

Master of Science in Sustainability Management

SUMA PS5199 - The Sustainable Transportation Economy

Date & Time: Refer to the Directory of Classes

3 credits

Instructor: Scott Fisher, sf2557@columbia.edu
Office Hours: By appointment
Response Policy: I generally respond within 24 hours. If I don't respond, please send a follow-up email or text me at 609-651-7061

Facilitator/Teaching Assistant, if applicable:

Office Hours: By appointment and will set up office hours based on student schedules
Response Policy: Within 24 hours

Course Overview

Transportation accounts for about 25% of global GHG emissions. Significantly reducing emissions in this sector is fundamental for addressing climate change. Historically, the technical and commercial tools for tackling emissions in this sector have lagged other sectors (for example, electricity production). But over the last several years, this dynamic has changed and there is now unprecedented capital and brainpower focused on transportation decarbonization. The course focuses on capturing the key elements that will speed the scale-up to low- and no-carbon transportation (“sustainable transportation”) across the breadth of transportation sectors. In doing so, this scale-up will create new industries and business models – and has the potential to benefit a wide group of people, including those who in the past have been disproportionately affected by poor air quality caused by existing transportation sources. The course is designed for any student who wishes to understand these elements in a deeper way.

The course will explore the decarbonization opportunities and challenges across the various transportation sectors, including light duty, commercial fleets, public transportation, aviation, and marine sectors – as well as areas that cut across all sectors, such as battery adoption, the supply chain for materials, fueling/charging, and the impact of hydrogen. Because the carbon content of propulsion fuels is dependent on other sectors (for example, the transition to renewable electricity), the course will examine the energy transition in transportation in the context of broader decarbonization trends. In exploring each transportation sub-sector, the course will focus mainly from the commercial perspective, but will incorporate the external factors (e.g., innovation, policy, macro-factors) that affect commercial success.

The course is intended for anyone wishing to further their knowledge or their career in the areas of sustainable transportation – especially in areas related to electric transportation. The course will rely on lectures and discussions, both led by the professor and guest lecturers. There are no prerequisites for the course. The course assignments will include a combination of problem sets, financial modeling, and case studies/written assignments. No previous financial modeling experience is required; the professor and/or TA will provide any extra help sessions required for any financial modeling work.

Learning Objectives

Upon successful completion of this course students should be able to:

- L1- Explain the challenges and opportunities for decarbonization across different transportation sectors
- L2- Gain fluency with the specific commercial questions that companies looking to develop scalable business models need to address in order to become successful
- L3- Analyze the impact of external factors (policies, technical innovation, macro issues) on commercial business models

- L4- Leverage the financial and analytical tools that companies and governments use to assess the market

Readings

Required Readings

Békés, Marton, Mladen Fruk, Eugen Hildebrandt, Kjartan Kalstad, Klaas Mantel, Florian Nägele, and Swarna Ramanathan (May 8, 2023) “What Norway’s experience reveals about the EV charging market” McKinsey (6 pages) <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/what-norways-experience-reveals-about-the-ev-charging-market#/>

Bobrowsky, Megan and Miles Kruppa (August 4, 2023) “America’s Most Tech-Forward City Has Doubts About Self-Driving Cars” Wall Street Journal (link in class files)

Carreon, Allesandra, EJ Klock-McCook, Sudeshna Mohanty, Caitlin Odom, Charles Teplin, and Sarah Toth, Increasing Equitable EV Access and Charging: A Path Forward for States, RMI, 2022 (61 pages) <https://rmi.org/insight/increasing-equitable-ev-access-charging/>

Carreon, Allesandra (May 5, 2023) The EV Battery Supply Chain Explained, RMI (22 pages) <https://rmi.org/the-ev-battery-supply-chain-explained/>

Chauhan, Saral, Malte Hans, Moritz Rittstiege, and Saleem Zafar (January 2023) “Why the economics of electrification make this decarbonization transition different” McKinsey (6 pages) <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-the-economics-of-electrification-make-this-decarbonization-transition-different#/>

Coy, Peter (July 14, 2023) “A Climate Hawk’s Issues with Electric Vehicles” The New York Times <https://www.nytimes.com/2023/07/14/opinion/electric-vehicles-toyota-hybrids.html>

Deichmann, Johannes, Eike Ebel, Kersten Heineke, Ruth Heuss, Martin Kellner, and Fabian Steiner (January 6, 2023) “Autonomous Driving’s Future: Convenient and Connected” McKinsey & Co <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected#/>

