heating cases should be viewed for various cases. Investment cost for district heating is for distribution network and consumer installation. The cheapest district heating schemes for low energy buildings are gas boilers and central heating and power plant surplus or waste. The cheapest decentralized heating solutions are solar panels, gas boilers, and electric boilers; however fossil fuels and electric boilers are inefficient and unsustainable ways to fulfill heating and cooling processes when compared to efficient electric heat pumps.[17]

4.2.5 Recommendations for the City of Ithaca

It is recommended that the City of Ithaca refrain from considering installing a citywide district heating mechanism. The project requires tens of millions of dollars in investment and getting the necessary piping into the ground would be extremely difficult in Collegetown

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[15] "The District Heating System," DLSC, accessed May 6, 2022, https://www.dlsc.ca/district.htm.
[16] "Develop District Heating System," Guide to District Heating, May 20, 2020, https://guidetodistrictheating.eu/.
[17] Gudmundsson, O., J. E. Thorsen, and L. Zhang. "Cost analysis of district heating compared to its competing technologies." WIT Transactions on Ecology and the Environment 176 (2013): 3-13.

and other densely built up areas. In the event that it chooses to move forward with district heating, it is recommended that Ithaca use hot water versus steam as it would make the project more affordable and much more efficient.

4.3 Shallow Geothermal Energy

4.3.1 Outreach to Professor Jefferson Tester

Outreach with Professor Jefferson Tester's group within the Department of Chemical and Biomolecular Engineering in Cornell University was done to explore the feasibility of geothermal energy within Ithaca. The two primary members of the group were Professor Jefferson Tester and Postdoctorate Adam Hawkins. Overall, the primary takeaway is that shallow geothermal can not be a reliable source of energy in Ithaca. Typically, an optimal temperature of 150℃ or higher is needed to produce electricity; however, this temperature is only achieved 5 km below the ground—which enters the deep geothermal realm. However, shallow geothermal heat pump systems may serve to mitigate energy consumption when compared to traditional heating and cooling systems.

Although Ithaca is not suited for electricity production from geothermal systems, shallow geothermal energy can be used for heating and cooling and can reduce energy use and costs. Considering that a significant portion of energy demand stems from heating and cooling, geothermal is a viable and effective method of reducing emissions and lowering costs in Ithaca—thereby helping Ithaca achieve its sustainability goals.

There are currently logistical challenges that prevent the transition towards geothermal energy such as government licensing and policies. New York State does not have well-established geothermal system policies considering that geothermal systems tend to be overshadowed by wind and solar energy systems. Permitting and planning must be considered before execution. Furthermore, shallow geothermal systems are not efficient at large scales. Additionally, there is a need for public support and a greater understanding of these systems in the general public. Social acknowledgement and acceptance of geothermal energy will improve the feasibility of these systems within Ithaca. Other challenges include a need for infrastructure to be updated.

Ultimately, Tester's group believes that larger geothermal systems may be better suited for cities that are focused on retrofitting since they are already trying to improve infrastructure. Although there are many present obstacles to the implementation of geothermal energy, the City of Ithaca should not exclude geothermal energy. Although larger deep drilled geothermal projects may not be feasible, shallow geothermal heat pump systems on a smaller and more individual basis are options that should be considered.

4.3.2 Laws and Regulations

There are many different regulations that depend on location and stakeholders. Serving a "private Property Owner: Served by system" is the simplest. The process is typically an agreement between developer and property owner and consists of installing the system on private property along with any further agreements regarding pricing, maintenance, and decommissioning.[18]

However, geothermal on a larger scale must consider environmental, permitting, zoning and municipal regulations. While most geothermal regulations are state or local requirements, the federal environmental protection laws may regulate certain aspects of geothermal energy systems. Due to the nature of drilling for geothermal system infrastructure, potential federal laws may include the Coastal Zone Management Act, the Clean Water Act, and the Safe Drinking Water Act and New York State environmental protection laws that could apply to geothermal energy systems as well as other "water protection and drilling regulations, and permitting regimes typically administered by municipalities."[19]

4.3.3 Preliminary Cost Analysis

The average starting cost for a house-hold scale geothermal heating and cooling system typically ranges from $18,000 to $30,000 with installation, or trenching, accounting for 55%-75% or more of the total system price.[20] Fortunately, geothermal systems that meet Energy Star requirements are eligible for the federal tax credit, and other local and state entities often offer incentives for renewable energy technologies. There are currently incentives that help with the prices of geothermal energy systems. Currently, the Federal Residential Renewable Energy Tax Credit offers a 26% personal tax credit on all geothermal systems installed through 2022, dropping to 22% at the start of 2023. Additionally, there are indirect cost cuts through programs and incentives such as NYSERDA Clean Heating and Cooling Screenings for Large Buildings.[21]

Geothermal is profitable over the long-term. Geothermal can easily save homeowners up to 70% on the heating and cooling costs and up to 40% on water heating costs. This is due to the fact that geothermal heat pumps are the most efficient heating and cooling solutions on the market—according to the EPA.[22] For reference, assuming that a homeowner quoted a geothermal system for $24,000 and is estimated to save $1,600 per year on utilities (to heat, cool, and provide hot water) for a 2,500 ft2 home. The Federal Residential Renewable Energy Tax Credit will effectively reduce that cost by $6,240 resulting in a cost of $17,760. Without financing, savings pay back the system in about 10.5 years. A homeowner who stays in his/her home for the national average of 13 years profits around $4,000 while a homeowner who stays in his/her home for 25 years profits $23,200.[23]

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[18] "Overcoming Legal and Regulatory Barriers to District Geothermal in New York State". NYSERDA. June 2021. Accessed May 5, 2022. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Clean-Power-Innovation/21-22-Overcoming-legal-and-Regulatory-Barriers-to-District-Geothermal-in-NY.ashx

[19] "District Geothermal"

[20] Buehrer, Bryson, "How Much Does a Geothermal Heating and Cooling System Cost?" October 28. Accessed May 5, 2022. https://blog.enertechusa.com/cost-of-geothermal-system

[21] "Renewable Technology Programs & Incentives" NYSERDA. Accessed May 5, 2022. https://www.nyserda.ny.gov/ny/PutEnergyToWork/Energy-Program-and-Incentives/Renewable-Technology-Programs-and-Incentives

[22] Buehrer, Bryson, "Geothermal Heating and Cooling System"

[23] Buehrer, Bryson, "Geothermal Heating and Cooling System"

Considering the breakdown of costs for shallow geothermal energy systems, the incorporation of geothermal energy within Ithaca is possible. However, based on data from 2019, the median household income is $34,424.[24] For homeowners, geothermal installation is most likely not a priority nor is it economically feasible given this data. From a short-term perspective, shallow geothermal may not be feasible within the City of Ithaca—especially if homeowners must bear the cost. However, with proper investment, planning and aid, shallow geothermal can be implemented and be profitable over the long-term.

4.3.4 Recommendations for the City of Ithaca

Shallow geothermal heat pump systems can be a path towards improving sustainability within Ithaca. However, due to infrastructure and economic constraints, it may not be the most favorable solution. It seems that shallow geothermal might best be explored on an individual homeowner basis rather than a large district basis.

The City of Ithaca should incorporate more programs that highlight the many benefits of shallow geothermal—particularly its renewability, profitability over time, and effects on climate change mitigation. High upfront costs are issues that affect the feasibility of not only shallow geothermal systems but many other renewable energy systems in general. By providing programs and subsidies that alleviate some of the costs, the City of Ithaca can encourage local efforts in improving sustainability. Overall, shallow geothermal can be feasible for sustainability efforts within Ithaca and should still be an available option; however, the City of Ithaca must be dedicated to making this a reality.

4.4 Hydrogen Storage

4.4.1 Technical Information

Green hydrogen is a universal, light, and highly reactive fuel produced using 100% renewable energy. Hydrogen can be produced in many ways, but currently green hydrogen accounts for less than 0.1% of total hydrogen production. Through a chemical process known as electrolysis, an electrical current can be used to separate water into its component parts – hydrogen and oxygen. When the electricity used to power the electrolysis is produced by renewable sources, the resulting hydrogen is considered green, as compared to other sources of hydrogen that depend indirectly on fossil fuels and their related greenhouse gas emissions. Hydrogen has many potential uses, but of most importance for the City of Ithaca is its ability to store renewable energy. Further technical information regarding hydrogen can be found in Appendix VII.

[24] "ITHACA, NY CENSUS PLACE" Data USA. Accessed May 5, 2022 https://datausa.io/profile/geo/ithaca-ny/.

4.4.2 Cost Analysis

When considering the creation of green hydrogen, there is both the capital expenditure cost (CAPEX) and operating cost (OPEX) to consider. The value chain can be broken down into the following steps: production, compression & storage, transportation, and usage. For the purpose of this cost analysis, compression & storage as well as transportation will be neglected. Although these represent relatively lower costs compared to production and usage, further research is required to get a more accurate picture of the true cost of hydrogen based energy storage. Table 4.1 summarizes the estimated costs for hydrogen storage. A more detailed explanation of how these costs were calculated can be found in Appendix VII.

Table 4.1: Estimated Costs for Hydrogen Storage

		5 MW Capacity		20 MW Capacity	
	Estimate	Low	High	Low	High
Electrolyzer	CAPEX ($/kW)	$1,000	$1,400	$800	$1200
	Total CAPEX	$5 million	$7 million	$16 million	$24 million
	OPEX (%CAPEX)	1%	2%	1%	2%
	OPEX	$50,000	$140,000	$160,000	$480,000
Turbine	CAPEX	$8 million	$10 million	$10 million	$12 million
	OPEX (%CAPEX)	1%	2%	1%	2%
	OPEX	$80,000	$200,000	$100,000	$240,000
Total	CAPEX	$13 million	$17 million	$26 million	$36 million
	OPEX	$130,000	$340,000	$260,000	$720,000

4.4.3 Recommendations for the City of Ithaca

The ability to store excess renewable energy created during periods of high supply and low demand is crucial in pursuing a carbon-neutral future. Producing green hydrogen to achieve this goal will require significant investment. For the electrolyzer and turbine alone, the estimated CAPEX would be between $13-$17 million for a 5MW capacity and $26-$36 million for a 20MW capacity. These costs are expected to decrease significantly in the next decade with technological improvements and tax legislation. While the above estimates include numerous assumptions and approximations, they are still valuable as a ballpark estimation and for comparison to other methods of storage. More precise estimates will be possible once more information is available on the specific supply and demand of renewable energy in Ithaca. To fully determine if hydrogen storage is a cost effective solution for Ithaca, it must be analyzed in greater detail and compared to similarly detailed analyses on the costs of other means of storage such as batteries, flywheels, or gravity-based mechanical storage.

4.5 Community Choice Aggregation

4.5.1 Goals and Projections for Tompkins County

A detailed introduction to Community Choice Aggregation can be found in Appendix VIII. Here, we discuss the progress of CCA implementation in Tompkins County, which has made the following goals and projections for each phase of CCA implementation in the following table:

Table 4.2: Tompkins County CCA Goals and Projections

	CCA 1.0	CCA 2.0	CCA 3.0
Goal	**Save money** by RFP to procure lower cost per kWh, green energy (RECs) @ sl. higher cost	Regional green energy procurement, goal = cost less or equal to utility supply, cheaper (brown) energy option, +/- local energy programs	**Save money by reducing energy demand.** Social and energy equity at core. Locally built, owned, managed green energy & storage, EV, heat pumps, local jobs; keep $ in the community.
Energy Source	Brown +/- Green energy option (RECs)	Green (RECs), + brown. RFP may specify NYS or regional RECs	Locally owned and sited green energy; regional, state RECs secondary
Aggregate size	150,000 households	75,000+ households	20,000 – 50,000 households
Local control	None (after contract)	Some, optional	High, customized, flexible; coop model, self-determination
Administration	Consultant and local	Consultant and local	Local coop, + muni +/- advisors
Level of effort	Low, short term	Low to medium, ? ongoing	High
Risk	moderate	moderate	New model. Community creativity & commitment are key.

4.5.2 Current Plan for CCA in Ithaca

The City of Ithaca is planning to pursue the required legislative process to approve a CCA system. The City has already drafted a local law, which has been informed by interviews with government officials. The local law has to be accepted by the Planning and Economic Development Committee, which should be completed in the April-May 2022 time frame. Then the law needs to be reviewed by the City's Common Council for approval. This would enable the City to pursue CCA.

The City is currently working with a consultant called Local Power. The sustainability office has collaborated with Local Power previously and they are experts in CCA integration. The plan is to define a new model for CCA, called CCA3.0. The goal is to add an option for enrollment in an investment for distributed energy resources, such as solar and storage, that could be funded with the same money we are using for building electrification.

The local law will include all elements of CCA, plus the new design elements. According to the requirements, to submit a proposal to the Public Service Commission, the City needs to develop an implementation plan, a data protection plan and a financial plan. Furthermore, the City needs to select a CCA administrator and define a plan for its long term sustainability. Additionally, the City will need to model the expected behavior of the community (opting out) to determine the potential revenue and determine how to fund the CCA administrator office, which may be done by the comptroller's office.

The City expects to have the implementation, data protection and financial plan ready by the end of June, when the Public Service Commission will be distributed for approval. After that, the City must have two RFPs, one for ESCOs, including perhaps some distributed community solar development.

Finally, all the elements – technical, financial and legislative – will be in place. If all adheres to the expected timeline, implementation will be ready by February 2023.

5. Transportation

5.1 Standing Charging Spots

5.1.1 Roadmap of Deployment

According to a study by the National Renewable Energy Laboratory, about 40 level 2 charging ports are needed per 1000 medium electric vehicles. In order to promote and increase the number of EV drivers in the City of Ithaca, it is necessary to have a sufficient number of charging stations and place them in the appropriate locations where supply meets demand. Tompkins County's report on the number of electric vehicles registered states that there were 202, 310 and 620 EVs registered at Tompkins County in the year 2017, 2018 and 2019 respectively. Based on this trend, in the mid-semester report, we predicted that there will be 1078 EVs registered in Tompkins County at the end of the year 2021. Comparing this result with the study done by NREL, we concluded that at least 43 level 2 charging ports are required in the City of Ithaca, and that the City is currently slightly surpassing the requirement with 47 level 2 charging ports.

Although the City is currently meeting the need, CUSD ICN team still recommends the City plan to increase their charge port footprint to keep up with the fast-growing EV market. Using the historical data above, we produced a visual forecast with a confidence interval of 95%, which predicts that there will be about 3236 medium-sized electric vehicles registered in Tompkins County by the year 2030. Based on this prediction, we used the guideline suggested by NREL again and produced an assessment on how many charging stations the City needs to install each year. This will allow the City to support an increased number of visitors and long distance travelers requiring EV charging capabilities on-the-go.

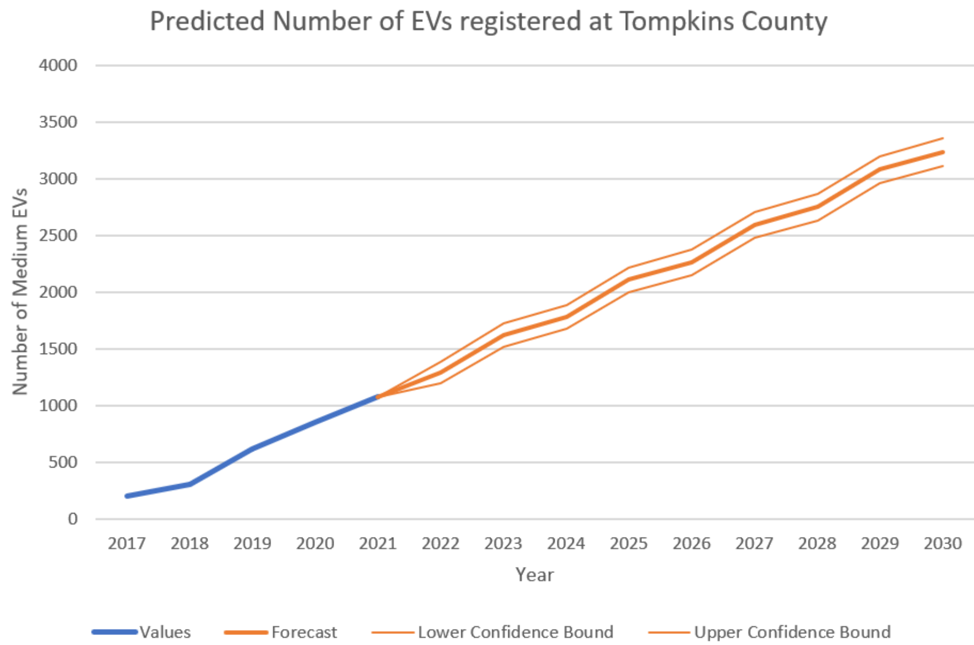

Figure 5.1: EV Market Prediction in Tompkins County

Table 5.1: Number of Charging Stations and Number of EV registered by year

Timeline	Number of EVs registered	Number of Charging Stations
2017	202	8
2018	310	12
2019	620	25
2020	849	34
2021	1078	43
2022	1291	52
2023	1623	65
2024	1777	71
2025	2109	84
2026	2263	91
2027	2595	104
2028	2750	110
2029	3081	123
2030	3236	129

5.2 Dynamic Wireless Charging

5.2.1 Technical Information

This semester ICN Policy extensively researched dynamic wireless charging (DWC) systems in the context of implementation for the City of Ithaca. DWC systems are a new technology where charging pads are buried underneath the road surface which supply an electrical charge to receiving pads in vehicles driving on top of the road. The benefits to such a technology are significant, for example a much smaller battery capacity requirement for EVs, and much farther distances for such vehicles. However, the costs are enormous, estimated as between $1.8 million to $5.6 million *per mile*.[25] There are two types of DWC systems in development. The first is magnetic based, and is the most commercially developed with one successful prototype track in existence. This technology poses considerable risks in addition to the high costs—the charging and receiving pads need to be insulated with ceramic-encased iron to limit the amount of free-floating electricity. These ceramic insulators are brittle and little is known about their durability under significant strain (e.g., buses and commercial trucks). Additionally, these magnetic-based systems pose a fire hazard risk. As one Cornell engineer who researches DWC systems put it "if an aluminum can lands on the road next to a pile of straw, a fire will likely occur." The other type of DWC system is electric-field based, but the research is in its infancy.

Currently with magnetic systems, power transfer efficiencies are estimated between 80 and 92%. Research funding for DWC development is extensive and global. The EU has a $10 million grant system and the NSF has a $50 billion grant program for related technology. Additional public funding is available in China and New Zealand, with more considerably more funding coming from the private sector. As for the developmental timeline, Michigan and some European countries are expected to implement DWC pilot programs within the next three years. These pilot programs have to be successful and then the technology price has to come down considerably before any consideration by Ithaca. A general estimate would be in the ballpark of 10 years before the technology could start to be considered for implementation.

If a DWC system is implemented in Ithaca, a considerable grid capacity overhaul would need to be conducted. However, the technology would allow for peak power draw to be spread out throughout the day instead of concentrated at night if EV ownership is very high. This would allow for more daytime charging that could theoretically take advantage of solar power generation.

5.2.2 Meeting with Cornell Wireless Charging Lab

This semester, ICN Policy met with Dr. Khurram Afridi, who runs an electrical engineering lab that researches dynamic wireless charging at Cornell. In our meeting, we discussed the state and possible future of the technology with respect to implementation and

[25] Afridi, Khurram. "The future of electric vehicle charging infrastructure." *Nature Electronics* 5, no. 2 (2022): 62-64.

feasibility. Dr. Afridi's lab works on the development of the electric field system technology and just received ~$1.5 million in federal funding for that research. He stressed the widespread funding that has been planned to be put behind development of these technologies from both public and private sources.

5.3 Pantographs

5.3.1 Technical Information

Unlike DWC systems, pantographs are considerably more feasible for the City of Ithaca. Pantographs are sets of scissor-like contact arms that draw their power for vehicle operation from stationary masts. The commercial vehicle industry adopted this idea from rail technology, in which pantographs have long been used to supply continuous power to electrically powered locomotives from overhead lines.[26] These are non-dynamic systems, meaning that buses need to be stopped in order to charge. Pantograph systems come in inverted and roof-mounted forms. Inverted pantographs are where the arms are attached at the charging station and come down into contact on a roof-based terminal on the bus roof. These seem to be better systems as they have less weight and infrastructure on the buses themselves. Roof-mounted pantographs are ones where the arms come up from the bus to meet a terminal on the charging terminal.[27] The primary advantage to pantographs is that they can be automated and can be strategically placed for on-route charging. Drivers can park at a designated station for ~10 minutes and charge their bus nearly full (depending on the battery capacity and power transfer rate) without leaving the vehicle. Because these are wired systems there is much more flexibility in terms of power transfer rates. Some existing pantographs have charging outputs of 800 kW or more. This rate of transfer is likely to increase as technology progresses.[28] A combination of strategically placed pantographs and standard wire charges should be used to optimize costs and installation space.[29]

En-route pantographs are best for short-range buses with fixed routes. These situations are best for the "top-off" charging that pantographs are best for due to their no human requirement for charging. Eventually these systems will be well integrated with autonomous buses. Pantograph networks are limited by the number of systems in close proximity to each other, however systems can support up to ~50 charging stations which is well beyond the needs of Ithaca. Some of the major pantograph companies (e.g., Solaris) offer consultations to municipalities to get estimations and recommendations for implementing these charging systems.

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[26] "Charging by Pantograph - Vector Informatik," accessed May 6, 2022, https://cdn.vector.com/cms/content/know-how/_technical-articles/Emobility_Pantograph_ElektronikAutomotive_202010_PressArticle_EN.pdf.

[27] Pollack, Brian and Spritzer, Torben. "Bridging eMobility and Energy - Depot of the future." *33rd Electric Vehicle Symposium (EVS33).* (2020)

[28] "Pantograph or Plug-in? How to Choose the Right Charging System," eCity powered by Solaris, August 16, 2021, https://ecity.solarisbus.com/en/knowledge-base/pantograph-plugin-charging-system.

[29] Judith Wiese, "Siemens to Support Zero-Emission Public Transport in Ostrava with ...," Siemens (Siemens, April 15, 2021), https://press.siemens.com/global/en/pressrelease/siemens-support-zero-emission-public-transport-ostrava-charging-solution.

Ithaca may want to reach out for a consultation if the City decides pantographs are a likely option.

Determining the price advantage of pantographs relative to overnight depot charging has a great deal of uncertainty as the difference is primarily driven by the differences in battery price. The pantograph charging station, due to the fact it can be utilized by more than 11 buses at a time, ends up not being hugely impactful when looking at the lifetime costs of a fleet of electric buses. A cost-benefit case study out of Germany directly compared the total lifetime costs of 11 buses with pantographs vs. overnight charging; the city was only slightly larger than Ithaca (by about 10,000 people). The body of 12m electric buses (without batteries) was priced the same, ranging from $250,000-$450,000.[30] Battery systems usually have about a 6-7 year lifespan, which is only half that of the bus itself. Battery prices have steadily declined and are projected to continue that trend, estimated at $96/kWh in 2025 and $70/kWh in 2030. The pantograph system requires low-capacity batteries, which are currently estimated at $1,000-$1200/kWh. The high-capacity batteries are priced between $635 and $740/kWh. If a typical 260 kWh battery is used for depot-charged buses, the total battery cost ends up being between $165,000 and $192,400. This is in contrast with pantograph buses, which can get by with a battery capacity of 90kWh, bringing the battery cost range per bus to $90,000-$108,000.

5.3.2 TCAT Route and Charger Location Analysis

TCAT's most used routes were analyzed using 2019's data - data points pre-COVID as these show more normal bus usage - were the circulator and connector routes. These routes make up about 80% of the ridership during the academic year and still about 60-70% otherwise. According to the Proterra spec sheet, the buses have a max range of about 220 miles which we will use as our basis. The overhead chargers, or pantographs for short, have about a higher charging speed than plug-in chargers and thus they would be optimal for on-route charging, we will be using the 300A overhead charging model for analysis which gives around 68% charging efficiency using the total battery pack energy and the time to charge. For one minutes' worth of stops, the bus could potentially recharge 1% of its battery and run for potentially an extra 4 minutes using pantographs. This may not seem much, but according to TCAT's data, the buses use about 4% of their battery per route and then using regenerative braking, they gain back about 2%. Which means that if the bus is charged for one minute under pantographs, recharging the bus along with the braking adds to about 3% energy recovery, so it could potentially run for twice the amount of time it's running now and achieve 12 hours during non-snowy days when regenerative braking is used.

Plug-in charging at 200A brings similar results, but around 0.4% charge for the same one minute stop, making it much better for longer stops - since it's less expensive and the bus driver has to get out of the bus as well - so it would charge around 5% of the battery in a 15

[30] Kim, Hanhee, Niklas Hartmann, Maxime Zeller, Renato Luise, and Tamer Soylu. "Comparative TCO Analysis of Battery Electric and Hydrogen Fuel Cell Buses for Public Transport System in Small to Midsize Cities." *Energies* 14, no. 14 (2021): 4384.https://doi.org/10.3390/en14144384

minute-stop. Taking that into the previous account where each route cycle would net use about 2% of the battery, this plug-in charging once every 3 rotations could keep the buses running without stopping for the whole day. For snowy days, plug-in chargers would yield the best results as batteries perform better in colder weather and the 15 minute charge would still cover the 4% energy usage per cycle.

Pantographs cost around $300,000[31] each from the ground up, so these projects are not to be taken lightly. To reduce the cost, TCAT could start by purchasing the on-site pantographs and test their efficiency along with any new nuances about the technology. Meanwhile, it would be best to install the off-site plug-in chargers - which can cost around $75,000 - in the A-lot, the P&C shops stop, East Green Street, and by the mall, by order of importance. After enough testing has been performed on the on-site pantographs, the best locations for off-site pantograph charging would be by RPCC, Goldwin Smith, Uris Hall, and East Green Street (pantographs make a bit of noise so this option may not be possible) by importance according to the most used routes. More data and analysis is available in Appendix II.

5.4 Small Electric Vehicles

5.4.1 Case Studies and Policy Recommendations

During the policy-making process for creating a locally ran bikeshare program in the City of Ithaca, the organization must cover questions of where bikes will be stationed, how will the bikeshare program uphold equity, how will safety considerations be enforced, and where/how will bikes be optimally distributed throughout the community as well as an analysis of capital and operating costs. Ithaca's first bikeshare program was introduced to the community by LimeBikes, and a detailed description of LimeBikes'along with other bike share companies' efforts and eventual downfall can be found in Appendix XI.

As bike travel becomes more widely used it is important that Ithaca offers enough active transportation infrastructure to support this method of travel. According to Ithaca-Tompkins County Transportation Council's Long Range Transportation Plan, there has been an increase in bikeable paths through the implementation of complete streets and extension of biking trails throughout the region. While this increase may make biking more accessible, when extending routes, one must focus on how they connect and what origin-destination pairs these routes connect. In addition, it is important to note how suitable these additions are for supporting active transportation. With concern to routes to popular recreational areas that promote health and well-being for the community, there appears to be a few trail routes as well as medium or low volume roads that connect the highly populated downtown to surrounding parks. When considering the availability of complete streets, there appears to be more connective streets inside the downtown area as opposed to connections to surrounding communities. Complete

[31] Nicholas, M. (n.d.). Estimating electric vehicle charging infrastructure costs across majorU.S. metropolitan areas. 11.

streets offer safe routes to travel to stores, markets, banks, churches, etc. in the downtown area[32]. The increased safety due to complete street design stems from the inclusion of a bike lane to the right of pre-existing traffic lanes. This added space gives cyclists room to travel without having to navigate around slower- and faster-moving vehicles. By extending their reach through the proposed complete streets, surrounding villages will be connected to the City and these vital destinations as well. LimeBikes discovered changes in transportation mode where "28% drove alone less often, and 24% took taxis or Ubers less often thanks to bikeshare".[47] As a result, more travel will be replaced by more sustainable options.

Bikeshare will offer social benefits to the community it operates for. Assuming that small electric vehicles would run on renewable energy sources, reducing the carbon footprint from the transportation sector, they would improve the quality of life for citizens that use them. Also, active transportation allows time for exercise that may not have happened otherwise, as citizens substitute this method for their daily commute. The bikeshare program can provide low-cost transportation for lower-income communities. A method of transportation with less emissions will improve the air quality for these communities that tend to have higher respiratory illness rates as well, according to a New York Times Article "Poor Americans More Likely to Have Respiratory Problems, Study Finds".[33]

Along with an increase in exercise, other health benefits will arise as air pollution levels begin to decline. There are also economic benefits for the community that follow the incorporation of a bikeshare program. A New York survey discovered that, by installing "a bike share station in the curb lane, replacing metered parking, increased total commercial spending by 52%, due to the increased turnover (one parking space can accommodate approximately ten bikes) and people walking or biking spend more money at local businesses than drivers"[34]. The community's local economy will flourish due to increased foot and bike traffic through the downtown area. The use of smaller vehicles allows for more people to experience the usually overcrowded downtown area and creates a safer environment with less large vehicle traffic.

5.4.2 Ongoing Survey

We are conducting a survey on the acceptability of small electric vehicles in Ithaca based on the interests of both BikeWalk and the Director of Sustainability of Ithaca. This survey consisted of finding whether electric scooters and bikes were currently being used, have been used, or would be used by the Ithacan population. It was co-created by policy and modeling to make sure we had questions that would envelope the equity, psychological, infrastructure, and budget factors into the decision making process.

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[32] "Long Range Transportation Plan- Executive Summary." Tompkins County NY. Ithaca-Tompkins County Transportation Council. Accessed May 4, 2022. Long Range Transportation Plan | Tompkins County NY.
[33] Rabin, Roni C. "Poor Americans More Likely to Have Respiratory Problems, Study Finds." *The New York Times*. May 28, 2021. Poor Americans More Likely to Have Respiratory Problems, Study Finds - The New York Times.
[34] "Bike Share Station Siting Guide." NACTO Bike Share Siting Guide FINAL. National Association of City Transportation Officials, 2016. Bike Share.

So far, the survey has amounted to 56 responses, but these are mostly from Cornell students in clubs that deal with sustainability. Thus, the results thus far are to be taken with that focus group in mind, which is why we would like to extend this survey to more Ithacan locals - perhaps through the public school system's mailing lists or through an Ithacan mailing list to get a better understanding of the population's interest or lack of interest in these small EV's for future installation.

The results thus far have shown that 75% of the students mentioned are interested in having small EV's in Ithaca. Of these 75%, half would be willing to pay $1-$5 per trip - which is about the same as companies like BIRD are charging for short trips. About 20% stated that they would also be willing to pay a $100 fee per year. Of the other 25% that would not like to have small EVs, most mentioned that for their short distances they have to travel from class to their homes they would rather just walk or use a manual bike. This is one of the questions in which opening up the sample size would be beneficial to find whether increasing the infrastructure for walking and biking on its own would increase the number of people using it or if the transition to EVs is necessary for car decongestion. 50% of all respondents said that the major roadblock for them to start using small EVs more was the lack of infrastructure, and then 25% stated that if driving was made more difficult, then they would be more likely to switch their commuting to small EVs.

