

**APPROACHING SUSTAINABLE ENERGY TRANSITIONS THROUGH BRINGING DISCIPLINES TOGETHER: AN EXAMINATION OF CARLETON UNIVERSITY’S GRADUATE CROSS-DISCIPLINARY COURSE IN SUSTAINABLE ENERGY**

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**Abstract** – Complex challenges in sustainable energy require innovation: new ways of approaching problems and new ways of collaborating. Bridging disciplines through teamwork is one way to address issues effectively. Drawing from the experiences of a graduate level cross-disciplinary course involving engineering and public policy at Carleton University, this paper seeks to provide insights on the practical side of bridging disciplines in the classroom. Offered since 2011, this is a core course of Carleton’s Master’s program in Sustainable Energy Engineering and Policy. Working in groups, students envision and develop plans for novel sustainable energy projects. Through our experiences we posit the following three suggestions for successful interdisciplinary teamwork. First, ensuring that students embarking on a course share a similar foundation. Second, lessons from literature regarding team dynamics can be applied to group project work. Thirdly, that group work, challenging at times, may later be found valuable in life beyond the classroom.

**Keywords:** Education, sustainable energy, engineering, public policy, interdisciplinary, cross-disciplinary, collaboration.

**1. INTRODUCTION**

One complex problem facing governments and institutions today is energy system transitions. Whether discussing the cause of protests about pipelines, concerns about climate change, or the rise of microgrids, there can be no doubt that how we produce, transmit, distribute and deliver electricity is in a state of flux. For instance, in 2017, two thirds of new power plant global investment was for renewables as they have become the least-cost option for a number of countries [1]. However, conventional energy sources remain dominant; in 2015 fossil fuels accounted for over 80 percent of global energy consumption [2]. Policy also plays an important role in these changes – for instance the World Energy Outlook (WEO) 2017 estimates that subsidies for fossil fuels were US$260 billion in 2016, nearly double the subsidies going to renewables [1]. These trends serve as the backdrop to the course and program.

The graduate level project-based course “SERG 5000: Cross-Disciplinary Course in Sustainable Energy” tasks students from the Faculty of Engineering and Design (FED) and the Faculty of Public Affairs (FPA)’s School of Public Policy and Administration (SPPA) with envisioning and developing project plans for novel sustainable energy applications and installations. Drawing on previous experience and coursework, students use a systems perspective to address the technical, environmental, policy/political, social, and economic/financial factors affecting the development of their proposed energy projects. As part of this, students engage with, bridge, and apply key perspectives, approaches, and concepts surrounding sustainable energy engineering and policy [3].

**2. CARLETON UNIVERSITY’S SUSTAINABLE ENERGY ENGINEERING AND POLICY PROGRAM**

Energy and energy policy are increasingly important concerns for governments around the world. Security of energy supplies and environmental consequences of the energy production and consumption process are forcing us to reconsider how we produce and use energy. In the coming decades we can anticipate a transformation towards carbon-neutral energy systems. This change will require scientific, technological and policy innovation.

SERG 5000 is a core course in Carleton’s Sustainable Energy Engineering and Policy Master’s Program. The program is offered jointly by FED and SPPA, and offers degrees in engineering (MAsc or MEng in Sustainable Energy Engineering) and public policy (MA in Sustainable Energy Policy). Students specialize in one side or the other,
while also taking courses where they engage with the other disciplinary component: public policy for those specializing in sustainable energy engineering; and engineering for those specializing in sustainable energy policy.

The program is designed to prepare students for work in sustainable energy fields in government, business, or the civil society sector, and/or to serve as a foundation for further graduate education at the doctoral level. An important way that is achieved is by providing students across the program an opportunity to work and learn together, garnering a greater understanding of the complexity of sustainable energy problems and acquiring an understanding of, and experience with, interdisciplinary collaboration [4].

3. SERG 5000: CROSS-DISCIPLINARY COURSE IN SUSTAINABLE ENERGY

SERG 5000 provides an interdisciplinary collaboration experience within the Sustainable Energy program. It is a mandatory course for all students across the program, at present offered in the Winter semester of the first year in weekly three-hour classes. The course has been running for eight years. It is taught by two co-instructors: one from FED and one from SPPA. Often one and/or the other has extensive experience outside of academia, adding to the expertise available to students.

