2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
Paper ID #53990

The Evolution of a First-Year Engineering Course: Key Takeaways and Lessons Learned

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WIP: Bridging the Green Divide: A Collaborative Inquiry Course on Equitable Decarbonization

Abstract

This Work-in-Progress paper reports on the first offering of *Bridging the Green Divide* at Saint Louis University, a Collaborative Inquiry course that integrates engineering and demographic techniques and analysis and sociological perspectives to examine the equity implications of decarbonization. The course is structured around a central question: *How can societies ensure that the transition to clean energy promotes social equity rather than deepening existing inequalities?* The course was designed within a university-wide Core requirement that emphasizes interdisciplinary integration, collaborative problem-solving, and inquiry into complex questions without singular solutions. Students from diverse majors engaged in a sequenced set of engineering-anchored sustainability methods (e.g., system boundaries, embedded energy, Life-cycle Assessment framing) alongside sociological and policy-oriented analyses of inequality, community participation, and ethics.

Across the semester, the class co-developed a shared knowledge base through rotating content-development teams and then re-formed into technical editing and synthesis teams to produce a unified final report and presentation. A capstone literature review and data-analysis assignment (five thematic lenses) required teams to generate evidence-based arguments supported by peer-reviewed literature, credible public datasets, and community-relevant indicators. Drawing from student reflections, course artifacts, and team outputs, we summarize early lessons learned about scaffolding sociotechnical reasoning, balancing technical rigor with justice-centered inquiry, and supporting productive cross-disciplinary collaboration. Findings highlight: (1) a measurable shift in students' framing of decarbonization from technology-only solutions toward sociotechnical trade offs; (2) increased attention to distributional, procedural, and recognition dimensions of energy justice [1]–[4]; and (3) persistent challenges in translating critique into actionable recommendations under real-world constraints. We conclude with refinements to strengthen assessment alignment, clarify engineering vs. sociology deliverables, and support deeper integration with the UN Sustainable Development Goals (SDGs) as a shared sustainability language [5], [6].

Nomenclature

EJ	Energy justice
SDG	Sustainable Development Goals (United Nations)
LCA	Life-cycle assessment
EM	Entrepreneurial mindset (or Entrepreneurial-Minded Learning)
KEEN	Kern Entrepreneurial Engineering Network
CI	Collaborative Inquiry

Introduction

Decarbonization is frequently presented as a technical systems challenge—integrating renewables, electrifying end uses, and optimizing infrastructure investments. However, the energy transition also reallocates benefits and burdens across communities, raising persistent questions of energy justice, legitimacy, and equitable access to clean energy gains [1]–[4]. Without explicit attention to equity, decarbonization policies and projects can amplify existing inequalities through uneven affordability, displacement pressures, and exclusion from decision-making.

This paper reports on the first iteration of Bridging the Green Divide at Saint Louis University, an interdisciplinary Collaborative Inquiry seminar that positions clean energy transitions as a sociotechnical challenge requiring both engineering analysis and social-science reasoning. The course fulfills a Core requirement intended to support collaboration across disciplines and inquiry into complex questions that lack straightforward answers. To anchor sustainability content in widely recognized global priorities, course activities were also mapped to the UN Sustainable Development Goals (SDGs), emphasizing the interdependence of climate, equity, health, infrastructure, and economic opportunity [5], [6].

Course Context and Design Rationale

Collaborative Inquiry within Saint Louis University Core

Collaborative Inquiry seminars at SLU are designed to help students integrate knowledge across disciplines and apply prior coursework to contemporary societal problems through team-based inquiry and synthesis. In this course, the societal problem space is equitable decarbonization, with an explicit framing that students must evaluate both technical feasibility and social consequences.

Course Description and Outcomes

Students explored technological, economic, and policy dimensions of decarbonization while addressing the guiding question on equity and clean energy. Core outcomes included:

- Analyzing renewable technologies and systemic impacts
- Evaluating policy frameworks through an equity lens
- Developing evidence-based approaches to energy justice dilemmas using demographic and environmental data
- Collaborating across disciplines to propose integrative solutions

To operationalize "sustainability + equity" beyond high-level discussion, the course made energy-justice concepts explicit (distributional, procedural, recognition) as analytic lenses for evaluating transitions [1]–[4].

