

# Building Skills for Sustainable Engineering: A Path to Carbon Emission Reduction

Conference Paper · June 2025



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# BUILDING SKILLS FOR SUSTAINABLE ENGINEERING: A PATH TO CARBON EMISSION REDUCTION

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**Abstract** – *Climate change necessitates a skilled workforce to implement sustainable solutions, particularly in high-emission sectors like buildings. However, a gap exists between industry demands for sustainability skills and workforce preparedness. This study examines the alignment of educational practices with industry needs, identifying critical skill gaps and proposing strategies for integration into higher education. For this research, a qualitative approach was used, with structured interviews conducted with fifteen (15) experts in sustainability-related fields. Findings reveal that technical (e.g., life cycle analysis, energy efficiency) and soft skills (e.g., communication, leadership) are essential. Systems thinking and regulatory knowledge were particularly emphasized. Experts advocated for stronger academic-industry partnerships, integrated learning, and real-world training opportunities. Through the interviews, thirteen out of fifteen experts believed that the students need to understand how technical design should focus on the system as a whole.*

**Keywords:** Sustainability Skills Gap; Green Engineering; Sustainable Education; Industry Involvement and Demand; Student Development; Undergraduate and Graduate Education

## 1. INTRODUCTION

Climate change adaptations and mitigations are at the forefront of the climate crisis faced by every nation. The unprecedented changes to the climate, driven by greenhouse gas (GHG) emissions into the atmosphere are resulting in rising temperatures, more frequent heat waves, rising sea levels, and catastrophic weather events. Decarbonization is at the heart of multiple global and local sustainability goals developed to tackle climate change [1]. In Ontario, the building sector has been at the centre of several sustainability plans, as it has been identified as a high-energy consumer and GHG emitter [2]. It is estimated that the building sector accounts for 22% of GHG emissions in Ontario. To reduce GHG emissions, Ontario has implemented sustainability plans, such as the Toronto

Green Standard (TGS), stating strategic goals and requirements to support Ontario's Climate Change Action Plan [2], [3].

The urgency to address sustainability skills within the workforce is critical to tackling climate change and global warming issues. The transition towards sustainable employment will require the deep knowledge and workforce needed to complete the transition towards clean technology and adaptation to reduce GHG emissions [4]. According to Boston Consulting Group (BCG), current education standards need to focus on clean technology by acknowledging practices surrounding, but not limited to, renewable energy projects, sustainable agriculture, green infrastructure, conservation efforts, sustainable manufacturing, resiliency, procurement and supply chain [5]. Furthermore, the need for an adequate and equipped workforce is now prominent in many engineering, architecture, and construction sectors. Recognizing the importance of GHG and the environment, sustainability is included in the Canadian Engineering Accreditation Board Graduate Attributes as *Impact of engineering on society and the environment*.

As many companies transition towards a clean technology future, they need talent to develop and understand the new sustainability landscape. According to Microsoft's Closing the Sustainability Skills Gap: Helping Businesses Move from Pledges to Progress, in 2022, there were more than 3,000 companies that have pledged to work towards sustainability [6]. However, the report describes a lack of talent as one of the prime reasons of not being able to meet sustainability targets. A 2021 published report by McKinsey showed that "between now, '2022', and 2030, the global renewables industry will need an additional 1.1 million blue-collar workers to develop and construct wind and solar plants and another 1.7 million workers to operate and maintain them" [7], [8]. The increase in workforce demand is governed through the sustainable targets set by companies. The clear evidence of the increase in sustainability targets was reported by BCG, which shows that "companies setting science-based targets have grown 36-fold since 2007, reaching over 4,200 companies [5].

This research aims to investigate the sustainability skills gap by conducting targeted interviews with industry professionals and academic experts. The goal is to foster a dialogue that leads to actionable changes in educational strategies and curriculum designs. This research will provide a foundation for developing more comprehensive and practical educational tools and methods that align with the evolving demands of the sustainability sector, ultimately enhancing the capacity of future engineers and architects to contribute to environmental preservation and GHG reduction efforts.

