ISEN 422 - Electrify Everything: Beneficial Electrification, EVs and Beyond
Winter 2021

Northwestern University

Target Instructors: Carla Frisch, Rocky Mountain Institute; Holly Benz, Northwestern University

Potential Guest Lecturers:

- Tom Ashley, Greenlots
- Norm Carlson, Metra
- Ken Colburn, RAP
- Sue Gander, Electrification Coalition
- Mark Henderson, EVBox
- Tom Hulsebosch, West Monroe
- Mary Joyce, UL, Group VP Global Vice President & GM; Mobility & Automotive Division
- Camille Kadoch, Regulatory Assistance Project
- Yann Kulp, EIQ Mobility
- Hani Mahmassani, Northwestern University
- Marco Nie, Northwestern University
- Karl Popham, Austin Energy
- Joe Schofer, Northwestern University
- Maaike Witteveen, Engagement Manager at McKinsey, Energy Insights

Other Stakeholders:

- Jeffrey Chamberlain, CEO, Volta
- Cory Gordon, Director Electrification Transportation, Duke Energy
- Bryan Howard, Director of Policy, ACEEE
- Samantha Hoyt, Ford, EV Marketing
- Adam Johnson, SAMO
- Mahesh Krishnamurthy, IIT, Professor
- Trieu Mai, NREL
- Amandine Muskus, Kia, Government Affairs
- Matt Nicholls, Invenergy Edge, VP
- Jessica Nigro, GM & Head of Innovation, Daimler
- Nathan Niese, BCG, Associate Director, Electrification & Climate Change
- Paul Pebbles, Chief Engineer, GM
- Fay Shong, EY
- Maaike Witteveen, Engagement Manager at McKinsey, Energy Insights
- Qi Zhu, Northwestern University
Teaching Assistant: None
Class Timing: Winter Quarter 2021, January 4 – March 12, 2021; Finals from March 15-19, 2021; Day / hour is to be scheduled; 3 hours of instruction per week; first two weeks of class are remote due to mandatory quarantine; Other courses should be 50%+ in person (assuming COVID conditions allow)
Office Hours: By appointment

Course Synopsis
This class introduces the concept of beneficial electrification -- the idea that switching from fossil energy to electricity in transportation and buildings holds tremendous potential to dramatically increase grid flexibility, reduce total household and business energy costs, and reduce air pollution and greenhouse gas emissions. We will explore the emerging state of electricity consumption and review how it relates to changing transportation markets.

Course Goals
• Build a foundation of understanding about beneficial electrification & its impact on energy markets
• Set a baseline knowledge level about electric vehicle technology, products and EV charging
• Understand the opportunities and risks associated with the emerging trends around beneficial electrification, electric vehicles, electric vehicle charging infrastructure, and impacts to popular services such as ridesharing and emerging technologies such as autonomous vehicles.

Students interested in energy, new technology and transportation should consider this course. It will also appeal to students intrigued by material market shifts that will impact greenhouse gas emissions and global warming Those who may want to explore a career in transportation, sustainability and energy should find the course helpful in preparing for many types of professions across disciplines.

Students will be exposed to topics such as evolving business models, GHG emissions, vehicle supply change, the electric grid, electrification options and EV technology. A common theme throughout the quarter will be the changing nature of the electric grid and the demands of the users of the grid. It will be up to participants to identify emerging issues and an opportunities associated with this evolution and their impact on society. This will not be a course grounded in heavy technical economic and financial analysis or market theory. You will not need an academic background in engineering or materials science to understand the topics of the class.

Because students are not expected to have previous knowledge of these topics, the reading list is significant. Students are expected to complete readings prior to class. Please refer to the reading list for primary texts that will be used for the class. There will also be supplemental readings, including articles and essays, that will be provided by the instructor. As part of the class, we will have a series of guest panels and lectures by business professionals from a variety of major players in the electrification and EV spaces, including car manufacturers, EV charging companies, utilities, rideshare / car share companies and software businesses. Speakers will include engineers, utility professionals, startup CEOs and other business executives.

Required Readings
The following readings are required for the class. Other articles and essays will be updated upon class scheduling.
Supplemental Reading List

The following readings are optional research on clean energy, advanced transport, digital industry, innovative materials, and commodities.