Students are assigned to teams based on identified interests (e.g. solar energy, energy provision in remote communities), while striving for a balance between engineering and policy students in approximately equal numbers. Gender balance is also considered. The groups are free to choose their own project topics or select a problem or project suggested by an external group or agency. Throughout the semester the teams work together to develop their projects, as in an engineering capstone design course.

3.1. Course Objectives

As stated in the course syllabus, the objectives of the course are: “(1) to develop and evaluate plans for the deployment and adoption of sustainable energy technologies; (2) to assess the social, technical, economic, political and environmental dimensions of sustainable energy deployment; (3) to present persuasive project plans to audiences from government, academia, civil society, and industry; and (4) to bridge engineering and policy perspectives in a collaborative setting” [3]. Throughout the course, students develop skills in crucial areas including teamwork and independent learning; critical thinking; research and analysis; as well as oral and written communication, particularly across disciplinary boundaries. Project topics have been both student-driven, as well as responses to requests from various actors involved in the energy space (for example, Natural Resources Canada, or the non-governmental organization Light Up the World out of Calgary). As such, the course also contributes to the program’s goal of preparing students for employment related to sustainable energy in government, business, and/or the civil society sector; areas where graduates will likely work in interdisciplinary settings. These objectives align with the literature on teaching public policy to engineering students, which highlights communication, decision making, and interdisciplinary work as three essential skills engineers need to participate in public policy processes [5].

3.2. Course Structure

This course is oriented around the development of the group project. There are a number of key deliverables associated with the project: (1) a preliminary presentation and discussion; (2) an abstract and outline; (3) a final in-class presentation; (4) a presentation to the broader community at the Sustainable Energy Showcase; and (5) a formal written report. The course also features some lectures as well as some individual assessment to better ascertain the common knowledge-base by students such as through a midterm or a quiz [3].

In the preliminary presentation and discussion, teams outline their preliminary findings and anticipated direction of their projects. Presentations cover the selected technology and provide a preliminary assessment of the technical, economic, environmental, social, political and policy aspects of the project. A team-led class discussion serves as an opportunity for teams to receive feedback early in the process so as to help them scope their project appropriately. The goal at this stage is to crystallize the project proposal and set the direction for future work. The next deliverable is the abstract and outline for the final report. The purpose of this is to get students to pivot from their project scope to turning towards their finished project and to ensure they have examined various dimensions noted above. The final in-class presentation serves as the dry run for the Showcase. At this stage, the project proposals are fully envisioned, compelling, and rich in detail. A question and answer period following each presentation allows for further feedback in preparation for the Showcase. At this stage, the presentations are more fully developed, and comments and feedback from the dry run are then incorporated.

The Sustainable Energy Showcase serves as a forum for students to present their projects to the broader community of scholars, policy makers, practitioners, and students in the sustainable energy field. Given Carleton’s location in the National Capital Region (NCR), the audience typically includes government officials at both the local and federal level. Like the dry run, presentations are 20 minutes each, followed by a question and answer period.

The formal written report is submitted at the end of the semester, and includes the context for the project, a technical description, project plan, market and business
overview, description of the environmental and social considerations, and a policy assessment. This final deliverable constitutes the largest portion of the final grade, about one-third.

4. WINTER 2018 PROJECTS

Five projects were produced in the Winter 2018 iteration of the SERG 5000 class:

- The 2030 Energy Landscape: Smart Grids, Artificial Intelligence and the Future of Utilities, presenting an alternative business model for Hydro Ottawa, outlining a strategy to transform local distribution of electricity through the deployment of artificial intelligence;
- Driving the Future-Electric Vehicles Powering Toronto; using a fleet of low-carbon electric vehicles (provided as part of a condo building lease arrangement) to support grid regulation and demonstrate the feasibility of vehicle to grid technology;
- A Feasibility Study for Pumped Hydro Storage in an Ontario First Nation; This study was done in response to a request from the Community Energy Planner, following up on an earlier proposal by an engineering firm.
- A Feasibility Study of Community-Owned Wind in Rural Saskatchewan; studying a possible wind power installation in Maple Creek, Saskatchewan, with community ownership and participation.
- A South-Eastern Alberta Solar Project; proposing a 15 MW utility-scale solar project in a power purchase agreement (PPA) with two school boards in Medicine Hat.