## 2. LITERATURE REVIEW

### 2.1. Sustainability Skills Gap Narrative

The narrative surrounding the sustainability skills gap is increasingly focused on the urgent need for upskilling and reskilling within emerging cleantech and environmental sustainability sectors. For this research, the cleantech and sustainability sectors are focused on GHG reductions. In addressing the sustainability skills gap, a comprehensive analysis of the current situation is critical. The current understanding of the investigation of the skills gap can be classified under (1) Workforce demand and (2) Corporate and public enterprise commitment toward the sustainable movement. Both of these points are co-dependent in providing adequate delivery and implementation of sustainable solutions.

As the global renewable energy sector anticipates the addition of 4.1 million workers by 2030, the necessity for expansive training programs in sustainable practices becomes apparent [5]. Concurrently, legislative measures like the EU's Corporate Sustainability Reporting Directive (CSRD), affecting approximately 50,000 companies [6]. Moreover, the trend of promoting sustainability leaders from within organizations suggests an urgent need for continuous internal training programs. This is particularly important as the industry looks to upskill as many as 150 million people across various sustainability domains by 2030 to meet imminent targets [4].

Global readiness for sustainability-focused training is also lacking, with less than 40% of UN member states involved in the Paris Agreement having plans for skills training to support its implementation [1]. This shortfall is echoed in the corporate sector, where a survey by Microsoft and BCG revealed that 76% of respondents pointed to the nascent and rapidly evolving nature of required sustainability skills as major hurdles in training efforts [6].

Recent surveys indicate a critical gap in educational offerings related to climate issues and green jobs. About 77% of industry professionals who participated in BCG survey actively seek to learn more about climate issues, acknowledging an educational deficit during their schooling years [9]. Moreover, a staggering 88% believe schools should have a responsibility to educate students

about climate and environmental issues, a sentiment echoed by another 88% who feel there is an urgent need for enhanced education on these topics compared to previous generations [10]. The call for specialized green skills is clear, with 57% of business leaders demanding sustainability competencies crucial for their operations [11]. Notably, there is a strong desire among employees for green skills training, with nearly one in four workers engaging in formal education to prepare for a career in green industries [9].

### 2.2. How are Green Skills Acquired, Integrated, or Developed?

Similar to all modern-day education paths, green skills can be gained through formal education, workplace training, and continuous professional development [12], [13]. Academic institutions play a key role by offering sustainability-focused curricula, while short courses and micro-credentials provide flexible learning opportunities for professionals. Developing these skills requires a tailored approach, distinguishing between technical expertise and managerial competencies [14], [15]. Embedding sustainability challenges in educational and workplace settings further enhances skill application.

To support this transition, workforce development initiatives are expanding within corporate and industry sectors, ensuring professionals across various fields can contribute to sustainability efforts. Collaboration among educational institutions, industry stakeholders, and learning partners is essential for scaling up green skill acquisition [16]. However, a major challenge persists—the need for accessible, purpose-driven training programs that effectively integrate sustainability principles into business and operational frameworks [17]. Addressing this gap will be critical in building a workforce equipped to drive decarbonization and environmental responsibility.

### 2.3. Carbon and Sustainability Integrated into Engineering Pedagogy

Addressing the climate crisis has become a fundamental challenge in engineering education, necessitating a strong focus on carbon reduction and sustainability. These concepts involve understanding emissions impacts, developing strategies for mitigation, and eliminating carbon footprints through a broad, systems-level approach. Integrating sustainability literacy into undergraduate engineering programs ensures that graduates are prepared to meet global, national, and institutional sustainability goals. However, a critical gap persists between the skills taught in current engineering curricula and those required by industry [16], [18], [19]. Many companies struggle to meet their sustainability targets due to a lack of skilled professionals, highlighting the urgent need for educational institutions to adapt their training programs.

