

**Course Syllabus – DRAFT**
ver. 2**ISEN 498 Energy & Sustainability Project Practicum**
Spring 2020**Northwestern University**

Instructor / Faculty Advisor: Holly Benz, Clinical Associate Professor, McCormick School of Engineering

Class Timing: Spring 2020; Tu, Thu 11-12:30 (Tuesday is lecture, Thursday is team meeting day)

Class Location: Annenberg G32; presentation rooms may be specially arranged for presentations

Office Hours: By appointment; Tech M486

Course Synopsis

This class is a practical course focused on experiential learning. It is targeted to students who are passionate about energy & sustainability and are seeking real-world project experience. The course is almost solely centered on a 10-week, team-based consulting project for a corporate, non-profit or government partner of Northwestern University. Student teams will be advised by the instructor but will work directly with the client organization. There will be limited traditional reading / lecture content and the topics covered will include project management and team collaboration.

Course Details

The projects will be pre-selected by the instructor and students can rank their preferences for the projects. All projects will have a clearly defined scope and deliverables and the projects will include economic, technical and regulatory / policy aspects to the analysis. The projects will vary and could range from a government sponsored project about electric vehicle infrastructure to a new market entry analysis for a corporation in circular economy to building a sustainable water strategy for a food manufacturer.

This course will be offered in the Spring quarter each year and priority for seats will be offered to MSES students. All graduate students are eligible to apply to MSES / the instructor to join the class. Due to the involvement of clients and the need to ensure teams are properly resourced, the class cannot be dropped once the Spring quarter has started ([March 31, 2020](#)). In Spring 2020, extra seats will be made available to non-MSES students.

This is a required course for all MSES students to ensure that they get real world, project experience through their course of study. Other students interested in energy & sustainable business should consider this course as well. It has a very similar structure to Kellogg's KPPI 936 and it may provide additional capacity to Kellogg students if the ISEN 498 projects are a better match for their interests. The class will also appeal to students studying engineering, economics, social sciences and natural sciences. Students from all schools including Medill, Pritzker, Feinberg and others may enroll in this class. Some undergraduate upperclassmen may be granted permission to enroll with department permission. Anyone exploring a career in energy or sustainability should find this course valuable.



Master of Energy & Sustainability Program *Project Practicum*

Selected partners will have the opportunity to propose a 10 week spring project. Sponsor will get a chance to have a key strategic question reviewed. This is a low-cost way to address project based topics.

Topic, Scope & Deliverables



- Each team will select a topic based on options provided by Master's program administration
- Partner will be asked to offer 2 topics of interest and the faculty leader will select one
- Scope & deliverables will be defined by student team and faculty liaison with agreement from partner
- Team will work independently but there will be an interim check in at 5 weeks with partner contact and a final presentation of all deliverables at 10 weeks

Timeline



- Jan 2020 - Sponsor to provide topics
- Feb / Mar 2020 – Teams selected
- April 2020 – Team kickoff meeting
- May 2020 – Midpoint check in
- June 2020 – Final deliverable presented

Role of Partner Contact



- Provide topics, agree scope and offer direction
- Participate in a minimum of 2-3 (phone) meetings
- Provide feedback on midpoint deliverables
- Attend final project presentation (ideally in person)

Team



Faculty Sponsor

Student Team (3-6 Students)

Consulting Project Coach

While this course is for credit, students should treat it as a professional project with a “real” client. Most clients schedule a weekly conference call and the class time on Thursday can be used for the client call and / or team meeting. A meeting of the project team and the faculty advisor may happen in addition to (and in advance of) that call. The entire team is expected to normally participate in each meeting in a timely and prepared fashion, though other work is normally divided up between team members. The meeting times are flexible, however, it is your responsibility to schedule team meetings and to organize work as necessary.

Course Goals

- Provide “on the job” training on how to successfully manage and deliver a project
- Offer exposure to leading companies / organizations
- Ensure teams have strong project management skills and have put them to the test
- Hone problem solving abilities
- Improve formal presentation skills and collaboration
- Learn to work successfully in teams
- Test ability to consider economic, technical and policy aspects of a problem / opportunity
- Demonstrate aptitude to craft a compelling business case

Format

- Work directly with corporate, government or non-profit client
- Includes individual, team and client facing work
- Requires clearly defined scope (agreed and sharpened with client and instructor in Week #1)
- Regular (weekly) meetings with team, client and instructor
- Mid-term progress presentation (to class & client)
- Final presentation (to class, client & other NU stakeholders)