So far, Cornell students seem to be responding positively to small EVs in Ithaca. Most of the locations that were added for where there should be chargers were near the most important bus stops mentioned for the pantograph charging - Risley, CTB, Dairy Bar, RPCC, Baker Flagpole, and East Green Street. Therefore, the conclusion so far is that bus stops have already become transportation hubs on campus and many of the current buses passing through the center of Cornell campus actually only service students for 2-3 stops. To alleviate the traffic into the buses in these locations and allow people who live farther away to use the bus more effectively, small EVs through the center of Cornell's campus would be a good place to start doing preliminary research on usage and maintenance. In this case, the bike lanes through Cornell's campus and the roads of East State St., College Ave, E. and W. Green St., W. Seneca St., E. Ave, Thurston Ave, Cradit Farm Rd., and Campus Rd. should have much more delineated bike lanes. Also, removing some parking from these streets would allow for the spacing as well as influence people to use small EVs, food and grocery delivery services (which can be a form of carpooling), walking, and manual biking more often. See the survey and map of the proposed bike lanes in Appendix III.

5.5 Medium Electric Vehicles Cost Analysis

The installation costs and fuel pricing for EV charging varies by charging type and location. On average, one charge event dispenses about $1.00 of electricity to an EV at about 7.7 kWh for $0.13 per kWh. With the mileage on EVs today, that means it could potentially cost less than $40 to drive 1,000 miles[35]. On average across New York State, public charging ports experience 2.5 charge events per week, so the average monthly electricity cost to operate a charging port is less than $10[36].

In terms of charging rates for different locations of charging stations, EV users will most likely undergo their longest charging times at residential stations. For a residential charging station, Level 1 charging is recommended as it is best suited for overnight charging. The typical cost associated with the installation of an electric car charger at home ranges from $1050 to $2300, depending on the region[37]. This includes installation of a 240V circuit, professional installation service and materials, permits, and inspection, among other additional costs. Public access Level 2 charging stations rarely serve as an EV driver's primary source of electricity as this is done at home or work. Thus, while electric vehicle battery capacities can be as high as 20 kWh or even 60 kWh or higher for the newest 200-mile range EVs, the average energy dispensed per charge event for public stations in New York is only 6.6 kWh.

New York State offers many purchasing incentives and payment programs to support an increase in installations of electric vehicle chargers. The Charge Ready NY program covers the cost of installation of Level 2 charging stations. The NYSEG Make-Ready program for businesses and contractors provides certain percentages of coverage on the development of Level 2 and DCFC stations at one's respective business. At the state level, the New York State Power Authority has set aside $250 million for the next three years to be used toward installing more charging stations through its EVolve NY program. Their goal is to have at least 800 new EV fast charging stations that are compatible with most electric vehicles installed along major highways throughout New York by the end of 2025.

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[35] Joe Bruzek, "How Much Does It Cost to Charge an Electric Car?," Cars.com (Cars.com, March 7, 2022), https://www.cars.com/articles/how-much-does-it-cost-to-charge-an-electric-car-447817/.

[36] Energetics Incorporated, Clean Communities of Central New York, and The Ithaca-Tompkins County Transportation Council, "Charging Station Installation Analysis," Tompkins County NY (Tompkins County, February 2017), https://tompkinscountyny.gov/files2/itctc/projects/EV/Tompkins%20EVSE%20Installation%20Analysis%20FINAL.pdf.

[37] "Home EV Charging Stations," Home & Residential EV Car Charging Stations | Enel X, accessed May 19, 2022, https://evcharging.enelx.com/store/residential.

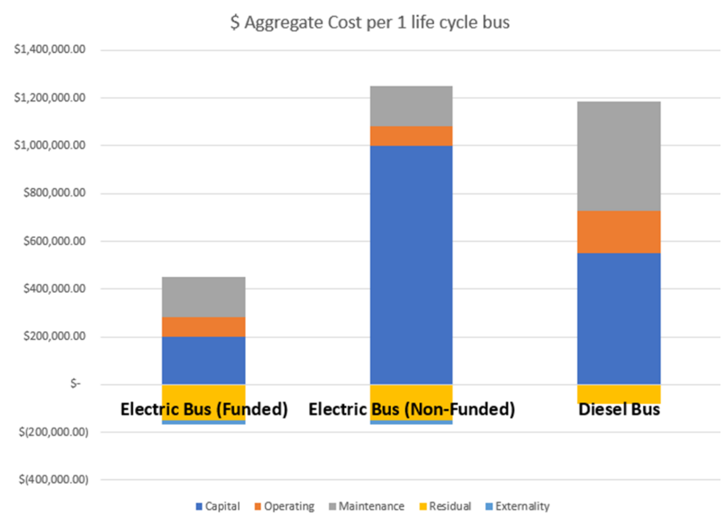

Figure 5.2. Aggregate Cost of Electric vs. Diesel Buses

In comparing diesel and electric buses, there are various costs that must be taken into account. As can be seen in Figure 5.2, the aggregate cost of a diesel bus is higher than the aggregate cost of an electric bus. Without the government funding, which is usually reported as 80% in the U.S., the difference in the aggregate cost of the two types of buses is not huge. However, with the funding, the difference becomes enormously large as the capital cost, which is the biggest cost, gets reduced by 80 percent. Nevertheless, it is important to note that the aggregate cost of an electric bus was still lower than the aggregate cost of a diesel bus even without government funding.

5.6 Integrated Transportation System Research

Integrated transportation systems are ones where connection and use between different modes are seamless. While there is no example of a perfectly integrated transportation system, the vast intermodal networks of large cities like New York City and Boston provide frameworks to aspire to. Ithaca faces a lot of innate challenges in developing an integrated transportation network, such as its small population rendering many forms of transportation unfeasible, its active-transportation-inhibiting topography and climate, and an overall lack of resources to develop and expand alternative transportation modes.

There are some aspects of Ithaca's current transportation system that are integrated. For example, TCAT's Park and Ride stations outside of Ithaca provide an intermodal connection for commuters that generally gets healthy use. However, where Ithaca's transportation system lacks integration the most is between modes of active transportation and other sustainable modes. Because of this, it is not feasible for most residents to live an SOV-free (Single Occupancy Vehicle) lifestyle, which is why developing a more integrated transportation system is vital.

Ithaca Carshare provides a good example of an innovative component to the local integrated transportation system. Its presence allows members to only use cars when they have to, and use alternative, more environmentally friendly modes of transportation at other times. Electrifying the carshare network in Ithaca will be an important step in decarbonizing its transportation sector, but progress is gradual due to funding restrictions and a general lack of charging infrastructure.

Developing EV charging infrastructure may play a large role in helping integrate Ithaca's transportation network with more sustainable modes (in this case, electric SOVs, such as private Teslas). An increased availability of public charging stations will make owning an EV more feasible for those who can afford it. This will play an important role as an intermediary step in decarbonizing our transportation network, as vehicle emissions are a majority contributor to the carbon footprint of Ithaca's transportation network.

However, in order to develop a carbon-neutral, healthy, and truly integrated transportation network, Ithaca needs to take more aggressive steps towards incentivizing the use of small personal vehicles and active transportation modes. The modes may include walking, skateboarding, scootering, and cycling. The latter 3 have electric-power-assisted alternatives, which help make the modes more attractive as a means of conquering Ithaca's challenging topography. However, their use will not be widespread until the City takes serious steps towards developing infrastructure with a focus on these modes.

Usage of a given mode of transportation is almost entirely dependent on the infrastructure available for it. For example, if a city builds high-capacity roadways meant for SOV use, the residents of that city will almost unanimously use SOVs. This phenomenon is called induced demand, and it should be used to inform policy making and physical development practices in the City moving forward in order to foster more usage of sustainable modes of transportation.[38] In terms of encouraging more active transportation use, the City needs to build more robust infrastructure for these modes, or else they will continue to be used fleetingly.

One of the reasons for the deficient state of active transportation infrastructure in Ithaca is the low standards for "complete streets".[39] Complete streets are streets that have designated space for a variety of modes of transportation, generally consisting of sidewalks, bike lanes, and lanes for automobiles. Many of Ithaca's complete streets meet the bare minimum complete standards, including all of these things. However, the degree of focus put on different modes of transportation within a complete street can have an overstated effect on their ability to encourage the use of a given mode. For example, the bike lanes on Tower Avenue are not separated from the part of the road that automobiles use by any physical barrier, and the lane is quite thin, so there is little room for error for cyclists and, in turn, a larger risk of an accident and/or injury. The quality of bike lanes have a profound effect on how well-used they are, so it is important for Ithaca to improve the quality of bike lanes to have as much physical separation from the road and width as possible.

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[38] Lee, Douglass B., Lisa A. Klein, and Gregorio Camus. "Induced Traffic and Induced Demand." Transportation Research Record 1659, no. 1 (January 1999): 68–75. https://doi.org/10.3141/1659-09.

[39] Ithaca-Topmkins County Transportation Council, "2040 Long Transportation Plan", Ithaca-Tompkins County Transportation Council (2019).
https://tompkinscountyny.gov/files2/itctc/lrtp/2040lrp/2040%20LRTP%20Exec%20Summary.pdf.

One of the main motivations behind adopting a well-integrated transportation network is providing alternative transportation forms to SOVs for everyday uses, such as commuting and doing errands. Currently, the best developed aspects of Ithaca's active transportation system are its recreational trails. These are well used, but they do not replace trips taken in high-emission vehicles like SOVs, so they do not necessarily play a large role in terms of decarbonization. This is why developing better infrastructure on roads used for everyday tasks is so important; decarbonization only happens if low-emitting modes are replacing high-emitting modes.

Better infrastructure for active transportation and electric vehicles is the centerpiece of decarbonizing Ithaca's transportation network. By using the principle of induced demand to inform the City's long-term transportation plans, Ithaca can develop a better-integrated transportation network that naturally facilitates higher use of transportation modes that are more environmentally friendly and healthier for residents than SOVs. Overall, developing a more integrated transportation network with a focus on integrating environmentally friendly transportation modes is a critical aspect of achieving carbon neutrality in Ithaca.

5.7 Site Suitability for Charging Stations

5.7.1 Introduction to Curbside Charging

Curbside charging is of particular interest to the City of Ithaca as it has a great potential to attract new Electric Vehicle (EV) owners. Electric Vehicle Supply Equipment (EVSE) installed in parking garages are usually reserved for patronage or limit access for a parking fee. However, curbside chargers are sited for greater public use. Coupled with reserved parking spaces and free parking for charging vehicles, curbside chargers reduce the barriers of entry to EV ownership, making EVs a comparable investment with traditional internal combustion engine (ICE) vehicles. Expanding accessibility to the community through curbside charging will make it easier to own an EV, increase patronage to local businesses, and increase the public health of the city.[40]

Over 2016 and 2017, the Ithaca-Tompkins County Transportation Council (ITCTC) produced reports to support community transition to increased EV usage as well as encourage residents to adopt and use EVs. The site suitability prepared by ITCTC does not consider potential curbside EVSE locations. We will expand on the framework crafted by the Council and will identify suitable curbside locations for new EVSE infrastructure.[41] For a detailed look into Ithaca's current EV infrastructure, please refer to Appendix X.

[40] Ithaca-Tompkins County Transportation Council, Energetics Incorporated, and Clean Communities of Central New York, "Tompkins County Plug-in Electric Vehicle Infrastructure Plan: Existing Conditions and Best Practices" (New York: New York State Energy Research and Development Authority, 2017).
[41] Ithaca-Tompkins County Transportation Council, Energetics Incorporated, and Clean Communities of Central New York, "Tompkins County Plug-in Electric Vehicle Infrastructure Plan: New Charging Station Site Suitability" (New York: New York State Energy Research and Development Authority, 2017).

5.7.2 Priorities for Curbside EV Charging

In addition to the location of the installing relative parking space, an analysis of the general location is highly important in siting. Factors that hold a high priority for siting can be split into market analysis, legal, economic feasibility, and operations categories. There are also signage and wayfinding as well as accessibility considerations. Refer to Appendix X for a detailed list of these factors.[42] The results of these considerations have resulted in several recommendations, including signage[43] (indicated below) and optimal locations (section 5.7.3). To meet accessibility concerns, all EVSE should clear the 36" minimum distance between building walls and street furniture and signage to minimize hazards. EV charging spaces may be combined with accessible parking spaces but must be clearly signed to indicate reserved spaces.

Figure 5.3: Sample Signs Recommended by US Federal Highway Administration

5.7.3 Optimal Location Highlights

Four sites were located which hold the most potential for possible curbside EVSE:

Table 5.2: Proposed Sites for Curbside EVSE

Location:	Pros	Cons
North Cayuga Street (between Seneca and State)	• One way street with left-hand parking • Proximity to Ithaca Commons • High turnover rates for optimized usage • Near Ithaca CarShare fleet	• Narrow sidewalks with moderate streetscape clutter • Unprotected from the elements (snow removal required if free standing unit) • Limited parking available
Markels Flats (Court and Plain Streets)	• Near outdoor/indoor recreational facilities • Near Seneca Street and somewhat close to Ithaca Commons	• May require (costly) trenching for connection to the grid and/or infrastructure upgrades • Two-way street - drivers may

[42] Ibid.
[43] WXY Architecture + Urban Design, "Siting and Design Guidelines for Electric Vehicle Supply Equipment".

	• City-owned property • Near residential homes • Intermodal transportation: Bike boulevards • Near Ithaca CarShare	have to park facing the opposite direction • Unprotected from the elements (snow removal required if freestanding unit)
State Street (Ithaca Commons)	• Year-round entertainment and dining venues • Intermodal transportation: Near many TCAT routes • Near Ithaca CarShare • Existing infrastructure very likely to support EVSE installation (lower costs)	• Narrow sidewalks with moderate streetscape clutter • Unprotected from the elements (snow removal required if free standing unit) • Limited parking available • Two-way street - drivers may have to park facing the opposite direction
N Meadow Street (between Court and Esty)	• Located on heavily-trafficked NY-13/34 • Near the West End commercial district • One-way street will accommodate left-side parking • Near many TCAT routes • Near Ithaca CarShare • Designated parking bay	• Narrow sidewalk with heavy street furniture • Unprotected from the elements (snow removal required if free standing unit) • May require disruptive infrastructure upgrades if installing a DC Fast Charger

6. Waste Management

6.1 Motivation

During the ICN team's beginning-of-semester meetings with Luis Aguirre-Torres and Rebecca Evans from the City's Carbon Neutrality team, Rebecca discussed a lack of coverage in the carbon neutrality mission where waste management is concerned. This is due to the fact that Waste Management in Ithaca is performed by Tompkins County and not on a city -level. Despite the lack of administrative potential, understanding greenhouse gas (GHG) emissions in this space is a beneficial exercise. Due to the educational nature and wide scope of the CUSD ICN team, the team offered to begin research in potential avenues for estimation and reduction of GHG emissions for waste management in Tompkins County.

Waste management does not neatly fit into any of the current projects teams (renewables, transportation, electrification) that ICN have this semester. Therefore a new, smaller project subteam was developed to begin this analysis. This semester the team is composed entirely of

Masters of Engineering students because of their broad skillset and flexibility in work schedules. In future semesters, this will hopefully be expanded to some undergraduate students as well.

To begin this research, the team started with an assessment of current state GHG emissions from waste in the Ithaca Metro area through developing a GHG calculation model. At present this model can only give an extremely rough idea of the GHG emissions from the City of Ithaca or any other part of Tompkins County. We recognize that the numbers used in this report to show the order of magnitude of the GHG emissions are very approximate. In lieu of City- and County-specific waste source totals, composition of waste, and destination of waste (i.e. landfill, waste to energy plant, recycling facility etc.), the team relied upon national data from the Environmental Protection Agency (EPA) and extrapolated said data using population.

In future work, the team looks forward to more accurately quantifying the various inputs needed to run the model and improve its probable accuracy to be used in evaluating possible potential ways of reducing those emissions. We will also identify and assess potential technology and policy to reduce waste's GHG emissions, using the model to facilitate the analysis.

Potential technology and policies could include waste-to-energy, changes in landfill designs and locations, and optimized waste collection streams among others. At this stage it is too early to know which policy or technology solution would have the most beneficial environmental impacts with the least detrimental social impacts within the context of Ithaca and Tompkins County, but the team hopes to use information to be eventually gathered for this model to determine avenues for future research into GHG emissions reduction in Tompkins County.

6.2 Context

Waste comes in multiple forms but can be classified into four major categories: municipal solid waste (MSW), industrial waste, agricultural waste, and hazardous waste. While the City of Ithaca produces all of the aforesaid, the scope of this initial analysis is constrained to MSW. MSW includes all domestic waste such as food scraps, paper, plastics, textiles, rubber, and certain metals among other household or institution generated waste. To provide additional context to the MSW Management system, a context diagram was developed (see Appendix XII). The context diagram defines the system that will be analyzed in the context of interfacing entities and stakeholders. In future iterations of this report, one could consider exploring the approximate GHG emissions by stakeholder, and address those emission contributions at the source.

The MSW Management System consists of a coordinated set of processes which enable the generation, collection, compositing, transportation, processing, recycling and or disposal of this domestic waste material (see Appendix XII). Fruition of this process effectively results in waste generated by constituents being removed from their homes, offices, cities, and institutions. Each process step has the potential to emit or sequester greenhouse gas emissions. The following section presents a model which calculates total emissions associated with current state MSW management in the City of Ithaca.

6.3 GHG Emissions Model

Using the MSW process steps as a guiding framework, a model to define current state GHG emissions for Ithaca was developed. The model simply computes current state greenhouse gas (GHG) emissions associated with MSW based on broad assumptions and extrapolated data. In subsequent semesters, it is our hope to incrementally expand upon the complexity of the model on a sub-system by sub-system basis. Additionally, it is our hope to include additional sub-systems (e.g. anaerobic digestion, pneumatic waste transfer etc.) to the model and assess implications of new technology on GHG emissions. Appendix XII contains the key equations, coefficients, and input data along with the team's assumptions. This information is also formalized in a spreadsheet for easy application in the future as more representative input numbers are obtained.

6.4 Preliminary Assessment of Current State GHG Emissions

Based on all assumptions above, the model estimates that Municipal Solid Waste (MSW) management produces approximately net **5,000 Mg CO2-eq (megagrams of carbon dioxide equivalents) annually**. To put this number into perspective, that is equivalent to the Mg CO2-eq emitted by 1,000 passenger cars on an annual basis. Landfill emissions exceed 60,000 Mg CO2-eq annually, accounting for the large majority of GHG emissions. This, however, is counteracted by the GHG emissions saved through recycling (approximately net negative 60,000 Mg CO2-eq) and composting (approximately net negative 2,000 Mg CO2-eq). Other sources of emissions include Combustion (Waste to Energy) at approximately 2,000 Mg CO2-eq and transportation at approximately 2,000 Mg CO2-eq.

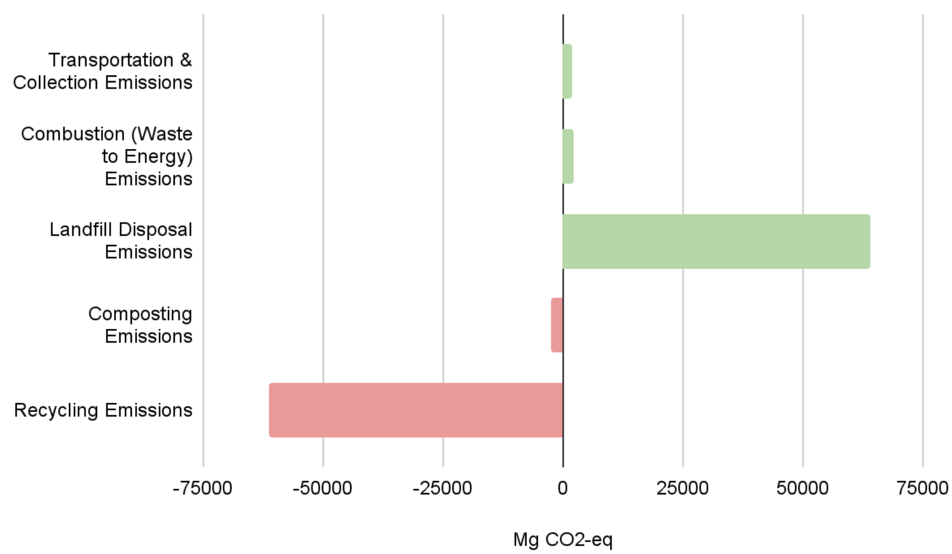


Figure 6.1: Estimated Emissions for Several Waste Management Processes

With that said, the accuracy of this model only gives an order of magnitude estimate. Without concrete data, change in assumptions could significantly alter the model's predictions. For example, if the assumption that all of Ithaca's landfill waste goes to the Ontario Landfill is wrong, and instead goes to a landfill 1,000 to 2,000 miles away, the emissions associated with transportation and collection would more than double. Alternatively, if landfill capture rates exceeded 70%, landfill disposal[44,45] emissions would significantly decrease. Further analysis and tuning of the model is required in subsequent semesters.

With that said, it is clear that landfills constitute the majority of emissions and may be a sensible place to start with respect to emission reductions. The following subsections identify a variety of GHG reduction measures for consideration and further exploration.

6.5 GHG Reduction Measures

Greenhouse gas (GHG) reduction measures can be adopted to further mitigate emissions. Some measures to consider exploring in future semesters include the following:

- As the US food waste makes up more than 24% of the municipal solid waste stream and is the nation's third-largest generator of methane gas as per the EPA, diverting landfill-bound food waste to composting sites can significantly reduce GHG emissions.
- Source reduction measures such as reusing, repackaging, repurposing can be used to mitigate waste generation are not only effective but also environment-friendly.
- Establishing a pay-as-you-throw waste fees to discourage indiscriminate waste disposal.
- A novel method to reduce GHG emissions associated with waste management is to use an efficient gas collection and control system that can tap into what is called landfill gas which is composed of 60% methane and 40% carbon dioxide which would otherwise be allowed to escape into the atmosphere thereby contributing to global warming. This is an area into which further research can be carried out to determine the exact emissions reduction potential of such a technique and how well this fits into Ithaca's carbon neutrality goals and present practices..
- Landfill gas recovery systems, while effective, are not the most optimal way of combating waste-related emissions. There exists another better alternative, using energy from waste or (EfW/WTE) systems. Sending waste to EfW facilities is the better option not only for generating electricity, as the technology is capable of producing 10 times more electricity than landfill-gas-to-energy technology, but also because greenhouse-gas emissions from landfills are two to six times higher than those generated from EfW facilities.

[44] https://www.epa.gov/lmop/frequent-questions-about-landfill-gas
[45] https://www.americanprogress.org/article/energy-from-waste-can-help-curb-greenhouse-gas-emissions

7. Ithaca Readiness Level (TRL) Assessments

In a previous deliverable to the City of Ithaca, the CUSD ICN team prepared a set of Technology Readiness Level (TRL) assessments of various technologies and programs for implementation in Ithaca. These TRL assessments are explained in detail in Appendix I of this report. This TRL scale is a system used to measure the maturity of a given technology and was first developed by NASA for the space exploration industry in the 1980s. This measurement system is now a standard practice in the research commercialization space across all industries. NASA's original criteria was written specifically in the context of spacecraft design, so a more generalized version was used from an intellectual property company called ProspectIP. This TRL assessment criteria is defined on a 10-point scale as follows[46]:

Table 7.1: Definition of TRL Scale

Technology Readiness Level (TRL) Scale	
TRL 0	Idea. An unproven concept, no testing has been performed.
TRL 1	Basic research. Principles have been observed but no experimental proof available.
TRL 2	Technology formulation. Concept and application have been formulated and validated.
TRL 3	Applied research. First laboratory tests completed; proof of concept.
TRL 4	Small scale prototype built in a laboratory environment.
TRL 5	Large scale prototype tested in intended environment.
TRL 6	Prototype system tested in intended environment and operating at close to expected performance.
TRL 7	Demonstration system operating in intended environment at pre-commercial scale.
TRL 8	First of a kind commercial system. Manufacturing issues resolved.
TRL 9	Full commercial application, with the technology available for consumers.

The objective of this TRL assessment was to show our stakeholders which technologies are on the near-term, mid-term and long-term horizon for implementation in Ithaca. Luis

[46] ProspectIP. "Technology Readiness Level Scale Explained." ProspectIP, November 19, 2018. https://www.prospectip.com/technology-readiness-level-scale-explained/.

Aguirre-Torres, Director of Sustainability for the City of Ithaca, provided the team with positive feedback on this approach and made some suggestions on how it can be strengthened. The team's TRL assessments were helpful, but they only tell part of the story. While a technology might be highly mature, the Ithaca market might not be ready to fully receive this technology at scale. To capture the rest of the story, the team assessed these same technologies and programs for their Market Readiness Level (MRL) for the City of Ithaca.

Starbridge, a venture capital firm that works in the space exploration industry, has developed a holistic approach to evaluating market readiness by merging the CloudWatch Consortium, Demand Readiness Level, and Lean Startup methods. Starbridge's approach takes a few concepts from each method to form a one-size-fits-all criteria for evaluating market readiness[47].

Table 7.2: Definition of MRL Scale

Market Readiness Level (MRL) Scale	
MRL 0	Perceived need. Market research and rough outline of problem.
MRL 1	Notional value proposition. At least one draft Customer Value Proposition.
MRL 2	Notional customer characterization. Right side of Business Model Canvas complete.
MRL 3	Customer discovery. Full Business Model Canvas completed with right side validated.
MRL 4	Low-fi MVP design. Metrics quantify effectiveness of initial Business Model Canvas.
MRL 5	Low-fi MVP campaign. Usage metrics and feedback from customers and stakeholders.
MRL 6	Revalidate solution and model. Final draft of Business Model Canvas.
MRL 7	High-fi MVP campaign. Data, customer feedback and metrics.
MRL 8	Validate model with MVP results. Fully validated and documented Business Model Canvas.
MRL 9	Go to market decision. Yes or no decision to launch.

The CUSD ICN team has assigned a Market Readiness Level (MRL) rating for each of the same technologies and programs in the context of Ithaca's market. The MRL assigned to each

[47] "Market Readiness Levels." Starbridge Venture Capital. Accessed May 13, 2022. https://www.starbridgevc.com/market-readiness-levels.

of these items captures how prepared the Ithaca market is to receive and adopt these technologies. Note that while a given program or technology might have a high MRL in one city or region of the world, that does not mean that it would have the same MRL in the City of Ithaca.

After the team assigned a TRL and a generic MRL rating to each technology and program, an overall Ithaca Readiness Level (IRL) was determined. This IRL rating is simply the average of the TRL and MRL and captures the overall readiness level for the City of Ithaca. The table below shows all of these readiness levels. Note that the table is sorted by IRL in descending order, showing which technologies and programs are the most feasible for the City of Ithaca today, and which ones can be explored for future opportunities.

	Technology Readiness Level (TRL)	Market Readiness Level (MRL)	Ithaca Readiness Level (IRL)
Heat Pump	9.0	9.0	9.0
Shallow Geothermal	9.0	9.0	9.0
Rooftop Solar	9.0	9.0	9.0
Solar Farms	9.0	9.0	9.0
Microgrid	9.0	3.0	6.0
Wind	9.0	3.0	6.0
Flywheel Mechanical Storage	9.0	3.0	6.0
Overhead Bus Chargers	8.0	4.0	6.0
Hydrogen Storage	7.0	3.0	5.0
Vehicle-to-Grid (V2G)	8.0	2.0	5.0
District Heating	4.0	5.0	4.5
Wireless Stationary Charging of EVs	7.0	2.0	4.5
Community Energy Storage System	7.0	2.0	4.5
Gravity-Based Mechanical Storage	5.0	3.0	4.0
Wireless Dynamic Charging of EVs	5.0	2.0	3.5
Deep Geothermal	2.0	1.0	1.5

Figure 7.1: Summary of Readiness Levels for Several Technologies

8. Conclusions and Next Steps

To summarize, the Ithaca Carbon Neutrality team looked at the feasibility of several potential solutions for carbon neutrality in building electrification, renewable energy, transportation, and waste management. On the building electrification side, we prepared an architecture model for mixed use buildings and conducted informational interviews with some of these building owners. We also rolled out retrofit brochures and began research on building energy performance standards. Next semester, we hope to test out use cases on our building models and combine the information we have collected over the past several semesters to develop an interactive website for building owners in Ithaca to determine what retrofits are best suited for them. On the policy side, we hope to research ways to improve retrofit labor shortages, utilize a budding relationship with BlocPower for community education, continue informational interviews with building owners, and further develop incentives for Ithacans to pursue electrification.

Our renewables modeling team determined a potential placement of solar panels on a TCAT microgrid and hopes to finalize these plans next semester. Our policy team determined feasibility for district heating, shallow geothermal energy, and hydrogen storage on citywide scales. Essentially, these do not seem feasible in Ithaca due to their high costs. Next semester, we want to perform cost analysis on electrochemical battery storage and assist with outreach campaigns for Community Choice Aggregation. We also want to collaborate with CUSD's own Solar Panel Reboot to distribute their refurbished solar panels to the Ithaca community via Ithaca ReUse.

On the transportation side, we reviewed feasibility for various charging options, including standing charging spots, dynamic wireless charging, and pantographs. We also performed basic cost analysis for bringing small EVs back to Ithaca in the form of bikeshare and medium EVs. Integrated transportation system outreach revealed a need for collaboration on the last mile issues (i.e. allowing users to combine TCAT, bikeshare, carshare, etc. for their regular trips). Finally, we looked for suitable sites for curbside EV charging all over Ithaca using GIS, which revealed four locations. Next semester, we will be continuing work with integrated transportation (specifically TCAT), and we will assist BikeWalk Tompkins with their life cycle analysis of DROP bikes.

Waste management was a new subteam this semester consisting primarily of MEng students. Analysis revealed an approximate total estimate of greenhouse gas emissions in Ithaca, and we determined potential reduction measures. Each of these measures should be looked into by the modeling and policy teams next semester. MEngs also finalized our Ithaca Readiness Levels for several technologies, including past semesters' research areas as well as this semesters' focuses. Ithaca Carbon Neutrality is excited to continue our work and is eager to receive feedback from all potential stakeholders on next steps.

9. Appendix I: Technology Readiness Levels (TRL)

District Heating: 4

There have been many locations across the world including Denmark, Tokyo, and a version of it in Ithaca which works with Lake Source Cooling. It is possible for larger buildings to run district heating easily (this small community of large buildings would have a TRL of around 8 as Cornell has shown) - but it might be more difficult to connect the greater residential grid to a district heating system since these systems haven't been used as long in residential districts. For district heating to become an 8, a system of residential buildings would have to be tested by a commercial company to see how well the district heating's energy recovery works in those smaller networks.