Course Cohort and Team Formation

The first offering enrolled 19 students spanning engineering, computing/data, business, and social sciences. The cohort included 6 engineering majors (≈32%)—mechanical (n=2), aerospace (n=3), and civil (n=1)—and 13 non-engineering majors (≈68%), including computer science (n=2), data science (n=1), mathematics (n=1), finance (n=2), accounting (n=2), sociology (n=3), psychology (n=1), and environmental studies/natural science (n=1). Students were primarily upper-division, with 11 seniors (≈58%) and 8 juniors (≈42%). Teams were instructor-assigned and implemented through a two-phase structure. For the first phase (content-development groups), students completed a brief survey and responded to topic prompts used to guide assignment into five content groups (3–4 students each). This grouping strategy was designed to allow students to contribute their existing disciplinary strengths while working in diverse, mixed-major teams, leveraging their interdisciplinary training as an intentional feature of the course design. In the second phase, students were reorganized into four technical synthesis teams (4–5 students each, each with a group leader) to integrate engineering and social-analytic perspectives into the final report and presentation.

Research Questions

This paper addresses the following questions:

- How do students' conceptions of decarbonization change when they engage both engineering methods and sociological perspectives?
- What themes emerge in student reflections and team outputs regarding equity impacts, trade offs, and stakeholder inclusion?
- Which course structures and assignments best support sociotechnical integration in a mixed-major classroom?

Instructional Sequence and Interdisciplinary Structure

To make the interdisciplinary design legible to reviewers, the course is summarized here as two intentionally interwoven lecture/activity streams.

Engineering-led modules (technical sustainability tools)

Engineering sessions introduced structured methods for analyzing energy systems and sustainability claims, including:

- System boundaries and control-volume reasoning (what is inside/outside the problem frame)
- Embedded/embodied energy and life-cycle thinking (how impacts shift across supply chains)
- Energy systems analysis methodologies and scenario comparisons
- Sustainability metrics and the limits of single-metric optimization

These modules were designed to strengthen students' technical confidence while creating "hooks" for later equity analysis (e.g., what happens to burdens when boundaries change).

Sociology-led modules (equity, community, and governance)

Sociology sessions foregrounded how energy transitions intersect with:

- Inequity and segregation patterns (place-based vulnerability and cumulative disadvantage)
- Community engagement, legitimacy, and trust-building
- Ethical reasoning and justice-centered critique of policy and infrastructure
- Institutional power, representation, and who is recognized as a stakeholder

This strand directly supported students' ability to interpret impacts beyond cost/carbon and to evaluate whether proposed solutions meet energy-justice tenets.

Bridging structures (explicit sociotechnical integration)

Several course structures were introduced specifically to force integration rather than parallel "two-track" learning:

- Stakeholder perspective simulations to compare technical optimization vs lived-experience outcomes
- Comparative case study analysis with multidimensional impact forecasting
- SDG mapping to connect local energy choices to global sustainability priorities [5], [6]
- Team norms and inclusion prompts to reduce disciplinary hierarchy and support equitable participation [7]–[9]

To strengthen transparency in how interdisciplinary intent translated into measurable learning evidence, the course also incorporated explicit entrepreneurial mindset (EM) habits language. Major engineering activities were intentionally mapped to Kern Entrepreneurial Engineering Network (KEEN)- aligned EM habits (Appendix A, Table A1) and paired with evidence artifacts (e.g., value-tension maps, reflections, report sections) to support reviewer-auditable interpretation of results [11].

A core integrative intervention—value tensions + multi-lifespan mapping using Envisioning Cards—is also documented as an Engineering Unleashed teaching activity card (Card ID 5772) to support transparency, transferability, and future adoption beyond this course context [12].

Class-wide knowledge building: Literature Review + Data Analysis

First-phase content development (thematic lenses)

The final report was built from five thematic lenses:

- Group 1: Renewable Integration Engineering
    - Explore the technical feasibility of integrating solar and wind into Ameren's grid.
    - Assess grid stability, storage needs, and cost efficiency.
- Group 2: Infrastructure and Innovation
    - Investigate new technologies (smart grids, battery storage, microgrids).
    - Consider engineering trade offs for long-term sustainability.
- Group 3: Policy and Regulatory Frameworks
    - Review state and federal policies that affect Ameren's clean energy transition.
    - Identify policy barriers and propose regulatory reforms.