Project Assignments

All students interested in the course must apply for projects (in rank order) **by March 11, 2020**. Project applications will open around **March 2, 2020** and MSES students must rank all projects (as this is a required core course). Other students taking ISEN 498 as an elective may rank as few as one project (meaning if they do not get that project, they will not enroll in the course). All students will be advised of their project assignment by **March 20, 2020** and they will be provided with a confidentiality agreement to sign. Once returned signed via email, the student will be introduced to his / her team and will be provided access to background information for that client. Some example projects include:

- **City Government**: Assessment of EV infrastructure in an urban area and recommendations on how to ensure regulatory policies promote equitable, economically attractive and technically feasible deployment of EV charging infrastructure (L2, L3 charging)
- **Microgrid Company**: Understand and update the value proposition for microgrids for an infrastructure and solutions player entering the “energy as a service” (EAAS) space
- **Food Retailer**: Evaluate opportunity to expand “circular economy” offering in grocery space. Perform market segmentation, assess cost impacts and recommend next steps. Consider attractiveness vs. other product innovations competing for scarce capital
- **Water Company**: Conduct customer interviews and market research to determine the appetite for increased water efficiency programs, top targets to deploy efficiency offers, key messaging and value proposition to focus on. Estimate cost / benefit to launch water efficiency as recommended.

Students may also be allowed to propose their own project if it meets the course objectives and a suitable client sponsor will commit to the requirements of ISEN 498.

The Role of Faculty Advisor (Instructor)

Teams are expected to manage their project independently with the client project liaison. The faculty advisor’s role is to help you structure and solve problems, to help avoid and remove roadblocks, to intervene in the case of conflicts within the team or with the client, and to suggest appropriate resources, such as experts and materials applicable to the project. Your team must serve as the project manager but the instructor will work to support you with appropriate resources. The student team, however, is responsible for the project, its deliverables and the communications of the team. The faculty advisor participates in all communication with the client and meets with the team once a week for about 30 minutes (and more often if needed).

Lecture Sessions

This course is mostly comprised of independent and team-based project work along with regular project meetings with both the client and the faculty advisor. In addition to the project-based work, there will be 3 class lecture sessions (Week #1, 3 and Week #6) and several presentation workshops (x2 for midpoint presentations, x2 for final presentations). Lecture content will cover project management skills and working in teams. The intent is to provide student with tools to deliver a better result in their consulting project and to practice using the tools in advance of entering (or re-entering) the professional world. In the weekly outline below, Session A is Tuesday and Session B is Thursday for Spring Quarter 2020. In general, students can plan to use the second scheduled class time (and space in Annenberg G32 for team meetings).



Expenses

Client organizations are expected to cover any project related expenses, such as travel, international calls, or purchase of data or reports, if necessary. Please verify with the client about their policies.

Course Grading:

Grading will be based on the following:

Component	Weight	Details	Due
Midpoint Presentation	25%	Intermediate readout by student teams on progress <ul style="list-style-type: none"> • 60% of grade from instructor • 40% based on client rating 	Week #5
Final Presentation	60%	Intermediate readout by student teams on progress <ul style="list-style-type: none"> • 60% of grade from instructor • 40% based on client rating 	Week #9/10
Peer Rating	10%	Students will be graded (on a 10-point scale) by their team peers; the simple average of team mate scores will be used; each team member has a fixed budget of points to allocate (8 per team member) <ul style="list-style-type: none"> • Fails to meet most or all expectations - 2 • Meets some expectations - 4 • Meets most expectations - 6 • Meets all expectations - 8 • Exceeds some expectations – 10 • Exceeds all expectations – 12 (this is a 120%) <p><i>An initial rating + anonymous comments will be provided at the mid-point to ensure that students have a chance to improve on their team behaviors over the course of the class</i></p>	Week #5 & #10
Feedback Participation	5%	<ul style="list-style-type: none"> • All students will be required to provide anonymous feedback to their team peers (Week #5 and Week #10) • All students will be required to provide live feedback on peer presentations at the midpoint (Week #5) <p><i>Failure to provide timely feedback will result in a zero on both Peer Rating (10%) & Feedback Participation (5%) – this is 15% of the total course grade</i></p>	Week #9/10

**Required Readings:**

Instructor will assign a selection of texts below.

- Course Packet: “Project Management Toolkit”
- Lencioni, Patrick. The Five Dysfunctions of a Team: A Leadership Fable. 2002.
- Lencioni, Patrick. The Ideal Team Player: How to Recognize and Cultivate The Three Essential Virtues. May 2016.