Hydrogen Storage: 7

A common method to store the surplus of renewable energy is to convert this to gas. Power-to-Gas (P2G) is a technology that takes the surplus of electrical power from renewable sources to produce gaseous fuel. The most common method in P2G systems is to produce "green" hydrogen by electrolysis. P2G technology is available from different sources and similar systems have been developed and deployed, accumulating several years of service. Examples of potential suppliers include Cummins, Nel Hydrogen, Plug Power, Fuel Cell Energy and Siemens. Most previous applications of P2G include blending hydrogen with natural gas. Systems running on 100% hydrogen will likely become more common as the cost of producing hydrogen decreases in the coming years.

Microgrid: 9

Microgrids help make communities more resilient and independent, while also allowing for more renewable energy penetration into the grid. Microgrids may be expensive to implement with the necessary upgrades to grid infrastructure and increased local electricity generation, but the technology is available and has already been implemented in other areas. Many successful microgrids have already been built elsewhere, and the number of microgrids in the US is growing quickly. In order to implement a microgrid, it is important to have close communication and collaboration with local utility companies and other stakeholders.

Wireless Dynamic Charging: 5

Wireless dynamic charging of electric vehicles (EV) has been demonstrated in a relevant environment but has not yet operated near commercial scale, thus it has been deemed TRL 5. One of the market leaders in the wireless dynamic charging space is IPT Technology. This company has demonstrated their Dynamic Road Charging solution in Belgium and Germany, achieving efficiencies greater than 90% with a dynamic charging speed of up to 80km/h (50 mph) on 100m (328 ft) stretches of road. These demonstrations validated this technology for buses, trucks, and cars with both concrete and asphalt top layers. Further research and discussion with this company is required to determine how Ithaca's harsh winter climate and steep grades will impact system performance. This technology will not advance to TRL 6 until the system can be demonstrated on longer stretches of roadways for extended periods of time and much lower costs per mile.

Wireless Stationary Charging of EV's: 7

A first-of-a-kind (FOAK) wireless stationary charging system has been completed and qualified in a commercial environment. Similar to the dynamic charging case, IPT Technology is one of the market leaders in the stationary charging space. This company has sold their product to many bus, car and ship customers worldwide. One project implemented wireless charging on three hybrid double-decker buses in London, England. From April 2016 to December 2019, this project alone was able to prevent more than 150,000 kg in carbon dioxide emissions. IPT has implemented this inductive charging technology on (53) buses in Europe. This technology works best when many charging periods are required in a day, making TCAT's buses a feasible use case for the City of Ithaca. This technology will advance to a TRL 8 when it has been proven for larger fleets and for longer periods of time, demonstrating system durability and manufacturing readiness.

Vehicle-to-Grid: 8

Vehicle-to-grid (V2G) bidirectional charging systems and electric vehicles (EVs) capable of supporting the technology have been developed and implemented in communities commercially, making this technology TRL 9. Currently, V2G is mostly leveraged using school buses due to how well the functioning characteristics of the two systems match. School buses generally operate only in the early mornings and afternoons on weekdays, following consistent schedules and spending all other time parked at the depot. During the time parked in the depot, an entire fleet of parked electric school buses can be connected to the grid through bidirectional charging, only charging during low community power demand periods and discharging during high demand periods to provide significant grid load leveling benefits. "Smart charging" through the use of IoT technologies allows these charging/discharging periods to be tightly controlled, also ensuring that the EVs are never discharged too much when needed for transportation.

V2G technology is applicable to all forms of EVs including consumer EV cars, small electric vehicles, and regular public transit buses as well but is much less developed due to reduced viability given the lower and less consistent time spent charging compared to school buses. As a result, many EVs do not support the bidirectional charging required for V2G. The longer EVs are plugged into the grid, especially during high and low demand periods, the more the electrical storage in the EV can be leveraged to benefit. For example, an electric car charging in a family home could provide significant load leveling benefits to the house's power demand, by discharging during evening high demand and charging during overnight low demand. However, if the car is used frequently and is used for transportation during most high demand periods then practically all benefits are lost.

In Ithaca, electric buses and charging stations that do not support V2G have been supplied to TCAT by Proterra. Proterra has already developed a line of commercial electric school buses and bidirectional charging systems, and has already supplied a number of communities with the technology. Given that contact with Proterra is already well established through TCAT with a proven viable financial outlook there is potential to leverage Proterra's V2G technology in the future.

Due to the current restriction of viable V2G to school buses while the technology has not been developed in other vehicle markets, it could also be interpreted to be TRL 8. The vast majority of the EV market has not leveraged the technology commercially and it is presently unclear if it is worthwhile to do so.

Air-Source Heat Pump: 9

The technology behind air-source heat pumps (ASHPs) is reliable and has been in use across different parts of the country and world. Since ASHPs use electricity only for powering heat transfer and not active heat generation, they do not emit CO2, have high efficiencies (up to 285%), and thus consume less electricity than with resistance heating. So electrifying buildings with heat pumps should lower energy consumption and consequently the load on the grid. Local companies like HeatSmart Tompkins have been involved and continue to carry out heat pump installations in the Tompkins County Area so the commercial viability of this technology is not in question. More recently, the City of Ithaca has added in BlocPower to lead the City's electrification drive which would largely consist of heat pump installations starting out with some early-adopter buildings and eventually expanding it to different building types. ASHPs can be installed in central or split configurations, with the split units providing heat to single rooms and central units providing heat to an entire building. With financing incentives in place, and the low installation costs of ASHPs compared to other heat pump types, (around $5000 for individual units and $12k-$20k for central configuration) public-adoption of heat pumps, specifically ASHPs, should not be an issue.   Finance will be particularly important for low income homeowners who will lose much of the benefits if they have to finance the installations and pay off the loans interest rates, thus continuously delaying the eventual payback from reduced utility bills.

Deep Geothermal: 2

We will discuss Cornell's Earth Source Heating project here, since this is directly related to the proposed implementation of deep geothermal technology in Ithaca. Cornell's Earth Source Heating Project plans to circulate cool water down beneath the Earth's surface to the high temperature basement bedrock 2 to 4 miles down. It then draws the heated water back up to be used as a heating source or even electricity production. This is a fairly new and unexplored technology. There are a few successful stories, however most of these stories are from the geologically favorable regions like Iceland and some parts of the Western United States. The Cornell University Borehole Observatory (CUBO) has a proposed schedule indicating that it may take another five years to verify the feasibility of the geothermal systems at Cornell and the actual project may not be completed by 2030. Hence, the TRL level for this technology in Ithaca is 2, where the technology concept and application are formulated, however,the concept still needs to be validated by more research and tests.

Shallow Geothermal: 9

Shallow geothermal, also known as ground source heat pumps, has been thoroughly tested, studied, and applied for many years now. It is fully commercialized, but it is still at a very high cost for areas that need more heavy duty excavation. Shallow geothermal is beneficial for cost reduction in heating and cooling due to high pump efficiency and the consistency of the system overall. The lowest cost and one of the best working versions is with lake/pond source cooling which greatly reduces the overall necessity for heavy machinery. In Europe the heavy excavation is often replaced by shallow drilled holes with a minimal surface footprint and that has proven to be a reliable alternative to digging up large areas of land to bury heat transfer piping.

Wind: 9

Wind capture technologies are reaching a plateau in their stages of development. Now fully commercialized, wind energy systems are looking to grow in size in order to produce the most amount of energy with the least amount of space and materials. There is a maximum efficiency that comes with wind power physically, which means that the technology can only grow a little more, although costs will still be coming down somewhat as turbine design, manufacturing, and operational costs are reduced incrementally.

Rooftop Solar: 9

Rooftop solar panel technologies are very mature and widely adopted both commercially and residentially. According to National Renewable Energy (NREL) analysis in 2016, there are over 8 billion square meters of rooftops on which solar panels could be installed in the United States, representing over 1 terawatt of potential solar capacity. All Ithaca residents can install the rooftop solar panels if their roofs are structurally sound and proved to support the weight of the panels. The technology level is a solid 9. However, there are studies and researches on improving the solar PV efficiency to make the solar panels more efficient.

Community Energy Storage System: 7-8

The grid in Ithaca is currently mired with a lot of problems regarding disruptions and oversaturation at certain sites, leading to congestion. While smart meters can help pinpoint the location of electric grid disruptions so that electric repairs can be completed faster, they cannot restart electric services after an outage. But energy storage units, such as batteries, can be placed at strategic points throughout electric distribution networks to restart electric grids when power generation fails. With the falling cost of battery technology and improvements to battery management systems, community storage projects offer renewed potential to strengthen electric grids and increase their efficiency. By deploying small energy storage systems across a utility service area at critical junction points such as transformers, utilities, energy storage companies can bolster electric grid resilience while selling the aggregate capacity of the systems in regional transmission capacity markets. The technology currently sits at a TRL of 7 or 8. However, CES could require huge funding for it to jump up in TRL. Investors, advisors, or grant application reviewers with technical expertise in a specific area are helpful to more accurately assess the funds needed to complete all development activities. This should be compared against projected revenue (if any) to understand how much additional funding will be required to reach commercialization.

Solar Farms: 9

At present there are already operating solar farms in the Ithaca area that provide power to Cornell University. The City of Ithaca also has plans to install a Solar Farm in “the Jungle” near the industrial center of the city. Because it has already been implemented, and can be done again the TRL is 9, demonstrating a full commercial system already available to customers.

Flywheel Mechanical Storage: 9

Ithaca currently has not implemented any flywheel mechanical storage systems, but the technology is here and ready to be used. This article, published in 2009, describes the specs of flywheel uninterrupted power supplies, and lists the cost per kilowatt as $330. And in Ontario, Temporal Power Ltd. has operated a flywheel storage power plant since 2014 consisting of 10 steel flywheels. Each flywheel weighs four tons and is 2.5 meters high, with maximum rotational speed as 11,500 rpm and maximum power as 2 MW, and after a successful three-year trial period, the system is to be expanded to 20 MW and 100 MW.

Gravity-Based Mechanical Storage: 5-6

There are currently two primary providers of gravity-based mechanical storage: Gravitricity and EnergyVault. EnergyVault finished construction of its first grid-scale gravity-based mechanical storage tower (called the EV1 Tower) in Switzerland in July 2020, and this tower has been labeled a Commercial Demonstration Unit. Building costs are $7-8 million with round trip efficiency of 88-92% and a levelized cost of storage of $0.05/kWh (which is half as much of the levelized cost of storage of lithium-ion batteries), but given that it has only been less than two years since their first large-scale prototype, it would perhaps not be wise to recommend EnergyVault’s products. Gravitricity constructed its first demonstrator in Edinburgh in 2021, and is still in progress of constructing its first full-scale prototype project, thus offering little to consider.

Lithium-ion batteries: 9

Lithium batteries are widely commercialized and popular for use in electric vehicle applications. They have a higher energy density, both volumetric and gravimetric, compared to most other battery technologies. Their volumetric energy density, for instance, is around 3-34 times that of vanadium redox flow batteries and 2-8 that of lead-acid. This makes them favorable for applications where spatial and/or weight limits are of particular concern. They also have a relatively high efficiency of 80-90%, higher than the other batteries analyzed.

The weight of a 10 MWh storage system based on these batteries was found to be about 29 -100 Mg, or 31.5-110 US tons. Such a system would take about 15-50 cubic meters space for the batteries themselves. Based on a wide range of price estimates found in literature review, the upfront cost of lithium batteries is 132-487 $/kWh. For the 10 MWh storage system, this leads to an upfront cost of $1.32-$4.87 million, a cost per year of use of $132-$487 thousand based on a 10 year life cycle, and a cost per cycle of $660-$9,740 per cycle. These estimates do not include additional maintenance costs. There are several different types of such batteries available; those analyzed here are lithium iron phosphate, lithium nickel cobalt aluminum, and lithium nickel manganese cobalt.

Limitations of lithium-ion include the need for precious metals of which availability may be limited, as well as a higher fire risk when compared to other batteries. It is important for thermal management and fire suppression to be considered when operating this technology. This issue also necessitates the spacing of batteries in order to mitigate such risks, which may counteract some of the benefits of lower spatial needs discussed above. The numbers presented include only the volume of batteries which would be required and do not account for such spacing. Currently, lithium batteries are not able to be recycled to the extent that lead-acid batteries are.

Lead-acid batteries: 9

These batteries have a high level of commercialization and availability. A 10 MWh lead-acid based storage system would weigh about 200-400 Mg, or 220 to 441 US tons, and would require about 100 to 125 cubic meters of space. Such a system would have an upfront cost of $2-$4.48 million, based on a cost of about $200 - $448 per kilowatt. The cost distributed over the batteries' lifetime ranges from $167 thousand to $1.5 million, as lifetimes of these batteries are dependent on several factors including whether they are properly maintained. The cost per cycle of such a system was estimated at $2000-$8960 per cycle.

Limitations include lower energy density compared to lithium batteries and lower cycle life compared to vanadium redox flow. Additionally, in applications involving solar energy, intermittency due to short-term variation in solar radiation has been found to impact the useful life of these batteries. They also contain a toxic metal, presenting safety concerns. In terms of environmental impacts, lead acid batteries require more raw material for the same amount of energy storage when compared to lithium-ion due to lower energy density. This results in a greater impact from mining and processing of these materials.

Vanadium Redox Flow Batteries: 8

These batteries are in the initial stages of commercialization. One of their main advantages that they offer is a greater cycle life compared to the other batteries analyzed, around 6-28 that of lithium-ion and 12-28 that of lead-acid. A 10 MWh Vanadium Redox Flow storage system would require about 143 to 500 cubic meters of space. Such a system would have an upfront cost of about $2.93-$6.09 million, based on a cost of $393-$609 per kilowatt. The cost distributed over the batteries' lifetime is estimated to range from $262-$406 thousand. The cost per cycle of such a system is estimated at $281-$508, lower than for the other batteries analyzed.

Overhead Bus Chargers: 8

Pantographs or overhead bus chargers are past the research phase. Many places in Europe have started charging and using them commercially, but many of these are small cities in small countries who are willing to use the commercial application as research. They have a much higher amperage than plug-in chargers and can be used without the driver leaving the bus. This technology is rapidly being implemented and is expected to reach TRL level 9 in the next five years. They are more expensive than plug-in chargers but can be used on routes to replenish quickly.

10. Appendix II: TCAT Charger Analysis

10.1 Introduction

TCAT is working on integrating its new electric buses into its everyday business as the gas, hybrid, and diesel buses do. To do so, the electric buses must maintain their energy for a longer period of time than they are currently - which is around 4-8 hours depending on the routes taken and the season, and then would be forced to charge for around 4 hours to replenish. The current combustion based buses can run for around 12 hours and don't take more than a few minutes to replenish completely. For the purpose of this study, we will assume the electric buses are using regenerative braking and can maintain their charge for 6 hours. The 40ft ZX5+ Proterra bus is the vehicle of this analysis.

To supplement the electric buses and get them running as close to optimal or possibly better than the combustion vehicles, new on-site and off-site charging techniques have to be put in places where the buses can frequently access them for shorter periods of time. According to our TCAT associates, the two most sought after charging stations for them would be on-site, in garage and under a new potential solar canopy, overhead charging and off-site plug in charging stations at places like the mall and A-lot on Cornell's Campus. The purpose of this study is to find the feasibility of these locations for the bus charging network along with suggesting others for further research.

10.2 Potential Chargers

TCAT's most used routes using 2019's data - data points pre-COVID as these show more normal bus usage - were the circulator and connector routes. As seen in Figure 1, these make up about 80% of the ridership during the academic year and still about 60-70% otherwise. According to the Proterra spec sheet as seen in Figure 2, the buses have a max range of about 220 miles which we will use as our basis. The overhead chargers, or pantographs for short, have about a higher charging speed than plug-in chargers and thus they would be optimal for on-route charging, we will be using the 300A overhead charging model for analysis which gives around 68% charging efficiency using the total battery pack energy and the time to charge. For one minutes' worth of stops, the bus could potentially recharge 1% of its battery and run for potentially an extra 4 minutes using pantographs. This may not seem much, but according to TCAT's data, the buses use about 4% of their battery per route and then using regenerative braking, they gain back about 2%. Which means that if the bus is charged for one minute under pantographs, recharging the bus along with the braking adds to about 3% energy recovery, so it could potentially run for twice the amount of time it's running now and achieve the 12 hours during non-snowy days when regenerative braking is used.

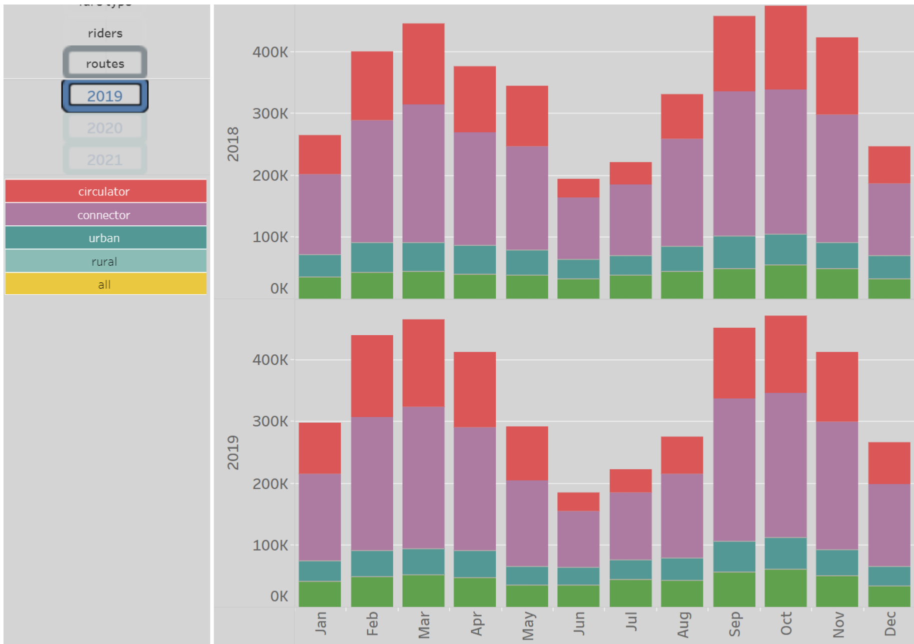


Figure 10.1: Total TCAT Ridership in 2018 and 2019

Plug-in charging at 200A brings similar results, but around 0.4% charge for the same one minute stop, making it much better for longer stops - since it's less expensive and the bus driver has to get out of the bus as well - so it would charge around 5% of the battery in a 15 minute-stop. Taking that into the previous account where each route cycle would net use about 2% of the battery, this plug-in charging once every 3 rotations could keep the buses running without stopping for the whole day. For snowy days, plug-in chargers would yield the best results as batteries perform better in colder weather and the 15 minute charge would still cover the 4% energy usage per cycle.

10.3 Locations

For the locations of these chargers, the most used routes have been selected to showcase potential charger types. As seen in Figures 3 and 4, for the circulator, the most used routes are the 81, 92, and mostly 82. For the connector, the most used routes are the 10 and 31. These will be the routes most focused on in this report. The connector and circulator routes would be the most important in the short-term to have chargers on their routes as they serve the highest number of people. The urban and rural routes are also highly important as shown in the graphs, and their most important routes run through the commons, stopping at East Green Street.

The connector's routes are shown in Figure 5. As shown, the mall and the shops by P&C would make great plug-in charging stops as these locations are long stay locations and they would work to service more than one route. The areas of Uris Hall, Goldwin Smith, and Statler Hall would be great for pantograph charging as these would be quicker stops and would work to function as a large percentage of the circulator and connector routes. Also, the RPCC stops could add to the mix and serve as a lower testing area for the pantographs as they would be less visible. The circulator's routes are shown in Figure 6. As shown, the A-lot stop would be great for plug-in charging and as the connector as well, the P&C stop. Both the connector and circulator's main routes run through the Cornell main road where placing a pantograph would be an awesome sight and attraction, as well as the RPCC stops.

Lastly, on-site overhead charging would allow for quicker charging and for more systematic charging and storage of the buses overnight as the buses closest to the exit are the ones to go first. The overhead chargers could be placed inside the facility, reducing the cost as much of the infrastructure is already there.

ZX5 VEHICLE WITH PRODRIVE 2.0 DRIVETRAIN				
Total Energy	kWh	225	450	675
Operating Efficiency*	kWh/mile	1.7-2.2	1.8-2.5	1.9-2.8
	MPGe	17.1-22.2	15.1-20.9	13.5-19.8
Operating Range*	Miles	91-117	154-216	205-297
Top Speed (Proterra-governed)	mph (per tire rating)	65	65	65
Acceleration (at SLW, seconds)	0 to 20 mph	6	6.2	6.5
	20 to 50 mph	20.8	22.1	24.5
Gradability (top speed at % grade, at SLW, mph)	5%	49	45.7	42.7
	10%	30.2	27.6	25.3
	15%	20.2	19.2	17.9
Max Grade (at SLW)		31%	28%	25.4%
Horsepower	Peak	335	335	335
	Continuous	170	240	240
Motor	Single 240kW permanent magnet drive motor	•	•	•
Gearbox	4-speed EV transmission	•	•	•
Curb Weight	lbs	26,850	30,050	33,350
Max Gross Vehicle Weight Rating	lbs	43,650	43,650	43,650
CHARGING				
Max Plug-in Charge Rate at 200A	kW	147	147	147
Max Overhead Charge Rate at 300A	kW	184	221	221
Max Overhead Charge Rate	kW	184	370	370
Overhead Charging	Miles replenished per 10 min**	13	24	21
	Est. time empty to full at 450 kW	3 hrs	3 hrs	3.4 hrs
Plug-in Charging	Est. time empty to full at 120 kW	3.1 hrs	4.3 hrs	5.8 hrs
	Est. time empty to full at 180 kW	3 hrs	3.8 hrs	4.3 hrs

Figure 10.2: Proterra Bus Charging and Usage Specs - ZX5+ is in the second column

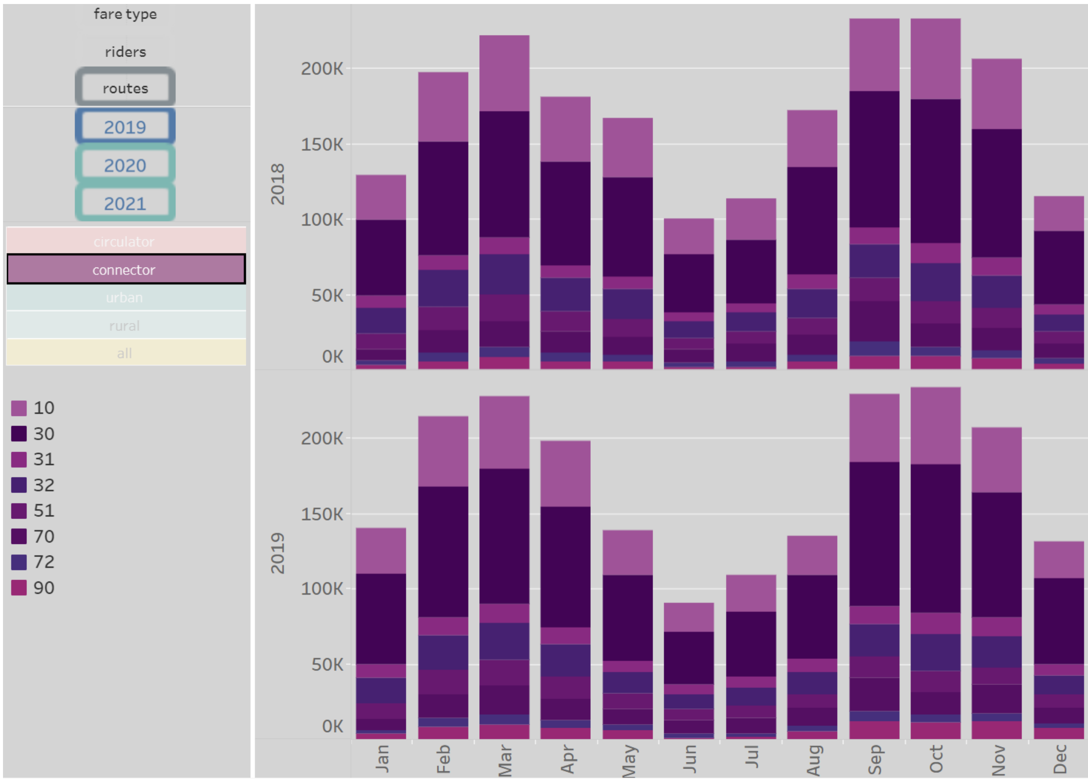


Figure 10.3: Connector Route Usage

Figure 10.4: Circulator Route Usage

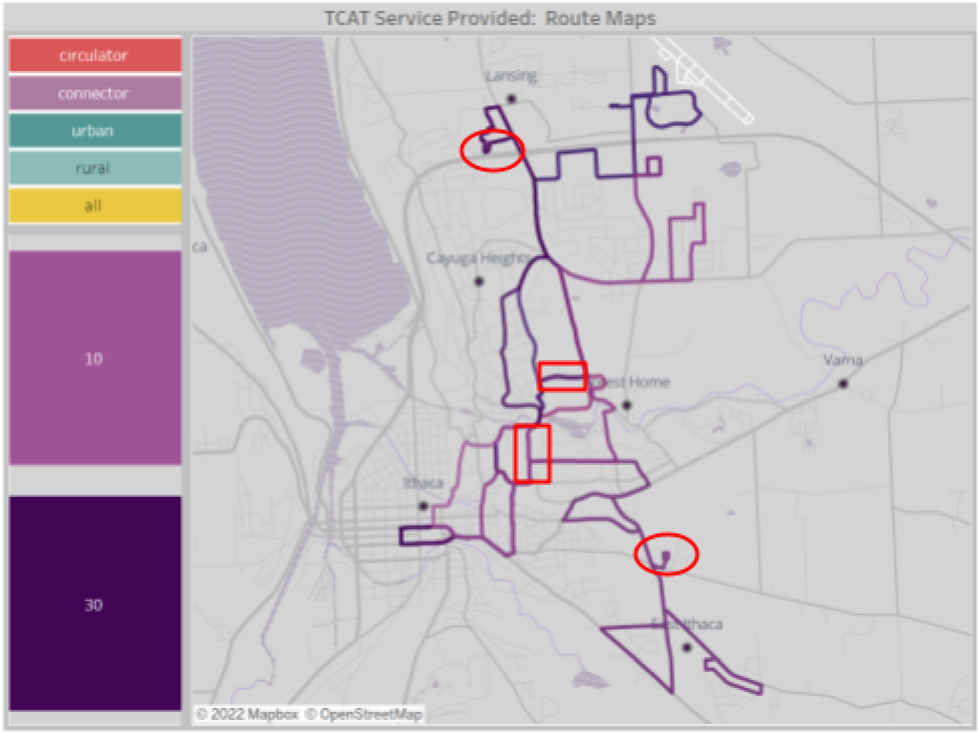


Figure 10.5: Circulator Routes and Potential Charger Locations (Pantographs in rectangles and Plug-In Charging in Ovals)

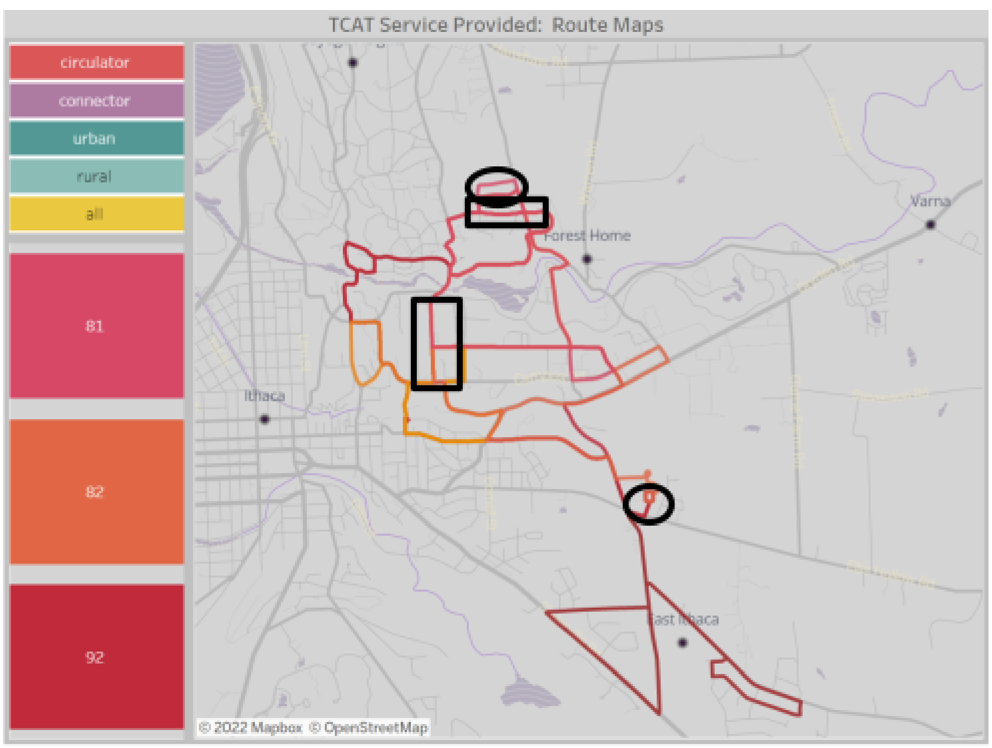


Figure 10.6: Circulator Routes and Potential Charging Locations (Pantographs in rectangles and Plug-In Charging in Ovals)

10.4 Conclusions

Pantographs cost around $300,000 each from the ground up, so these projects are not to be taken lightly. To reduce the cost, TCAT could start by purchasing the on-site pantographs and test their efficiency along with becoming familiar with any new nuances of this technology. Meanwhile, it would be best to install the off-site plug-in chargers - which can cost around $75,000 - in the A-lot, the P&C shops stop, East Green Street, and by the mall, by order of importance. After enough testing has been performed on the on-site pantographs, the best locations for off-site pantograph charging would be by RPCC, Goldwin Smith, Uris Hall, and possibly East Green Street (pantographs make a bit of noise so this option may not be possible) by importance according to the most used routes.