Ewing, Jack (April 11, 2022) “Truck Makers Face a Tech Dilemma: Batteries or Hydrogen?” <https://www.nytimes.com/2022/04/11/business/electric-hydrogen-trucks.html>

Fitzgerald, Garrett (February 8, 2024) “EV Charging Infrastructure: Trends, Requirements & Costs” Smart Electric Power Alliance (Blog Post 14 pages) [EV Charging Infrastructure: Trends, Requirements & Costs \(sepapower.org\)](https://www.sepapower.org/ev-charging-infrastructure-trends-requirements-costs)

Grant, Andrew et al (March 6, 2024) “Driving the Next Phase of Electric Mobility in Europe: Tools for a fully decarbonized on-demand transport industry” Bloomberg New Energy Finance and Uber [Driving-the-Next-Phase-of-Electric-Mobility-In-Europe_Uber-and-BloombergNEF-for-publication.pdf \(bbhub.io\)](https://www.bbhuh.io/driving-the-next-phase-of-electric-mobility-in-europe-uber-and-bloombergnef-for-publication.pdf)

IEA (2024), Global EV Outlook 2024, IEA, Paris (~174 pages) [GlobalEVOutlook2024.pdf \(iea.blob.core.windows.net\)](https://www.iea.blob.core.windows.net/global-ev-outlook-2024)

Ortiz, Guillermo (January 18, 2024) “The Legal Battle to Preserve the Advanced Clean Fleets Rule” NRDC [The Legal Battle to Preserve the Advanced Clean Fleets Rule \(nrdc.org\)](https://www.nrdc.org/legal-battle-to-preserve-the-advanced-clean-fleets-rule)

Kahn, Ari, Dave Mullaney, Caitlin Odom, Nocona Sanders and Gerard Westhoff (May 2023) “Preventing Electric Truck Gridlock: Meeting the Urgent Need for an Updated Electricity System” RMI (22 pages)

<https://rmi.org/insight/preventing-electric-truck-gridlock/>

Lopez, Nadia (January 17, 2023) “Race to zero: Can California’s power grid handle a 15-fold increase in electric cars?” CalMatters (19 pages) [Can California’s grid handle 12 million electric cars? - CalMatters](#)

Lopez, Nadia (April 28, 2023) “California Phases Out Diesel Trucks: What Happens Next” Calmatters <https://calmatters.org/environment/climate-change/2023/04/california-phases-out-diesel-trucks/?series=california-electric-vehicles>

McNamara, Marie et al., (June 2023) How Policy Actions Can Spur EV Adoption in the United States, RMI, (42 pages) [How Policy Actions Can Spur EV Adoption in the United States - RMI](#)

Reichmuth, D et al (July 2022) “Driving Cleaner: Electric Cars and Pickups Beat Gasoline on Lifetime Global Emissions” Union of Concerned Scientists (36 pages) <https://www.ucsusa.org/sites/default/files/2022-09/driving-cleaner-report.pdf>

St. John, Jeff (June 8 2023) The US has big EV goals. Can the domestic EV industry meet them? Canary Media (15 pages) <https://www.canarymedia.com/articles/electric-vehicles/the-us-has-big-ev-goals-can-the-domestic-ev-industry-meet-them>

Tumurbat, Tem (October 14, 2022) “Mining through the Valleys of Death” Climate Tech VC (12 pages) <https://www.ctvc.co/mining-through-the-valleys-of-death/>

Various Authors (April 4, 2023) “Hydrogen Trucks: Long Haul’s Future?” North American Council for Freight Efficiency (81 pages) <https://nacfe.org/research/electric-trucks/hydrogen/#login-register>

Zeng, T., Zhang, H., Moura, S.J. *et al.* Economic and environmental benefits of automated electric vehicle ride-hailing services in New York City. *Sci Rep* **14**, 4180 (2024). <https://doi.org/10.1038/s41598-024-54495-x>

Optional Readings

Bearak, Max (July 11, 2024) “A.I. Needs Copper. It Just Helped to Find Millions of Tons of It” The New York Times [A.I. Helped to Spot a Copper Mining Bonanza in Zambia - The New York Times \(nytimes.com\)](#)

Fernando, J (2021) “Internal Rate of Return” Investopedia (2 pages) <https://www.investopedia.com/terms/i/irr.asp>