Supplemental Readings:

- Milton Friedman (1970), “The Social Responsibility Of Business Is To Increase Its Profits”, New York Times Magazine, September 13.
- Douglas Beal, Robert Eccles, Gerry Hansell, Rich Lesser, Shalini Unnikrishnan, Wendy Woods, and David Young. “Total Societal Impact: A New Lens for Strategy” BCG, October 25, 2017.¹²

Project Summary:

Each client will draft (and review with the instructor in advance of the course) a project summary (~1-3 pages) that includes the following:

- **Organization Overview** – Mission, Size, History, Current Operational Areas, Revenue / Other Indicator of Scope, # of employees, typical customer base
- **Market Background** – Size of market, key players, major trends
- **Problem Statement** – Outline of the challenge or opportunity your organization wants to address or learn more about
- **Project Description & Scope of Work** – Overview of the major activities the team should engage in 3-8 bullets plus any relevant details
- **Deliverables** – List of the work product the team should provide at the end of the project; include deliverable format (Powerpoint, Word Document etc); offer any guidance on expectations of length / depth of analysis to be provided

Additional information may be appended as deemed relevant. These summaries will be made available to prospective students interested in registering for the courses and should be used to set priorities on project preference.

¹ <https://www.bcg.com/publications/2017/total-societal-impact-new-lens-strategy.aspx>

² <https://www.forbes.com/sites/bobeccles/2017/10/25/total-societal-impact-is-the-key-to-improving-total-shareholder-return/#3f72282c2113>



Class Schedule:

Class will likely meet for two 90 min sessions per week, however, many class times will be dedicated to team working sessions.

Weekly Topic	Description
<p>1: Introduction to Project Management & Effective Teams (week of March 30, 2020)</p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> • <u>Lecture</u>: Project Management Toolkit (40 min) <ul style="list-style-type: none"> ○ Discuss Project Scope & Timeline ○ Hypothesis Development ○ Workplan ○ Roles & Responsibilities ○ Meeting roadmap ○ Client management & major milestones ○ Kick off, wrap up and regular team meetings ○ Faculty Advisor Engagement • BREAK (10 min) • <u>Lecture</u>: Effective Teams (40 min) <p><u>Session B</u></p> <ul style="list-style-type: none"> • Brief initial, in-person discussion with client team leader, data and project discussion & networking (60 min) <ul style="list-style-type: none"> ○ Client to review scope and objectives ○ Q&A from team ○ Scheduling & managing your client kick off meeting ○ Wherever possible, data from the client and the project management toolkit will have been shared before this first class; students must have reviewed both before the first class
<p>2: Project Planning (week of April 6, 2020) <i>*instructor travelling first half of week</i></p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> • Team Meeting • Send initial project plan to instructor • Draft and send initial project plan to instructor <p><u>Session B</u></p> <ul style="list-style-type: none"> • Project plan review with instructor (Friday, April 10th – to be scheduled via Calendly)
<p>3: Client Hypothesis Review (week of April 13, 2020)</p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> • <u>Lecture</u>: Energy & Sustainability Strategy and Opportunity Assessment • Independent team work to draft initial “hypothesis” <p><u>Session B</u></p> <ul style="list-style-type: none"> • Hypothesis review with instructor (to be scheduled via Calendly) - 30 min • Client call



<p>4: Project Work Time (week of April 20, 2020)</p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> Independent team work Project meeting with instructor (to be scheduled via Calendly) - 30 min <p><u>Session B</u></p> <ul style="list-style-type: none"> Independent team work Client call
<p>5: Midpoint Presentations (week of April 27, 2020) <i>*will need to arrange appropriate presentation room for this week</i></p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> Extended class for presentations; 120 minutes of “class” time per day 3 teams will present for 40 minute team slots – 20-25 minutes presentation, 10-15 min Q&A / input from client; 5 min break between presentations Clients will attend individual sessions All ISEN 498 students will attend all six presentations to observe, learn from & support classmates and their clients <p><u>Session B</u></p> <ul style="list-style-type: none"> Extended class for presentations (120 minutes) for second set (3 teams) of presenters <i>Online peer assessments + feedback for team mates will be due at end of this week; this feedback is purely for development purposes – it will not factor into course grade</i> <i>Each student will comment on all other teams’ midpoint presentation – offering a quantitative rating + qualitative comments on both strengths and areas for development</i>
<p>6: Acting on Feedback (week of May 4, 2020)</p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> <u>Lecture</u>: Managing Feedback, Agility & Adaptability (45 min) <u>Discussion</u>: Individuals and teams review feedback (45 min) <p><u>Session B</u></p> <ul style="list-style-type: none"> Extra office hours to discuss specific personal or team feedback, changes in project direction etc (class time + appointments as needed) Independent team work Regular weekly call with client
<p>7: Project Work Time (week of May 11, 2020)</p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> Independent team work Project meeting with instructor (to be scheduled via Calendly) - 30 min <p><u>Session B</u></p> <ul style="list-style-type: none"> Independent team work Client call