11. Appendix III: Bike Lanes and Small EVs

Survey Link:
https://qfreeaccountssjc1.az1.qualtrics.com/jfe/form/SV_aVQFLsZFRX6Zch0

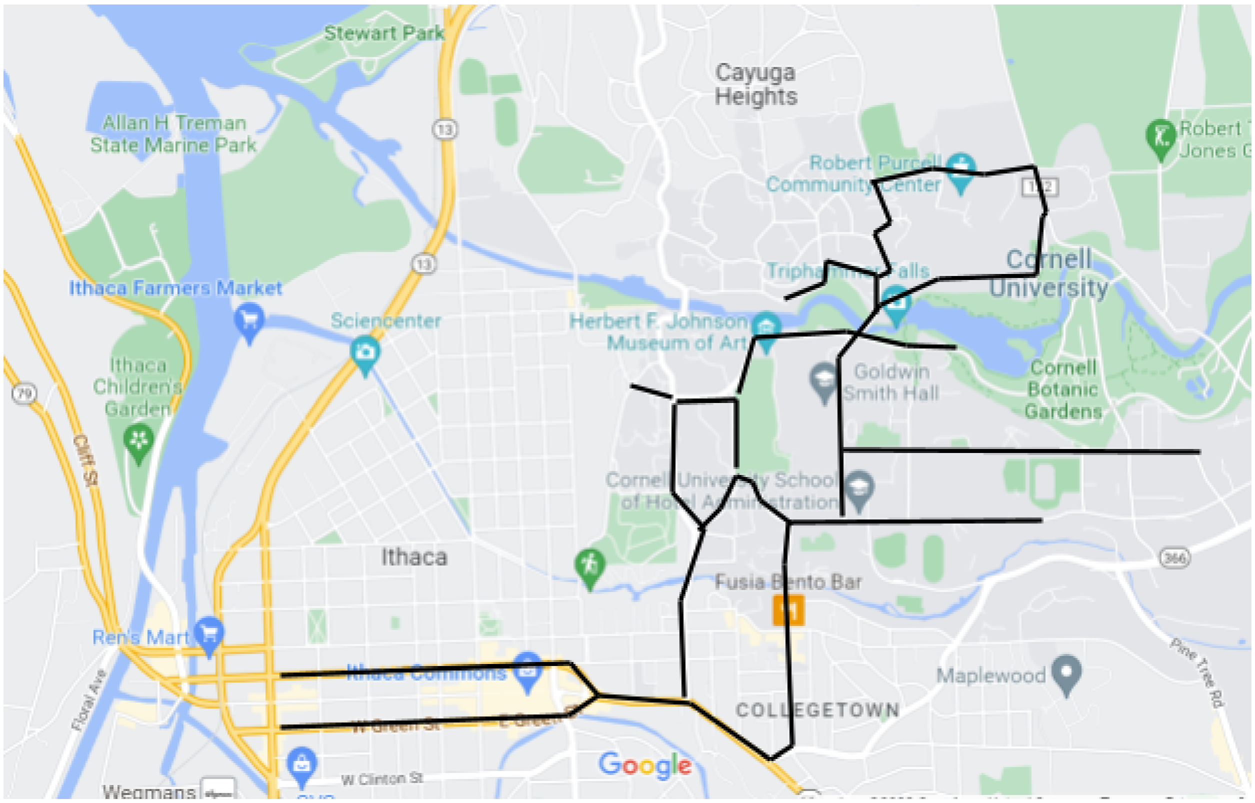


Figure 11.1: Proposed Bike Lanes for EVs and Manual Bikes according to Cornell Student Results

12. Appendix IV: EV Cost Benefit Analysis

12.1 Background

Cost Benefit Analysis is conducted so that the audience can weigh between electric vehicles and non-electric vehicles in a data-driven way to make decisions in a systematic way. This is intended to deliver various potential costs and benefits associated with transition to electric vehicles, which can help to uncover less-than-obvious factors, such as indirect or intangible costs.

12.2 EV Life Cycle Cost Analysis

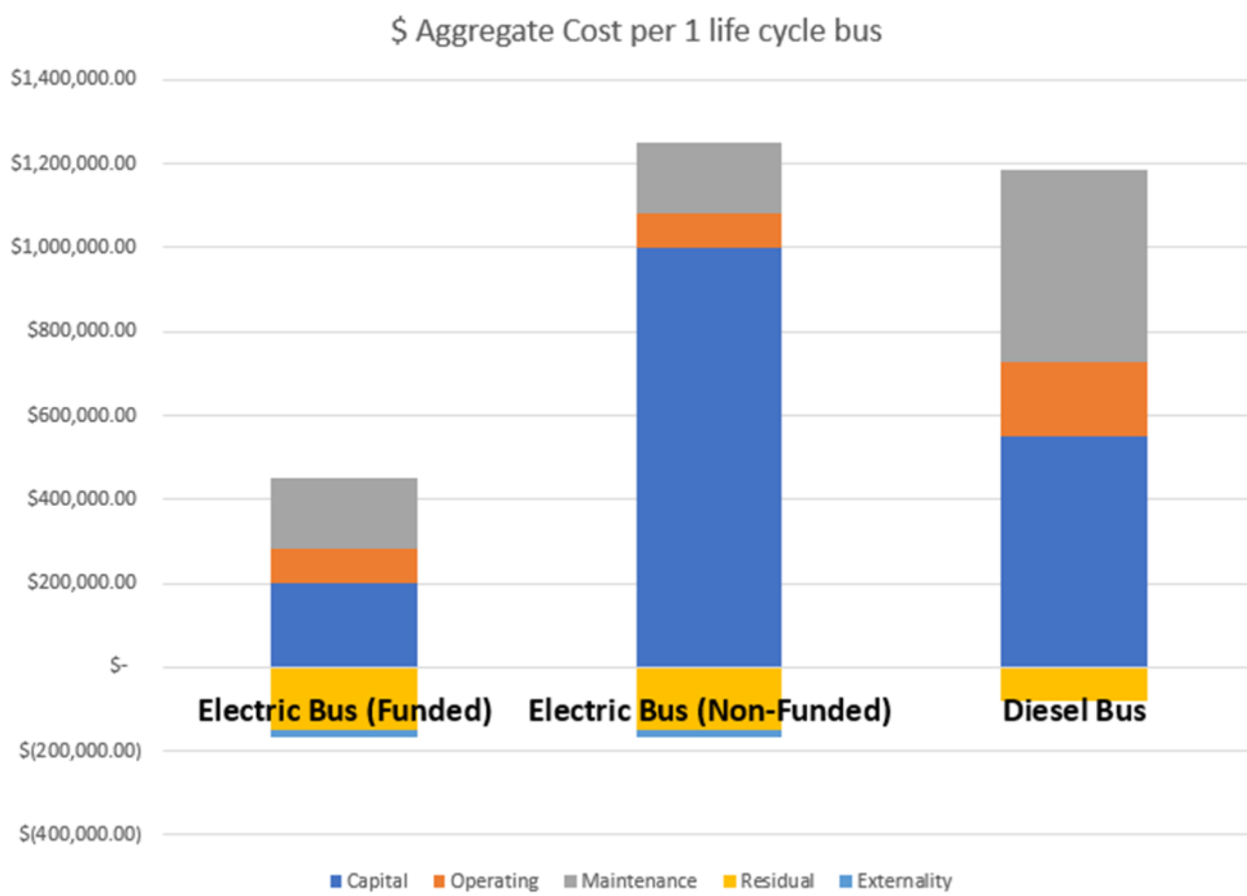


Figure 12.1: $ Aggregate Cost per bus by Life Cycle Stage

The "capital cost" category refers to the one-time expenditure that incurs at the purchase of the bus. According to a TCAT representative, each electric bus is purchased at $1 million (Feischman 2021) while the average diesel bus in the US costs about $550,000 (Aber, 2016). This capital cost for an Electric Bus (EB) can be greatly reduced with external funding which is usually about 80% of vehicle purchase expenditure for U.S. transit agencies (Tong, 2017). The “operating cost” category refers to the costs that are generated due to the operation of the business. In the US, most American transit systems expect their buses to have a useful life of 12 years and 250,000 miles (Mackechnie, 2019). Since this study was done in 2019 and we expect technological advancement, for this analysis, we will assume 300,000 miles and 12 years for each bus’s end of life. The operating cost of each diesel bus and the electric bus was calculated to be $0.59 per mile and $0.28 per mile respectively. (Horrox, 2019) Therefore, the life cycle operating cost of each diesel bus and the electric bus is calculated to be $177,000 and $84,000 respectively. The “maintenance cost” refers to the costs generated from possible repairing, replacements, functional checks, and machinery. The maintenance cost of each diesel bus and the electric bus was calculated to be $1.53 per mile and $0.55 per mile respectively. (Horrox, 2019) Assuming the same life cycle of each bus, the life cycle maintenance cost of each diesel bus and the electric bus is calculated to be $459,000 and $165,000 respectively.

The “residual cost” is the value of each bus after it has fully depreciated, which is after 12 years. Based on information from Bus Transport: Economics, Policy, and Planning, the residual value of a bus is 15%. (Johnson, 2020) For this purpose of analysis and simplicity, we will assume both electric bus and diesel buses were reclaimed immediately and all of the materials including steel, plastic, engine, and batteries are recycled. Additionally, assume the residual value of an EB to be the same as for a diesel bus in percentage and assume this includes the residual value of a battery. As a result, the residual values of each diesel bus and electric bus were calculated to be -$82,500 and -$150,000 respectively. According to Alexander, “Replacing one diesel bus with an electric one can reduce greenhouse gas emissions by 54,000 pounds each year. That’s the equivalent of 3.75 pounds of carbon dioxide for every mile driven.” (Alexander, 2022) Converting this into the total amount of carbon reduction under 12 years of life cycle, an electric bus can save about 324 tons of carbon emission. Such externality is usually not monetized, but there exists the social cost of carbon which Beckman acknowledges as “the main components are what happens to the climate and how these changes affect economic outcomes, including changes in agricultural productivity, damages caused by sea-level rise, and decline in human health and labor productivity.” (Beckman, 2021). The Biden administration estimates that this social cost of carbon is $51 per ton. Therefore, the external cost of an electric bus is -$16,524. The values of “residual cost” and “external cost” are negative, which means that these are subtracted from the aggregate cost per bus.

Table 12.1: $ Aggregate Cost per Bus with References

Category	**Electric Bus (Funded)**	**Electric Bus (Non-Funded)**	**Diesel Bus**	**References**
Capital Cost	$200,000.00	$1,000,000.00	$550,000.00	Fleischmann (2021), Aber (2016), Tong (2017)
Operating	$84,000.00	$84,000.00	$177,000.00	MacKechnie (2019), Horrox (2019)

Maintenance	$165,000.00	$165,000.00	$459,000.00	MacKechnie (2019), Horrox (2019)
Residual	$-150,000.00	$-150,000.00	$-82,500.00	Johnson (2020)
Externality	$-16,524.00	$-16,524.00		Alexander (2022), Beckman (2021)
Agg Cost (Sum)	$282,476.00	$1,082,476.00	$1,103,500.00	

12.3 Interpretation

As can be seen in Figure 1 and Table 1, the aggregate cost of a diesel bus is higher than the aggregate cost of an electric bus. Without the government funding, which is usually reported as 80% in the U.S., the difference in the aggregate cost of the two types of buses is not huge. However, with the funding, the difference becomes enormously large as the capital cost, which is the biggest cost, gets reduced by 80 percent. Nevertheless, it is important to note that the aggregate cost of an electric bus was still lower than the aggregate cost of a diesel bus even without government funding.

There are a few limitations of this study. As one may notice from the references listed in table 1, even though the majority of these are studies done by reliable organizations such as universities and public/government organizations, since they are all done separately with various methods and standards, these may be lacking in consistency. Additionally, for the aggregate cost of a funded electric bus, it is calculated based on the ideal assumption that full funding will be provided, but in reality, not every bus receives this much funding, and there exists variability. In order to account for some consistency, a few educational assumptions were set up as mentioned in the discussion above -for example, this study assumes the life cycle of a bus to be 12 years and 300,000 miles.

The completeness of this LCC provides logical extrapolation and gives a reader some proper insight into how an electric bus could be a better option both environmentally and economically. Since the purpose of this LCC was to obtain data and compare the total cost required by the two types of buses throughout their lifecycle, it can be concluded that the goal and scope were met.

12.4 Purchasing Incentives

New York State has developed many purchasing incentives for the consumption of electric vehicles as well as the construction and implementation of charging infrastructure. These aspects of electrifying Ithaca's transportation system go hand-in-hand as the increasing availability of charging stations will also motivate buyers to invest in electric vehicles.

The NYSEG Make-Ready program for businesses and contractors provides certain percentages of coverage on the development of L2 and Direct Current Fast Charging stations at one's respective business. This financial support offered by NYSEG covers the construction of electrical infrastructure, meters and service lines for the utility company, and readying the site for the installation of the charging stations. For a business or contractor to be eligible to participate in this program the location must be available to a large group of people whether it be a workplace or a common destination venue. Also, the infrastructure being installed must include two ports to be eligible for the program. The amount of financial support is determined by three factors: accessibility of the charging station, the plug type, and the community's demographics. Public locations with standardized plugs will receive the most coverage on installation of a charging station, up to 90%. If this criteria is not, the most a qualified business or contractor can receive in coverage is 50%. The development of charging infrastructure will receive up to full coverage of the installation process if the site is within a one mile radius of Disadvantaged Communities in service territories covered by Con Edison, Central Hudson, O&R, or RG&E or within 2 miles of these communities inside NYSEG or National Grid areas. A disadvantaged community is defined as a community with an annual median household income less than 80 percent of the statewide annual median household income. The program's distributed coverage is based on social factors to ensure the highest level of equity in their program as well as to reach the largest populations possible that would benefit the most from this program. The operation of electric vehicles tends to have lower energy costs compared to gas-powered vehicles and purchasing incentives for electric vehicles help to increase their affordability.

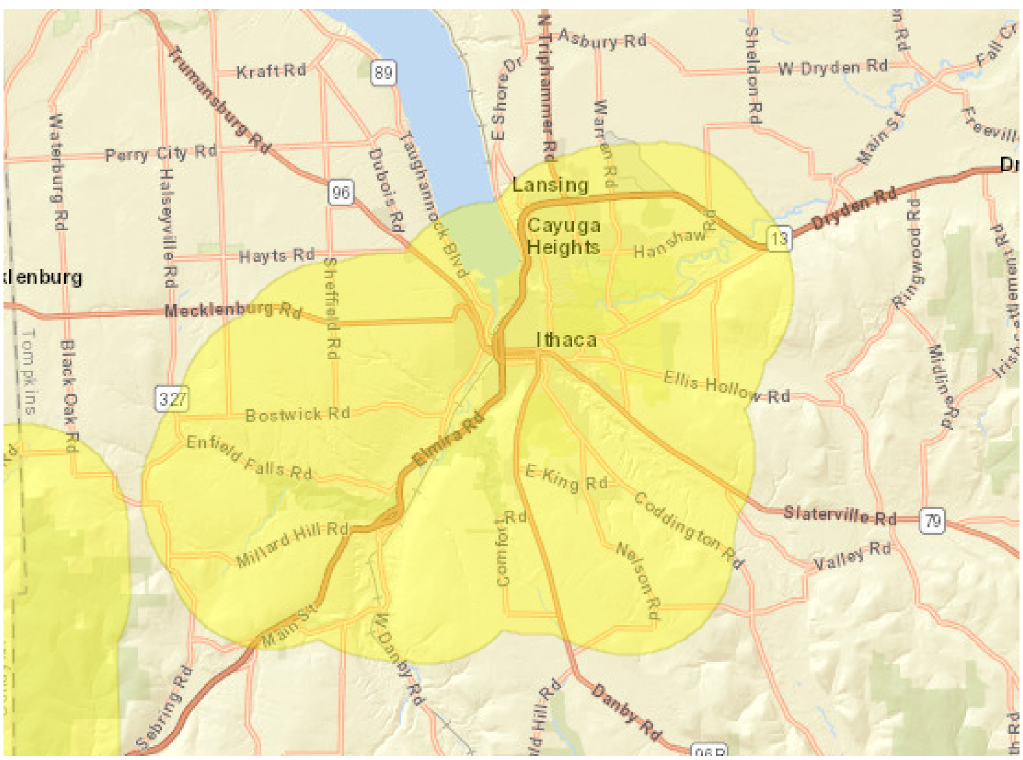


Figure 12.2: The highlighted area outlines the NYSEG disadvantaged community boundary for Ithaca, NY. (Source: RG&E Disadvantaged Communities Map)

New York State also offers a tax credit for public and workplace areas owned by businesses if they invest in alternative fueling infrastructure such as a charging station for these areas. The amount of credit received is determined by 50% of the cost of installing the charging property or $5,000 if it is greater than the $5,000 base value.

In the realm of electric vehicles for public transportation, the Low and No Emissions Grant aids with the transition of a local or state government's transit fleet from gas-powered to electric. This grant includes a total of $1.1 billion in available grant money for the 2022 year that can be used for the purchase of buses that emit lower or no emissions as well as improving the bus facilities to store the expanded fleet. Also, 1% of the grant awarded can be used for workforce development training. For zero-emission vehicles, 5% must be used for staff training. Some requirements with the grant include that the new buses purchased must be compliant with the Clean Air and/or the Americans with Disabilities Act and the federal grant must cover up to 85% of any new buses purchased and up to 90% of any improvements done to the bus facilities. Currently, TCAT has applied for this grant and they plan to use the awarded money toward expanding their electric bus fleet from 7 buses to 12 buses. The new buses TCAT will be receiving have a larger battery capacity.

An example of a purchasing incentive for electric vehicles is the NY Drive Clean Rebate Program. Buyers can participate in this program by purchasing qualifying electric vehicles at Maguire Dealership which has multiple locations in Ithaca and the surrounding Ithaca area. The higher the range of the battery, the higher the rebate the consumer will receive for the purchase of the electric vehicle. Along with the rebate on one's purchase, the consumer will also save money in the long term as there are fewer maintenance costs associated with owning an electric vehicle compared to a gas-powered vehicle and federal tax credits up to $7,500, except for Tesla models. This includes increased longevity of brake pads and the elimination of the need for an oil change. The federal tax credit for each electric vehicle purchased is broken down into components to determine how much money one earns for their vehicle purchase. If the vehicle is electric or hybrid, the buyer will receive $2500 automatically. Also, $417 will be included for a battery with at least 5 kilowatt hours worth of capacity and an additional $417 for each hour above the 5 kilowatt hour capacity.

At the state level, the New York State Power Authority has set aside $250 million for the next three years to be used toward installing more charging stations through its EVolve NY program. Their goal is to have at least 800 new EV fast charging stations that are compatible with most electric vehicles installed along major highways throughout New York, preferably near exits, by the end of 2025. Currently, 100 charging stations have been installed at intervals of 50 miles along the state's major highway routes. The program's next phase includes plans to work with public transportation fleets, make charging stations more available and, therefore, expand the use of electric transit vehicles.

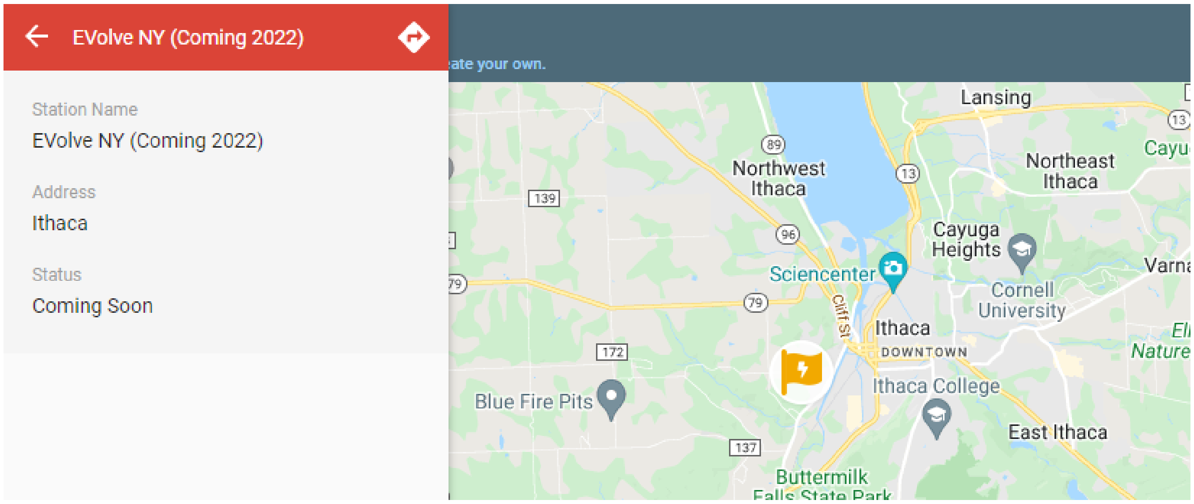


Figure 12.3: Location of a charging station planned to be installed in Ithaca, NY that is funded by the EVolve NY Program.

12.5 Fuel Pricing

Fuel pricing for electric vehicle chargers varies by charging station and vehicle type, but on average one charge event dispenses about \$1.00 of electricity to an EV at about 7.7 kWh for \$0.13 per kWh. With the mileage on EVs today, that means it could potentially cost less than \$40 to drive 1,000 miles (12).

Public access Level 2 charging stations rarely serve as an EV driver's primary source of electricity as this is done at home or work. Thus, while electric vehicle battery capacities can be as high as 20 kWh or even 60 kWh or higher for the newest 200-mile range EVs, the average energy dispensed per charge event for public stations in New York is only 6.6 kWh. At \$0.13 per kWh which is a typical electrical energy rate in Tompkins County, this is a cost of only \$0.86 per charge event. On average across New York State, public charging ports experience 2.5 charge events per week, so the average monthly electricity cost to operate a charging port is less than \$10 (13).

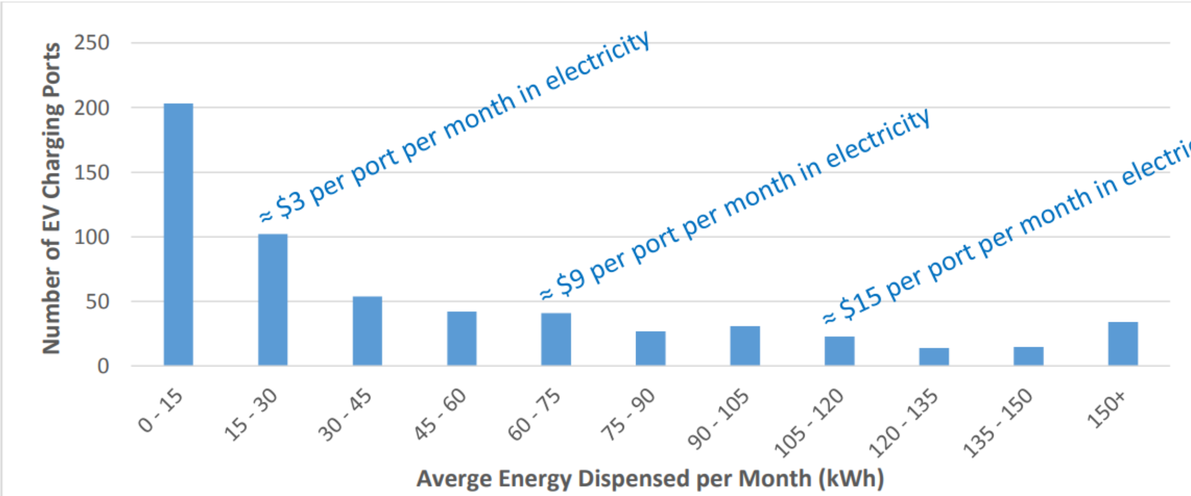


Figure 12.4. Electricity costs per charging port in 2015 for the stations in the NYSERDA Deployment Program (Source: [Charging Station Installation Analysis]())

For a residential charging station, Level 1 charging is recommended as it is best suited for overnight charging. For every hour the vehicle is charged, 3-4 miles of range are added to the battery's capacity as it utilizes a 120-volt charging cord. Due to its slower charging rate, Level 1 charging stations are the most affordable option for a single-household charging unit. A Level 2 charging station is also an option for residential charging that charges vehicles at a rate twice as fast as a Level 1 charger as it utilizes a 240-volt cable. This option is also suitable for public and workplace areas such as supermarkets, hotels, parks, and other places that the majority of the population frequent often. Level 2 charging stations are the most common and use a standardized plug that most electric vehicles should be compatible with. The most efficient charging stations are DCFC chargers which are analogous to the functions of a gas station. This type can achieve close to a full charge in under an hour. Due to its high speed charging, these stations are most likely to be found along major highways to support long road trips. A drawback to this type is that not all EV models are compatible with this type of charging.

In terms of charging rates for different locations of charging stations, EV users will most likely undergo their longest charging times at residential stations. EV users can purchase a single at-home charging station with an upfront cost of around $600 depending on the amount of charge generated by the station. Some stations are easier than others to install, can be weatherproofed for outdoor charging situations, and can be controlled by a smartphone to avoid peak times when charging to save money. As most people will likely undergo long charges outside of peak working hours, the best times to charge would be later in the evening or night when less electrical appliances are being used. When an EV is not at home and needs to charge their vehicle, businesses and public places can offer charging stations that support a short-term charge while the vehicle is not in-use.

12.6 Emissions

The costs of the impacts of electric vehicles are varied and not yet fully understood. Mainly, the costs of installing, implementing, and maintaining charging stations is the biggest issue. NYSERDA says that a Level 2 Charging Station costs somewhere in the ballpark of $3,000 - $14,000. Charge Ready New York covers the costs of the stations, however[48]. The City of Ithaca should be able to take advantage of this and virtually have all of their costs covered. By looking at our model of EVs in Ithaca, by 2025 Ithaca is expected to house around 2,100 electric vehicles, which is over 1,000 electric vehicles Ithaca currently has. Electric vehicles would also eliminate a significant amount of air pollution. Electric vehicles "can still reduce CO2 emissions by 60 percent compared with internal-combustion engines"[49]. Considering more than 20% of emissions come from vehicles, this would be a significant decrease in global emissions, and would improve air quality. Reducing air pollution "improves crop and timber yields,"[50] and it reduces "premature deaths and diseases from stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma."[51] Also, the Bipartisan Infrastructure Bill would allow additional funding to the City of Ithaca. With the U.S. federal government committing billions of dollars across the next few years, it is possible for Ithaca to gain further funding to help sustain the inevitable demand that Ithaca will feel[52].

Timeline	Values	Forecast	Lower Confidence Bound	Upper Confidence Bound
2017	202			
2018	310			
2019	620			
2020	849			
2021	1078	1078	1078.00	1078.00
2022		1291.4517	1193.19	1389.71
2023		1622.7174	1521.38	1724.05
2024		1777.4736	1673.11	1881.84
2025		2108.7393	2001.43	2216.05
2026		2263.4955	2153.28	2373.71
2027		2594.7612	2481.71	2707.81
2028		2749.5174	2633.66	2865.38
2029		3080.7831	2962.18	3199.38
2030		3235.5393	3114.22	3356.86
2031		3566.805	3442.82	3690.79
2032		3721.5612	3594.94	3848.19
2033		4052.8269	3923.61	4182.04
2034		4207.5831	4075.79	4339.38
2035		4538.8488	4404.53	4673.17

It is difficult to measure the full monetary extent that reducing pollution would completely do for Ithaca. Considering Ithaca is still a pretty rural city, a city with a population under 100,000, reducing pollution with the implementation of EVs would be significant however tough to measure monetarily. However the environmental impact is immeasurable. It is clear that we can no longer support our current way of life, so it is imperative that Ithaca takes the steps to prepare for a city that is less dependent on fossil fuels. The demand for charging stations will

48 "Charge NY," NYSERDA, accessed May 20, 2022, https://www.nyserda.ny.gov/All-Programs/ChargeNY/Charge-Electric/Charging-Station-Programs/Charge-Ready-NY/Installing-a-Charging-Station.

49 "3 Ways That Cities Can Unlock the Benefits of Electric Vehicles," Greenbiz, accessed May 20, 2022, https://www.greenbiz.com/article/3-ways-cities-can-unlock-benefits-electric-vehicles.

50 "Progress Cleaning the Air and Improving People's Health," EPA (Environmental Protection Agency), accessed May 20, 2022, https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health.

51 "Better Air for Better Health," World Health Organization (World Health Organization), accessed May 20, 2022, https://www.euro.who.int/__data/assets/pdf_file/0019/341137/Fact-Sheet-10-Better-air-for-better-health.pdf.

52 Casey Murphy, "Electric Vehicle Infrastructure Impact: How Is the Infrastructure and Jobs Act Rollout Going?," Investopedia (Investopedia, May 4, 2022), https://www.investopedia.com/electric-vehicle-infrastructure-impact-5220675.

rise, and Ithaca must be ready to support it. Supporting sustainable change is important, as it will improve the health of the residents of Ithaca, as well as the environment.

12.7 Results and Conclusion

There is growing evidence that public transit systems have made the most progress in implementing new technologies toward achieving sustainable goals in transportation. Public transportation companies are more likely to transition to more sustainable methods of transport as the fuel benefit cost they will receive from this switch are amplified by their high mileage levels and fuel efficiency (Tong, 2017). As many of these changes are supported with grant funds and many public transit companies are state run, they are required to uphold higher standards than privately owned transit companies. For example, NYC’s Bus Transit System has a partnership with the NYPA (10) which has pushed them along to reach the Transit’s goal of providing a fleet of zero-emissions buses by 2040. Since many of these buses provide the main method of transportation for lower-income community, providing buses with lower emissions will have health benefits, due to improved air quality, for these communities that tend to have higher respiratory illness rates as well, according to a New York Times Article “Poor Americans More Likely to Have Respiratory Problems, Study Finds”(11). As a result, the social cost to providing more sustainable means of transportation will also be positively reflected in a community’s overall health levels.

13. Appendix V: Retrofit Brochures

13.1 Historical Archetype Brochures

Lighting/Plugs/Appliances

ENERGY SAVINGS: ★★☆☆☆
COMPLETION TIME:
COST: $$$$$

Description: LEDs and ENERGY STAR appliances use less energy than their typical counterparts, and smart plugs reduce equipment loads when the spaces are empty. Programmable thermostats automatically regulate your building's temperature.

Benefits: Upgrading lighting, appliances, and equipment are quick and easy ways to lower your building's carbon footprint!

Recommendation: Setting a heating schedule with a programmable thermostat is is a great way to reduce your building's energy usage without impacting it's historical integrity!

Financial Incentives

- If your building is being used for commercial purposes, NYSEG's Commercial and Industrial (C&I) Rebate Program offers a variety of rebates for energy-efficiency equipment, including thermostats, lighting, and appliances.

Ithaca's historic buildings are a reminder of our past and contribute to the personality and beauty of the city. However, they are often energy inefficient, which is harmful to the environment because it increases Ithaca's carbon footprint. Ithaca passed its Green New Deal in June of 2019 with the aim of achieving community-wide carbon neutrality by 2030. While doing this in less than 10 years seems like a daunting task, it is possible with the implementation of proper green building updates—typically referred to as retrofits. Read about how you can retrofit your historic building to save money and help make a green Ithaca for everyone!