Reports by the BCG and Microsoft reinforce this issue. BCG projects that within the next decade, up to 150 million workers will require upskilling to meet the growing demand for sustainability expertise [4]. Similarly, Microsoft has identified a lack of skilled talent as a primary reason for companies failing to meet their sustainability commitments. Despite widespread claims by higher education institutions that sustainability has been integrated into curricula, the effectiveness of these initiatives remains uncertain. Research by Perpignan et al. (2020) examined the fundamental knowledge and competencies associated with sustainable development in engineering education, with a particular focus on eco-design [14]. Their literature review found that the Accreditation Board for Engineering and Technology (ABET) identified 11 key sustainability competencies, while the Co-Active Training Institute (CTI) defined 14, and Energieeffizienz-Netzwerk Architekten und Ingenieure für Energieeffizienz (ENAE) outlined 22. Studies have consistently highlighted several core competencies necessary for sustainability-focused engineering, including critical thinking, interdisciplinary collaboration, problem-solving, systemic thinking, normative competence, and self-awareness. Further research confirms consensus on the importance of systems thinking, interdisciplinary teamwork, and professional skills in engineering sustainability education.

Historically, sustainability has been incorporated into engineering education through various pedagogical approaches, including curriculum development, project-based learning, interdisciplinary collaboration, and experiential learning [1], [19]. One approach is the development of dedicated sustainability courses covering topics such as renewable energy, sustainable manufacturing, green infrastructure, and conservation. These courses provide both theoretical knowledge and practical applications, ensuring that students develop a strong foundation in sustainability principles. Additionally, integrating sustainability objectives into existing engineering courses exposes all students, regardless of specialization, to critical sustainability concepts.

Project-based learning has also proven effective in embedding sustainability education. Capstone projects that address real-world sustainability challenges encourage students to apply theoretical knowledge in practical scenarios [19]. These projects often require interdisciplinary collaboration, reinforcing the complexity of sustainability issues and fostering teamwork across different engineering and non-engineering disciplines. Further, interdisciplinary coursework—integrating engineering with environmental science, policy, and business—helps students understand the broader implications of sustainability beyond technical solutions [14], [20].

Guest lectures, workshops, and seminars featuring sustainability experts provide valuable industry insights,

keeping students informed of emerging trends and real-world applications. These approaches collectively contribute to equipping future engineers with the competencies necessary to drive sustainable innovations, ensuring that engineering education remains aligned with evolving industry needs and sustainability goals. However, challenges persist in making sustainability education more effective, requiring continued efforts to refine pedagogical strategies and ensure meaningful integration into engineering curricula.

#### **2.4. Steps Taken by the Industry to Contribute to Sustainability**

The engineering industry has implemented various strategies to address sustainability challenges, focusing on carbon reduction, renewable energy adoption, sustainable manufacturing, and energy efficiency. Companies are actively working toward net-zero emissions through multiple approaches. Carbon capture and storage (CCS) technologies are being deployed to prevent CO<sub>2</sub> from entering the atmosphere. Shell's Quest CCS project in Alberta, Canada, captures and stores over one million tonnes of CO<sub>2</sub> annually from its oil sands operations [21]. Companies are also adopting GHG inventory and reporting systems to track emissions and set reduction targets. For instance, Google's Environmental Report outlines its progress toward operating on 24/7 carbon-free energy by 2030 [3]. Process optimization is another key strategy; General Electric (GE) has reduced energy consumption by 20% in its manufacturing plants through operational improvements.

Investments in large-scale renewable energy projects help reduce reliance on fossil fuels. The Ørsted Hornsea One offshore wind farm in the UK provides clean energy to over one million homes. Companies are also installing on-site renewable energy systems to lower their carbon footprint. Apple's solar panels at Apple Park generate 17 megawatts (MW) of clean energy [22]. Additionally, Power Purchase Agreements (PPAs) enable companies to source renewable energy at scale. Amazon has signed multiple PPAs, including a 100 MW solar farm in Virginia, USA [23].

Industries are embracing circular economy principles by designing products for longevity and recyclability. Companies are increasingly using sustainable materials such as recycled content and biodegradable components. Lean manufacturing techniques are improving efficiency while reducing waste and energy consumption. Toyota's Toyota Production System (TPS) has resulted in lower energy use and minimized waste [24].