<p>8: Project Work Time (week of May 25,2020)</p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> Independent team work Project meeting with instructor (to be scheduled via Calendly) - 30 min <p><u>Session B</u></p> <ul style="list-style-type: none"> Independent team work Client call
<p>9: Project Work Time & Final Draft Review (week of June 1,2020)</p>	<p><u>Session A</u></p> <ul style="list-style-type: none"> Independent team work Extended Project meeting with instructor (to be scheduled via Calendly) - 30 min <p><u>Session B</u></p> <ul style="list-style-type: none"> Independent team work Client call <i>(Recommended) Dry Run / Peer Review of final presentation with another team</i>
<p>10: Final Presentations (week of June 8,2020 - FINALS) <i>*will need to arrange appropriate presentation room for this week</i></p>	<ul style="list-style-type: none"> 2 separate days (6 hours total) 60 minute team slots – 40 minutes presentation, 15 min Q&A from client; 5 min break between presentations Clients will attend individual sessions All ISEN 498 students will attend all six presentations to observe, learn from & support classmates and their clients <i>Final online peer rating for team mates will be due at end of this week</i>

About the Instructor

Ms. Benz is a Clinical Associate Professor at the McCormick School of Engineering and Applied Sciences and Director of the Master of Science in Energy & Sustainability Program (MSES) at Northwestern University. She teaches graduate level courses at Northwestern and is responsible for all aspects of the MSES program including staff, budgets, faculty, courses, facilities, and initiatives, Holly has worked in the energy & sustainability space in executive roles (VP, SVP) since 2005:

- CLEARresult (2016-2018)
- Schneider Electric (2010-2016)
- Centrica / British Gas / Direct Energy (2005-2010)

In her professional roles, Ms. Benz has led strategy for \$6-16B divisions of international energy companies, managed P&Ls including a team of 225 electrical engineers. Before working in the Energy sector, Holly was a strategy consultant with Bain & Company in the UK and worked in Andersen Consulting's Internet Center of Excellence in the US, Brazil and Argentina. She speaks Spanish and

Portuguese. Holly obtained her MBA at The Wharton School and earned an MA in International Studies at The Lauder Institute at the University of Pennsylvania. She is a graduate of Northwestern University, where she majored in economics.

Holly Benz
Northwestern University
Technological Institute, 2145 Sheridan Road, M486
Evanston, IL 60208
E-mail: Holly.Benz@northwestern.edu
Phone: 847-867-7712

Northwestern University Policies & Resources:

Academic Integrity

Academic integrity is taken very seriously at Northwestern. Students are responsible for reading and understanding Northwestern's Academic Integrity policies. All suspected violations will be reported to the McCormick College of Engineering's Dean's Office. These include: cheating, plagiarism, fabrication, unfair advantage, unauthorized collaboration, and aiding and abetting of academic dishonesty. Students found in violation of academic integrity may receive a zero on the assignment or a failing grade for the course, and may be suspended or permanently expelled from the University. See [Academic Integrity: A Basic Guide](#) for more information.

AccessibleNU and Disability Accommodations

Any student requesting accommodations related to a disability or any other condition is required to register with AccessibleNU (847-467-5530) and provide professors with an accommodation notification from AccessibleNU, preferably within the first two weeks of class. All information will remain confidential. See the [AccessibleNU website](#) for more information.

Illness and Medical Leave of Absence

Review the University's [policy](#) on missing academic work due to illness. Your instructor cannot waive an assignment missed due to illness unless she can verify your illness with Health Services.

**Discrimination and Sexual Harassment**

Northwestern's Policies on Discrimination, Harassment, and Sexual Harassment apply to all members of the University community, including students, staff, faculty, and third parties. Any student, staff, faculty member, or third party who believes that they have been discriminated against or harassed on the basis of their race, color, religion, national origin, sex, sexual orientation, gender identity, gender expression, pregnancy, parental status, marital status, age, disability, citizenship, veteran status, genetic information or any other classification protected by law, should contact the Office of Equity at (847) 467-6571. Additional information about the University's discrimination and harassment policies, including the campus resources available to assist individuals with discrimination or harassment concerns, is available online on the [Office of Equity Website](#). Students, staff, and faculty who report harassment, discrimination, or sexual misconduct are also protected under the [University's Policy on Non-Retaliation](#).