5. INSIGHTS

As there are very few engineering-policy collaborations in Canada (at least within academia), this course is valuable for both instructors and students. At the same time, given its novelty in Canadian academia, there have been a number of challenges involved in designing and implementing this course. For instance, in the first semester, the two groups of students take a course separately. This course is specifically tailored for them (e.g. a course about energy policy for engineering students and a course about energy technologies for policy students) – namely, the group of students taught have come from a similar foundation. By contrast, in SERG 5000, these two groups of students come together to work on a respective sustainable energy project. The projects must be designed and executed by students in such a way so as to draw upon their respective strengths, while also exposing them to different disciplines, and challenging them to work out of their comfort zone. Nevertheless, these experiences have also brought about the cross fertilization of ideas, enriching their student experience while also better preparing students for life beyond the classroom. Each team in each iteration of the course has a unique experience, and insights can be gathered on what works as well as what does not.

5.1. From the Instructors’ Perspective

The instructors interact with teams every week, and the insight gained from these experiences can inform practices when it comes to facilitating these interdisciplinary collaborations.

One instructor noted that the cross-disciplinary nature of the course, by its very nature, presents challenges but also rewards for both the teaching process and learning outcomes: “You have to integrate perspectives but also juxtapose them. The balance can be difficult. Students often find this particularly challenging as they may be used to having one instructor teaching from one point of reference and disciplinary perspective… the applied orientation of the course is also something that raises issues but also benefits. One of the most rewarding aspects can be where course objectives and external aims align (i.e., finding ways for projects to feed into real world processes and make concrete impacts for engaged organizations. However, keeping projects closely tied to ‘client’ or ‘stakeholder’ agendas but still deliver on course outcomes is something that requires balance.”

The current course instructors provided comments noting similar challenges and issues. They found the level of technical and policy work generally very high, involving close collaboration between stakeholders and group members: “The course provides a good opportunity for exchange and interaction between policy and engineering students who may not normally have had chance to work together. Group work permits both sets of students to consider and develop their types of expertise, while being aware of other viewpoints and influences… Group work posed some challenges in communication and division of labour for some. Experience gained in resolving these challenges will be useful to students in future when they may be called upon to work with other disciplines, or those with different educational backgrounds.”

In addition to the technical or policy knowledge developed and built upon in the course project work, the class presentations encouraged students in development of presentation skills and professional conduct in conveying their project’s results to audiences of varied backgrounds. One instructor noted that graduates indicated that this course helped them to work in interdisciplinary teams when they left Carleton to work in engineering firms, non-profit organizations, government agencies, etc. Some students were inspired to undertake further interdisciplinary research such as incorporating a policy chapter in an engineering master’s thesis or technical analysis (e.g. energy simulation software analysis) in a policy master’s thesis.
5.2. From the Students’ Perspective

Students’ experiences in the course can be mostly attributed to their team dynamics. Of course, some teams work better than others, and in some cases, students can pinpoint why their team worked well together or why it did not.

One student whose team worked well compared his team dynamic to an integrated design approach, attributing his team’s success to their openness to work with each other: “We were genuinely interested in each other’s part of the work. It wasn’t a siloed process where each of the four of us had a piece and we met at the end (although of course each of us was responsible for specific sections/content). Instead, we worked through as a team, explained the details of our work to each other, and iterated the content. So there probably was some impact on the engineering component based on the policy work and vice-versa; they didn’t exist in a vacuum… My takeaway from this is that the engineering/policy cross-disciplinary teams should seek to work in an integrated, as opposed to siloed, fashion.” Here, one is drawn to parallels from the integrated design process where disciplines work together during planning and design stages of a project. For example, for a building, architects, geotechnical, structural, mechanical and electrical engineers would work together at each stage of planning and design.