Companies conduct energy audits to identify inefficiencies and implement solutions. Siemens' energy audits have led to a 30% reduction in energy consumption [6]. Adoption of advanced building technologies, including smart lighting, energy-efficient HVAC systems, and IoT-

enabled automation, helps optimize industrial processes and reduce overall energy usage.

### 3. METHODOLOGY OF STRUCTURED INTERVIEWS

#### 3.1. Expert Selection

For this research, expert selection was a very important step. The importance of expert selection is not only limited to capturing a diverse group of individuals but also to ensuring that all of the collected information is relevant and insightful on the sustainability skills gap. The following metrics were used to identify suitable experts:

- **Professional Experience:** Individuals with at least 5 years experience in roles related to sustainability, environmental science, or clean technology within various sectors such as construction, manufacturing, energy, or consulting.
- **Diverse Representation:** Representation from multiple sectors to understand the sustainability skills gap across different industries such as architecture, construction, engineering, manufacturing, research and sustainability.
- **Geographically Confined:** Experts from Greater Toronto Hamilton Area (GTHA) or working within the GTHA region were preferred to capture a local perspective.
- **Contribution to Sustainability Initiatives:** Individuals who have actively contributed to or led sustainability initiatives, projects, or programs that have demonstrated measurable impact.

#### 3.2. Process of Scheduling an Interview

The interview scheduling process was conducted before finalizing the expert selection criteria and followed a structured approach.

- **Step 1: Identification:** Experts were sourced from professional networks, industry associations, academic institutions, and conference proceedings.
- **Step 2: Screening:** Candidates' professional backgrounds, publications, and contributions to sustainability initiatives were reviewed to ensure alignment with the selection criteria.
- **Step 3: Primary Communication:** Formal invitations were sent to selected experts, outlining the interview's purpose, format, and significance in the research.
- **Step 4: Confirmation:** Experts confirmed their participation and availability and were provided with preparatory materials to facilitate a productive discussion.

This structured process ensured that relevant experts were engaged effectively, contributing valuable insights to the study.

#### 3.3. Interview Process

A structured approach was used to conduct 20-minute remote interviews with experts, ensuring systematic data collection on the sustainability skills gap within industry and academia. This methodology facilitated a comprehensive analysis of sustainability education and workforce needs.

- **Step 1: Introduction (3 minutes):** The interview began with a warm greeting and introduction, where the purpose of the study was briefly explained. The interviewee was reassured of confidentiality, and verbal consent was obtained for recording. Any technical issues were addressed before proceeding.
- **Step 2: Research Premise (2 minutes):** A summary of the research background was provided, outlining key sustainability skills gaps and their relevance to industry and academia. The interviewee's expertise was emphasized, highlighting their role in contributing valuable insights.
- **Step 3: Research Questions & Answers (12 minutes):** The core part of the interview focused on collecting expert perspectives:
  - **Question 1:** What skills do you think recent engineering and architecture graduates and /or young professionals need to contribute to decarbonization and carbon reduction strategies on the job or in academia?
  - **Question 2:** What are your thoughts on how a university education could bridge sustainability skills gaps in delivering and implementing carbon reduction?
- **Step 4: General Discussion (3 minutes):** Facilitated open discussion to capture additional insights and reflections from the interviewee:
  - **Open-Ended Discussion:** Interviewees were invited to elaborate on key points or introduce additional insights.
  - **Closing Remarks:** A summary of key takeaways was provided, and the expert was thanked for their time and contributions.

## 4. RESULTS AND DISCUSSION

### 4.1. Expert Approached

Selecting experts for the interviews was a critical aspect of the research, ensuring diverse and comprehensive insights into the sustainability skills gap. To maintain relevance and depth in the findings, experts were chosen based on their expertise in green skills, sustainability, and academic structures while acknowledging potential biases inherent in individual perspectives. Transparency in

selection was prioritized by incorporating a range of professional backgrounds. A total of 15 experts were interviewed, representing key sectors:

- Energy and Architecture – 6 experts
- Engineering Process Operations and Manufacturing – 3 experts
- Research and Innovation – 2 experts
- Construction – 2 experts
- Sustainability Consulting – 2 experts

This diverse representation ensured that insights reflected multiple dimensions of sustainability implementation across industries, contributing to a well-rounded understanding of the existing skills gap and potential solutions.