- [https://about.bnef.com/electric-vehicle-outlook/](https://about.bnef.com/electric-vehicle-outlook/)
- [https://www.navigantresearch.com/research-solutions/electric-vehicles](https://www.navigantresearch.com/research-solutions/electric-vehicles)
- Joseph L. Schofer and Hani S. Mahmassani, editors, Mobility 2050: A Vision for Transportation Infrastructure, prepared for the Association of Equipment Manufacturers and published by the Transportation Center, Northwestern University, June, 2016

Course Grading:

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<tr>
<th>Area</th>
<th>Weighting</th>
<th>Timing</th>
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<tr>
<td>Class Participation</td>
<td>20%</td>
<td>Ongoing</td>
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<td>Papers (x2) roughly 3-5 pages</td>
<td>40% (20% for each paper)</td>
<td>Week #3, #7</td>
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<td>Final Paper &amp; Presentation</td>
<td>40% (20% on paper, 20% on presentation)</td>
<td>Week #10 and Finals Week</td>
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2. [https://www.politico.com/story/2019/09/16/oil-industry-electric-car-1729429](https://www.politico.com/story/2019/09/16/oil-industry-electric-car-1729429)
Grading Policy:
- 10% will be deducted from late homework assignments turned in within 24 hours of the deadline. 50% will be deducted from late homework assignments that are more than 24 hours but less than 7 days late. No credit will be given for homework turned in more than 7 days after the deadline. All questions and problems regarding grades must be presented in writing within one week after the test, homework, or project has been returned. Grades will be assigned based on all the work you have completed during the semester following the traditional practice of A=90-100, B=80-89, C=70-79, D=60-69, F<60.