Sexual Misconduct and Reporting

Northwestern University is committed to fostering an environment where students are safe and free from sexual misconduct. [Confidential resources](#) are available to those who have experienced sexual misconduct. Faculty and instructors are not confidential resources and are required to report incidents of sexual misconduct, whether discussed in your assignments or in person, to the Office of Equity, which can provide information about resources and options. We encourage students who have experienced sexual misconduct to talk with someone to get support. For more information, including how to request interim protective measures and academic accommodations or file a complaint, see the [Get Help page](#).

Other Resources

Students can find useful resources for safety and security, academic support, and mental and physical health and well-being at the [NUhelp website](#).

Project Divining Rod – Targeting tool for Microgrid Solutions (Schneider Electric)



Organization Overview

- Schneider Electric provides energy and automation digital solutions for efficiency and sustainability. We combine world-leading energy technologies, real-time automation, software and services for homes, buildings, data centers, infrastructure and industries. With revenues of ~€26 billion in FY2018, our 137,000+ employees serve customers in over 100 countries
- <http://www.se.com>

Market Background

- Size of market
 - >\$2B in US 2020
- Key customers
 - Municipalities, universities, commercial / industrial campus, health care, data centers
- Key competitors
 - Incumbent regulated electric utilities, oil and gas companies
- Other stakeholders
 - State regulators, Federal and State politicians
- Major trends in your industry
 - Electrical consumption doubling by 2040
 - 1B people without access to energy, 1.5B people with only intermittent access to energy
 - Electrification of heating and cooling systems (displacing combustion of fossil fuel)
 - Electrification of transportation segment (EV, seaports, airports)
 - Edge computing
 - Indoor agriculture
 - Digitization of energy infrastructure
 - Decarbonization of energy
 - Decentralization of generation, grid controls, etc.

Problem Statement

- It is very difficult for consumers, utilities, and solutions providers alike to understand where microgrid projects will create the most benefit. Regulation of the electric industry and associated policy vary state by state. Incentives vary at the Federal, State, and Local levels. Electrical tariffs and gas prices can vary consumer-by-consumer. Another major variable is weather which influences both the efficacy of renewable energy (solar and wind) and the likelihood of power outages.

**Project Description & Scope of Work**

- Define / Deliver a targeting tool (or methodology) that synthesizes various energy-related data lakes to deliver actionable insight to all stakeholders.
- Such a tool would significantly contribute to the proliferation of distributed, digitized, decarbonized energy. Specific outcomes from the tool would include detailed reports on some geographies that illustrate how microgrid solutions would be best supported by the convergence of weather, policy, incentive, and utility tariff factors.

Deliverables

- The deliverables for this project include:
 - Methodology (5-page PPT that outlines the variables that influence the ROI of microgrid solutions and the data sources that could be synthesized)
 - Market Analysis (2-3 page PPT summary, 8 page Word backup with details – either high level generalizations that apply to many territories, or very detailed analysis on 1-2 specific areas.)
 - Financial Summary (2-3 page PPT summary of costs to develop, launch, and operate a microgrid targeting tool, Excel model with summary page outlining key assumptions)

Additional information may be appended as deemed relevant. These summaries will be made available to prospective students interested in registering for the courses and should be used to set priorities on project preference.

Other relevant information:

- Schneider Electric has developed a Microgrid Design tool that determines the optimal microgrid configuration once a location is known. The Microgrid Targeting Tool would serve to inform business developers where to engage and gather data necessary to preform the Design Tool analysis.

Key Dates for Project Client Involvement:

- Weekly client checkpoint on project (30 min, 10 weeks from March 31 – June 13, 2020)
- Midpoint Presentations (week of April 27, 2020)
- Final Presentations (week of June 8, 2020)

Instructor / Faculty Advisor:

Holly Benz, Clinical Associate Professor, McCormick School of Engineering
Northwestern University
Technological Institute, 2145 Sheridan Road, M486
Evanston, IL 60208
E-mail: Holly.Benz@northwestern.edu
Phone: 847-867-7712

Client Lead:

Gregg Morasca, Vice President
200 Martingale Road
Schaumburg, IL 60173
615-584-3529
gregg.morasca@se.com

Project SAVE: Long-Duration Energy Storage Economic Analysis (Invenergy)