Why should I make my building more efficient?
Increasing efficiency can save you thousands of dollars and pay back the upfront costs many times over in the long term. It can also make your building safer and less harmful to the environment.

What local resources are available if I have more questions?
Taitem Engineering (taitem.com, 607.277.1118) performs energy audits across Tompkins county. Halco Energy (halcoenergy.com, 315.279.3003) offers a variety of commercial energy upgrades including renewable energy, HVAC, plumbing services, electrical services and more! For more information, contact Cornell Cooperative Extension or visit smartenergychoices.org.

Made by Cornell University Sustainable Design

DO YOU OWN A HISTORICAL BUILDING IN ITHACA?

Here's how to preserve its historic identity while reducing your energy use and saving money!

Air Sealing & Insulation

ENERGY SAVINGS: ★★★★★
COMPLETION TIME: ◷◷◷◷○
COST: $$$

Description: Sealing and insulating a building's 'envelope' (including its outer walls, ceiling, windows, and doors) reduces heating and cooling demand.

Benefits: Fewer leaks mean your heating and cooling systems use less energy to regulate your building's temperature. Sealing your envelope with improve air quality, provide more comfort, and stop drafts, so you're able to stay warmer in the winter and cooler in the summer!

Recommendation: Replacing windows is often not possible in historic buildings, so sealing existing windows with good insulation in their seams is a great way to reduce energy use!

Heating & Cooling

ENERGY SAVINGS: ★★★★☆
COMPLETION TIME: ◷◷◷○○
COST: $$$$

Description: Heat pump systems use electricity to move heat from a cool space to a warm space. Air Source Heat Pumps transport heat from the outside air, and Ground Source Heat Pumps transport heat from the ground.

Benefits: Heat pump systems provide not only heating for the cold Ithaca winters, but also air conditioning for Ithaca's sunny days!

Recommendation: Installing an air source heat pump will maintain your historic building's aesthetic while saving money and energy; you would only see a grille or lourve on the outside wall!

Financial Incentives

- Ground source heat pumps:
  - NYSEG rebates of $1,500 per 10,000 Btuh/hr
- Air source heat pumps:
  - NYSEG rebates of $1,000 per 10,000 Btuh/hr
- NYSERDA's Green Jobs Green New York program provides money for an energy study to determine whether heating/cooling upgrades are right for your building!

Hot Water

ENERGY SAVINGS: ★★★☆☆
COMPLETION TIME: ◷◷◷○○
COST: $$$

Description: Heat pump water heaters use electricity to move heat from a cool space to a warm space without using fossil fuels (i.e. gas).

Benefits: Heat-pump water heaters are 2-3 times more efficient than conventional heaters, so they save you energy and money!

Recommendation: If your historic building uses lots of hot water, consider installing a heat-pump water heater to save energy! This will not impact the structure or aesthetics of your building.

Financial Incentives

- NYSEG provides rebates of $80 per MMBTU of annual energy savings for Air Source heat-pump water heaters that hold more than 120 gallons of water.

13.2 Residential Archetype Brochures

Lighting/Plugs/Appliances

ENERGY SAVINGS: ★★☆☆☆
COMPLETION TIME:
COST: **$$**$$$

Description: LED lights and ENERGY STAR appliances use less energy than their typical counterparts, and smart plugs reduce equipment loads when the spaces are empty. Programmable thermostats automatically regulate your building's temperature when you're home, asleep, or away.

Benefits: Upgrading lighting, appliances, and equipment are quick and easy ways to lower your home's carbon footprint!

Recommendation: Turning your thermostat back 10-15% for 8 hours can save you 10% on your heating/cooling bills, and installing ENERGY STAR appliances can save you about $575 on your annual energy bills!

In 2019, Ithaca passed its Green New Deal to achieve community wide carbon neutrality by 2030. To achieve this goal, we have to improve the energy efficiency of our buildings, which are responsible for over 50% of greenhouse gas emissions in Ithaca! By installing retrofits, or updating certain equipment/ structures in your own home, you can lower your carbon footprint and save both energy and money. Read about how you can retrofit your home to help make a cleaner and greener Ithaca for everyone!

DO YOU OWN A HOME IN ITHACA?

Here's how to increase your home's comfort and energy-efficiency while saving money!

Local Resources

- The Finger Lakes Climate Fund provides grants for income-eligible homeowners of up to $2,500.
- Snug Planet (snugplanet.com, 607.277.7684) performs energy audits and installs retrofits in homes across Tompkins County!
- HeatSmart Tompkins (solartompkins.org, 607.500.4328) is an incredible resource for heating and energy information!
- For more information, contact Cornell Cooperative Extension or visit smartenergychoices.org.

Made by Cornell University Sustainable Design

Air Sealing & Insulation

ENERGY SAVINGS: ★★★★★
COMPLETION TIME: ◷◷◷◷◷
COST: $$$$$

Description: Sealing and insulating a building's envelope (its outer walls, ceiling, windows, and doors) reduces heating and cooling demand by closing up the holes that let your regulated air leak out.

Benefits: Fewer leaks mean your heating and cooling systems use less energy to regulate your building's temperature. Sealing your envelope will improve air quality, provide more comfort, and stop drafts, so you're able to stay warm in the winter and cool in the summer!

Recommendation: Air seal and add insulation to your home to save (on average) 18% of heating/cooling costs or 14% of your total energy costs annually!

Financial Incentives

- EmPower NY can provide up to $10,000 in grants for insulation and air sealing for income-eligible households.
- The Assisted Home Performance program can provide up to $5,000 in matching funs for insulation and air sealing for higher income households.

Heating & Cooling

ENERGY SAVINGS: ★★★★☆
COMPLETION TIME: ◷◷◷◷◷
COST: $$$$$

Description: Heat pump systems use electricity to move heat from a cool space to a warm space. Air Source Heat Pumps transport heat from the outside air, and Ground Source Heat Pumps transport heat from the ground.

Benefits: Heat pump systems provide not only heating for the cold Ithaca winters, but also air conditioning for Ithaca's sunny days!

Recommendation: Installing heat pumps can lead to savings of up to $900 (air-source) or $1,500 (ground source) when compared to oil-fueled systems!

Financial Incentives

- Ground source heat pumps have a 26% federal tax credit, and NYSEG provides rebates of $1,500 per BTUh
- Air source heat pumps have a $300 tax credit for ENERGY STAR qualified equipment, and NYSEG provides rebates of $1,000 per BTUh

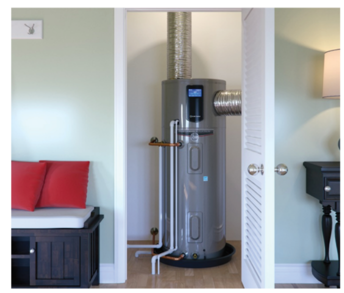
Domestic Hot Water

ENERGY SAVINGS: ★★★☆☆
COMPLETION TIME: ◷◷◷◷◷
COST: $$$$$

Description: Heating your water takes up about 18% of your home's energy usage! Heat pump water heaters use electricity to move heat from a cool space to a warm space without using fossil fuels (i.e. gas).

Benefits: Heat-pump water heaters are 2-3 times more efficient than conventional heaters, so they save you energy and money!

Recommendation: Consider installing a heat-pump water heater to save energy and $350 per year when your replace your conventional electric unit!



Financial Incentives

- Through NYSEG, you can save up to $1,000 by purchasing a qualifying heat-pump water heater.

13.3 Commercial Archetype Brochures

Financial Incentives

- New York State's Green Jobs Green New York Program provides financial support for completing an energy study to identify and evaluate opportunities to reduce energy costs and incorporate clean energy into capital planning.
- A tax deduction of up to $1.80 per square foot is available to owners of commercial buildings that demonstrate a 50% reduction in energy usage accomplished solely through improvements to the heating, cooling, ventilation, hot water, and interior lighting systems.

Local Resources

- NYSEG provides eligible small businesses with free energy assessments and up to 70% of the cost of recommended equipment upgrades.
  - nyseg.com
  - 877.359.9814
- NYSEG's Commercial and Industrial (C&I) Rebate Program offers a variety of rebates for energy-efficient projects.
  - nyseg.com
  - 888.316.8023
- Taitem Engineering performs energy audits across Tompkins County.
  - taitem.com
  - 607.277.1118
- Halco Energy offers a variety of commercial energy upgrades including renewable energy, HVAC, plumbing services, electrical services and more.
  - halcoenergy.com
  - 315.279.3003

Ithaca passed its Green New Deal in June of 2019 with the aim of achieving community-wide carbon neutrality by 2030. While doing this in less than 10 years seems like a daunting task, it is possible with the implementation of proper green building updates—typically referred to as green retrofits. This is because Ithaca's buildings are responsible for over 1/2 of greenhouse gas emissions! This pamphlet includes information about how you can retrofit your business to not only make a greener Ithaca but also help your business become more efficient!

Why Retrofit?

- Retrofitting your business can help you significantly cut back on your utility costs by reducing your energy and operating costs, which can then be invested back into your business.
- Facilitating a green business can improve your employees' health, productivity, and satisfaction. It can also improve the value of your property. Customers also show greater loyalty when they know that a business is invested in the wellbeing of the community.
- Switching to more sustainable business practices also means less frequent repair and maintenance is needed. This could cut back on your costs in the long run!

Made by Cornell University Sustainable Design

DO YOU OWN A BUSINESS IN ITHACA?

Here's how to upgrade your business' building, reduce your energy use, and save money!

Air Sealing & Insulation

ENERGY SAVINGS: ★★★★★
COMPLETION TIME: 4 of 5 clocks
COST: $$$ (of $$$$$)

Description: Resealing the "envelope" of your business environment, such as the outer walls, ceiling, windows, and doors, can significantly improve its energy performance while also improving the interior air quality. Properly sealing the windows and doors can stop drafts and allow the business space to be cooler in the summer and warmer in the winter.

Benefits: Upgrading your building's envelope improves interior air quality and provides comfort all year round!

Heating & Cooling

ENERGY SAVINGS: ★★★★☆
COMPLETION TIME: 3 of 5 clocks
COST: $$$$ (of $$$$$)

Description: Installing a heat pump is one of the most powerful steps you can take to reduce your building's energy use. This is because heat pump systems use electricity, instead of natural gas or coal, to move heat from a cool space to a warm space. There are two types of heat pumps (air-source and ground-source), and the right choice depends on your building. Air-source heat pumps transfer heat between your building and the outside air, and ground source heat pumps transfer heat between your building and the ground.

Benefits: Heat pump systems provide not only heating for the cold Ithaca winters, but also air conditioning for Ithaca's sunny days!

Financial Incentives
- Ground source heat pumps:
  - NYSEG rebates of $1,500/10,000 Btuh
- Air source heat pumps:
  - NYSEG rebates of $1,000/10,000 Btuh
- For large commercial buildings (with a > 300,000 BTUH heating load):
  - NYSEG rebates of $80/MMBTU of annual energy savings

Lighting/Plugs/Appliances

ENERGY SAVINGS: ★★☆☆☆
COMPLETION TIME: 2 of 5 clocks
COST: $$ (of $$$$$)

Description: Install LEDs in light fixtures, use ENERGY STAR appliances, and use smart plugs to reduce equipment loads when the spaces are unoccupied. It is also recommended to install a programmable thermostat that saves energy by automatically regulating your building's temperature when you're during and outside of business hours!

Benefits: Efficiency upgrades to lighting, appliances, and equipment are quick and easy ways to lower your building's carbon footprint!

Hot Water

ENERGY SAVINGS: ★★★☆☆
COMPLETION TIME: 3 of 5 clocks
COST: $$$ (of $$$$$)

Description: If your business uses a lot of hot water, that takes up a significant proportion of your building's energy use. Instead of a fossil-fuel based system that generates heat directly, heat-pump water heaters use electricity to move heat from a cool space to a warm space.

Benefits: Heat-pump water heaters are 2-3 times more efficient than conventional heaters!

Financial Incentives
- Air-Source heat-pump water heaters (above 120 gallons of tank capacity):
  - NYSEG rebates of $80/MMBTU of annual energy savings

14. Appendix VI: Building Energy Performance Standards Case Studies

14.1 City Case Studies

Boulder, CO established its own rental licensing program in 2010. Called the SmartRegs program, it adds to an existing rental licensing program in which every unit is required to obtain a license. If the City of Ithaca has or creates a similar licensing program, it can consider adding energy efficiency standards to it. It mandates that property owners comply with a set of energy efficiency standards, in addition to health and safety measures, and that they undergo inspections every four years.[53] To be in compliance, the property owner must "achieve a score of 120 or better through the Home Energy Rating System (HERS), a nationwide scoring system; or (2) achieve at least 100 points on a prescriptive scoring checklist the City of Boulder developed based on energy and carbon savings for specific measures."[54] Since its implementation, Boulder, CO has been successful in reducing its energy consumption: by 2018, it was estimated that the City reduced 1.9 million kWh in electricity, 460,000 therms of natural gas, $520,000 in energy costs, and 3,900 million metric tons of CO2. The average upgrade cost was $3,022 per unit, with rebates covering around 20% of the total cost.

Gainesville, FL established a similar program in 2018, following the rental licensing program format of Boulder, CO. This program is notable because it was created through the Alachua County Labor Coalition, a broad group of members who "helped offer some of the energy efficiency standard recommendations and put together the new ordinance while collaborating with City and County commissioners, landlords and renters."[55] The City also established a housing subcommittee with landlords and renters where they eventually brought forth seven recommendations to the City Council.

This program stipulates quite manageable and low cost energy efficiency upgrades such as attic insulation, sealing visible duct joints, and efficient plumbing fixtures.[56] Because the program was implemented so recently, not enough data has been collected to understand the effects of these new standards. However, the City of Ithaca can look to Gainesville for an example of crafting policy with direct input from its community members.

Burlington, VT has also recently established a minimum energy efficiency standard for its rental units. Burlington has similarities with Ithaca, including their cold climates, so it may be wise for the City of Ithaca to look to Burlington for the specific kind of energy efficiency

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[53] Steven Nadel and Adam Hinge, "Mandatory Building Performance Standards: A Key Policy for Achieving Climate Goals" (Washington D.C.: American Councik for an Energy-Efficient Economy, June 2020), 7, https://www.aceee.org/sites/default/files/pdfs/buildings_standards_6.22.2020_0.pdf.
[54] Ibid.
[55] Charlene Medders, "City of Gainesville Adopts New Rental Ordinance, Takes Effect in October," *WUFT News*, April 26, 2021, https://www.wuft.org/news/2021/04/26/city-of-gainesville-adopts-new-rental-ordinance-takes-effect-in-october/.
[56] "Rental Housing Permits & Fees," City of Gainesville, accessed May 5, 2022, http://www.cityofgainesville.org/CodeEnforcement/RentalHousingPermitsFees.aspx.

standards to implement. While it did not adopt a rental licensing program unlike Boulder or Gainesville, its program focuses on weatherization. This consists of sealing up drafts to prevent heat loss, as well as other measures to better insulate the home.[57] Similar to Gainesville, Burlington just passed its weatherization ordinance, so it is difficult to determine the program's effectiveness in reducing overall greenhouse gas emissions.

In terms of financing, the City of Ithaca must arrange provisions for a comprehensive set of incentives, rebates, and other mechanisms to help with financing such upgrades in its building stock. We can look to Burlington VT as an example of the different options the City of Ithaca could provide to property owners. Vermont Gas Systems currently provides rebates that cover between 50-75% of the total costs up to a certain amount.[58] VGS has also partnered with a local credit union to secure special financing for weatherization upgrades. The City of Burlington also hosts a number of other rebates on energy efficiency technologies, and they have committed themselves to cover the full costs of upgrades for affordable housing providers and providing expanded rebates to their low and moderate-income customers.[59]

More generally, it may be worth looking into residential PACE financing to assist with the costs of retrofits in all residential properties, but some of the issues concerning PACE are well warranted, such as the increased risk of foreclosure. Further research into policy solutions to address the pitfalls of PACE would be recommended to see if PACE is a viable financing option for the City of Ithaca. As of now, however, the City of Ithaca is committed to climate and economic justice and currently plans on covering the costs of retrofits for a number of low and moderate-income households.

14.2 Building Rating System Case StudiesI

LEED is the globally recognized leader and most used green building certification system in the world.[60] The system exists for all building types and phases, where projects go through a verification and review process on adhering to prerequisites to be assigned a tier of platinum, gold, silver or certified. However, LEED is very costly and therefore has discouraged many federal agencies from pursuing certification. Additionally, certification can take around a year while another year of post-certification monitoring is also required. Furthermore, the certification is only good for 5 years creating the need to apply for recertification, increasing costs and time invested. [61] Moreover, LEED for existing buildings requires all buildings to have an Energy Star rating of 69, which needs to be tracked for a minimum of 12 months before it can apply for certification, further elongating the process. Finally, unlike LEED for new construction,

[57] "Minimum Housing Code Weatherization Ordinance," Burlington Electric Department, accessed May 5, 2022, https://www.burlingtonelectric.com/weatherization-ordinance/.
[58] "Residential Energy Audit & Weatherization," Vermont Gas Systems, accessed May 5, 2022, https://vgsvt.com/savings/residential-energy-services/energy-audits-weatherization/.
[59] "Green Stimulus – Burlington Electric Department," Burlington Electric Department, accessed May 5, 2022, https://www.burlingtonelectric.com/greenstimulus.
[60] USGBC. 2022. "LEED rating system | US Green Building Council." USGBC. https://www.usgbc.org/leed.
[61] PDH Academy. 2018. "What You Need to Know About LEED for Existing Buildings." PDH Academy. https://pdhacademy.com/2018/05/30/what-you-need-to-know-about-leed-for-existing-buildings/.

certification can not be accomplished through an outside consultant. It requires direct consent and involvement of agency stakeholders including tenant agencies and units, building operations staff, janitors and base engineers creating more obstacles a homeowner would have to go through to certify their buildings.[62] Therefore, due to these drawbacks LEED certification would not be applicable for use on existing buildings in Ithaca as a result of the long certification process, high and rising costs and the bureaucracy involved in the process.

PassivHaus is a certification system that focuses on the design process integrated with architectural planning. Its uses have principally been limited to new buildings but has also been used on existing buildings.[63] Similar to LEED, the focus is primarily on reducing the negative effects of building operations by using climate data to determine specific performance criteria. These assessments are performed by PassivHaus US raters or verifiers who determine if the building passes the criteria. Overall, to meet PassivHaus requirements, a fundamental shift in building approach is required, to design and construct a home along Passive standards. This makes it problematic to use for existing buildings due to fundamental differences in building design, hence the greater application for new constructions.

Green Globes is an online nationally recognized green building rating and certification system based on BREEAM, the Building Research Establishment Environmental Assessment Method, the world's first and oldest established method of assessing and certifying the sustainability of buildings.[64] LEED and multiple other building rating systems were also developed using BREEAM as a foundation. Green Globes standard for existing buildings was developed in 2000 and undergoes periodic updates to account for the latest updates in sustainability. It is a structured self-assessment using a questionnaire and the knowledge of building owners to produce sustainable designs and recommendations. [65] In 2017 the company was acquired by GBI, the Green Building Initiative who administer the certification. After the questionnaire has been filled out, a third-party assessor will travel to the building and complete the assessment, where the homeowner will receive a final report with rating, certificate and suggested improvements. The Green Globes rating system works on a scale from 1 to 4 Globes, where 4 globes represent 85-100% of the predetermined requirements have been met.[66]

[62] Leising, Luke. 2010. "LEED for Existing DOD Buildings." The Military Engineer 102 (665): 62-64. https://www.jstor.org/stable/44532101.
[63] Breck Life Group. n.d. "What is a Passive House and How is it Made?" Breck Life Group. Accessed May 17, 2022. https://www.thebrecklife.com/passive-house-sustainability-guide/#Passive_House_Construction_and_Design_Features.
[64] BREAAM. n.d. BREEAM - Sustainability Assessment Method. Accessed May 4, 2022. https://www.breeam.com/.
[65] Green Globes Building Certification. 2021. "About Green Globes." Green Globes. https://www.greenglobes.com/about.asp.
[66] Green Building Initiative. 2022. "How To Certify." Green Building Initiative. https://thegbi.org/green-globes-certification/how-to-certify/.

15. Appendix VII: Detailed Hydrogen Information

15.1 Extended Technical Information

Wind and solar can both create large amounts of electricity, but only when it is windy or sunny, so it is difficult for renewable sources to keep up with periods of peak demand. During periods of low demand, surplus renewable electricity can be used to power an electrolyzer to produce green hydrogen. A polymer electrolyte membrane (PEM) electrolyzer would best suit the City of Ithaca's needs when used with excess renewable energy. PEM electrolysis has lower minimum load requirements and greater flexibility, enabling it to run only when needed. The hydrogen can then be compressed and stored in tanks. When energy demand is high, the stored hydrogen can be burned in a combined cycle gas power plant or used in fuel cells to produce zero greenhouse gas electricity for the grid.

While the burning of hydrogen does not result in any carbon emissions, it can generate nitrous oxide emissions which contributes to acid rain[67]. More research is required to determine the best way to minimize NOx emissions to a level that is safe in Ithaca.

Another method to store and convert hydrogen to electricity is through hydrogen fuel cells. Two types of fuel cells currently available include solid oxide fuel cells (SOFC) and proton exchange membrane fuel cells (PEMFC). SOFCs are more efficient and can run at larger capacities, but there are currently few suppliers available who sell them. There are companies working on hydrogen SOFCs, but a commercial solution will likely not be available in the next decade. PEMFCs are much smaller and lighter than SOFCs and are thus generally used for mobile applications such as cars and trucks. They use pure hydrogen as fuel in order to produce electricity. Due to their smaller size, PEMFCs are not commonly used for stationary applications, although this may change as technology improves. More research can be done on the feasibility of hydrogen fuel cells in Ithaca in upcoming semesters, but for now the analysis focuses mainly on burning hydrogen in turbines.

15.2 Detailed Cost Analysis

Production of green hydrogen through electrolysis requires inputs of electricity and water, as well as an electrolyzer. More research is required to determine the exact capacity needed for an electrolyzer, but for now we will consider a 5 MW capacity as a low estimate and a 20 MW capacity as a high estimate. CAPEX for PEM electrolyzers is measured as dollars per kW of capacity and is generally lower for higher capacities. OPEX is measured as a percentage of CAPEX and estimates the annual operating and maintenance costs. See the figure below for total CAPEX and annual OPEX estimates.

[67] Ben Emerson and Tim Lieuwen, "Hydrogen substitution for natural gas in turbines: Opportunities, issues, and challenges," POWER Engineering, last modified June 18, 2021, https://www.power-eng.com/gas/hydrogen-substitution-for-natural-gas-in-turbines-opportunities-issues-and-challenges/#gref.

Inputs for hydrogen production are electricity and water. Since only excess electricity from renewable sources is being used, the cost of electricity is considered to be $0. A kilogram of H2 requires approximately 9L of water[68], so assuming a utilization rate of 25%, between 5,000 to 20,000 liters of water will be required daily (for 5MW and 20MW respectively). More research is needed to determine the cost and availability of water in Ithaca at that scale.

The levelized cost of hydrogen (LCOH) is a measure of the average cost per kilogram of hydrogen produced through electrolysis. It takes into account many variables, but is mainly impacted by electrolyzer CAPEX, electrolyzer utilization rate, and electricity cost. Higher utilization rates and lower CAPEX (as $/kW of capacity) and electricity costs result in a lower LCOH. Current estimates put the LCOH at between $2 to $4 per kilogram[69], which converts to an energetic equivalent cost of $17.55 to $35.10 per MMBTU. This can be compared to natural gas prices, which have historically been between $2.50 to $4.50 per MMBTU, but is currently over $7 per MMBTU. Despite abnormally high natural gas prices, green hydrogen is still not yet cost competitive. However, electrolyzer technology and efficiency is expected to rapidly improve in the coming years as the global demand for green hydrogen increases. Government policy also plays a key role, and current proposed US legislation includes a production tax credit of $3 per kg of near-zero emission hydrogen production[70]. With improvements in technology and favorable tax credits, the LCOH could decrease drastically within the next decade, with some estimates putting the cost at under $2 per kilogram.

Once hydrogen is produced, it can be compressed and stored until needed. To convert the hydrogen back into electricity during periods where the supply of renewable energy can not meet demand, it can be burned in a gas turbine. The size and configuration of the turbine depends on its intake of hydrogen, which in turn depends on the size of the electrolyzer and its utilization rate. Much more research is required to determine the timing and amount of surplus renewable energy that will be generated and potentially turned into hydrogen. One turbine that serves as an example of what may fit Ithaca's needs is the General Electric LM25000+G4 DLE (60 Hz) turbine configured as a 2x1 combined cycle. This turbine is capable of running on 100% hydrogen and its flexibility allows for it to be started and stopped multiple times daily[71]. The CAPEX is approximately $11.4 million but could vary based on Ithaca's specific requirements. No OPEX figure was found, but an assumption of 1-2% of CAPEX yields $114,000 to $228,000 per year.

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[68] Cummins, HyLYZER® Water Electrolyzers, (Hydrogenics Corporation, 2020), https://www.cummins.com/sites/default/files/2021-08/cummins-hylyzer-1000-specsheet.pdf.
[69] Lazard, Levelized Cost of Hydrogen Analysis, (2021), https://www.lazard.com/media/451779/lazards-levelized-cost-of-hydrogen-analysis-vf.pdf.
[70] Tom DiChristopher, "Hydrogen Tax Credit Hangs in Balance As Dems Aim to Revive Build Back Better," S&P Global, last modified January 3, 2022, https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/hydrogen-tax-credit-hangs-in-balance-as-dems-aim-to-revive-build-back-better-68254984.
[71] General Electric, "LM2500 & LM2500XPRESS Gas Turbines," GE Gas Power, last modified 2022, https://www.ge.com/gas-power/products/gas-turbines/lm2500.

16. Appendix VIII: Community Choice Aggregation

16.1 Introduction to Community Choice Aggregation

Community Choice Aggregation (CCA), at its most basic level, is a bulk-buying club for energy supply (electric and/or gas) that allows local elected officials to choose a particular source of energy supply for their community. According to NYSERDA [insert footnote], a city enters into a bulk purchasing arrangement and competitively procure energy supplies with the help of a CCA Administrator. The purpose is to build market clout and negotiate better prices and terms on energy supply and other clean energy products and services. A CCA would guarantee 100% renewable energy to the City and Town of Ithaca, and all residents would be enrolled unless they opt out. The City and Town would eventually need to pass ordinances to negotiate and establish a CCA.

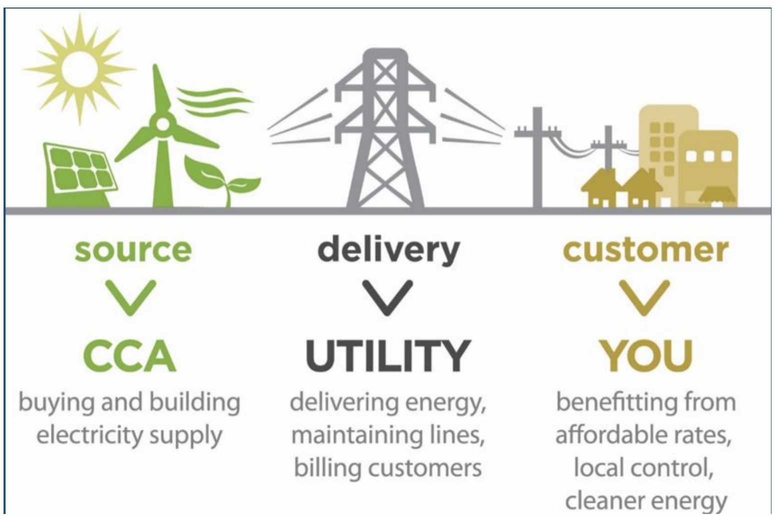


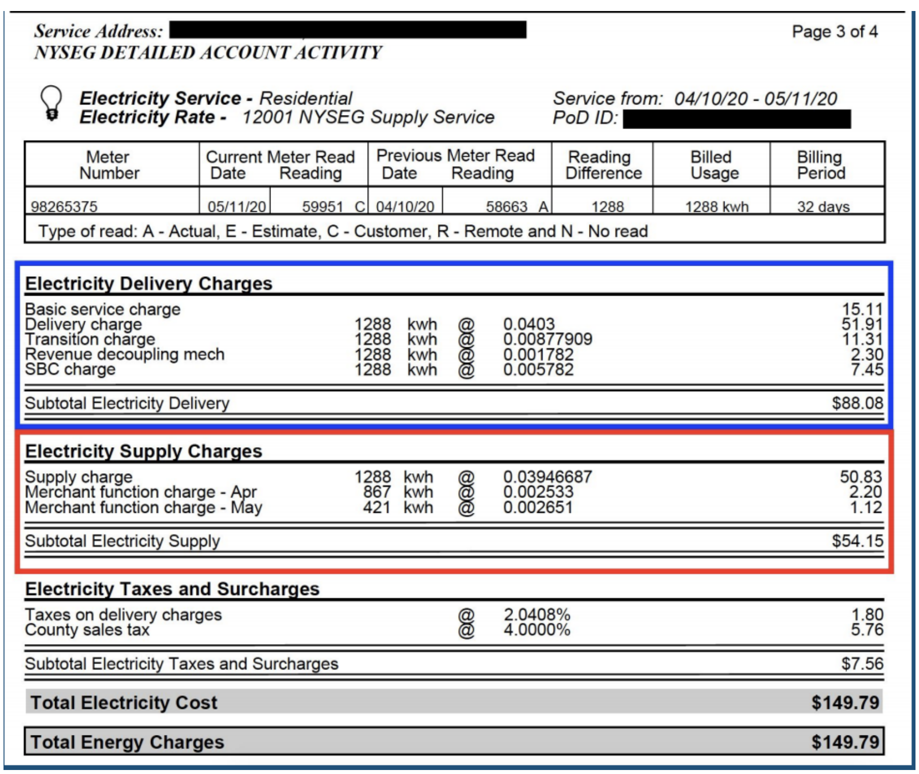
Figure 16.1: Schematic of the CCA Process

Aguirre-Torres said he anticipates the savings could be 20-30% compared to the retail price, and that they could likely lock those savings into a long-term price with a 15- 20-year deal. The administration of the program would be paid for through the electric bill. He said that even with paying for those administrative fees, residents would still see around 20% in savings on electric bills. In addition to the above energy savings, CCA has the following potential benefits:

- Predictable energy supply costs via Power Purchase Agreement (PPA)
- Purchase 100% renewable energy supply
- Enhance community energy literacy
- Develop local or regional renewable energy resources
- Local/regional job creation
- Develop/support local energy services; efficiency, heat pumps, EV, storage
- Develop/support programs for low-income residents
- Keep our energy investments local, strengthen local economy

Joining a CCA is low-risk, as customers likely would notice no difference to their service other than a lower cost and knowing they were consuming clean energy. The only potential downside is if for some reason electricity prices drop dramatically, the City and Town could still be locked into the previously agreed upon rate. In this case, the City would need to find other ways to reduce cost efficiency and the demand response. Furthermore, there are potential customer concerns with moving homes, opting in or out, and billing questions. If Ithaca were to decide to go with a CCA, they would likely partner with groups like Sustainable Tompkins to provide administrative support to take the burden of customer service off of the City. CCAs would charge a fraction of a cent, “like .002,” which will go toward the admin of the program.