#### 4.2. Responses and Analysis of Interview Question 01?

Interviews with industry experts emphasized the need for a balanced skill set, integrating both technical (hard) skills and non-technical (soft) skills. While quantitative analysis is essential, experts stressed that it must be paired with effective communication to translate findings into actionable insights. A strong understanding of policies, regulations, and compliance standards is also critical for achieving sustainability goals.

A key theme identified was systems thinking, which involves understanding the interconnected nature of sustainability challenges. Experts highlighted the importance of multidisciplinary problem-solving, where professionals recognize how their actions impact broader systems. Additionally, a reflective approach to problem-solving—thoroughly analyzing implications before acting—was encouraged to ensure long-term effectiveness.

The skills gap is task-dependent, meaning different projects require different skill sets. This underscores the need for tailored training programs aligned with industry demands. Experts debated which skills should be taught in academia versus those best acquired through workplace experience, reinforcing the need for stronger collaboration between academia and industry.

Key findings from both the literature review and expert interviews confirmed the following skills for students to acquire:

- Interdisciplinary knowledge to address sustainability issues holistically.
- Practical experience through internships, co-ops, and industry projects.
- Communication skills to convey complex sustainability concepts to various audiences.
- Regulatory awareness to navigate evolving sustainability policies.
- Innovation and creativity to develop new solutions.
- Collaboration and teamwork in multidisciplinary settings.

These insights highlight the necessity of integrating core sustainability principles into education while fostering real-world experience through industry partnerships. The next sections further analyze the identified soft and hard skills.

Experts also confirmed soft skills as essential for addressing the sustainability skills gap. These skills enhance professional effectiveness and ensure individuals are well-equipped to implement sustainability initiatives. Below are the key findings, including expert consensus on each skill.

Table 1. Summary of soft skills highlighted by 15 experts, including definitions and relevance to sustainability skills gap

Skills (Experts Agreement out of 15 experts)	Description and Relevance
Communication Skills (14)	Clear and concise communication enables professionals to translate complex sustainability concepts for diverse stakeholders, including teams, clients, and communities. Effective communication is crucial for gaining support and ensuring the successful implementation of sustainability initiatives.
Stakeholder Engagement (12)	Engagement with policymakers, community members, and industry partners fosters collaboration, inclusivity, and support for sustainability projects, ensuring diverse perspectives are considered in decision-making.
Leadership Skills (9)	Guiding teams and managing change toward sustainability goals. Strong leaders inspire teams, manage change, and integrate sustainability into organizational strategies, ensuring long-term impact.
Socio-Economic Awareness (8)	A comprehensive understanding of social, economic, and environmental factors was emphasized by 8 experts. This skill allows professionals to develop balanced, economically viable, socially responsible, and environmentally sustainable solutions.
Problem Solving Skills (7)	Devising solution based on the ability to identify real-world problems as an essential component, requiring professionals to stay informed about trends, policies, and best practices.
Systems Thinking (Context-Dependent Skill)	While systems thinking can be classified as either a hard or soft skill, many experts believe it should be taught within academic institutions. This approach enables professionals to analyze the interactions and long-term impacts of sustainability strategies. Systems thinking helps develop holistic, adaptive solutions that integrate environmental, social, and economic considerations.
Critical Thinking (5)	Fosters innovation, strategic analysis, and the ability to address unforeseen challenges, making it invaluable for professionals working in rapidly evolving sustainability fields.
Ethical Judgment (1)	Applying integrity and responsibility in sustainability decisions. The low number of experts recognizing ethics as an important skill was likely due to the focus of discussions being within sustainability topics, rather than an intentional dismissal of ethics as a relevant skill. Ethical judgment is still essential in ensuring fair, responsible, and integrity-driven sustainability decisions.



Fig. 1. Soft skills noted by the experts during the interview.