Fernando, J (2021) “Net Present Value” Investopedia (2 pages) <https://www.investopedia.com/terms/n/npv.asp>

Hagenmaier, M. Wagener, C. Bert, J and Ohngemach, M (2021) “Winning the Battle in the EV Charging Ecosystem” Boston Consulting Group (28 pages) <https://www.bcg.com/en-us/publications/2021/the-evolution-of-charging-infrastructures-for-electric-vehicles>

Heyford, S (2022) “Understanding the Time Value of Money” Investopedia (2 pages) <https://www.investopedia.com/articles/03/082703.asp>

Liu, Xinyu, Elgowainy, A. Vijayagopal, R and Wang, M (2021) “Well-to-Wheels Analysis of Zero-Emission Plug-In Battery Electric Vehicle Technology for Medium- and Heavy-Duty Trucks” Environmental Science &

Technology 2021 55 (1), 538-546 DOI: 10.1021/acs.est.0c02931 (9 pages)
<https://pubs.acs.org/doi/10.1021/acs.est.0c02931>

Kann, Shayle (June 20, 2024) “Demystifying the Chinese EV Market” The Catalyst Podcast [Demystifying the Chinese EV market \(latitudemedia.com\)](https://www.latitudemedia.com)

Assignments and Assessments

The purpose of the assignments is to build an understanding of the relevant tools needed to assess and create sustainable transportation business models. The first assignment will ensure that students are conversant with the various metrics in assessing a business or a policy initiative. The second assignment will focus on building a financial model to evaluate the viability of a sustainable transportation business. The third assignment will be a case study/in-depth analysis of important cross-cutting transportation decarbonization topics. The fourth assignment will be a group presentation on a particular sustainable transportation business, business strategy, or policy initiative.

For each assignment, feedback will be provided that will allow students to more successfully complete the subsequent assignment. For example, an understanding of the key evaluation metrics from the first problem set will help students complete the financial analysis in the second assignment.

All assignment page lengths are based on using times new roman 12 pt font and double spacing (where applicable). Page numbers do not include notes or works cited. Title pages are not needed.

Participation, Attendance: Please be prepared to participate in the class discussion. Relevant, respectful dialogue, thoughtful comments and active listening are all required as important elements of learning in a graduate environment. Active participation in class will lead you to contributing to all of the course learning objectives. **(L1, L2, L3, and L4)**

Problem Set: The purpose of this assignment is to level-set all students with the fundamental building blocks of clean transportation. The assignment will include quantitative and short-answer questions focusing on topics such as the relative carbon content of transportation fuels, basic commercial and financial analyses, the influence of policy incentives, and the impact of technology innovation. **(L2, L3)**

Financial Modeling Assignment: An important element in creating the business case to undertake a particular project is to prepare a financial model for that project. Students will be given certain basic parameters about a clean transportation project, and then asked to use those parameters to build a financial model to assess the business case for an investment in that project. **(L2, L4)**

Case Study Analysis: Students will be provided with a case study on a topic related to clean transportation. The assignment will have several questions (both quantitative and qualitative) that will relate to the topic of the case. **(L1, L2, L3, L4)**

Final Group Presentation: Students will be asked to research a particular topic related to clean transportation and present their finding on that topic to the class. The assignment will be a group assignment. **(L1, L2, L4)**

Discussion of Assignments

Successful practitioners in the transportation economy understand not only the qualitative/contextual elements of their work, but also the quantitative/analytical tools for advancing projects, policy objectives, and business strategies. The course is designed to cover both aspects, but because the quantitative/analytical concepts are best learned through doing the work, the first three assignments are focused on using spreadsheets for data analysis and making financial projections of projects. In the course of completing those assignments, students will gain insights

on the broader contextual and macro issues discussed in class and during the reading. For the final assignment, the students will select a specific topic related to the transportation economy and integrate both the quantitative/analytical learnings and the qualitative/contextual learnings from the semester.

The grading for each of the first two assignments is objective, and based on the accurate completion of each of the questions. The first assignment is based on short answers to specific questions, while assignments two and three are more focused on analysis of projects, with each assignment generally building on the previous assignment. By completing the first two assignments, the students will gain a progressively stronger grasp of the analytical/quantitative aspects of the transportation economy and will be prepared for the third and fourth assignment. For the third and fourth assignments, I will provide a set of criteria on which I grade the material. The grading for the fourth assignment (a group assignment) will be based on the following criteria: 1) the overall level of student engagement in the topic (cursory analysis vs trying to get a deeper understanding); 2) the extent to which the students integrate analytical concepts from the semester into the project; and 3) the clarity and organization of the presentation and presentation materials.