For the typical City resident, electricity bills contain two categories: Energy Delivery and Energy Supply. In NYS, our electric utilities are decoupled from energy production - they only deliver electricity. Essentially, we pay NYSEG for energy delivery services (wires, pipelines), and all rate increases are for operations and maintenance and/or improvements to their delivery infrastructure. NYSEG itself buys energy supply (electricity, gas) on the wholesale market and delivers it to us. The supply cost for this is pass-thru (e.g. NYSEG makes no profit on the supply). As a result, consumers can choose where they buy their electricity supply, and ~ 20% choose Energy Service Company (ESCO) and/or solar farm. Because the purchase energy at market value, their delivery rate increases will continue under CCA. The following figures depicts how the electricity bills would be altered with and without CCA implementation:



Service Address: [redacted] Page 3 of 4

NYSEG DETAILED ACCOUNT ACTIVITY

Electricity Service - Residential
Electricity Rate - 12001 NYSEG Supply Service

Service from: 04/10/20 - 05/11/20
PoD ID: [redacted]

Meter Number	Current Meter Read Date	Current Meter Read Reading	Previous Meter Read Date	Previous Meter Read Reading	Reading Difference	Billed Usage	Billing Period
98265375	05/11/20	59951 C	04/10/20	58663 A	1288	1288 kwh	32 days

Type of read: A - Actual, E - Estimate, C - Customer, R - Remote and N - No read

Electricity Delivery Charges					
Basic service charge					15.11
Delivery charge	1288	kwh	@	0.0403	51.91
Transition charge	1288	kwh	@	0.00877909	11.31
Revenue decoupling mech	1288	kwh	@	0.001782	2.30
SBC charge	1288	kwh	@	0.005782	7.45
Subtotal Electricity Delivery					$88.08

Electricity Supply Charges					
Supply charge	1288	kwh	@	0.03946687	50.83
Merchant function charge - Apr	867	kwh	@	0.002533	2.20
Merchant function charge - May	421	kwh	@	0.002651	1.12
Subtotal Electricity Supply					$54.15

Electricity Taxes and Surcharges			
Taxes on delivery charges	@	2.0408%	1.80
County sales tax	@	4.0000%	5.76
Subtotal Electricity Taxes and Surcharges			$7.56
Total Electricity Cost			**$149.79**
Total Energy Charges			**$149.79**

Figure 16.2: Example NYSEG Electricity Bill without CCA Implementation

NYSEG

Account Number:
Statement Date: May 08, 2020

Service Address:
NYSEG DETAILED ACCOUNT ACTIVITY

Page 3 of 6

Electricity Service - *Residential*
Electricity Rate - *12001 ESCO Supply Service*

Service from: 04/04/20 - 05/05/20
PoD ID:

Meter Number	Current Meter Read Date	Current Meter Read Reading	Previous Meter Read Date	Previous Meter Read Reading	Reading Difference	Billed Usage	Billing Period
77581114	05/05/20	34364 A	04/04/20	33840 C	524	524 kwh	32 days

Type of read: A - Actual, E - Estimate, C - Customer, R - Remote and N - No read

Electricity Delivery Charges

Basic service charge				15.11
Delivery charge	524 kwh	@	0.0403	21.12
Transition charge	524 kwh	@	0.00898141	4.71
Revenue decoupling mech	524 kwh	@	0.001782	0.93
SBC charge	524 kwh	@	0.005782	3.03
Subtotal Electricity Delivery				$44.90

Electricity Taxes and Surcharges

Taxes on delivery charges	@	2.0408%	0.92
County sales tax	@	3.0000%	1.37
Subtotal Electricity Taxes and Surcharges			$2.29

Total Electricity Cost **$47.19**

Constellation.

CONSTELLATION NEW ENERGY INC
PO BOX 4911
HOUSTON TX 77210-4911

www.constellation.com/ny-mega

Account number:

Messages

Your community participates in a Community Choice Aggregation (CCA) bulk electricity purchasing program run by MEGA. CCA offers you the benefits of a competitive rate, supply price certainty (price/kWh is the same through June 2021) and access to renewable electricity. Visit megacca.org or call MEGA's CCA Helpline 518-533-5399.

Electricity Supply Detail

Contract Charges	524 kwh	@	0.0541985	28.40
State and Local Sales Tax				0.86
State and Local Sales Tax				0.29
Current Electricity Supply Charges				$29.55

Figure 16.3: Example NYSEG Electricity Bill with CCA Implementation

16.2 New York State's History with CCA

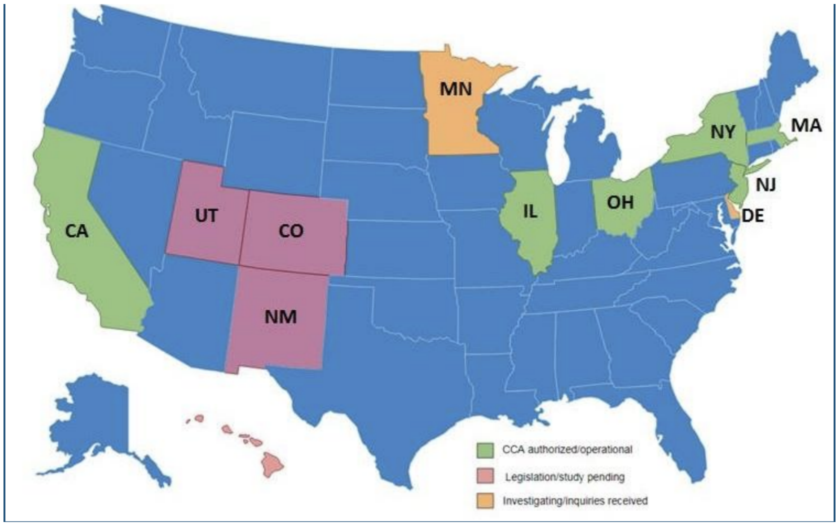


Figure 16.4: States that have Implemented CCA

While several states have implemented CCA (see Figure 8), New York's Public Service Commission first authorized the program in April 2016. They stated that a given municipality could pass local law to purchase energy supply on behalf of residents and small commercial accounts with the stipulations that it was done at the lowest level of government (i.e. village, city, town) and the option for opting out of CCA was presented to individuals. While there is a opt-out threshold at which CCA would become unfeasible, Aguirre-Torres stated that public outreach is part of Ithaca's program. Currently, there are 61 municipalities with active CCA programs serving ~170,000 residential and small commercial electricity accounts, with another 19 fully authorized for CCA (but on hold pending better pricing or not moving forward at this time for other reasons). Furthermore, 38 municipalities are currently receiving 100% renewable energy as their default supply. Current CCA administrators include Good Energy, Joule Assets, Municipal Electric and Gas Alliance (MEGA), and Westchester Power. A summary of these administrators can be found in Table 2.

Table 16.1: CCA in NYS (July 2019)

Administrator	# members	# municipalities*	# 100% green municipalities
Westchester Power (est. 2016)	~ 91,000	27	24
MEGA (est. 2019)	~ 37,000	21	6
Joule Assets (est. 2019)	~ 28,000	8	8
Good Energy (est. 2019)	~ 7,100	5	0

17. Appendix IX: Solar Contractor Outreach

Sungineer Solar is a local contractor in Ithaca, NY that focuses mainly on small scale residential projects. An inquiry meeting was conducted on 5/5/2022, where Nicole and Dave Tedeyan relayed information on solar panel integration, maintenance, incentives, and common motivators they see for residents wanting to transition to solar energy sourcing.

The first set of questions we asked about was pricing related to the microgrid on the TCAT site. Nicole and Dav estimated that the pricing would be based on the DC rating as opposed to the square footage of the roof. While they personally do mostly residential and small commercial buildings (the company is primarily two administrative workers and a few people in construction), they estimated a price of $2.00-$2.50 per Watt. How this relates to the roof is more difficult, as the amount of solar that would fit in a given area depends on the racking setup, the tilt of the roof, and the direction that the roof is facing. There are also constraints for installation on flat roofs in accordance with NYSERDA documentation, including existing equipment, keeping pathways available around the perimeter and between rows of panels, and other fire code/electric code/regulatory requirements.

Next, we discussed the types of panels used in industry. Sungineer Solar mainly uses monocrystalline panels, which are most often used in large scale commercial projects. They also recommended using Q-cells (480 W), which can be sourced from Canada, due to their efficiency metrics. Other manufacturers that they recommended were Trina (which has bi-facial panels) and Canadian Solar. In terms of installing a large commercial site, they recommended installing fewer larger sized panels, rather than a larger quantity of smaller ones, as it is more cost-effective due to lower racking and labor costs.

Upkeep costs were dependent on the type of installation: a typical roof installation or a ground mount. On a typical home, there’s two things to be looking at: the age of the roof (which may result in the need for reroofing) and whether or not the installation uses a string inverter or a microinverter. String inverter lifespans are usually shorter, so one may need to replace them at least once during the lifespan of the system, which is an added cost. The biggest maintenance for ground mount upkeep is mowing to reduce the amount of weeds. Cleaning is not really an issue in the northeast because of rain, and going out of your way to clean the panels doesn’t really increase the power output by that much in this region either. Snow removal is not worth the time because you won’t get much power in the winter anyway, and snow tends to slide off when the sun comes up.

All small scale projects are fronted by both Nicole and Dave. However, when asked about a large-scale project, they recommended looking at Renovus Solar, or perhaps contacting Fred Gage at Delaware River, who has worked with projects ranging from 30-60 acres.

Nicole and Dave noticed three main factors that their clients have cited as to why they're interested in installing solar: economic feasibility, wanting energy independence, and environmental awareness. In light of this, if another public education campaign was to be conducted, these three draws should be emphasized.

When it comes to creating coherence between landlords since theand tenants who want to pursue solar sourcing, if a tenant is interested, a landlord has to get on board. The landlord pays for the system, utility account is shifted to landlord's name, and then rent is increased. For logistical reasons, meters have to be in landlord's name. In regards to rent pricing, it is theoretically illegal for landlord to change rent each month - so they have to create a general estimate (ie: a fixed increase of + $150/month) in order to compensate for electric bills. The biggest barrier will be figuring out how to incentivize landlords to take the time to do this, and let alone, invest, when the typical goal is to maximize profits as quickly as possible, which they can easily do without looking into solar. CUSD's next steps in regards to this topic should be focusing on the social and financial pressures of landlords, and determining what would incentivize landlords to do this. Since the tenants will not see any expense benefits, it will also be worthwhile to look into how tenants can be motivated to operate their rental unit in an energy efficient way.

The main items Nicole and Dave mentioned as being a nuisance when working with clients for residential solar integration was the compliance with fire code. Right now, fire code specifies that there needs to be a certain boundary between the panels and the roof, so that firefighters can do work if need be. City of Ithaca takes these rules very strictly, in some cases more than necessary according to Nicole and Dave. They noted that in most cases, exceptions to the fire code are possible. For example, if solar contractors ask the Fire Chief if a panel system on a building's roof is a concern and the Chief approves it, the project can then move forward. However, the City of Ithaca has rarely allowed these exceptions and has instead been very stringent on the rules.

Another concern that Nicole and Dave mentioned is that the certification process to become a licensed electrician in the City of Ithaca is overly difficult. Anecdotally, Dave mentioned that he was one out of seven people who passed when he took the test, despite the other test-takers having much more experience in the industry. According to Dave, the test to become certified is unnecessarily complex and expects a high engineering background. The City of Ithaca can use a lot of licensed electricians, according to Dave, especially with its plans for electrification, so it's best to lower the barriers in becoming a licensed electrician.

As far as items that do not need streamlining, Nicole and Dave said that the permitting process was simple, and usually has not produced any set back. A significant part of what has made this easy was utilizing the Unified Solar Permitting process (USP). They mentioned that if the City were able to utilize this more often, it would be helpful.

Nicole and Dave recommended that educational campaigns that focus on incentives for solar would be very beneficial for spreading the word to the community about the different options that are available to them. Specifically, they recommended modeling it off of **Solarize Tompkins** 2014/2015/2016, as they noted a large increase in clients after these events. Furthermore, Nicole and Dave said that if the City is able to produce any more incentives (additional tax credits or funding) perhaps based on income level, it would be helpful for drawing people to consider solarizing their property.

18. Appendix X: Curbside EV Charging Proposal

18.1 Introduction

Electric Vehicle (EV) charging stations are essential to the successful operation of a new generation of electric vehicles. As of March 2022, only 62,000 of 11 million vehicles registered across New York state were solely electric. Increasing EV usage to meet local and international sustainable development goals requires upfront investment of more EV stations. The equivalent of traditional gasoline fueling stations, these EV stations are more flexible in their placement. Electric vehicle supply equipment (EVSE) can be installed in parking lots, in personal residential facilities, and on public streets. Curbside charging is of particular interest to the Ithaca Carbon Neutrality 2030 (ICN 2030) Policy team of Cornell University Sustainable Design. On behalf of the team, this report aims to suggest suitable curbside EVSE locations to the City of Ithaca.

18.1.1 Curbside Charging

Curbside charging has a great potential to attract new EV owners. EVSE installed in parking garages are usually reserved for patronage or limit access for a parking fee. However, curbside chargers are sited for public use. Coupled with reserved parking spaces and free parking for charging vehicles, the barriers of entry to EV ownership are reduced making them a comparable investment with traditional internal combustion engine (ICE) vehicles. Expanding accessibility to the community through curbside charging will make it easier to own an EV, increase patronage to local businesses, and increase the public health of the city.

18.1.2 Electric Vehicle Infrastructure Plan for Tompkins County

Over 2016 and 2017, the Ithaca-Tompkins County Transportation Council (ITCTC) produced reports to support community transition to increased EV usage as well as encourage residents to adopt and use EVs. The reports produced include:

- Existing Conditions and Best Practices
- EV Charging Station Site Suitability
- Preliminary Engineering and Cost Analysis for EV Charging Stations
- Charging Station Implementation Strategies

The EV Charging Station Site Suitability identified the following sites (in Ithaca) as highly suitable for new charging stations in Tompkins County: Cornell Cooperative Extension of Tompkins County, Seneca Street Parking Garage, Sciencenter, Ithaca College, and more. The site suitability prepared by ITCTC does not consider potential curbside EVSE locations. This report, however, will expand on the framework crafted by the Council and will identify suitable curbside locations for new EVSE infrastructure.

Additional sources of information guiding this report include, but are not limited to the following organizations:

- New York State Energy Research and Development Authority (NYSERDA)

- New York State Department of Transportation
- WXY Architecture + Urban Design

18.2 Ithaca's EV Infrastructure

18.2.1 Current EV Charging Infrastructure

The City of Ithaca currently hosts 22 EV Charging Stations, none of which are curbside charging stations. These EVSE are located in parking lots or parking garages in the following locations:

Location	Count
Cornell Campus	6
Ithaca Commons	4
Route 13 (near Wegmans)	4
Southwest Ithaca	3
near Stewart Park	3
Collegetown (Dryden Garage)	1
Treman Park	1

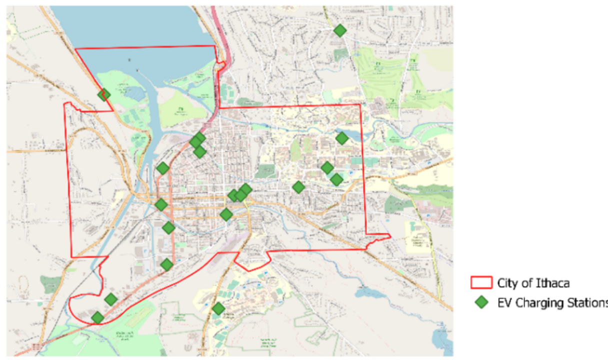


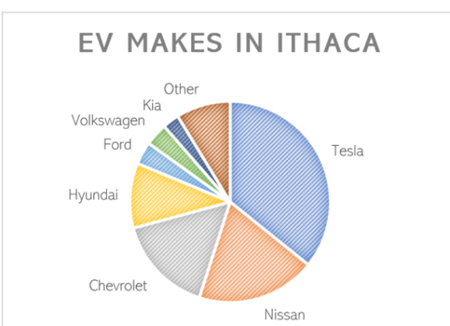
Figure 18.1: EVSE Locations in Ithaca. Sources: US Dept of Energy – Alternative Fuels Data Center, Open Street Map

18.2.2 Ithaca's EV Inventory

As of 1 May 2022, the following electric vehicles were actively registered in Ithaca, New York.

Make	Count	Charging Port Location
Tesla	147	Left rear
Nissan	79	Front grill
Chevrolet	65	Left front
Hyundai	43	Front grill
Ford	15	Left front
Volkswagen	15	Right rear
Kia	11	Front grill
Other	47	Variable

The Chevy Bolt EV charging port is located above the front driver's side tire.
Image Source: ChargePoint



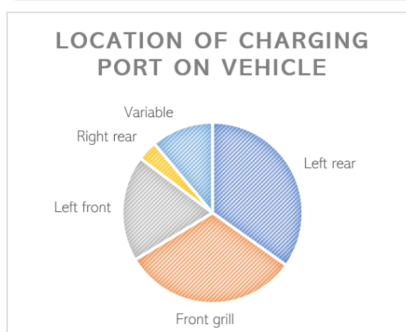


Figure 18.2: Ithaca's EV Inventory. Source: NYS DMV – Vehicle, Snowmobile, and Boat Registrations

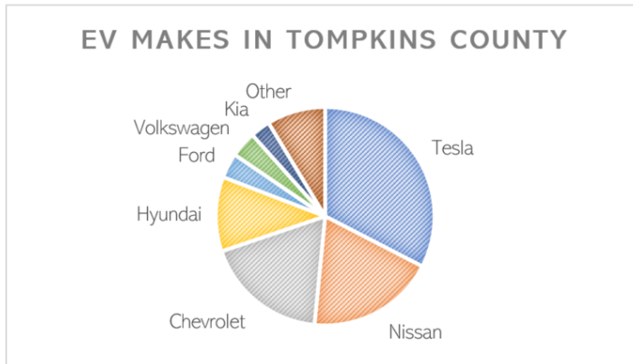
Over a third of registered EVs in Ithaca are Tesla models which have charger ports on the driver's side at the rear of the vehicle. Including these Tesla models, over half of the EVs have charging ports on the driver's side of the vehicle while a third have a charger at the front grill. Therefore, it would be optimal to install the curbside EVSE on the left side of the road which requires a one-way street with left side parking capacity.

18.2.3 Tompkins and Surrounding Counties' EV Inventory

As of 1 May 2022, the following electric vehicles were actively registered in Tompkins County and several surrounding counties of which residents visit Ithaca on a semi-regular basis. Trips may be recreational, occupational, or may involve passing through Tompkins County. These surrounding counties include Cayuga, Chemung, Cortland, Schuyler, Seneca, and Tioga.

Tompkins County

Make	Count	Charging Port Location
Tesla	177	Left rear
Nissan	103	Front grill
Chevrolet	99	Left front
Hyundai	60	Front grill
Ford	20	Left front
Volkswagen	21	Right rear
Kia	16	Front grill
Other	47	Variable



Surrounding Counties (including Tompkins)

Make	Count	Charging Port Location
Tesla	347	Left rear
Nissan	148	Front grill
Chevrolet	143	Left front
Hyundai	98	Front grill
Ford	45	Left front
Volkswagen	29	Right rear
Kia	33	Front grill
Other	86	Variable

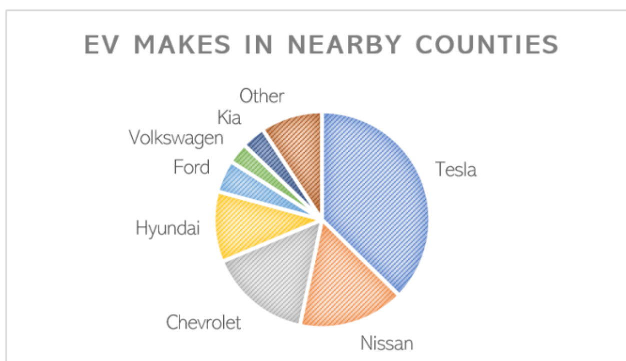


Figure 18.3: EV Makes in Tompkins and Surrounding Counties. Source: NYS DMV – Vehicle, Snowmobile, and Boat Registrations

The composition of the EV inventory in Tompkins County and its surroundings are largely similar to that of Ithaca. In conjunction with the Tompkins County Tourism Program, Visit Ithaca, and the Census Bureau, the City of Ithaca should accommodate both residents and out-of-town visitors when considering installing EVSE. Since most EVs have charging ports either on the left or the front of the vehicle, the analysis is consistent that the charger should be installed within the front third of the parking space.

18.3 Priorities for Curbside EV Charging

18.3.1 Market Analysis

(Community Demand, Host Location)

Factor	**Explanation**
Length of Stay	Public curbside EV Charging Stations work best when drivers can leave their vehicles to charge for up to 4-8 hours. Examples of high demand locations include near offices and workplaces, entertainment venues, eateries, or commercial areas.
Signage and Wayfinding	EV owners can only use public chargers if they know their locations. The Federal Highway Administration sets standards for clear and consistent signs to direct drivers the EV stations. *[More information below]*
Visibility	Promoting EV exclusive parking can encourage usage in the community. Street paint and curb markings can denote exclusive EV spaces.
Charge Level	EV Chargers are designated as Level 1, Level 2, and DC Fast Chargers. Curbside Charging would ideally be either level 2 or DC Fast Chargers. This allows for a quick turnover rate and high usage when people park for a quick recharge and explore the community. *[See Section 18.6: EV Charger Levels]*
Proximity to Building Entrance	EV Chargers are optimally placed near (but not directly in front of) building entrances. EVSE placement near building entrances often increases its visibility and accessibility.

18.3.2 Economic Feasibility

(EVSE Cost, Construction, Service Upgrade, Maintenance, Fiscal Impacts)

Factor	**Explanation**
Proximity to Power	EVSE installation near the power source reduces costs incurred by cutting, trenches, and drilling of the sidewalk and street. Installing an EVSE that is compatible with existing infrastructure again reduces the costs of adding new conduits.
Parking Space Dimensions	A larger parking space may need to be considered when allocating spots for EV charging. The charging equipment should not interfere with accessibility, pedestrian and vehicular traffic, nor other parking spaces.
Mounting Approach	Different mounting approaches are suitable for different EVSE types. The correct mounting approach will minimize the space it takes up as well as the cost to install. For curbside charging, free-standing or hanging chargers may be optimal.
Metering	Most EVSE utilize integrated payment technology where users may pay on the charger or through an app on their personal devices. More research is needed to determine an appropriate rate for the community.
Charge Level	The EVSE levels each require different infrastructure capabilities. If the existing infrastructure is inadequate, additional costs may be incurred to improve the infrastructure for installation.
Host-Operator Agreements	Ownership and management structures are dependent on the host of the EVSE. Hosts will likely be responsible for installation, maintenance, and communications with the EVSE operator.

18.3.3 Legal

(Regulations, Liability)

Factor	**Explanation**
Accessibility	EV dedicated spaces and routes should be safe and accessible to all drivers (regardless of physical abilities). More time is usually required to line up the vehicle with the EVSE as well as operating the charger. Increasing accessibility includes reducing tripping hazards and minimizing liability concerns. *[More information below]*
Lighting	Adequate lighting is essential for efficient operation of charging units. Lighting increases safety of users and deters vandalism of the equipment. Appropriate and/or sustainable lighting technologies may incur additional costs above installation alone.
Pedestrian Traffic	Though high pedestrian traffic corridors increase visibility, it also presents another challenge. Installing an EV charger must not interfere with pedestrian traffic and must not present tripping hazards. In addition, equipment should not interfere with building entry ways, street crossings, or pedestrian facility usage.
Proximity to Traffic	Like pedestrian traffic, proximity to highly trafficked streets increases visibility, but also presents a challenge. Initial installation may cause traffic disruptions. Large-scale traffic patterns should be researched to determine optimal EVSE locations.
Hazards	Potential hazards should be reduced at all costs. Examples include tripping over equipment, improper usage of EVSE, and increased exposure to vehicular traffic while using the charger.

18.3.4 Operations

(Management, Utility, Equipment, Scenarios)

Factor	**Explanation**
Charge Level	The different EVSE levels have different electricity requirements and must be considered when choosing a curbside charger. Level 1 chargers often do not require additional configuration, but Level 2 and DC Fast Chargers often require rewiring and testing the electrical load capacity in the community before installation.
Network Connection	A network connection may be required to remotely check the status of the installed EVSE. Connections may also be used for mobile payments. Thus, the infrastructure should allow for at least a 3G connection.
Environmental Conditions	A site with poor environmental consideration will degrade the EVSE faster than a protected EVSE. Curbside chargers are often exposed to the elements at a higher rate than ones in parking garages or sheltered parking lots. The mounting approach should also be considered if the site is prone to flooding or high snowfall.
Parking Space Dimensions	Since EV spaces often require slightly more space than regular parking spaces, EV spaces should be clearly marked to ensure space optimization. The community should also consider the total number of spaces available for parking (standard, EV, accessible, etc.).

18.3.5 More Information for Curbside Priorities

Signage and Wayfinding

Clear and consistent signage is a goal for helping drivers navigate towards the nearest EV station. The Federal Highway Administration sets signage standards for usage on all public and private roads. The City of Ithaca should adapt these standards for a best fit case and use around the city. Signs should be located near their respective chargers on appropriate major thoroughfares which point drivers toward the charger using the simplest route possible. Wayfinding signs for community destinations are to be placed at a lower priority than other guide signs. The EV station shall be considered a community destination (e.g., Sciencenter, local park, etc.). The Federal Highway Administration recommends colored signs to differentiate between community destinations and primary destinations such as hospitals. Clear and concise information must be delivered regardless of sign color as certain colors already have a general association (blue – accessibility, red – prohibited action).

Electric transportation company ECOtality recommends regulatory signage at the curbside charger to employ both a pictograph and words to denote EV charging spaces. Reserving curbside EVSE for actively charging vehicles is a key priority for efficient usage. Therefore, the wording recommended by ECOtality for a no parking sign is as follows: "No Parking Except for Electric Vehicle Charging." This will prevent combustion and hybrid vehicles from parking there as well as EVs that are not actively charging. The time of the day for such space reservation should be evaluated by the city and another sign highlighting the times of parking restriction may be necessary. The city must also enforce the parking restrictions for the sign and curbside charger to be effective. Other regulatory cues may also be present in the form of curb or pavement markings.

Additional information that may be necessary are time limits for parking, costs associated with charging, and instructions to use the charging station. Safety information may be necessary that specifies voltage, amp levels, and safety information. State and federal laws may require the indication of the date of installation, equipment type, model of EVSE, and contact information of the owner.

For images, see Section 18.7: Regulatory Signage.

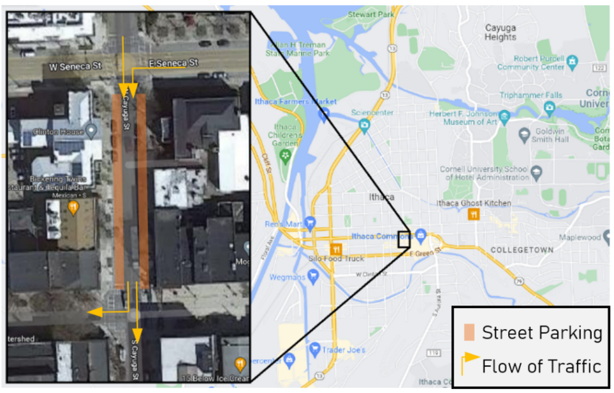
Accessibility

Curbside charging spaces require more planning such that the space is accessible and able to be used by all drivers. General safety precautions for driving and parking should be considered as well as EV charger specific precautions. Most EVs in Ithaca have charger ports either on the left side of the vehicle or at the front grill while 1 in 10 have a charging port on the right side. Thus, the curbside EVSE should be installed at the front third of the parking space to minimize tripping hazards over the charging cable. ADA-compliant designs must also be highly considered. An example of ADA compliance is the maintenance of a 36" minimum clearance between building walls and street furniture and signage. Therefore, all EVSE should clear this distance to minimize hazards. EV charging spaces may be combined with accessible parking spaces but must be clearly signed to indicate reserved spaces.

18.4 Location Profiles

18.4.1 North Cayuga Street (between Seneca and State)

North Cayuga Street is a two-lane one-way local street directly next to the Ithaca Commons pedestrian plaza. Businesses located on the street include the Ithaca Times building, Bickering Twins restaurant, Handwork craft shop, and John's Tuxedo Shop. Limited metered parking up to 2 hours is available on both sides of the street. The rest of the street has been marked as loading zone with a maximum standing time of 30 minutes.



N Cayuga Street Location in Ithaca, NY
Image Source: Google Maps

Potential Charger Installation on N Cayuga
Image Source: Google Maps

Market Analysis: Level 2 chargers would be most suitable for curbside charging on N Cayuga Street. There are plenty of entertainment venues and eateries due to the proximity to the pedestrian plaza at Ithaca Commons. Considerable charging can be achieved from a multi-hour stay in the area and high rates of turnover increase the usage of the charging station.

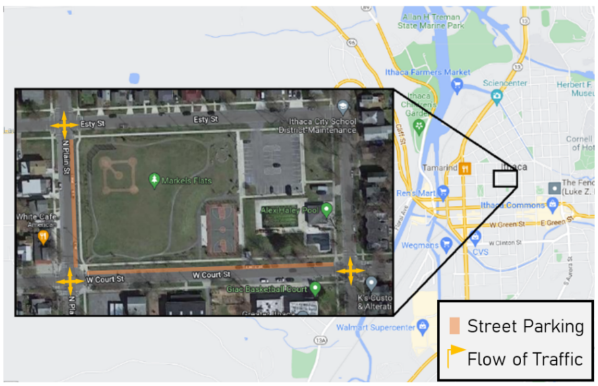
Economic Feasibility: More research is needed to determine if any infrastructure improvements are needed to install a Level 2 charger, but it is highly likely for an easy connection to the grid. A mounted EV charger would be optimal for this site, but a free-standing station would reduce costs for installation. There is a designated parking bay, but much of the street is reserved for loading. Incentives such as free parking for charging may be implemented to encourage more EV ownership.