Along with soft skills, industry experts highlighted several hard skills essential for addressing sustainability challenges and ensuring the effective implementation of sustainability initiatives. These skills encompass technical knowledge, regulatory compliance, financial management, and energy efficiency - all critical for developing sustainable solutions.

Table. 2. Summary of hard skills highlighted by 15 experts, including definitions and relevance to sustainability skills gap

Skills (Experts Agreement out of 15 experts)	Description and Relevance
Policies, Codes, and Standards (13)	Knowledge of compliance frameworks critical to sustainability planning. Compliance with policies ensures that sustainability practices align with legal and industry requirements.
Life Cycle Analysis (5)	Evaluating the total cost of ownership across a product or system’s lifespan was noted as essential. Experts emphasized the importance of quantifying GHG emission reductions to make informed sustainability decisions
Setting Appropriate Targets (3)	Establishing realistic sustainability goals ensures effective project planning, execution, and compliance with evolving industry standards.
Energy Generation & Use (4)	Understanding macro-scale energy flows and implications for design. Furthermore, Understanding geographical and temporal energy variations allows for the development of more efficient and sustainable solutions.
Operational Energy Savings (8)	Strategies to reduce energy consumption in buildings, processes, and systems, leading to lower costs and reduced environmental impact.
Energy Modeling (2)	Experts from the building industry emphasized the importance of simulation tools to predict energy performance and optimize efficiency
"Using Less Energy for All Tasks" (4)	The need to minimize energy use across all processes, promoting energy-conscious decision-making.
Risk Assessment (4)	Identifying environmental, social, and economic risks in project planning.
Financial management (10)	Budgeting, cost analysis, and investment strategies to support the economic viability of sustainability initiatives.

Selected expert quotes in response to Question 01:

- "Without communication, none of the technical knowledge matters. You can have the best scientific

model in the world, but if no one understands it, it’s useless." – Expert in Energy and Architecture

- "Systems thinking means being able to see how your decisions impacts all components." – Engineering Process Expert
- "Most graduates don’t know how to read or apply a building code. That’s a basic but critical skill if we want compliance and change." – Construction Industry Expert
- "Risk is often overlooked. But without assessing risks, sustainability projects are on shaky ground." – Research & Innovation Specialist

### 4.3. Responses and Analysis of Interview Question 02

Industry experts provided valuable insights on how academia can address the sustainability skills gap. Academia needs to produce talent that can be most effectively used within the industry. The topics of integrated multidisciplinary learning strategies, clarity on what skills the students are going to learn, engagement with innovative solutions, and real-world systems thinking were most common during conversations with interviewees. It should be noted that this solution provided by industry experts may be hard to implement within an academic setting. The major goal of the industry, which is focused on solving problems, might not accurately align with the knowledge-based courses that students need to learn.

#### 4.3.1 Possible Methods of Bridging the Green Skills Gap from Industry Experts’ Point of View:

Industry experts identified several methods for integrating green skills into academic programs to better prepare students for sustainability challenges. These strategies focus on multidisciplinary learning, industry collaboration, real-world applications, and innovative teaching approaches.

##### 1. Systems Thinking Modules (12 out of 15 experts)

Experts emphasized the need for systems thinking education to help students understand complex sustainability interactions. Among these, seven experts also stressed the importance of interdisciplinary learning, integrating diverse fields to develop holistic sustainability solutions. Two experts specifically noted not to have tunnel vision when thinking about systems thinking. Ideally, they believed that forming focused multidisciplinary groups can encourage broader perspectives and collaborative problem-solving.

##### 2. Industry Collaboration (14 out of 15 experts)

Industry collaboration was the most commonly suggested method. Experts recommended:

- Seminars & Workshops – Industry-led discussions on sustainability applications and case studies.
- Industry-Sponsored Projects – Real-world capstone and research projects provide hands-on learning.

- Internships & Co-op Programs – Workplace experience ensures students gain practical sustainability skills.
- Technical Labs & Facility Tours – Visits to sites, labs, and manufacturing facilities with industry partners to expose students to the industry operations.