Invenergy

Organization Overview

- **Overview:** Largest privately-owned developer of renewable and clean energy projects in North America; Invenergy develops, finances, owns and operates sustainable energy projects
- **Mission:** Innovators Building a Sustainable World
- **Accomplishments / Size:**
 - 24,400 MW of wind, solar, battery storage and natural gas plants developed (equivalent to taking 7.3 million cars off the road annually)
 - \$33 billion in completed transactions
 - 1,100 employees
 - HQ in Chicago; Offices in Colorado, New York, Texas, Oregon, Mexico, Japan, Colombia, Israel
- **Customer Base:** Corporates (e.g. Google, Facebook, Bimbo Bakeries, AT&T) and Electric Utilities (e.g. ComEd, Xcel Energy, Southern Company, Berkshire Hathaway Energy)
- **Website:** www.Invenergy.com

Market Background

- **Size of market:** Global clean energy market = \$363 billion (North America = \$104 billion)
- **Market segment:** Invenergy is a “renewable energy project developer” – Project developers devise the concept for a renewable energy project, acquire a site, conduct permitting/interconnection, perform preliminary engineering, procure major equipment (turbines, panels, etc.), finance the project with debt/equity investors, arrange and manage engineering & construction contracts, contract with customers to sell the power, and ultimately operate and maintain the project for its ~30 year lifetime
- **Key competitors (other renewable energy project developers):** NextEra Energy, Avangrid, Enel Green Power, ENGIE, EDF Renewables, EDP Renewables, E.On, 8minute Energy, First Solar, Apex Clean Energy, Longroad Energy, Cypress Creek
- **Other stakeholders:** Renewables equipment suppliers (e.g. GE, Siemens, Sunpower, Tesla); Renewable project financiers (e.g. investment banks, pension funds, private equity)
- **Major trends in the industry:** Wide-scale deployment of wind and solar, significant growth in battery energy storage deployment, early retirement of coal and nuclear plants, sustained competitiveness of natural gas plants, electrification of transportation, shifts in state and federal climate policy



Problem Statement

- The electricity generation mix is on a clear trajectory towards becoming deeply decarbonized. The intermittent and not fully-dispatchable nature of renewables presents a challenge in making sure demand is always met. Furthermore, the best renewable resources tend to be geographically dislocated from where the energy is being consumed, which creates a need to be strategic about how the existing transmission infrastructure is utilized. Energy storage is expected to play a key role in providing solutions to many of the challenges that arise as the system moves towards increasing levels of renewable penetration.
- While most new energy storage being deployed today is lithium-ion battery storage, which excels at storing energy for short periods of time (2-4 hours) and providing fast ramping and ancillary services, the prevailing thought is that other technologies may supplement or win out over lithium-ion for longer duration (5-24+ hour) applications needed to address the issues above.
- Existing long-duration storage technologies are in various stages of market-readiness and most have not been widely deployed at commercial scale. Invenery is looking to better understand the pros/cons of various long-duration storage technologies and the economics compared to lithium-ion batteries to support our strategy for long-duration storage projects going forward

Project Description & Scope of Work

- Invenery is seeing increased customer and market interest in deployment of long-duration storage technology. The scope of this project will be to evaluate and compare the following long-duration storage technologies to assist with future Invenery development efforts:
 - Liquid Air Energy Storage
 - Compressed Air Energy Storage
 - Flow Battery Energy Storage
 - Thermal Energy Storage
 - Pumped Hydro Energy Storage
 - Gravity Energy Storage

**Deliverables**

- **Technology Overview Presentation:** 2-3 pages for each technology that outlines plant design, technology specifications, use cases, key players, market activity, and project development considerations. Comparison matrix showing pros/cons across all technologies
- **Key Cost Drivers & Learning Rate Analysis:** Identification of key cost drivers for each technology (e.g. electrolyte cost, storage tank cost, O&M cost) and methodology for modeling the learning rate and forecasting expected cost reduction of these key drivers through 2030
- **Cost of Duration Analysis:** Economic model in Excel for each technology (including pro-forma) to determine how costs scale with added storage duration (e.g. at what rate do costs increase as a Liquid Air Energy Storage plant is increased from an 8-hour storage duration to 12-hour?) and comparison to equivalent lithium-ion battery cost curves (to be provided by Invenergy)

Other relevant information:

- Invenergy will provide an initial list of companies for each technology that Invenergy has engaged with previously. Relevant data will be shared for analysis purposes subject to confidentiality constraints
- Invenergy will provide an excel model template for Cost of Duration Analysis pro-forma model
- Invenergy will provide access to interviews with Invenergy employees as needed

Key Dates for Project Client Involvement:

- Weekly client checkpoint on project (30 min, 10 weeks from March 31 – June 13, 2020)
 - Flexible on meeting times – To be discussed with the team
- Midpoint Presentations (week of April 27, 2020)
- Final Presentations (week of June 8, 2020)

Instructor / Faculty Advisor:

Holly Benz, Clinical Associate Professor, McCormick School of Engineering
Northwestern University
Technological Institute, 2145 Sheridan Road, M486
Evanston, IL 60208
E-mail: Holly.Benz@northwestern.edu
Phone: 847-867-7712

Client Lead:

Maggie Pakula, Vice President of Strategy
1 S Wacker Dr, Suite 1800, Chicago, IL 60606
mpakula@invenergy.com
(312) 582-1587

ISEN 498 *Energy & Sustainability Project Practicum*

Spring 2020

(March 31, 2020 – June 12, 2020)

Project EV Friendly: An analysis of EV charging needs for Chicago

(City of Chicago, Department of Transportation)

Organization Overview

- Chicago is the third largest city in the U.S. with ~2.7m residents and approximately 10m in the metro area
- The current mayor is Lori Lightfoot and the city has 50 wards, 77 community areas, 100 neighborhoods
- 70% of residents live in multi-family housing and
- Depending on the particular year, the city's O'Hare International Airport is routinely ranked as the world's fifth or sixth busiest airport according to tracked data by the Airports Council International.^[13] The region also has the largest number of federal highways and is the nation's railroad hub.
- Chicago had 58 million domestic and international visitors in 2018 made it the second most visited city in the nation, as compared with New York City's 65 million visitors in 2018.
- <https://www.chicago.gov/city/en.html>

Market Background

- ~350,000 cars registered³
- Illinois ranked seventh in EV sale in 2018, at 6,400 vehicles, with about 15,000 electric vehicles registered in the state⁴
- 2344 (through 2017) electric vehicles registered in Chicago, 6380 (through 2017) in Cook County and 30% of EV owners live in multi-family dwellings
- Low / middle income customers and multi-family dwellers are likely under-represented in EV ownership in Chicago
- Currently there are 62 DC fast chargers within the City of Chicago and 141 in Cook County; the City has an estimated 382 L2 public chargers as of 3/3/2020 and an unknown number of private L2 chargers
- Recent ordinances have been introduced and passed by Chicago aldermen to require new developments to be EV-Capable
- It is also anticipated that ComEd, the utility that serves Chicago will introduce new legislation to consider the role of the utility in EV charging as well
- 80% of electric vehicle charging takes place at home but this can be a challenge for multi-family dwellers
- ComEd must also consider issues around balancing the demand on the grid and associated grid infrastructure investments that are needed (esp for DCFC)
- IL is not a ZEV state and as such, it lags other areas of the country in supply and adoption of EVs
- Key trends on EVs and charging in the City of Chicago include:
 - The Chicago City Council voted Oct. 16 to require new buildings with 24 residential units or more to have at least two electric vehicle charging-ready spaces.⁵
 - *“West Ridge, a far north Chicago neighborhood that she described as a lower-income “transit desert” with sparse public commuting options”*⁶

³ http://www.cata.info/assets/1/12/AO_Dec_20.pdf

⁴ <https://www.chicagotribune.com/business/ct-biz-illinois-ev-fee-hike-20190603-story.html>

⁵ <https://energynews.us/2019/10/21/midwest/chicago-apartment-renters-push-for-better-access-to-electric-vehicle-charging/>

⁶ <https://energynews.us/2019/10/21/midwest/chicago-apartment-renters-push-for-better-access-to-electric-vehicle-charging/>



- Both New York and San Francisco, for example, have stipulations requiring buildings undergoing renovations to include upgrades so they can accommodate chargers. And while requiring 20% of spots to be charging-ready is standard, Deylami said she'd like to see that amount increased. Vancouver, for example, previously had a 20% requirement, but as of this year, new multifamily buildings in Vancouver must have chargers available at all residential spots.
- By 2030, when Chicago could have as many as 81,000 electric vehicles on its roadways, the city will need about 2,700 publicly available charging stations, according to the study. Currently, there are fewer than 300 stations in the city.⁷