Legal: Designated parking bays and a wide street are suitable to provide adequate space for parking and lining up the vehicle with the charging station. The charging station and all its equipment should clear the sidewalk and still comply with ADA standards if placed near the curb, in line with existing light posts and meters.

Operations: More research is needed to determine the number of chargers to install as parking is already limited on N Cayuga Street. The City of Ithaca would be the ideal host of the charging stations to provide free charging and parking for charging vehicles. Local businesses should be consulted before installing the charging station near their storefronts. One vehicle of the Ithaca CarShare fleet is located on the street with two others only a block away. The Ithaca CarShare fleet can be plugged in overnight to maximize usage of the charger. Extra care should be taken in the winter months to prevent damage to the EVSE.

18.4.2 Markels Flats (Court and Plain Streets)

Markels Flats is a public park located in the heart of Ithaca at the site of the former Markels school campus. The park is bordered by four two-way local streets meeting at four-way intersections. Recreational facilities at the park include a baseball field, basketball courts, and a pool. Nearby attractions include the Greater Ithaca Activities Center, a café, and the Ballet Center of Ithaca. Across the street from the park are residential homes.



Markels Flats Location in Ithaca, NY
Image Source: Google Maps

Potential Charger Installation on W Court
Image Source: Google Maps

Market Analysis: Level 2 chargers would be most suitable for curbside charging near Markels Flats. The presence of the park, outdoor, and nearby recreational facilities attract families that can easily spend a few hours in the area throughout the year. The facilities may experience decreased usage in the winter, but the Flats are only two blocks away from Ithaca's commercial district. The residential community in the area may also use the charger if one is not installed at their residence, making it easier for renters to own an EV.

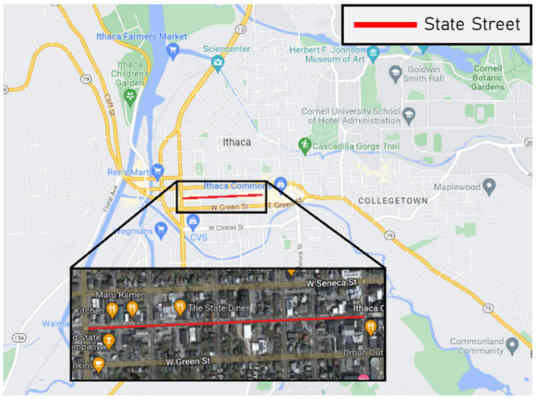
Economic Feasibility: More research is needed to determine if any infrastructure improvements are needed to install a Level 2 charger, but there is a reasonable possibility that construction would be required depending on the placement of the charger. The NYSEG West Court Street Station is located on Court Street, which holds a possibility for a rather easy connection. There are utility poles on Plain Street which can accommodate a hanging charger, but a freestanding unit may also be considered. Plenty of parking is available on both Court and Plain Streets, so reserving a few spaces for EV charging will not be a problem.

Legal: Both Court and Plain Streets are two-way streets which would not accommodate left-side parking unless *extreme caution* is taken by drivers to park facing the opposite direction. The sidewalk and grass lawn between the sidewalk and the street are wide enough to accommodate EVSE without creating interference with pedestrians. Both streets are designated as Bike Boulevards and care must be taken to reduce obstacles when charging.

Operations: More research is needed to determine the number of chargers to install, but two to three chargers will likely maximize usage while minimizing costs. The city would be the ideal host since the park is within city jurisdiction and free charging may be an option given street parking is already free. One vehicle of the Ithaca CarShare fleet is located nearby on Albany Street which can be plugged in overnight to maximize usage of the charger. Extra care should be taken in the winter months to prevent damage to the EVSE.

18.4.3 State Street (Ithaca Commons)

North Cayuga Street is a bi-directional secondary street through Ithaca's commercial district and near the pedestrian plaza at Ithaca Commons. Local businesses on State Street include the State Theatre, Tompkins County Office for the Aging, and John's Convenience. Limited metered parking up to 2 hours is available on both sides of the street and municipal lots are located on street corners for the local businesses.



State Street Location in Ithaca, NY
Image Source: Google Maps

Potential Charger Installation on State (between Corn and Plain)
Image Source: Google Maps

Market Analysis: Level 2 chargers would be most suitable for curbside charging on State Street. The commercial district along State Street presents year-round entertainment and is a hub for many TCAT bus routes. The chargers on State will primarily be used for several hours at a time and experience a high turnover rate due to the great number of businesses nearby.

Economic Feasibility: More research is needed to determine if infrastructure improvements are needed, but it is highly likely that the current infrastructure will support such an installation. Parking is in high demand in the area but replacing spaces with EV charging only ones will provide an incentive for higher EV ownership. There are utility poles on State Street which can accommodate a hanging charger, but a freestanding unit may also be considered.

Legal: State Street is a heavily trafficked two-way street which would not accommodate left-side parking unless extreme caution is taken by drivers to park facing the opposite direction. There is a reasonable space between the sidewalk and the curb to install an EVSE without creating interference with pedestrians. TCAT Route 14 runs on State Street and extreme caution must be taken while parking. Sites should also avoid installation near bus stops.

Operations: More research is needed to determine the number of chargers to install under current parking availability. The City of Ithaca would be the ideal host of the charging stations to provide free charging and parking for charging vehicles. Local businesses should be consulted before installing the charging station near their storefronts. One vehicle of the Ithaca CarShare fleet is located at State and Corn which can be plugged in overnight to maximize usage of the charger. Extra care should be taken in the winter months to prevent damage to the EVSE.

18.4.4 North Meadow Street (between Court and Etsy)

N Meadow Street is a unidirectional, three-lane primary street co-signed as New York State Routes 13 and 34. Local businesses near this portion of the street include Ithaca Bakery, Friends of the Library, and Tamarind. Free parking is available in designated parking bays on the left-side of the street.

N Meadow Street Location in Ithaca, NY
Image Source: Google Maps

Potential Charger Installation on N Meadow St
Image Source: Google Maps

Market Analysis: Level 2 chargers or DC Fast Chargers would be suitable for curbside charging on N Meadow Street. The street is located near several businesses and is within walking distance of the West End commercial district. As a major thoroughfare through Ithaca, out of town commuters may find the fast chargers helpful for a quick recharge. Level 2 chargers would also be useful for multi-hour visits to the area.

Economic Feasibility: More research is needed to determine if infrastructure improvements are needed. The current infrastructure will likely support Level 2 chargers, but improvements will probably be required for a DC Fast Charger. The City must also determine the optimal time for construction, if needed, to minimize disruptions. Replacing parking spaces with charging spaces will provide an incentive for EV ownership. There are utility poles on N Meadow Street which can accommodate a hanging charger, but a freestanding unit may also be considered.

Legal: N Meadow Street is a heavily trafficked one-way street which accommodates left-side parking. The installation of EVSE on a moderate width sidewalk may create obstacles for pedestrian traffic. The first few spots on the street have more sidewalk space whereas Ithaca Bakery set up public benches and tables along the curb in front of their store. Ideally, the charger would be installed near Court Street for increased visibility and more curb space.

Operations: More research is needed to determine the number of chargers to install under limited parking availability. The City of Ithaca would be the ideal host of the charging stations to provide free charging and parking for charging vehicles. Ithaca Bakery is the primary storefront on the street and should be consulted before installation. Extra care should be taken in the winter months to prevent damage to the EVSE.

18.5 Economic Reductions

18.5.1 EV Make-Ready Program

New York State Electric and Gas (NYSEG), a subsidiary of Avangrid serves the Ithaca community, providing electricity and natural gas. This company also participates in the statewide Electric Vehicle Make-Ready Program (EV Make-Ready Program) which provides rebates to support development of EV infrastructure by lowering the high-cost barrier.

To access the highest rebate available, municipalities would have to submit a design plan to install publicly accessible chargers in a disadvantaged community. For multiple installations, the number of standard plugs (from a list of approved suppliers) must be equal or greater than the number of proprietary plugs installed. Each of the four selected locations would ideally be publicly accessible and the City of Ithaca falls under a Disadvantaged Community defined by NYSEG. The City should mainly install standard plugs to access the highest rebate. Therefore, installation costs for the EVSE will likely be largely covered by state and federal funding.

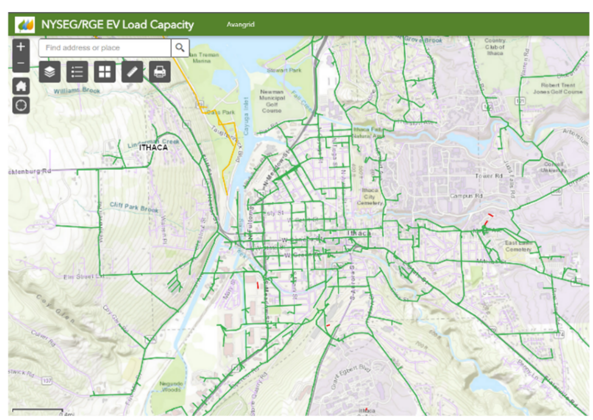
Potential Rebate	**Up to 100%**	**Up to 90%**	**Up to 50%**
Site Characteristics			
Public Access		x	x
Non-Public Access			x
Disadvantaged Community	x		
Multi-Unit Dwelling	x		
Plug Types			
Standard ≥ Proprietary Chargers	x	x	x
Proprietary > Standard Chargers			x

Source: NYSEG – Electric Vehicle Charging Station Make-Ready Program

Costs not covered by the Make-Ready Program include charging hardware and other soft costs including signage and maintenance fees. The customer is intended to own the hardware under this program, but NYSEG and NYSERDA offer incentives to cover a portion of the EVSE purchase cost.

18.5.2 DC Fast Charger Feasibility

Though the cost of DC Fast Chargers installation may be reduced by the state, most costs stem from infrastructure improvements. On behalf of Avangrid, NYSEG and Rochester Gas and Electric (RGE) released a map detailing remaining capacity on the electric lines. DC Fast Chargers would need to be connected to 3-phase lines and 500V, many of which are available in Ithaca. The City should review the availability of existing electrical infrastructure to better determine which level of charger is most suitable for the area.



Map of remaining electrical capacity in Ithaca
Source: NYSEG/RGE

18.6 EV Charger Levels

Electric Vehicle Supply Equipment comes in three levels: Level 1, Level 2, and DC Fast Chargers. Most EVs can be charged with Level 1 or Level 2 chargers at the base level, but some models may require an upgraded package for DC Fast Charging capabilities. Their ideal use cases are as follows:

- Level 1 – Ideal for overnight parking and charging at home (AC)
- Level 2 – Ideal for multi-hour public charging while parked at local establishments (AC)
- DC Fast Charger – Ideal for a quick recharge placed at a rest stop (DC)

The batteries in most EVs are charged by direct current (DC). Level 1 and Level 2 chargers both supply alternating current (AC) power. Thus, the AC power supply is converted to DC through the vehicle's on-board converter which also limits charging speed. DC Fast Chargers eliminate this step by converting the current within the charging station which allows the charging stations to supply more power and charge vehicles faster.

The City of Ithaca should consider Level 2 or DC Fast Charger installation for curbside charging locations as people are not likely to park at the selected sites overnight. Both Level 2 and DC Fast Chargers will also promote higher turnover rates and increased usage as more vehicle owners will benefit from a quick charge. A more detailed comparison of the levels is summarized in the table below:

Charger Level	**Miles of Range per Hour of Charging (RPH)**	**Time to Fully Charge**	**When to Use**	**Connector**
Level 1 – Standard Wall Outlet (AC)	5 RPH	- 16 hrs (80-mile battery) - 40 hrs (200-mile battery)	Charge while you sleep	 Personal cable
Level 2 – Charging Station (AC)	- 12 RPH (3.7kW on-board charger) - 25 RPH (6.6kW on-board charger)	- 3.5 hrs (80-mile battery) - 8 hrs (200-mile battery)	At work While sleeping Running errands Dining Entertainment	 J1772 connector
DC Fast Charging	100+ RPH depending on power level of charger - 24kW (up to 100 RPH) - 44-50kW (up to 200 RPH)	Depends on charger and car model. Most EVs can be charged to 80% within 30 minutes	Short Stops Express-Corridor locations	 SAE Combo (CCS)  CHAdeMO  Tesla

Source: ChargePoint, Wikimedia Commons.

18.7 Regulatory Signage

The Federal Highway Administration (FHWA) regulates national sign usage through the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) to ensure clarity and consistency. High usage of curbside chargers relies on easily identifiable and uniform signage to direct both City residents and out-of-town commuters. EVSE signage falls under three categories: General Service, Regulatory, and Trailblazing.

18.7.1 General Service (Guidance)

This category of signage is used to provide general guidance towards the charger which should be installed near major roadways and at nearby intersections. The standard color scheme for the signs are white text and symbols on a blue background. The following signs are recommended for most use cases by the MUTCD:

D9-11b
Electric Vehicle
Charging

D9-11bP
Electric Vehicle
Charging

Sizes:	D9-11b	24” x 24” on conventional roads
		30” x 30” on freeways
		12” x 12” at parking facilities
	D9-11bP	24” x 18” on conventional roads
		30” x 24” on freeways
		16” x 12” at parking facilities

18.7.2 Regulatory (Enforceable)

This category of signage is used to enforce parking restrictions and inform drivers of time limits for parking and/or charging at the charger itself. There are currently no national standardized signs for EV parking by the MUTCD and many states have their own set of signage. The following signs are recommended by the FHWA and may be used in most locations of EV chargers:

Regulatory signs should be no smaller than 12” x 18” and should be placed immediately adjacent to the charger at a height of 7 feet.

18.7.3 Trailblazing (Special)

Special signs may be installed by hosts to provide additional information to drivers and visitors. The signs do not follow any general MUCTD design standards and are not intended to be enforceable. Special signs should not be more prominent than regulatory signs.

Examples of custom signs for EVSE

A hybrid sign by ECOtality

18.8 Conclusions

The City of Ithaca should greatly consider implementing curbside charging to expand the city's current EV infrastructure, provide incentives for higher EV ownership, and to promote public health. There are currently 422 electric vehicles registered in Ithaca which will likely increase with the installation of publicly accessible curbside charging stations. Level 2 and DC Fast Chargers would be the primary chargers for consideration to provide substantial charging in a reasonable amount of time.

Four possible locations were identified as possible contenders for curbside chargers and are summarized in the table below. At the sites, chargers should be installed at the front third of the designated parking space to minimize charging cable length and tripping hazards for most vehicles. Additional criteria to determine site suitability are listed below as well.

Location	Pros	Cons
N Cayuga Street	Left side parking available Adequate sidewalk width Near Ithaca Commons Near Ithaca Carshare Dedicated parking bays Near TCAT stops	Exposed to the elements Not much standard parking currently available (truck loading zones)
Markels Flats	Near recreational facilities Not too far from Ithaca Commons Near Ithaca Carshare Adequate sidewalk width	Left side parking not available Exposed to the elements Streets are designated as Bike Boulevards
State Street	Many local businesses near Ithaca's commercial district Many TCAT stops nearby Near Ithaca Carshare	Left side parking not available Exposed to the elements Heavily trafficked street
N Meadow Street	Left side parking available Near local businesses on NY-13 (outside Ithaca Bakery) On a major route (out-of-town commuters can quickly recharge)	Exposed to the elements Sidewalk is narrow Heavily furnished sidewalk Heavily trafficked street

Criteria	Least suitable	Suitable	Most Suitable
Street Type	Arterial Roads Two-way Collectors	One-way Collectors Two-way Local Roads	One-way Local Roads
Street Parking	Only right-side parking	Front angled parking	Left-side parking availability
Physical Constraints	Many curb cuts Protected bike lane		Minimal curb cuts Dedicated parking bay
Sidewalk	Narrow sidewalk (<1.2m) Heavy streetscape clutter Heavily furnished sidewalk (benches, lampposts, planters)	Medium width sidewalk (1.2—2.5m) Moderate streetscape clutter Moderate sidewalk furniture	Wide sidewalks (>2.5m) Minimal streetscape clutter Minimal sidewalk furniture

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19. Appendix XI: Small EV Case Studies and History

From the data collected while the bikeshare program was operating, it was found that 1,000 rides were taken in the winter and peak use occurred in the fall at 18,500 rides per season in LimeBikes second year of operation, 2019.[47] As a result, over $40,000 was lost in revenue during the winter season as LimeBikes charged $1 to unlock and 15 cents/minute where the average trip duration was 12 minutes. LimeBikes began experiencing a loss in profit which was only escalated by the onset of the pandemic, and the company was finding success in other cities of larger population and temperate climates, so they left Ithaca. To prevent this situation from repeating, it is recommended by Better Bikeshare for the program to hold community engagement events during the holiday season and winter months to keep the bike option at the forefront of the user's minds. In Philadelphia, the bikeshare program, Indego, hosts bike safety and instructional classes to expand their user field and promote well-being or, Divvy, in Chicago, hosts challenges to inspire members to use bikes in the winter.[72] Creativity and community engagement are two major strategies bikeshare programs need to implement to keep the excitement around bikes alive when the conditions are not favorable.

Small electric vehicles serve as healthy forms of transportation that help keep a community active while also reducing emissions. Although there are concerns about Ithaca's steep topography, according to LimeBike's data analyzed by BikeWalk Tompkins, it is more probable for bike trips to begin uphill and end downhill from the trip's origin.[73] To improve safety when using bikes, it is strongly recommended by NATCO that bike stations are placed at the middle or bottom of hills to limit travel downhill at unsafe speeds. Designated parking for bikes, whether it is in the form of bike racks or marked boxes, are vital to the organizational aspect of the program. Sidewalk bike racks help reduce clutter and are obvious places to lock up bikes. However, they take up space on narrow sidewalks and will be used for personal bikes as well if signage is not clear. Street corrals, which are painted parking boxes on sides of streets, would reduce street parking for cars, but are easy to identify, reduce clutter on sidewalks and would promote the use of bike lanes in streets as opposed to pedestrian areas such as sidewalks.[74] Another important safety feature is that the program is responsible for taking care of damaged and abandoned bikes. Many bike share programs hire staff to redistribute bikes and declutter areas where bikes have been left behind. To improve equity, the program could offer discounts to users who return abandoned bikes to stations after they have been used.

To enforce equity in the bikeshare process, discount programs are vital for verifying which users qualify for low-income discounts as well as ways to use bikes if one does not own a cell phone. The best programs are simple, fast, and do not require the participant to share personal information that could put them at risk. In NYC, Citi Bike determines a user's income levels based on their membership with the Community Development Credit Union. Through this

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[72] Cox, Stefani. "How Bike Share Can Be a Winter Community Engagement Tool." Better Bike Share. Social Ink, December 8, 2016. BetterBikeShare.
[73] "Lime Data Reports." Bike Walk Tompkins, 2019. Lime Data Reports — Bike Walk Tompkins.
[74] "NACTO Shared Active Transportation Guidelines." National Association of City Transportation Officials, July 2018. In this guide: Guidelines for the Regulation and Management of Shared Active Transportation.

program, eligible members receive a discount of $5/month on their bikeshare membership. To sign up, users do not need a cell phone, but only access to WIFI and a computer which is offered by public libraries. They will receive a code after completing five simple steps which includes registering for an account. Once the eligible user becomes a member, they have an annual unlimited access to bikes with a 45-minute maximum for each ride.[75] As another option, the program can distribute their own discount code to eligible groups of their choosing that qualify as low-income. Portland, Oregon's "Biketown for All" program offers free rides for up to 60 minutes, with a 5-cent charge for each minute over, free bike unlocking, and discount on helmets. Their eligibility requirements include certification of affordable housing, unemployment assistance qualification, health plan member or other ways of determining low-income levels without asking for too much personal information[76] . To encourage participation in the bike sharing program for all community members, it is stressed that the company or organization hold community events and group rides.

It is important for the company or organization running the bike share program to determine the correct fleet size and keep track of ridership data to optimize the user experience. According to Lime Bike's data collection, about 25% of the rides taken originated or ended in the Downtown Ithaca area. It was more probable that a trip began in the downtown area.[77] Therefore, it is important to track the number of bikes in this area to ensure there are enough bikes available during the day. Another important place that would need available bikes are transit stops as this is a solution to the last mile problem.

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[75] "Annual Membership – Citi Bike Help." Citi Bike. Lyft. Accessed May 4, 2022. Annual Membership – Citi Bike Help.
[76] Motivate International, Inc. "Biketown Reduced-Fare Memberships." Biketown. Lyft, 2022. BIKETOWN Reduced-Fare Memberships.
[77] "Lime Data Reports." Bike Walk Tompkins, 2019. Lime Data Reports — Bike Walk Tompkins.

20. Appendix XII: Additional Information About Waste Management

20.1 Context

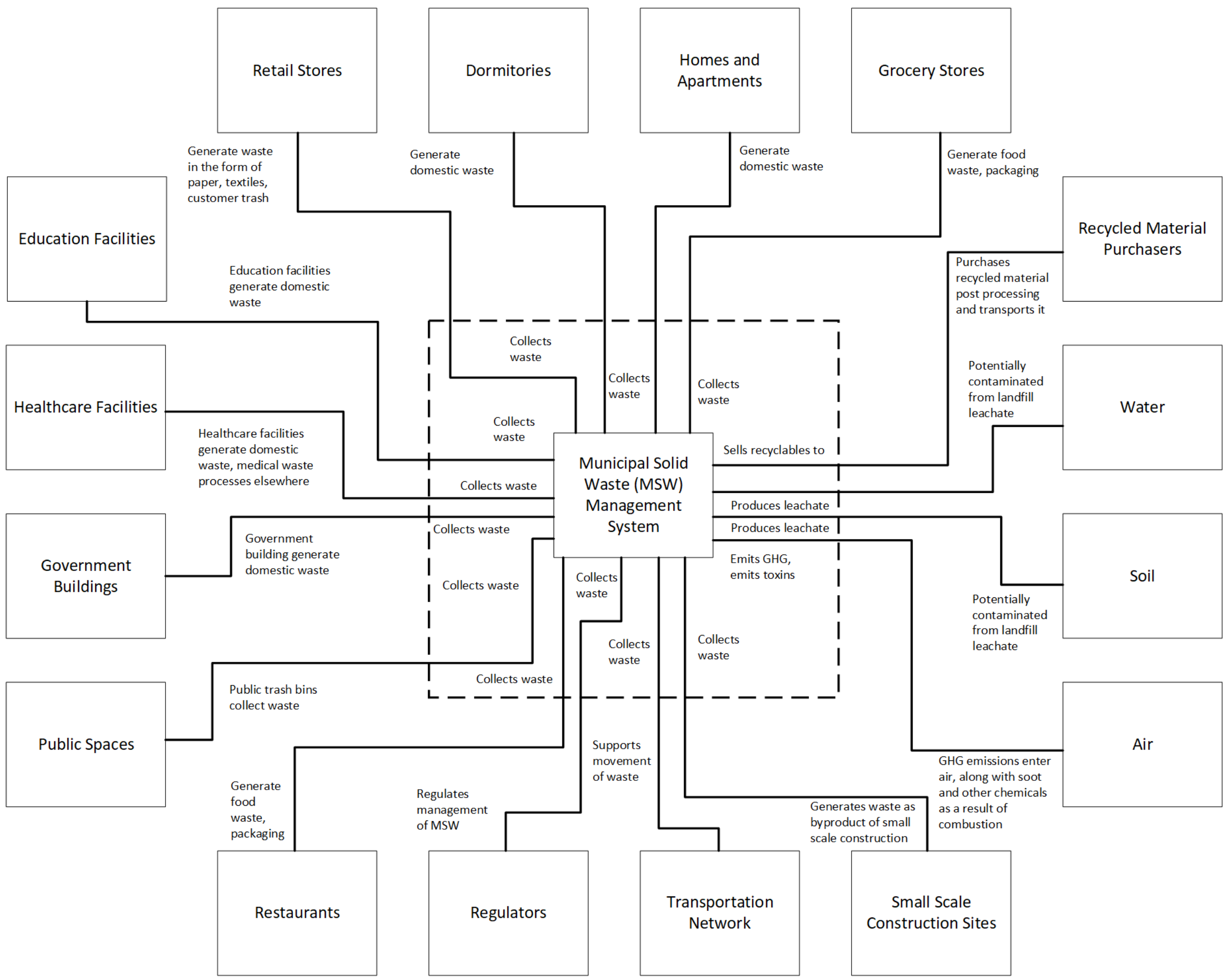

Figure 20.1: Context Diagram for Generic Waste Management System

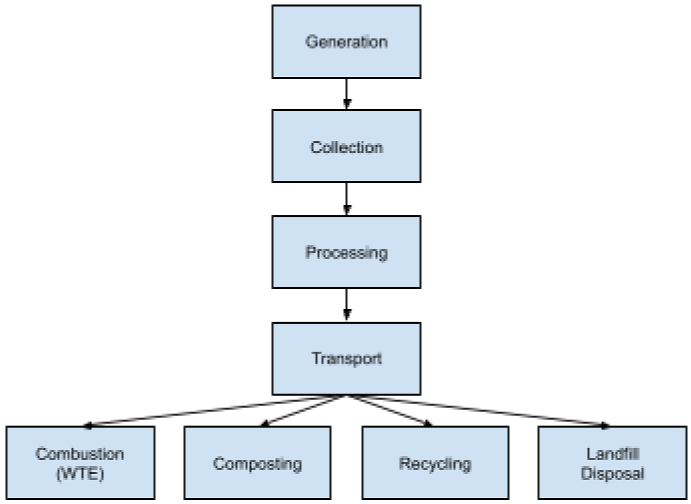

Figure 20.2: Life Cycle Process for MSW

The following table describes each process step in context of the City of Ithaca.

Table 20.1: Life Cycle Processes for MSW in Ithaca

Generation	Municipal Solid Waste (MSW) is generated from houses, apartments, dormitories, educational facilities, healthcare facilities, grocery stores, retail and other community entities. In the United States, each person generates over 5lbs of waste per day, equating to almost 1 ton of MSW per person per year. Taking the population of the Ithaca Metro area, over 100,000 tons of waste are generated annually.
Collection	Residents of Ithaca can purchase trash tags from city hall or local grocery stores, which are used to offset the cost of trash collection. Non-recyclable waste is collected once a week and recyclables every other week. Trash is not collected on Sundays or holidays.[78]
Processing	Waste is presently processed and sorted at the Tompkins County Recycling and Solid Waste Center in Ithaca.
Transport	After being processed, waste is either transported to a Landfill (likely the one in Ontario County), a Waste to Energy Plant (likely the Onagonda Covanta facility), a composting location, or to another recycling facility or vendor.
Composting	Organic waste in Tompkins county can be recycled through composting. Composting collection services are provided through drop off points throughout the county. The compost is primarily household food scraps which are broken down to create nutrient-rich fertilizer through Cayuga Compost, a private company which manages composting facilities.
Recycling	During processing at the Tompkins County Recycling and Solid Waste Center in

[78] "Trash Collection." *Trash Collection | Ithaca, NY - Official Website*, https://www.cityofithaca.org/239/Trash-Collection.

	Ithaca, single stream recyclables are sorted based on type in preparation for a recyclables buyer. Currently the County is able to recycle metal cans and foil, cardboard and paper, paper cartons, glass containers, and 1, 2 & 5 type plastic recyclables.
Landfill Disposal	Modern landfills are well-engineered and managed facilities for the disposal of solid waste. Landfills are located, designed, operated and monitored to ensure compliance with federal regulations. Once at a landfill, waste decomposes over time and the generated methane is ideally captured.[79]
Combustion (WTE)	Waste to Energy Plants burn MSW to produce steam in a boiler that is used to generate electricity. Depending on the technology in place, WTE facilities attempt to prevent the escape of harmful chemicals and generate energy as cleanly as possible.

20.2 GHG Emissions Model Calculations

Generation:

This process step does not inherently have GHG emissions associated with it. As such, no GHG emission equations are presented here. However, calculations for total MSW generated by the City of Ithaca are roughly estimated here.

Across the US, 292.4 million tons of MSW are generated annually (a 2018 value). Operating under the assumption that MSW generation per capita can be estimated by dividing total waste by population (i.e. assuming everyone produces equal waste), each American produces 292.4 million tons / 326.8 million people = 0.9 tons per person. Taking the population of the Ithaca Metro Area, which is around, 102,000, total annual MSW equates to 91,465 tons of waste per year.[80]

Collection and Transportation

(0.0001618 Mg CO2-eq Emissions / Ton-Mile)[81](Annual Ton Miles from Source to Transfer Station + Annual Ton Miles from Transfer Station to Landfill + Annual Ton Miles from Transfer Station to WTE)

Without access to granular ity data, estimates on the total ton-miles from originating sources (e.g. homes, schools, shopping centers etc.), to the landfill, and to the WTE were estimated.

[79] "EPA - Landfills." *EPA*, Environmental Protection Agency, https://www.epa.gov/landfills/basic-information-about-landfills.

[80] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials

[81] *Environmental Defense Fund*, https://www.edf.org/.

- Source to Transfer Station was estimated based on the total number of street miles in the City of Ithaca which was identified to be 70 miles based on data from the department of roads. Total tonnage of waste produced annually by the city was multiplied by miles to get ton-miles.
- Source to Landfill was estimated based on the assumption that the Ontario Landfill is the only landfill that received the city's waste; the landfill is located 52 miles away. Total tonnage of waste heading to the landfill was multiplied by miles to get ton-miles.
- Source to WTE was estimated based on the assumption that the Covanta's Onodaga facility is the only WTE that receives the city's waste; the WTE is located 60 miles away. Total tonnage of waste heading to the landfill was multiplied by miles to get ton-miles.

Combustion (WTE)

(0.202 MgCO2-eq / Mg MSW)[82](Annual Mg of Waste to WTE Plants)

Without access to granular city data, estimates on total waste sent to WTE were estimated.

- Across the US, 292.4 million tons of MSW are generated annually. Of this, 34.5 million tons were processed as WTE (combustion with energy recovery); approximately 12%. Assuming this percentage can be applied to the MSW combusted in the Ithaca Metro area, the result thus obtained is 10,976 Mg annually

Landfill Disposal

(3.96 MgCO2-eq / Mg MSW)[83](Annual Mg of Waste to Landfills)(Recovery Percentage)

Without access to Ithaca specific data, estimates on total waste sent to Landfills was estimated.

- The annual quantity of waste sent to landfills in the US in 2018 was 146,100,000 Mg, which is around 50% of the total MSW generated in the US (292,400,000 Mg). Assuming this percentage can be applied to the MSW landfilled in the Ithaca Metro Area, the result thus obtained is 45,733 Mg annually. With that said, based on available data and insight regarding landfill disposal rates, this figure was increased to 53,954 Mg to ensure the model remains whole (i.e. ensure total generated equals total managed)[84]

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[82] Haith, Douglas. "Greenhouse Gas (GHG) Emissions Associated with MSW." Cornell University - BEE 4760 - Solid Waste Engineering.
[83] Haith, Douglas. "Greenhouse Gas (GHG) Emissions Associated with MSW." Cornell University - BEE 4760 - Solid Waste Engineering.
[84] "What Does New York Do with All That Trash? One City's Waste – in Numbers." *The Guardian*, Guardian News and Media, 27 Oct. 2016, https://www.theguardian.com/.