- Group 4: Equity Impact Assessment
    - Use Census and Ameren data to analyze who benefits and who bears the costs of the energy transition.
    - Focus on income, race, and geographic disparities.
- Group 5: Community Engagement and Social Equity
    - Investigate public perception and community trust.
    - Propose strategies for Ameren to ensure inclusive participation in the clean energy shift.

Teams produced literature review sections (1500–2000 words per lens) and 3–4 data outputs, each with interpretations.

Second-phase synthesis (editing teams)

After initial content creation, students were re-assigned into technical synthesis roles:

- Group 1: Editing/citation/formatting;
- Group 2: Introduction/conclusion/reflection;
- Group 3: Visualization/presentation;
- Group 4: Policy and ethics synthesis.

This deliberate restructuring aimed to simulate interdisciplinary collaboration workflows where knowledge must be consolidated into coherent public-facing deliverables.

Methods

Three complementary lenses were used to structure learning evidence and interpretation. Table 1 provides an overview of the activities used as data sources, along with the objectives for each.

Table 1. Methods and Data Sources

Data source	What it captures
Student reflection prompts	Shifts in mindset, perceived learning, equity/justice framing
Group literature review + data outputs	Evidence selection, analytic framing, integration quality
Final report + final presentation	Synthesis quality, sociotechnical coherence
Course artifacts	Instructional intent, scaffolding, rubric alignment
EM habits activity–habit mapping (KEEN-aligned)	Which habits were targeted, how explicit they were to students, and what evidence was collected
Enrollment distribution	Interdisciplinary composition; trends across majors

- Energy justice as a multi-dimensional framework (distributional, procedural, recognition) for evaluating who benefits, who bears burdens, and who is included in decision-making [1]–[4].

- UN Sustainable Development Goals (SDGs) as a shared sustainability language to connect climate/energy topics to equity, health, infrastructure, and economic outcomes across disciplines [5], [6].
- Entrepreneurial mindset (EM) habits as an intentional "habits-of-mind" framework for making mindset development explicit to students and for documenting how course activities targeted specific patterns of thinking and action. Engineering activities were mapped to the KEEN 3Cs (Curiosity, Connections, Creating Value) and expanded habit categories that include Action Orientation/Agency and EM-Enhancing Foundations [11].

In-class Activities and Artifacts

To prepare students for the culminating sociotechnical project, in-class activities were organized into two complementary sequences: the Engineering energy-systems activity sequence and the Sociology energy-justice activity sequence. Appendix B documents these sequences in parallel through Table B1 (engineering) and Table B2 (sociology), each summarizing the instructional activities, their intended purpose, and the resulting student artifacts used as preliminary Work-in-Progress evidence. Taken together, the two sequences produced a coherent set of analyzable artifacts that capture students' progression in technical reasoning, equity-centered analysis, and sociotechnical integration. The engineering sequence emphasizes boundary-setting, estimation, and sustainability-method selection, while the sociology sequence emphasizes demographic/equity measurement, spatial analysis, and interpretation of community-level disparities.

Findings

Across artifacts and reflections, students increasingly positioned equitable decarbonization as a problem requiring both technical reasoning and social-system awareness. Student reflections also showed early evidence of entrepreneurial mindset habit development (e.g., embracing ambiguity, systems thinking, implications thinking, opportunity seeking, and metacognition), particularly when students were required to justify trade offs and propose actionable recommendations. The activity-to-habits mapping in Appendix A (Table A1) is used in this manuscript to (1) document instructional intent and (2) connect observed reflection themes to specific course interventions, improving interpretability of emergent findings.