### **3. Encouraging Innovation & Creativity (6 out of 15 experts)**

Experts stressed that innovative problem-solving is vital for sustainability. Universities should:

- Encourage creative project-based learning to explore novel sustainability solutions.
- Foster an innovation mindset through experimentation and real-world challenges.

### **4. Real-World Learning Approaches**

- Case Studies (5 experts) – Teaching sustainability concepts using industry examples enhances critical thinking and problem-solving.
- Stakeholder Analysis & Human-Centric Design (7 experts) – Understanding stakeholder needs ensures that sustainability solutions are socially and economically viable.

### **5. Dedicated Sustainability Courses (5 experts)**

Experts noted a lack of specialized sustainability education in undergraduate programs. Some only encountered one deep-dive sustainability course during their graduate studies, which proved critical to their careers. Introducing early-stage sustainability education would provide foundational knowledge in environmental science, energy efficiency, and policy analysis.

### **6. Teaching Industry-Specific Vocabulary (3 experts)**

Sustainability professionals must effectively communicate complex concepts. Experts suggested training students in sustainability terminology to enhance clarity and stakeholder engagement.

### **7. Supply Chain Education (2 experts)**

Sustainability practices require an understanding of supply chain dynamics. Experts recommended integrating supply chain courses and seminars to enhance students' awareness of sustainable production and distribution.

### **8. University-Industry Advisory Committees (2 experts)**

Academic institutions should form advisory committees with industry professionals to tailor sustainability education to local needs. Different industries (e.g., agriculture vs. technology) require different sustainability competencies, making localized training essential.

### **9. Articulating Desired Skills**

Universities must clearly define and communicate the sustainability competencies they aim to teach. This allows (1) industry to engage with universities that focus on specific sustainability skill sets and (2) more targeted internship and co-op opportunities based on university strengths.

### **4.3.2 Methods to Include Industry with Skills Gap Bridging:**

Experts emphasized the need for greater industry involvement in training future sustainability professionals. Effective collaboration between academia and industry requires a multi-faceted approach, ensuring students acquire practical experience and industry-relevant skills. Industry participation with academia can be unfocused or multi-focused. In an unfocused opportunity, the academic institution will cater to a single organization for an event or a project, whereas a multi-focused industry participation involves multiple industry partners at the same time for involvement in larger projects.

### **4.3.3 Key Methods for Industry-Academia Collaboration**

#### **1. Knowledge Sharing & Networking**

Experts believed that there are many ways for industry and academia to flourish together and solve the sustainability skills gap. One of the prime ways to complete this is through knowledge sharing and networking. The following methods were discussed during the interviews to be used as a method of knowledge sharing:

- Seminars: Experts from various engineering and sustainability fields present case studies and lessons learned, helping students understand real-world applications of sustainability solutions.
- Industry Guest Lectures: Professionals share industry trends, best practices, and sustainability challenges, bridging the knowledge gap between academia and practice.
- Networking Sessions: These events connect students with industry professionals, fostering mentorship and collaboration.

#### **2. Hands-On Learning & Training**

Practical, hands-on experience is crucial for developing sustainability skills that cannot be fully grasped through traditional lectures alone. These methods provide real-world exposure to sustainability concepts, tools, and techniques.

- Workshops: Interactive sessions focus on emerging technologies and sustainability techniques, such as carbon accounting or energy modeling.
- Technical Lab Sessions: Practical training in sustainability-related technologies and methodologies, enhancing technical skills.
- Certification Training: Industry-aligned certifications validate expertise, making graduates more competitive in the job market.
- Site & Facility Tours: Visits to labs, manufacturing plants, and sustainability projects expose students to real-world sustainability applications.

#### **3. Industry-Sponsored & Collaborative Projects**

Collaboration between academia and industry ensures that students work on meaningful, real-world sustainability challenges. These projects bridge the gap between academic research and practical implementation

- Industry-Sponsored Projects: Students work on real-world sustainability challenges provided by companies.
- Capstone Projects: Experts recommend breaking large capstone projects into smaller, manageable sustainability-focused tasks, enabling deeper learning.
- Industry-Collaboration Projects: Joint initiatives between academia and industry foster innovative problem-solving and resource sharing.