Problem Statement

- EV penetration is low in Illinois and Chicago
- Charging stations are similarly sparse in Chicago
 - Currently there are only about 1,500 public charging outlets in the state of IL and ~1,900 in total
 - Currently there are 382 Level 2 public charging stations. Public charging stations are not equitably distributed in Chicago leaving many communities unable to access recharging options.
 - The City of Chicago only has 62 DCFC options (42 only accessible to Tesla owners) which are critical to those who face “range anxiety” and those, such as ride share drivers, that need a quick charging option
- However, ComEd has stated that upwards of 3 million drivers may trade gas pumps for plugs over the next decade⁸ and the ICCT suggests that about 56,000 of these cars will be in Chicago by 2025.⁹ This is a growth of 30,000 cars in the next 5 years
- It is unclear how much charging is needed to encourage city residents (especially multi-family dwellers) to adopt EVs and there is not currently a plan on what sort of charging should be located in each part of the city
- Given the potential for positive environmental (CO₂, air quality) impact and financial benefit to residents of the City of Chicago, building a clear roadmap for expansion of EV charging infrastructure is key
- While fleet charging will require a different approach, residential, suburban and rideshare driving uptake of EVs all depend upon the existence of a quality charging network
- To clarify the optimal plan, the City of Chicago needs to consider the economics, technology and regulatory / legal components of EV charging
- Building a fact-based, unbiased view of an optimal charging infrastructure for the city (DCFC and L2) is critical to address the inertia in Chicago around EVs

Project Description & Scope of Work

Therefore, there are several key questions to address in this proposed project:

- How many L2 and DCFC stations are needed in the city limits of Chicago to enable **25,000** (*target to be confirmed*) multi-family dwellers to switch to become EV drivers and to feel comfortable with charging options from a cost and convenience perspective by **2030**?
- Where should these charging stations be located? Why?
- How can we ensure that EV charging is accessible to all residents of the city – but especially multi-family residents and low / moderate income households considering the likely lower range offered by EVs for sale at under \$15,000?
- Who should own DCFC stations? Why? L2?
- What regulatory and legal questions must be answered to enable a scale improvement in charging infrastructure?
- What are the technical requirements to build out the infrastructure?

⁷ <https://news.wttw.com/2018/02/22/study-chicago-could-see-80000-electric-cars-2030>

⁸ <https://www.govtech.com/transportation/Chicago-Area-Power-Utility-Gears-Up-For-Electric-Vehicles.html>

⁹ https://theicct.org/sites/default/files/publications/US_charging_Gap_20190124.pdf



- What special issues must be taken into account – especially for DCFC? Permitting? Utility connection?
- What stakeholders should play a role in promoting the build out of an optimal EV charging network in Chicago?
- What are a couple of ways to get started on the path of substantial expansion of EV charging options in the City of Chicago? What recommended projects or efforts would help the City begin on the journey? Who should be involved?
- **Note:** While recognizing that there are MANY facets to be addressed to drive adoption of electric vehicles including but not limited to customer education, dealer education, incentives for cars and charging etc, **this project will limit its scope to EV charging in Chicago that serves multi-family housing dwellers**

Deliverables

- The deliverables for this project include:
 - Market Summary (5 page Powerpoint that outlines key facts and factors in the Chicago market for EV charging to serve Chicago residents of multi-family dwellings)
 - Customer Needs Analysis (2-3 page PPT summary, 8 page Word backup with details) that addresses
 - What segments of the multi-family dwellers in Chicago are likely adopters of EVs?
 - How can the city ensure that low and moderate income households benefit from an increase in charging infrastructure?
 - Where do multi-family unit dwellers need charging? Why?
 - Current State of EV charging in Chicago (2-3 page PPT summary, Excel backup with details) that maps where EV charging exists today (and is planned)
 - Key Issues or Challenges to grow charging to meet demand (economic, technical, regulatory, other)
 - Recommended “ideal” deployment of charging to support MUD EV drivers
 - Overview of Investment Required (2-3 page PPT high level estimate of costs to build “ideal”, Excel model with summary page outlining key assumptions)
 - Key Recommendations to “get started” on this path
 - Pilots
 - Key Target Neighborhoods / Technologies / Models to Test
 - Summary of Risks & Opportunities

Other relevant information:

- [City’s guidelines for installing chargers at Multi-Unit Dwellings](#)
- [City’s grant program for DCFCs, Drive Clean Chicago](#)

Potential Stakeholders to Interview:

- ComEd
- ICC
- Department of Housing
- MUD residents

Key Dates for Project Client Involvement:

- Weekly client checkpoint on project (30 min, 10 weeks from March 31 – June 13, 2020)
 - Tuesdays any time or Wednesdays before 1pm
- Midpoint Presentations (week of April 27, 2020)
- Final Presentations (week of June 8, 2020)

Client Lead:

Samantha Bingham, City of Chicago Department of Transportation
30 N LaSalle St., Suite 500
samantha.bingham@cityofchicago.org
312-744-8096