Assignments will be graded and returned generally within two weeks of submission, although sometimes that slips a few days.

Grading

The final grade will be calculated as described below:

FINAL GRADING SCALE

Grade	Percentage
A+	98–100 %
A	93–97.9 %
A-	90–92.9 %
B+	87–89.9 %
B	83–86.9 %
B-	80–82.9 %
C+	77–79.9 %
C	73–76.9 %
C-	70–72.9 %
D	60–69.9 %
F	59.9% and below

Assignment/Assessment	% Weight	Individual or Group/Team Grade
Participation / attendance	10%	Individual
Problem Set	20%	Individual
Financial Modeling Assignment	25%	Individual
Case Study Analysis	25%	Individual
Final Group Presentation	20%	Group

Course Schedule/Course Calendar

Date	Topics and Activities	Readings (due before the class session and required unless noted as optional)	Assignments (due on this date)
Clean Transportation Foundations – The Technology, Policy, Ethical, and Economic Building Blocks for Understanding the Current Market			
Week 1 – Sep 5	Course Intro – History of Clean Transportation and the Challenges Ahead	No reading assigned	
Week 2 – Sep 12	Global Clean Transportation Policies and Regulations	IEA (2024), Global EV Outlook 2024 (read Executive Summary and then skim through first 3 chapters) McNamara, Marie et al., (2023) “How Policy Actions Can Spur EV Adoption in the United States” Ortiz, Guillermo (Jan 2024) “The Legal Battle to Preserve the Advanced Clean Fleets Rule” <u>Optional</u> Kann, Shayle (June 2024) “Demystifying the Chinese EV Market”	
Week 3 – Sep 19	Environmental and Economic Analysis of Clean Transportation	Reichmuth, D et al (July 2022) “Driving Cleaner: Electric Cars and Pickups Beat Gasoline on Lifetime Global Emissions” Coy, Peter (July 14, 2023) “A Climate Hawk’s Issues with Electric Vehicles” <u>Optional</u> Liu, Xinyu et al Well-to-Wheels Analysis of Zero-Emission Plug-In Battery Electric Vehicle Technology for Medium- and Heavy-Duty Trucks”	
Week 4 – Sept 26	Guest Lecturer – Transportation Policy	No Reading	Problem Set Due
Fueling the Transportation Transition: Batteries, Charging Infrastructure, and the Transportation Economy			
Week 5 – Oct 3	Charging Infrastructure for Consumers and Fleets	Fitzgerald, Garrett (Feb 2024) “EV Charging Infrastructure: Trends, Requirements & Costs”	

		<p>Carreon, Allesandra, et al, (2022) “Increasing Equitable EV Access and Charging: A Path Forward for States”</p> <p>Békés, Marton, et al (May 8, 2023) “What Norway’s experience reveals about the EV charging market” McKinsey</p> <p>Lopez, Nadia (January 17, 2023) “Race to zero: Can California’s power grid handle a 15-fold increase in electric cars?”</p>	
Week 6 – Oct 10	Financial Modeling of Fleet Electrification and Charging	<p>Chauhan, Saral, Malte Hans, Moritz Rittstiegl, and Saleem Zafar (January 2023) “Why the economics of electrification make this decarbonization transition different” McKinsey (6 pages)</p> <p><u>Optional Reading</u> Heyford, S (2022) “Understanding the Time Value of Money” (2 pages)</p> <p>Fernando, J (2021) “Internal Rate of Return” (2 pages)</p> <p>Fernando, J (2021) “Net Present Value” (2 pages)</p> <p>Also, Khan Academy has some good videos on finance fundamentals https://www.khanacademy.org/economics-finance-domain/core-finance/interest-tutorial/present-value/v/time-value-of-money</p>	
Week 7 – Oct 17	Guest Lecture – Scaling Fleet Electrification		Financial Modeling Assignment
Week 8- Oct 24	The Battery Supply Chain	<p>Carreon, Allesandra (May 5, 2023) “The EV Battery Supply Chain Explained”</p> <p>St. John, Jeff (June 8 2023) “The US has big EV goals. Can the domestic EV industry meet them?”</p> <p>Tumurbat, Tem (October 14, 2022) “Mining through the Valleys of Death” Climate Tech VC (12 pages)</p>	