Another student who had a “really great” group experience noted that her group included a physicist, architect, and policy analyst: “Bringing together this diversity of perspectives was one of the most interesting and enriching experiences of the Sustainable Energy program… We utilized the diversity in our team to identify a truly unique energy policy opportunity… one of the main benefits of working with such a multidisciplinary team is that it allowed us to tackle this extensive project in a systematic way. Essentially, we were able to delegate the project components to the team member with the given expertise… the engineer was largely responsible for the technology selection and engineering components of the project. I, myself, handled the policy/political challenges and opportunities… we were fortunate to be part of a team where each member had previous experience working in a multidisciplinary setting. We were upfront from the outset about our expectations and capacity. We built a detailed critical path to identify deadlines for each project component… The main difficulty was finding times to work together on the project with differing schedules and workloads.”

Another student whose team did not work so well attributed her challenges to an uneven spread of disciplinary expertise: “It was a confidence boost for me early on to realize that I had the background and knowledge to tackle multiple parts of this project on my own… Unfortunately, I also realized early on that there was a huge knowledge gap between me and my teammates… It seemed like nobody brought the expertise to the table that I expected them to have.” This experience left the student frustrated and disappointed: “I’m really sad to say that I am really disappointed with this interdisciplinary experience. I know that the knowledge gap is a large factor… one of the crucial ingredients of successful interdisciplinary teams is that everyone brings their own specialized expertise to the table.” This speaks to one of the challenges faced when designing and implementing a course involving two or more sets of students with various backgrounds to address a common issue.

6. EVOLVING THE COURSE

Over the next year the course will be undergoing a redesign process, so the next offering of the course will not be until the 2019-2020 academic year. A cross-disciplinary committee has been struck to facilitate this process, including faculty and students from both the engineering and policy sides of the program. It is worth noting that a student member of the Committee joined the program having designed an interdisciplinary engineering-policy education experience during her undergraduate degree.

There are a number of changes proposed for the Committee to consider, most of which are rooted in the model for interdisciplinary collaboration shown below. This model is derived from the field of social work but can be brought back into an engineering-policy education context [6]. The model identifies five core components essential to successful interdisciplinary collaboration, as well as four influences on the success of the collaboration [7].

![Diagram of Interdisciplinary Collaboration Model]

Some proposed changes include:
- Incorporating a lesson on the ingredients of successful interdisciplinary collaboration. Students would be introduced to the model, in particular, highlighting the personal characteristics required as an interdisciplinary team member: trust, respect for others, ability to compromise, adaptability, empathy and understanding between team members.
• Forming teams based on more than just general interests. Other factors could include personality types (possibly based on the Myers-Briggs test), previous experience working with certain classmates, work styles, and expertise (referring to the professional role influence: how team members are grounded in their own profession yet are able to become part of an interdisciplinary team). In addition, an exercise on establishing team norms early in the process could prove valuable.

• Changing the timing of the course in the program might allow students to gain more expertise in their own discipline as well as the energy field (again referring to the professional role). The course would be moved from the end of first year to the beginning of second year; a foundational “Energy Tools” course is being added in the first semester of the first year for all students in the program.

• Creating deliverables that are too large to be completed by one person, or more deliverables between the larger ones. Ideally this would avoid the situation described by the third student, who indicated that she did much of the early deliverables independently.

• Adding a reflection (or multiple reflections) on the interdisciplinary collaboration process as a deliverable. There is currently a requirement for self and peer review, but the criteria for that is relatively minimal. An effective reflection would force team members to pay attention to the process of working together, and incorporate feedback to strengthen collaborative relationships and effectiveness.

7. CONCLUSION

As problems become increasingly complex, it is clear that conventional ways of tackling them, such as through interdisciplinary silos and a pedantic approach towards others outside of their discipline, are inadequate. Providing opportunities to create and foster interdisciplinarity in the classroom serves as one alternative mechanism that is being explored. However, less evidence exists about their practical application. Through our experiences with SERG 5000 we posit the following suggestions regarding interdisciplinary teamwork. First of all, different disciplines are rooted in vernacular and norms that is akin to a ‘language’ – thus, before embarking upon such an interdisciplinary course, ensuring students have a similar foundation in certain aspects would be useful. Second, lessons from literature regarding team dynamics in general become even more relevant in the context of interdisciplinarity. Thirdly, these experiences may prove ‘messy’ for instructors and students, but later on, former students have indicated that this experience proved invaluable as they embarked upon their life course beyond the classroom.

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