Table 2. Preliminary Findings, Themes, and Representative Evidence

Theme	What students demonstrated	Evidence type
Boundary shifting reveals hidden burdens	Recognized how "clean" solutions displace impacts geographically/socially	Reflections; team writing
Energy justice framing becomes explicit	Used distributional/procedural/recognition language to critique solutions	Final report sections
SDGs support shared cross-major language	Connected local energy decisions to broader goals (e.g., health, jobs, equity)	Presentations; conclusions
Translating critique → action remains hard	Identified trade offs but struggled to propose implementable steps	Reflections
Collaboration benefits and status tensions	Mixed-major teams gained perspective but faced confidence gaps	Reflection + process notes

Discussion

What worked well

Early evidence suggests the course structure promoted sociotechnical reasoning by requiring students to move between technical evaluation and equity critique rather than treating them as separate "add-ons." This aligns with broader calls for critical sociotechnical literacy in engineering learning environments [10]. Additionally, the two-phase group structure supported accountability for both knowledge creation and synthesis. This collaborative inquiry class invited students to apply the *sociological imagination* perspective to questions of energy use and equity. Guided jointly by an engineering professor and a sociology professor, students learned to move between technical measurement and structural interpretation. From the engineering perspective, they calculated electricity, gas, transportation fuel, and water use at the census tract level, standardizing indicators and assessing system efficiency. From the sociological perspective, they examined poverty, racial diversity, and economic vulnerability, asking who bears the greatest energy burden and why. The *sociological imagination* allowed students to connect private utility bills to public infrastructure, housing policy, labor markets, and historical patterns of segregation. Working across disciplines, students saw that energy consumption is not merely a technical problem of supply and demand, but a social issue shaped by inequality and opportunity. By integrating quantitative analysis with structural insight, they developed a deeper understanding of energy equity and place.

Key challenges

Two challenges emerged repeatedly. First, students could identify equity and injustice concerns, but often lacked a decision framework for translating those concerns into defensible priorities under real constraints. Energy-justice lenses supported critique, yet additional scaffolding is needed to convert critique into transparent decision criteria and actionable recommendations. Second, mixed-major teamwork created disciplinary status dynamics that occasionally shaped whose ideas carried weight, underscoring the need for more intentional structures to support equitable participation in technical tasks.

Planned refinements

Planned refinements will strengthen two areas: actionable decision-making without false certainty and equitable interdisciplinary collaboration. In the next iteration, teams will be required to use a structured recommendation protocol that moves from equity critique to feasible action: they will (1) state an explicit equity objective, (2) justify priorities using two to three measurable proxies with documented limitations, (3) identify a responsible actor and realistic implementation timeframe, and (4) include an uncertainty statement that distinguishes evidence, inference, and value judgments. To reinforce this protocol, instructors will implement a shared rubric that integrates technical feasibility with equity implications, explicitly teach how to propose policy/community actions without overstating certainty, and provide additional Sustainable Development Goals–aligned metrics and stakeholder datasets for local context exploration [7], [8]. See Table 3 for a summary of challenges and planned refinements.

Table 3. Challenges and planned refinements observed in the first offering

Observed challenge	Why it matters	Planned refinement
Equity criteria feel abstract to students	Risks superficial equity language	Add a shared decision rubric requiring equity proxies and an uncertainty statement
Disciplinary status dynamics	Risks unequal participation	Add rotating roles, structured collaboration protocols, and peer feedback checkpoints
Balancing breadth vs depth	Risks cognitive overload	Offer two core pathways (technical depth vs stakeholder depth) with a shared synthesis deliverable
Replicability for other instructors	Creates an adoption barrier	Publish assignment templates, sample prompts, and grading rubrics
Data access and quality	Creates uncertain conclusions	Provide a curated dataset pack plus guidance on reporting limitations

Web presence (in development). Course activity descriptions, prompts, and rubrics are being developed as instructional cards on the KEEN Engineering Unleashed platform to support adoption, iteration, and cross-disciplinary collaboration [11].

Conclusion

This paper documents the first iteration of an interdisciplinary course designed at Saint Louis University to help students analyze decarbonization as a sociotechnical challenge. Preliminary findings indicate meaningful shifts in student framing and improved equity-centered critique, while also revealing persistent challenges in moving from critique to implementable action. The next phase of this work will strengthen the assessment strategy and expand evidence coding across reflections and final products.