		<u>Optional Reading</u> Bearak, Max (July 11, 2024) “A.I. Needs Copper. It Just Helped to Find Millions of Tons of It” The New York Times	
Week 9 – Oct 31	Guest Lecture		
Sector Case Studies: Deeper Dive into Specific Transportation Sectors			
Week 10 – Nov 7	Autonomous, Electric, Shared and the Future of Personal Transportation	Zeng, T., Zhang, H., Moura, S.J. <i>et al.</i> “Economic and environmental benefits of automated electric vehicle ride-hailing services in New York City” Grant, Andrew et al (March 6, 2024) “Driving the Next Phase of Electric Mobility in Europe: Tools for a fully decarbonized on-demand transport industry” Johannes Deichmann, et al (January 6, 2023) “Autonomous Driving’s Future: Convenient and Connected” (12 pages) Meghan Bobrowsky and Miles Kruppa (August 4, 2023) “America’s Most Tech-Forward City Has Doubts About Self-Driving Cars”	
Week 11 – Nov 14	Hydrogen’s Role in the Future of Transportation	Various Authors (April 4, 2023) “Hydrogen Trucks: Long Haul’s Future?” (Pages 1-21) Ewing, Jack (April 11, 2022) “Truck Makers Face a Tech Dilemma: Batteries or Hydrogen?” Anna Phillips (June 6, 2022) ”Ship pollution is rising as the U.S. waits for world leaders to act”	Case Study Analysis
Week 12 – Nov 21	Company Case Study		
Week 13 – Dec 5	Student Presentation		
Week 14 – December 12	Potential additional session for student presentations		

Course Policies

Participation and Attendance

Strong participation and attendance from all students will be a critical element in having a successful semester. Participation is more than attendance. Your participation will require that you answer questions, defend your point of view, and challenge the point of view of others, all in civil fashion. Students are responsible for identifying and learning material missed due to absence.

If you are unable to attend a class, please email me ahead of the lecture.

Late work

There are times when work, family, or just needing to maintain the right mental frame of mind will get in the way of submitting work on time. I will grant extensions if you notify me ahead of the due date. However, I will start reducing the grade for the assignment if not submitted in a reasonable period of time after the original due date.

School and University Policies and Resources

Copyright Policy

Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

Academic Integrity

Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. It is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.

SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at <https://sps.columbia.edu/students/student-support/academic-integrity-community-standards>. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

Diversity Statement

It is our intent that students from all diverse backgrounds and perspectives be well-served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that the students bring to this class be viewed as a resource, strength and benefit. It is our intent to present materials and activities that are respectful of diversity: gender identity, sexuality, disability, age, socioeconomic status, ethnicity, race, nationality, religion, and culture.

Accessibility

Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation

and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: <https://health.columbia.edu/services/ods/support>.

Class Recordings

All or portions of the class may be recorded at the discretion of the Instructor to support your learning. At any point, the Instructor has the right to discontinue the recording if it is deemed to be obstructive to the learning process.

If the recording is posted, it is confidential and it is prohibited to share the recording outside of the class.

SPS Academic Resources

The Office of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: <https://sps.columbia.edu/students/student-support/student-support-resources>.

Columbia University Information Technology

[Columbia University Information Technology](#) (CUIT) provides Columbia University students, faculty and staff with central computing and communications services. Students, faculty and staff may access [University-provided and discounted software downloads](#).

Columbia University Library

[Columbia's extensive library system](#) ranks in the top five academic libraries in the nation, with many of its services and resources available online.

The Writing Center

The Writing Center provides writing support to undergraduate and graduate students through one-on-one consultations and workshops. They provide support at every stage of your writing, from brainstorming to final drafts. If you would like writing support, please visit the following site to learn about services offered and steps for scheduling an appointment. This resource is open to Columbia graduate students at no additional charge. Visit <http://www.college.columbia.edu/core/uwp/writing-center>.

Career Design Lab

The Career Design Lab supports current students and alumni with individualized career coaching including career assessment, resume & cover letter writing, agile internship job search strategy, personal branding, interview skills, career transitions, salary negotiations, and much more. Wherever you are in your career journey, the Career Design Lab team is here to support you. Link to <https://careerdesignlab.sps.columbia.edu/>