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<tr>
<th>Weekly Topic</th>
<th>Description</th>
<th>Guest Speaker</th>
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| **1: Business Models and Beneficial Electrification**  
Week of Jan 4, 2021 (REMOTE) | • Course Introduction and Expectations  
• Fundamentals of Beneficial Electrification (BE)  
• Key business models & stakeholders in BE  
• Overview of electrified market today and in future | Carla Frisch, Rocky Mountain Institute  
REMOTE |
| **2: Carbon / GHG Impact of electrification**  
Week of Jan 11, 2021 (REMOTE) | • Scale – How big of an impact does BE have on climate? How does it split out for various “measures” (heating, cooling, water, electric transportation)?  
• Variability – What are the regional / other variations in carbon impact? | Carla Frisch, Rocky Mountain Institute  
Guest Speaker: Tom Hulsebosch, West Monroe  
REMOTE |
| **3: The Ingredient Parts for Beneficial Electrification**  
Week of Jan 18, 2021 (IN PERSON) | • What does it take to “Electrify Everything”?  
• What are the practical changes in transportation, heating, and industry?  
• What do you have to believe for these conversions to take place? | Carla Frisch, Rocky Mountain Institute  
In-Person  
Holly Benz, Northwestern University |
| | • Brief Discussion: Transportation 101 -- basic business economics, regulation  
• Utility readiness for increased electrification (transportation, other)  
• Current electric utility barriers requiring resolution  
Guest Speaker: Joe Schofer, Northwestern University - TBC  
REMOTE |
• Barriers – What are the challenges associated with beneficial electrification?  
Guest Speaker: Camille Kadoch, Regulatory Assistance Project  
REMOTE |
| | • How and where has this transformation occurred successfully?  
• What investment or conditions were required to achieve “full electrification”?  
• What is the role of policy? What should be considered?  
  o Investment and Tax Credits / Reinstate the advanced manufacturing tax credit from ARRA to support domestic manufacturing  
  o Performance Based Rate making  
  o Offer federal debt financing for utilities |
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<th>Week</th>
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<td>4:</td>
<td><strong>The Evolution of Transportation</strong>&lt;br&gt;Week of Jan 25, 2021 (IN PERSON)</td>
<td>- How has transportation evolved for Rail, Sea, Air and Road?&lt;br&gt;&lt;br&gt;<strong>Holly Benz</strong>, Northwestern University&lt;br&gt;<strong>Guest Speaker:</strong> <strong>Hani Mahmassani</strong>, Northwestern University&lt;br&gt;<strong>In-Person</strong>&lt;br&gt;- What is the future of Rail, Sea, Air and Road? How has COVID changed the trajectory&lt;br&gt;&lt;br&gt;<strong>Guest Speakers:</strong> <strong>Nathan Niese</strong>, BCG, Associate Director, Electrification &amp; Climate Change;&lt;br&gt;<strong>Norm Carlson</strong>, Metra;&lt;br&gt;<strong>REMOTE</strong> (or In-Person, TBC)&lt;br&gt;&lt;br&gt;<strong>Opinion Paper #1 Due at beginning of class:</strong> <em>Is beneficial electrification a viable path to address climate change? Why / why not?</em></td>
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<td>5:</td>
<td><strong>Fundamentals of EV markets &amp; cars</strong>&lt;br&gt;Week of Feb 1, 2021 (IN PERSON)</td>
<td>- <strong>Global Trends</strong> – what are the global trends on cars? How does that impact the N. American market?&lt;br&gt;- <strong>Regulation (Stick)</strong> – <strong>Paris</strong> Climate Accord, California, 2030 Districts; what impact do EVs have on GHG / energy efficiency?&lt;br&gt;- <strong>Market Incentives</strong> - How are tax credits and other incentives structured to get people into cars?&lt;br&gt;- <strong>The Chicken / Egg challenge for EVs</strong>&lt;br&gt;&lt;br&gt;<strong>Holly Benz</strong>, Northwestern University&lt;br&gt;<strong>In-Person</strong>&lt;br&gt;- <strong>Technology</strong> – how have EVs evolved? How is the newest Honda different than the first generation Leaf? What does the roadmap for EVs look like? How do PHEVs / EVs work? What is different from ICE?&lt;br&gt;- <strong>Customer Experience &amp; Education</strong> – how do drivers learn about EVs? What tools do dealers and other stakeholders offer to help buyers understand the value proposition? For private owners &amp; rideshare drivers – do EVs make sense? How is this different for buses &amp; trucks?&lt;br&gt;&lt;br&gt;<strong>Guest Speaker:</strong> <strong>Paul Pebbles</strong>, Chief Engineer, GM - TBC</td>
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<td>6:</td>
<td><strong>Fundamentals of EV charging &amp; utility distribution</strong>&lt;br&gt;Week of Feb 8, 2021 (IN PERSON)</td>
<td>- <strong>Technology</strong> – what are the types of EV chargers? Who makes them? How many companies are out there? How do chargers work? How are the wall chargers different from chargers in cars or charging pads? What technologies are in development? What is the relative importance of SW vs HW for both cars and charging?&lt;br&gt;- <strong>Business Models &amp; Costs</strong> – who owns chargers? What does EV charging cost?&lt;br&gt;&lt;br&gt;<strong>Holly Benz</strong>, Northwestern University&lt;br&gt;<strong>In-Person</strong>&lt;br&gt;- <strong>Regulation</strong> – Who is allowed to own EV charging? How is it regulated / legislated? Does it vary state to state?&lt;br&gt;&lt;br&gt;<strong>Guest Speaker:</strong> <strong>Tom Ashley</strong>, Greenlots&lt;br&gt;<strong>REMOTE</strong> - TBC</td>
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<td>7</td>
<td>Economics of Electrification &amp; EV markets</td>
<td>Jeffrey Chamberlain, CEO, Volta REMOTE (or In-Person, TBC)</td>
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<td><strong>Week of Feb 15, 2021 (IN PERSON)</strong></td>
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<td>Sue Gander, Electrification Coalition</td>
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<td>8</td>
<td>Building Electrification - Electric Heating &amp; other BE technologies</td>
<td>What are the opportunities in Building Electrification?</td>
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<td><strong>Week of Feb 22, 2021 (IN PERSON)</strong></td>
<td>• Heating, Hot Water, Other Shifts</td>
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<td>Carla Frisch, Rocky Mountain Institute In-Person</td>
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<td><strong>Week of Feb 22, 2021 (IN PERSON)</strong></td>
<td>Review of expectations for final presentations on Risks &amp; Opportunities in Beneficial Electrification; including final presentation schedule</td>
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<td>Industrial Electrification</td>
<td>What are the opportunities in Industrial Electrification?</td>
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<td><strong>Week of March 1, 2021 (IN PERSON)</strong></td>
<td>• Potential: today, about 20 percent of the energy consumed in industry is</td>
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<td>10: Presentations</td>
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<td><strong>- Risks &amp;</strong></td>
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<td><strong>Electrification</strong></td>
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<td><strong>Week of March 8, 2021 (IN PERSON)</strong></td>
<td><strong>Week of March 15, 2021 (IN PERSON)</strong></td>
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<td>Each student team should be prepared to give an oral presentation on a major risk or opportunity (linked to their paper – x2 presentations of 40 min each including Q&amp;A)</td>
<td>Remaining presentations (x2 @ 40min each)</td>
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<td><strong>Holly Benz</strong>, Northwestern University In-Person</td>
<td><strong>During Finals week March 15-19</strong></td>
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<td><strong>Carla Frisch</strong>, Rocky Mountain Institute REMOTE</td>
<td><strong>Holly Benz</strong>, Northwestern University In-Person</td>
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**Guest Speaker:** [Maaike Witteveen](#), Engagement Manager at McKinsey, Energy Insights

**FINAL PAPER (Group Assignment) Due at beginning of class:** *What are the risks and opportunities associated with driving a single aspect of electrification? [could be a technology, policy or other area like financing mechanism or consumer education]*

- **Carla Frisch**, Rocky Mountain Institute In-Person
- **Holly Benz**, Northwestern University In-Person
- **Carla Frisch**, Rocky Mountain Institute REMOTE
- **Holly Benz**, Northwestern University In-Person