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Appendix A. EM Habits Targeted by Major Course Activities (KEEN-aligned)

This appendix summarizes how major course activities were intentionally designed to cultivate specific Kern Entrepreneurial Engineering Network (KEEN) entrepreneurial mindset (EM) habits. The mapping supports transparency for reviewers by making the "habits of mind" explicit and linking them to student evidence artifacts.

Table A1. EM Habits Targeted by Major Course Activities

Activity	Targeted EM habits	Evidence artifact
Energy system explainer (diagram + short video)	Inquisitive; systems thinking; value awareness; metacognition	Explainer video + diagram; short written rationale
Embedded/embodied energy and lifecycle framing	Implications thinking; embracing ambiguity; assess/manage risk	Problem set outputs; discussion notes; report methods framing
Energy systems analysis methodologies + scenario comparisons	Strategic thinking; risk awareness; experimentation; intellectual humility	Data outputs + 50–75 word interpretations; methodology section
Value tensions + multi-lifespan mapping	Contrarian thinking; implications thinking; socially mindful; character; metacognition	Value-tension map; reflection artifact/video; synthesis narrative
Stakeholder perspective simulation / role-based critique	Customer-centric thinking; recognition; intellectual humility; accountability	Stakeholder memos; reflection prompt responses
Demographic diversity/segregation metrics activity	Systems thinking; implications thinking; intellectual humility	Quantitative outputs; interpretation paragraph in report
Spreadsheet error-checking and data reliability activity	Accountability; continuous improvement; resourcefulness; metacognition	Corrected formulas; short reliability reflection
Literature review (Phase 1 thematic lenses)	Opportunity seeking; creativity; socially mindful; strategic thinking	Lens section draft; annotated sources; evidence table
Re-grouping into synthesis/production teams (Phase 2)	Initiative; resilience; accountability; adaptability; resourcefulness	Edited report sections; citation log; version history
Policy and ethics section development	Character; socially mindful; value awareness; scale	Policy/ethics report section; recommendations list
Final report + presentation (unified deliverable)	Scale; persistence; strategic thinking; metacognition	Final report; slide deck; team reflection summary

Appendix B. Engineering Energy-Systems and Sociology Activity Sequences and Artifacts

This appendix provides a structured overview of the two complementary in-class activity sequences that scaffold the culminating sociotechnical project: the Engineering energy-systems activity sequence and the Sociology energy-justice activity sequence. Tables B1 and B2 document each sequence using a parallel summary format that reports the instructional activity, intended purpose, and resulting student artifacts collected as preliminary Work-in-Progress evidence.

Table B1. Engineering energy-systems activity sequence: activity goals and resulting student artifacts.

Topic	Activity	Purpose	Artifact(s) collected
Energy systems	**Topic introduction:** foundational overview of how an energy technology functions and why system boundaries matter. **Main activity:** Energy system explainer + links to sustainability goals + stakeholder mapping.	Establish a shared technical baseline and connect technical function to sustainability trade offs and community impacts.	Explainer resource + system diagram/sketch; links to United Nations Sustainable Development Goals with trade offs; stakeholder map (benefits/burdens/exclusions + fairness mechanisms).
Embedded/embodied energy	**Topic introduction:** definition and rationale for embedded/embodied energy as an assumption-driven estimate. **Main activity:** Embedded/embodied energy warm-up problem (Golden Gate Bridge).	Practice order-of-magnitude estimation, unit conversions, and explicit assumptions before a complex case application.	Completed problem solution with stated assumptions and embedded/embodied energy computed in energy units.
Embedded/embodied energy - Massive Events Energy Consumption case	**Topic introduction:** case framing and boundary options for a large event system. **Main activity:** Massive Events (1) stakeholders + value-chain/process map; (2) embedded/embodied energy estimation + reflection.	Move from boundary definition to quantification and reflection; identify dominant energy contributors and trade offs without overstating precision.	Stakeholder list + value-chain/process map poster/diagram; embedded/embodied energy worksheet with energy estimates by value-chain link + totals; short reflection (dominant contributors, surprises, improvement opportunities).
Energy systems analysis methodologies	**Topic introduction:** overview of alternative sustainability analysis approaches and what claims each approach can support. **Main activity:** practice problems and short interpretations applying multiple methods and boundary choices.	Develop method awareness so teams can justify method selection and communicate limitations/uncertainty in conclusions.	Problem outputs + short written interpretations integrated into team work. Methods include process-chain reasoning, input-output reasoning, greenhouse gas accounting, life-cycle assessment framing, and energy return on energy invested.
Value tensions + Envisioning Cards [12]	**Topic introduction:** recurring sustainability trade offs (e.g., efficiency vs equity; short-term vs long-term) and why tensions persist. **Main activity:** paired set: value-tension mapping + multi-timescale Envisioning Cards worksheet.	Make trade offs explicit and forecast consequences across time horizons/dimensions to support defensible recommendations.	Completed multi-timescale map/worksheet (dimensions × time horizons) + proposed design principle/policy idea; optional short reflection artifact (e.g., brief team video).