#### 4. **Co-Curricular Development & Work Experience**

Integrating sustainability-focused programs into co-curricular activities ensures that students develop practical competencies beyond theoretical knowledge.

- Co-Curriculum Development: Aligning coursework with industry needs ensures graduates possess relevant sustainability skills.
- Internships & Co-Op Programs: Hands-on work experience enhances industry-specific competencies.
- Undergraduate Co-Ops: Experts noted that companies prefer hiring undergraduates due to recent financial constraints, making these opportunities more viable than graduate placements.

#### 5. **Mentorship & Professional Development**

Mentorship helps bridge the sustainability skills gap by offering personalized career guidance and real-world insights. Industry professionals play a critical role in shaping the next generation of sustainability leaders.

- Industry Mentorship: Experts provide guidance on real-world sustainability applications, helping students transition into the workforce.

#### 4.4. **Connecting Findings to Literature Review**

The valuable insights covered from the industry professionals have a direct impact on engineering education. Primarily, the findings from the interview affirm the widespread recognition in the literature of growing need to bridge the skills gap, particularly emphasising skills such as systems thinking, regulatory awareness, and communication skills. Additionally, the literature review highlighted the need for interdisciplinary education, experiential learning and integrating real-world exposure through co-ops, site tours, and capstone projects [12], [13], [19], [25]. This is similar to the interviews where 14 out of 15 experts noted industry collaboration, and systems thinking was noted by 12 out of 15 experts. Furthermore, the emphasis placed on introducing well-defined sustainability curricula early in educational program echoes literature and industry interview findings.

## 5. STUDY LIMITATIONS

While the structured interview method provided valuable insights, the study is limited by its small sample size and geographic focus on the Greater Toronto and Hamilton Area (GTHA). This regional scope, along with the selection of experts primarily focused on sustainability, may have introduced bias and limited the generalizability of the findings. The participants' perspectives may also reflect individual or sector-specific priorities. To improve future research, studies should include experts from a wider range of disciplines and regions, especially those not already focused on sustainability, and consider using randomized selection and quantitative methods such as surveys to validate and expand on the findings.

This study provides a foundation for future research by establishing the rationale for a broad scope. However, future studies should narrow their focus to a specific sector or theme to allow for deeper analysis. The wide scope of this study required a general literature review; in contrast, future research should tailor the literature review to align with the chosen area of focus.

## 6. CONCLUSION

Effectively preparing students and early-career professionals for the green economy requires a balanced combination of technical and soft skills. Advanced knowledge of policies, codes, energy management, and sustainability frameworks must be complemented by communication, leadership, and systems thinking to ensure professionals can drive meaningful environmental change. A systems-based interdisciplinary approach is essential in sustainability education. By understanding the complex interconnections between environmental, social, and economic systems, professionals can develop innovative and long-term solutions rather than short-term technical fixes. Collaboration between industry and academia is paramount in bridging the sustainability skills gap. Industry-driven training, mentorship, and practical learning opportunities ensure that graduates enter the workforce with relevant, applicable skills aligned with real-world demands.

#### **Key Findings include:**

- Communication (13 out of 15 experts) and systems thinking (12 out of 15 experts) were the most critical soft skills, enabling professionals to translate sustainability concepts into impactful strategies.
- Understanding policies, codes, and standards (13 out of 15 experts), life cycle analysis (5 experts), and energy efficiency at a macroscale (4 experts) is crucial for ensuring compliance, setting realistic sustainability targets, and optimizing resource use.
- Financial management (10 experts) and risk assessment (4 experts) were identified as key

competencies for ensuring the economic viability and resilience of sustainability initiatives.

- Industry-academia collaboration (14 out of 15 experts) was highlighted as essential for bridging the sustainability skills gap through industry-sponsored projects, site tours, guest lectures, internships, and mentorships.

By integrating technical expertise, systems thinking, and industry collaboration, sustainability education can evolve to equip future professionals with the skills and knowledge necessary to address complex global challenges and drive a sustainable future.

### Acknowledgements

This research was funded by Ontario Society of Professional Engineers (OSPE) and Mitacs.

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