- CH_4 when burned is converted to biogenic CO_2 (not considered a GHG). However, landfill liners are not impervious to leaks. A recovery percentage was estimated to be 70% (i.e. 30% leakage) based on Sierra Club investigations[85].

Composting

(-0.312 MgCO2-eq / Mg MSW)[86](Annual Mg of Waste Composted)

Without access to Ithaca specific data, estimates on total waste Composted was estimated.

- The total MSW generated in 2018 for the whole of the US is 292,400,000 tons. Of this 8.5% or 24,890,000 tons of MSW were processed by composting. Assuming this percentage can be applied to the MSW composted in the Ithaca Metro Area, the result thus obtained is 7775 Mg MSW annually.

Recycling

(-3.89 Mg CO2-eq / Mg of Paper)(Paper Mg) +
(-3.44 Mg CO2-eq / Mg of Cardboard)(Cardboard Mg) +
(-1.13 Mg CO2-eq / Mg of Plastics)(Plastics Mg) +
(-0.3 Mg CO2-eq / Mg of Glass)(Glass Mg) +
(-2 Mg CO2-eq / Mg of Steel Cans)(Steel Cans Mg)
(-10.04 Mg CO2-eq / Mg of Al Cans)[87]Al Cans Mg)[88]

Without access to Ithaca specific data, estimates on consistency of recyclables were estimated as follows:[89]

- Paper and Paperboard Recycling: The total MSW generated in 2018 for the whole of the US is 292,400,000 tons. Of this around 16% or 45,970,000 tons of paper and paperboard MSW were recycled nationwide. Assuming this percentage can be applied to the paper and paperboard MSW recycled in the Ithaca Metro Area, the result thus obtained is 14,634 Mg MSW annually.
- Plastics Recycling: The total MSW generated in 2018 for the whole of the US is 292,400,000 tons. Of this around 1.06 % or 3,090,000 tons of plastic based MSW were

[85] *Sierra Club*, https://www.sierraclub.org/.
[86] Haith, Douglas. "Greenhouse Gas (GHG) Emissions Associated with MSW." Cornell University - BEE 4760 - Solid Waste Engineering.
[87] "Facts about MSW." *EPA*, Environmental Protection Agency, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials.
[88] The CO2-eq Emissions / Mg of waste recycled (by types) was identified in BEE 4760 - Solid Waste Engineering - lecture notes and originally derived from material developed by the International Finance Corporation (IFC).
[89] "Facts about MSW." *EPA*, Environmental Protection Agency, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials.

recycled nationwide. Assuming this percentage can be applied to the plastic based MSW recycled in the Ithaca Metro Area, the result thus obtained is 970 Mg MSW annually.

- Glass Recycling: The total MSW generated in 2018 for the whole of the US is 292,400,000 tons. Of this around 1.05 % or 3,060,000 tons of glass based MSW were recycled nationwide. Assuming this percentage can be applied to the glass based MSW recycled in the Ithaca Metro Area, the result thus obtained is 957 Mg MSW annually
- Ferrous Metals Recycling: The total MSW generated in 2018 for the whole of the US is 292,400,000 tons. Of this around 2.17 % or 6,360,000 Mg of ferrous metals based MSW were recycled nationwide. Assuming this percentage can be applied to the ferrous metals based MSW recycled in the Ithaca Metro Area, the result thus obtained is 1989 Mg MSW annually.
- Aluminum Recycling: The total MSW generated in 2018 for the whole of the US is 292,400,000 tons. Of this around 0.23 % or 670,000 Mg of ferrous aluminum based MSW were recycled nationwide. Assuming this percentage can b[90]e applied to the ferrous metals based MSW recycled in the Ithaca Metro Area, the result thus obtained is 210 Mg MSW annually.

[90] "Facts about MSW." *EPA*, Environmental Protection Agency, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials.

21. Appendix XIII: Energy Battery Storage

Table 21.1: Energy Density and Other Characteristics for Various Batteries

	Lithium-ion (all chemistries)	LiFePO4	LiNiCoAl	LiNiMnCo	VRFB	Lead-acid	Nickel-based
Volumetric Energy Density (Wh/L)	200-670	220-250	210-600	325	20-70	80-100	
Gravimetric Energy Density (Wh/kg)	100-350					25-50	50-95
Volumetric Power Density (W/L)		4500	400-500	6500		500	
Gravimetric Power Density (W/L)	250-350					150-250	
Efficiency	80-90%				60-91.98%	79-85	
Cycle life (cycles)	500-2000				12000-14000	500-1000	
Lifetime (yrs)	10				15	12	
Development stage	Widely commercial				Initial Commercial	Widely commercial	
Cost ($/kWh)	132-487				393- 609	200-448	
Cost ($/kW)	1408-1947				1995- 2438	1520- 1792	
Voltage Max (V)	3.6-4					2.05-2.15	

Table 21.2: Electrochemical Energy Storage Characteristics (based on 10 MWh system)

	Li Ion (all chemistries)	LiFePO4	LiNiCoAl	LiNiMnCo	VRFB	Lead-acid	Nickel-based
Weight (Mg)	28.6-100					200-400	
Space (cubic meters)	14.92-50	40-45.5	16.7-47.6	30.8	142.9- 500	100-125	
Upfront Cost (million $)	1.32- 4.87				3.93- 6.09	2.00-4.48	
Yearly Cost (thousand $)	132-487				262-406	167-149	
Cost per cycle ($)	660-9740				281-508	2000-8960	

22. Appendix XIV: Feasibility Analysis for Electrification of Ithaca's Municipal Buildings

22.1. Introduction

Climate change is a growing concern as greenhouse gas emissions continue and the earth's temperature keeps rising. Many nations and organizations have a goal of becoming carbon neutral by 2050, but by then it might be too late. In Ithaca's Green New Deal, Ithaca has made an aggressive goal to reach carbon neutrality by 2030 in an equitable way which benefits the entire community. Ithaca has the potential to be a trailblazer in sustainability and serve as a role model for other cities to follow suit. Thus, this project could not only cut many tons of carbon emissions from Ithaca's community, but also have wide-reaching impacts for communities across the country.

Reaching carbon neutrality has two main steps: electrifying anything which currently runs on fossil fuels, such as vehicles and building heaters; and switching over to renewable sources of energy generation such as solar, wind, hydro, or nuclear. As part of Ithaca's initiative, Tompkins Consolidated Area Transit (TCAT) has been switching out its transit buses from diesel to electric. One future project is to implement smart microgrids to accommodate the new increase in electric demand and intermittency from renewables. Additionally, the City is encouraging businesses and residents to decarbonize and electrify their buildings. If every building is electrified, Ithaca could cut its 400,000 tons of carbon emissions by a staggering 40%.[2]

However, to be able to convince others to electrify their buildings, Ithaca must lead by example. This report describes a preliminary feasibility analysis for electrifying seven of Ithaca's municipal buildings. The findings are presented to the City of Ithaca with the intention of helping them make informed decisions on building electrification.

22.2. System of Requirements

In November 2021, Luis provided an initial list of goals for the project:

1. Asset inventory (thermal loads)
2. Efficiency analysis (energy use, comparing nameplate and actual efficiency, and carbon emissions)
3. Electrification feasibility analysis (load increase and energy efficiencies associated with air- and ground-source heat pumps)
4. Implications (necessary upgrades to the building electrical systems and grid infrastructure)
5. Recommendations to eliminate carbon emissions from energy use through electrification

These goals were for the most part maintained throughout the project, but there were some adjustments made. For example, the second goal asks to compare nameplate to actual efficiency, which would require using a sensor and measuring the input and output of each unit. This would be overly complicated, so instead, between 0 and 5% was deducted from each nameplate efficiency based on the age of the unit.

After some planning and discussion, it was decided that both energy and power calculations were necessary for the project. Yearly energy consumption both before and after electrification help to calculate yearly savings and reductions in carbon emissions. Peak power demand is required to investigate implications for grid infrastructure.

Initially, it was assumed that air source heat pumps would be the most cost-effective option. However, it was decided that relevant values would be computed for both air source and geothermal heat pumps to provide a second option. Values provided in this report can help to compare the two options.

A full financial analysis comparing different options is needed to make informed recommendations to the City. Due to time constraints, this report only provides some of the necessary financial details. Section 22.8 describes next steps that can be taken to be able to make informed decisions.

The following list is the updated system of requirements completed in this project:

1. Take inventory of existing thermal loads in each building
2. Extract units' efficiencies and maximum outputs from nameplates
3. Estimate yearly increase in electric energy usage and decrease in natural gas usage from electrification to calculate yearly savings
4. Estimate maximum power demand increase from electrification
5. Estimate minimum size and price of batteries for energy storage possibility
6. Perform steps 3 through 5 for both air source and geothermal heat pumps, then compare results
7. Present findings and suggested next steps to the City of Ithaca

22.3. Background Information

The following section describes relevant technologies and concepts related to building electrification.

22.3.1. Heat Pumps

Heat pumps are an excellent alternative to heaters that run on fossil fuels. Heat pumps move heat from one place to another instead of generating it, which makes it possible for them to have efficiencies over 100%. In fact, some heat pumps can reach up to 450% efficiency, meaning the heat energy output is four and a half times the electric energy input.[3] Another benefit is that heat pumps can both heat and cool a building and have high efficiencies for both applications.

There are three main types of heat pumps: air source, water source, and geothermal. Geothermal heat pumps, also known as ground source heat pumps, are more expensive than air source heat pumps, but they are also more energy efficient. Geothermal heat pumps draw heat from several feet underground where the temperature does not fluctuate nearly as much as it does above ground. This attribute helps the heat pump maintain its efficiency in extremely cold or hot climates. In contrast, an air source heat pump's efficiency can drop from its usual efficiency of about 350% down to 150% or lower in extreme temperatures. Since Ithaca has particularly cold winters, it is important to take account of this drop in efficiency when considering installing air source heat pumps.

22.3.2. Grid Infrastructure

All grid infrastructure has limits for the amount of power flow it can handle. Most of the grid infrastructure in Ithaca is already either near or at full capacity, and electrification would cause a significant increase in peak power demand. There are several possible solutions to mitigate this problem.

One possible solution is to update the infrastructure by replacing cables, transformers, substations etc. with new ones which can handle greater power flow. Grid upgrades are expensive, but they can last a long time. Perhaps some of the costs can be offset by the fact that some of the infrastructure already needs to be replaced soon.

There are also non-wires solutions to accommodate the new increase in power demand. Local energy storage can help to "peak shave" a building's load profile, as shown in Figure 22.1. Energy storage is usually accomplished with large batteries. The batteries discharge during peak hours of the day and discharge during off-peak times. Peak demand usually lasts for about three hours in the middle of the day. Additionally, solar panels can be installed on the building's roof to provide local power generation. Both batteries and solar panels serve to lessen the power demand on the grid. However, solar energy generation is intermittent, so solar panels are more effective when used with batteries.

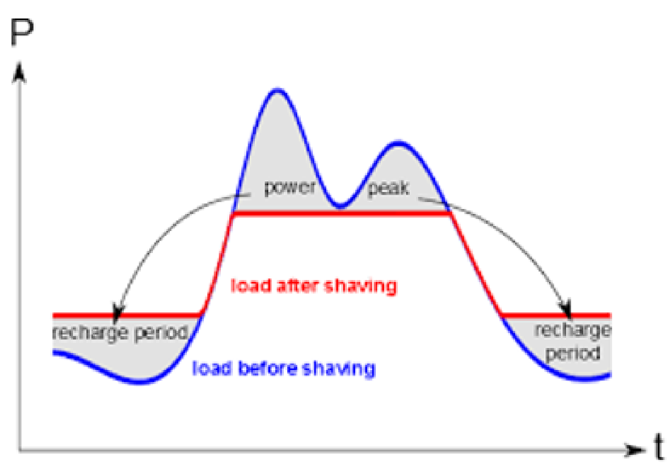

Figure 22.1: Peak shaving with energy storage.[4]

The costs incurred from either solution will likely be shared between NYSEG (the local utility company) and Ithaca, so it will be necessary to have communication and collaboration between the two stakeholders.

22.4. Range of Solutions

It is important for a heat pump to be an appropriate size for a particular building; if it is too small, it will work overtime and possibly not be able to meet the building's heating and cooling needs, and if it is too big, it will degrade at a faster rate. Properly sizing heat pumps usually involves looking at a range of factors, including building volume, insulation quality, climate, temperature preferences, and heating generation appliances such as ovens and refrigerators.

For the purposes of this project, it was simpler and possibly more accurate to instead use the existing units in the buildings to calculate the new energy and maximum power usage. For example, if a boiler is to be replaced with a heat pump, the new yearly energy usage can be calculated by multiplying the boiler's efficiency by its yearly natural gas usage, converting from BTU to kWh, and dividing by the efficiency of the new heat pump. To calculate maximum power usage in this example, the boiler's maximum output power can be converted from BTU/hr to kW and divided by the coefficient of performance (CoP) of the heat pump. If a building's current HVAC system cannot keep up with heating demand, the estimated heat pump size can simply be increased. Further explanation of calculations can be found Section 22.6.

This technique has enough accuracy partly because the building "envelope" is assumed to not change, so insulation will have the same quality for the old and new systems. Thus, heating needs will largely stay the same as what they were when the original units were sized. Additionally, the former technique would require knowledge of the insulation quality, and since most of the municipal buildings are quite old, the insulation quality is likely poor and difficult to estimate accurately.

22.5. Data Acquisition

Information on all existing "thermal loads," which are units that use natural gas, needed to be gathered for each building. A site survey was performed at each municipal building. Each thermal load was documented using the Fast Site Survey™ app by EMPEQ. Pictures of each unit and their nameplate were taken and stored in the app. Later, relevant information such as efficiency and peak power was extracted from the nameplates.

A spreadsheet was provided with yearly electric and natural gas bills for each building spanning back approximately ten years. After further examination, it was discovered that monthly electric bills would help in calculations, so monthly bills for the past year and a half were also provided for each building.

22.6. Calculation Methods

Tables 22.1 and 22.2 show an example of power and energy calculations for one building, specifically the Greater Ithaca Activity Center (GIAC). There are four existing thermal loads in the building: the north rooftop unit, south rooftop unit, boiler, and water heater. In order to electrify the building, all four of these units would be replaced with electric alternatives. Calculations for each building followed the same general method, so this building's calculation description can serve as an example of how others were done.

22.6.1. Power

As shown in Table 1, the total increase in peak power demand was calculated by converting the peak power demand from BTU/hr to kW, then divided by the efficiency of the replacement unit. For heating units, the peak power output was provided on each of their nameplates. However, the water heater's peak power was not provided on its nameplate, so it was calculated by multiplying its input power by its thermal efficiency.

Power

Existing Unit	Input (BTU/hr)	Thermal Efficiency	Maximum Power Output (BTU/hr)	Maximum Power Output (kW)	Replacement Unit	Minimum Efficiency	New Max Electric Power Input (kW)
North Rooftop Unit	-	-	426,400	125	Heat Pump	150%	83.31
South Rooftop Unit	-	-	426,400	125	Heat Pump	150%	83.31
Boiler	-	-	2,000,700	586	Heat Pump	150%	390.90
Water Heater	75,100	80%	60,080	18	Heat Pump Water Heater	200%	8.80

Total Increase in Peak Energy (kW)	**399.70**

Table 22.1: Example calculation for a building's increase in maximum power demand

The minimum efficiency for the heat pump was assumed to be 150%, which is considerably lower to a heat pump's typical efficiency of around 350%. This lower efficiency was used because an air source heat pump's efficiency usually drops at extremely cold temperatures. The water heater heat pump's efficiency was assumed to be 200%. This type of heat pump usually draws air from inside the building where the surrounding temperature will not drop as low as it will outside.

22.6.2. Energy

Energy

Natural gas to electric

Existing Unit	% of Natural Gas Usage	Yearly Natural Gas (therms)	Existing Unit Efficiency	Energy Output Per Year (Therms)	Energy Output Per Year (kWh)	Replacement Unit	Replacement Unit Efficiency	Electric Energy Usage of Replacement Unit
North Rooftop Unit	11%	2478.95	75%	1859.21	54475	Heat Pump	350%	15,564
South Rooftop Unit	11%	2478.95	75%	1859.21	54475	Heat Pump	350%	15,564
Boiler	53%	11631.42	77%	8956.19	262417	Heat Pump	350%	74,976
Water Heater	24%	5199.06	80%	4159.25	121866	Heat Pump Water Heater	300%	40,622

Air conditioner to heat pump

% of electric usage	Yearly electric usage (kWh)	Existing Unit EER Rating	Heat pump EER Rating	New Electric Usage (kWh)	Difference in electric usage
14.00%	32,086	13	18	23,173	8,913

Total Increase in Electric Energy Usage (kWh)	**137,814**
Reduction in Yearly Natural Gas Bill	$9,337.66
Increase in Yearly Electric Bill	$7,395.51
Total Yearly Savings	**$1,942.15**

Table 22.2: Example calculation for a building's yearly increase in electrical energy use

The yearly increase in electric energy usage was calculated by using the average yearly natural gas usage and the energy efficiencies of both the existing and replacement units, as demonstrated in Table 22.2. The energy efficiencies of the heaters were calculated by dividing the output by the input. If the unit was old, between one and five percent was subtracted from the calculated efficiency to account for decreasing efficiency due to age.

However, since each unit has a different efficiency, the percentage of natural gas usage for each unit needed to be approximated. The monthly natural gas bill was acquired in order to make these percentages more accurate. The natural gas usage was separated into two categories: (1) gas used to heat the building, and (2) gas used for other usages such as water heaters or stoves. It was assumed that (1) was not used at all in the summer months, while (2) was used all year round. Thus, the natural gas usage during the summer months was assumed to be constant year-round, and the gas use that exceeded this monthly amount represented (2). A visual representation of this strategy is shown in Figure 22.2.

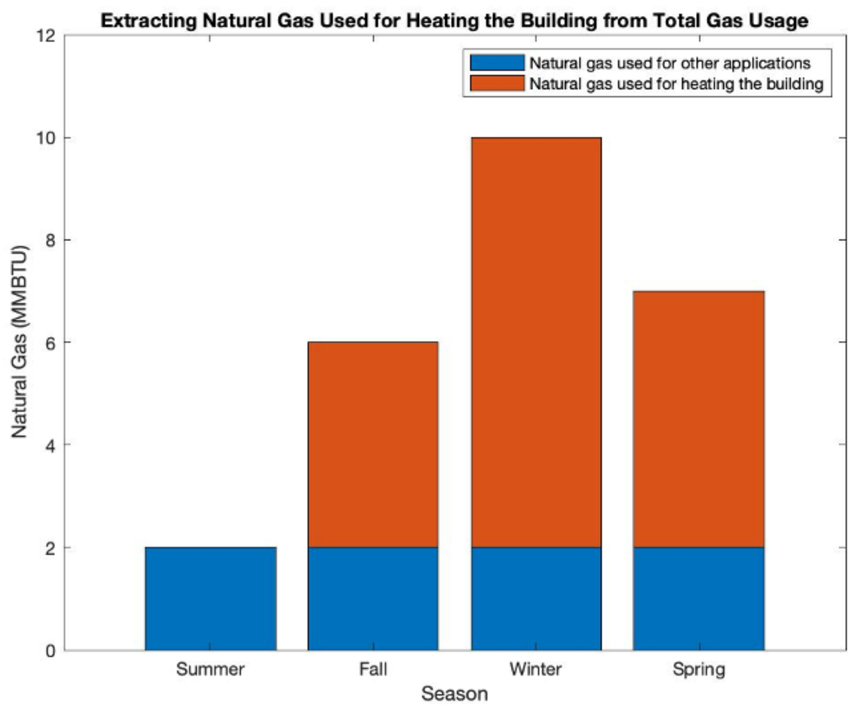

Figure 22.2: Visual representation of extracting natural gas used for heating the building from total gas usage.

Figure 22.3 shows an example calculation for the percentage of natural gas to heat the building and not to heat the building. Since there are three units which heat the building, the percentage of heating contribution was estimated for each heating unit using ratios of their maximum power output to the total maximum power output. These percentages were multiplied with the percentage of natural gas used to heat the building to arrive at the values seen in Table 22.2.

Monthly Natural Gas Usage

Read Date	Read Type	Use (therms)	therms per day
2/22/22	NYSEG	3405.9	121.64
1/25/22	NYSEG	3632.5	121.08
12/26/21	NYSEG	3015	91.36
11/23/21	NYSEG	2077.8	74.21
10/26/21	NYSEG	1586.4	49.58
9/24/21		1146.3	38.21
8/25/21	NYSEG	1052.9	36.31
7/27/21	NYSEG	1504.7	45.60
6/24/21	Estimated	849.1	28.30
5/25/21	NYSEG	1420.6	48.99
4/26/21	NYSEG	2011.2	59.15
3/23/21		2926.5	100.91
2/22/21	NYSEG	3468.7	128.47
1/26/21	NYSEG	4343.6	131.62
12/24/20	NYSEG	3493.1	112.68
11/23/20	NYSEG	2091.1	74.68
10/26/20		1495.9	46.75
9/24/20	NYSEG	1943.1	12.95
8/26/20	Estimated	452.3	0.01
7/27/20	Estimated	494.4	0.01
6/24/20	Estimated	565.9	0.01
5/25/20	NYSEG	1525.1	0.03
4/27/20	NYSEG	2299.1	0.05

Average cost per therm:	$0.43
Average daily therms:	68.16
Average daily summer therms:	16.26
Daily therms used to heat:	51.90
% of nat gas used for heating:	76.14%
% of nat gas used for others:	23.86%
% of heating used by North	15%
% of heating used by South:	15%
% of heating used by Boiler	70%

Figure 22.3: Example calculations for separating heating and non-heating from natural gas bill.

It was also desired to calculate the percentage of electric power used for cooling the building. This percentage is useful because heat pumps have both heating and cooling capabilities, so they would essentially replace the existing air conditioners. Heat pumps have a higher Seasonal Energy Efficiency Ratio (SEER) than air conditioners, meaning they are more efficient. Thus, the increase in electric energy use from replacing natural gas units with electric units is slightly offset by the electric energy saved from using the cooling function of heat pumps instead of air conditioners.

To estimate this cooling percentage, a similar strategy was tested as described above but this time starting with the monthly electric bill and the assumption that all monthly winter electric usage does not include air conditioning. However, this method also requires the assumption that units which use electricity in the winter use the same amount of electricity year-round, which is usually not true. For example, some buildings have space heaters which would use more electricity in the winter than in other months. Thus, when the method was used, the percentages calculated for cooling were calculated to be either unrealistically small or negative values. Due to these findings, it was decided that a researched value of 14% would be used for all buildings instead.[5]

Information about air conditioners was gathered by building managers so that their efficiencies could be acquired. However, many of the models did not have available information about their efficiencies. Of the air conditioners that did display their efficiencies, they all had a seasonal energy efficiency ratio (SEER) of 13. Thus, it was assumed that all air conditioners had a SEER rating of 13 and that the new air source heat pumps would have a SEER rating of 18.[6]

As shown in Table 22.2, after calculations were complete for electric energy increase for each thermal load and electric energy decrease from cooling, the latter value was subtracted from the sum of the former to calculate the net electric energy increase. This value was multiplied by the cost per kWh, which is about 5¢, to calculate the total increase in the yearly electric bill. The average yearly natural gas usage was multiplied by the cost per therm, which is about 43¢, to calculate the yearly decrease in the natural gas bill if the building is electrified. Thus, the increase in electric bill can be subtracted from the decrease in natural gas bill to calculate the total yearly savings. For the GIAC building, the savings is estimated at $1,942.15 per year.

6.3. Energy Storage

Total Power

Building	Total Power Increase (kW)	Total Energy Storage Need (kWh for 3 hours)	Total Cost for Energy Storage Batteries
Fire Station 1	121	364	$125,596
Fire Station 3	84	252	$87,086
City Hall	273	818	$282,298
IPD & Courthouse	401	1,202	$414,844
South Side Community Center	171	512	$176,537
Greater Ithaca Activity Center (GIAC)	400	1,199	$413,692
Ithaca Youth Bureau (IYB)	146	438	$151,070
Total	1,595	4,786	**$1,651,123**

Table 22.3: Total power increase and energy storage needs for each building

As demonstrated in Section 22.6.1, the total increase in peak power was calculated for each building. Table 22.3 shows the totals. To calculate the battery size for energy storage, it was assumed that the grid is already at peak capacity, so any increase in power demand would cause the power flow to exceed the grid's thermal limits. This is a fair assumption because most of the power lines are indeed near or at their full capacity. In calculations, it was also assumed that the peak powers would occur for three hours during the day. Thus, the power increase in kW was multiplied by 3 hours to get the required battery size for energy storage in kWh. This value was then multiplied by the typical cost per kWh for battery storage, which is $345/kWh.[7]

22.6.4. Yearly Cost Savings & Reductions in Carbon Emissions

The total yearly savings for each building is shown in Table 22.4. While the grand total savings of $6,981 per year may seem small compared to the upfront costs, it must be remembered that the main purpose of electrification is to reduce carbon emissions. Using the estimate of 12 pounds of carbon dioxide emissions per therm of natural gas burned,[8] it was calculated that the total reduction in carbon emissions for all seven buildings is 505 tons of CO_2 per year to put this figure into perspective, Ithaca as a whole emits 400,000 tons of CO_2 per year.[9]

Total Energy

Building	Total Natural Gas Decrease (therms)	Total Electric Energy Increase (kWh)	Total Yearly Savings	Yearly Reduction in Carbon Emissions (tons)
Fire Station 1	6,780	46,582	$406	41
Fire Station 3	4,395	27,487	$408	26
City Hall	13,616	90,265	$991	82
IPD & Courthouse	19,165	105,011	$2,578	115
South Side Community Center	9,330	60,571	$748	56
Greater Ithaca Activity Center (GIAC)	21,788	137,814	$1,942	131
Ithaca Youth Bureau (IYB)	9,063	62,890	$509	54
Total	84,138	530,620	**$7,584**	**505**

Table 22.4: Yearly savings and reduction in carbon emissions for each building

22.6.5. Air Source vs. Geothermal

All above calculations were performed for all buildings and for both air source and geothermal heat pumps. For air source, the normal efficiency was 350% and the minimum efficiency, which would occur in extremely cold weather, was 150%. For geothermal, the normal efficiency was 450% and minimum efficiency was 400%. As discussed in Section 22.3.1, geothermal heat pump efficiency is not as affected by extreme temperature as is air source efficiency.

22.7. Results & Conclusions

Figures 22.5 and 22.6 show a comparison of estimations for air source and geothermal heat pumps. As seen in Figure 22.6, the yearly savings for geothermal is more than double than for air source. Perhaps more significant is the fact that air source would cost nearly one million dollars more than geothermal in initial energy storage costs to accommodate for power demand increases. This gaping difference in battery costs is because air source efficiency drops significantly in cold weather, but geothermal does not. Therefore, even if the cost of installation for geothermal is more than that of air source, geothermal might still be the more cost-effective option.

Building	Air Source: Total Power Increase (kW)	Air Source: Total Cost for Energy Storage Batteries	Geothermal: Total Power Increase (kW)	Geothermal: Total Cost for Energy Storage Batteries
Fire Station 1	121	$125,596	57	$58,864
Fire Station 3	84	$87,086	40	$41,587
City Hall	273	$282,298	102	$105,862
IPD & Courthouse	401	$414,844	156	$161,262
South Side Community Center	171	$176,537	67	$69,235
Greater Ithaca Activity Center (GIAC)	400	$413,692	155	$160,829
Ithaca Youth Bureau (IYB)	146	$151,070	60	$62,346
Total	1,595	**$1,651,123**	638	**$659,984**

Table 22.5: Comparing energy storage cost for air source vs. geothermal heat pumps.

Building	Air Source: Total Yearly Savings	Geothermal: Total Yearly Savings
Fire Station 1	$406	$1,129
Fire Station 3	$408	$782
City Hall	$991	$2,549
IPD & Courthouse	$2,578	$4,799
South Side Community Center	$748	$1,621
Greater Ithaca Activity Center (GIAC)	$1,942	$3,556
Ithaca Youth Bureau (IYB)	$509	$1,510
Total	**$7,584**	**$15,946**

Table 22.6: Comparing yearly savings for air source vs. geothermal heat pumps.

22.8. Further Studies

This project was a preliminary assessment. This section describes further studies and analysis that can be performed to make more informed decisions regarding electrification of the buildings.

In practical application, improving the buildings' envelope could help to reduce the size of new heat pumps and yearly electric energy use. Envelope improvement usually involves measures such as replacing windows and adding insulation.

For simplicity, energy storage calculations were performed with the assumption that the infrastructure is now at full capacity at each building. For more accurate estimates, a smart meter such as an Advanced Metering Infrastructure (AMI) meter should be installed at each building's feeder to acquire a daily load profile. Energy storage can help to levelize the load profile by charging at off-peak hours and discharging at peak hours. If a larger battery were to be installed than the minimum necessary size, the battery could reduce peak power and the building could have a higher load factor. This way, there is less stress on the grid, which defers grid investments.

Solar panels could also be installed on the roof of buildings. The panels could charge the battery during off-peak hours and sell power to the grid during peak hours when electricity is more expensive. This income could help offset the cost of battery storage and/or solar panels.

Energy storage and solar panels are non-wires alternatives to updating the grid infrastructure. In this case it may be more cost effective to update grid infrastructure, especially since the City's ultimate goal is to electrify all buildings; if grid upgrades could be performed all at once based on the forecasted increase in peak power for the entire city, it may be cheaper than installing energy storage in each individual building. Some of the infrastructure may already be nearing the end of their useful life, so it would need to be replaced anyways.

A full financial analysis could be conducted for electrification using the figures provided in this report. Other relevant costs include installation costs, maintenance, and cost for infrastructure upgrades. There are several stakeholders for this project, including the City of Ithaca, Avangrid/NYSEG, and potential investors. An internal rate of return (IRR) and net present value (NPV) could be calculated for the project, where the NPV's discount rate would be based on the cost of capital from investors. Different IRR's and NPV's could be calculated if there are several options in consideration (for example, air source vs. geothermal heat pumps, energy storage vs. infrastructure upgrades). The NPV would likely be negative, and even the IRR might be negative since the upfront costs are so high. However, a cost per ton of carbon emissions could be calculated using the net in cost in order to put the positive environmental impact in a financial perspective.

22.10. References

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