Table B2. Sociology energy-justice activity sequence: activity goals and resulting student artifacts.

Activity	Instructional approach	Purpose	Artifact(s) collected
Energy Use at the Census Tract Level	The activity focused on teaching students how to calculate and analyze energy use at the census tract level using real-world data. Students began by downloading and cleaning datasets from sources such as the American Community Survey and regional utility records. They learned how to merge census tract shapefiles with tabular energy data and calculate standardized measures such as per-capita and per-household consumption. Through guided instruction, students conducted exploratory data analysis, examining variation, identifying outliers, and comparing high- and low-energy-use tracts. Small group discussions encouraged them to interpret patterns and consider structural drivers such as housing age, transportation dependence, and income levels.	To strengthen quantitative literacy and spatial reasoning skills by grounding analysis in real demographic and environmental data. Rather than working with abstract examples, students engaged with the lived geography of energy consumption and began to see how infrastructure, inequality, and behavior intersect at the neighborhood level.	Student-built database containing four key indicators of energy use: electricity consumption, natural gas consumption, transportation fuel usage, and water usage. Students demonstrated the ability to standardize measures and interpret geographic variation. Each student produced summary tables and a short analytical memo explaining the spatial differences they observed and proposing hypotheses for why those differences exist.
Diversity and Equity Measurement at the Census Tract Level	In the second activity, students learned how to calculate diversity and equity measures at the census tract level. Using census data, they constructed racial and ethnic diversity indices and calculated poverty, extreme poverty, and a composite measure sometimes referred to as a “misery index.” Instruction included both technical and conceptual components. Students discussed the differences between diversity, inequality, and segregation, and examined the strengths and limitations of each metric. Working in groups, they compared tracts that were highly diverse but economically distressed with those that were less diverse but more economically stable. Classroom dialogue emphasized the importance of margins of error and the limits of quantitative proxies for lived experience.	To deepen students’ understanding of how equity can be measured while cultivating critical awareness of what data can and cannot capture. Students were encouraged to move beyond descriptive statistics and consider normative questions about fairness, opportunity, and structural inequality.	Creation of a tract-level equity database that included a racial diversity index, poverty rate, extreme poverty rate, and the composite misery measure. Students wrote interpretive summaries explaining the patterns they identified and reflecting on the conceptual assumptions behind their measures. By the conclusion of the activity, students demonstrated the ability to both compute and critically evaluate demographic indicators.
Mapping and Synthesizing Energy and Equity Data	The third activity required students to integrate their energy and equity datasets into spatial visualizations at the census tract level. Students received instruction in cartographic principles, including classification methods, legend construction, and color selection. They created choropleth maps for individual indicators before learning how to layer or compare datasets to identify spatial correlations. Each student worked with two different software platforms, strengthening technical flexibility and reinforcing core spatial concepts. Presentations required students to explain how patterns of energy consumption intersected with measures of poverty and diversity.	To teach students how to synthesize disparate data sources into a coherent analytical narrative. Mapping was presented not simply as visualization but as a method of inquiry that allows patterns of inequality and infrastructure to become visible in new ways. Students were challenged to distinguish correlation from causation and to consider the policy implications of their findings.	Each student generated multiple maps, including single-variable maps and composite maps that combined energy and equity indicators. Students demonstrated the ability to interpret spatial clustering and articulate the relationship between environmental burden and socioeconomic vulnerability. The final product included a brief policy-oriented memo in which students connected their spatial analysis to potential interventions or planning strategies.