EGD Stakeholder Summit Whitepaper

ENGINEERING WORKFORCE ADVANCING SUSTAINABLE DEVELOPMENT

A long-standing not-for-profit membership organization, ASME enables collaboration, knowledge sharing, and skills development across all engineering disciplines and continents, to advance engineering for the benefit of humanity. ASME's Engineering Global Development (EGD) team works to improve the quality of life by building engineering capacity and talent around the world to solve urgent, local and global challenges, including access to clean water, adequate sanitation, housing, reliable electricity, transportation, food production, accessible education, health care, information, and communications, among others. Through partnerships, training, resources, and platforms that accelerate the development of long-term solutions for vulnerable populations, ASME advances the UN Sustainable Development Goals (SDGs) through a global network at Engineering for Change (E4C), applied Impact Projects, codified engineering knowledge, domain expertise and prepared social ventures around the globe. These EGD platforms connect and catalyze the technical workforce for good, as engineers increasingly seek to use their skills to create positive social and environmental impact.

READERS GUIDE

As stakeholders and others who are interested in the ways in which engineering can drive sustainability across the globe, we invite you to review this report for a small window into the discussions that took place at the Summit. We highlight some of the most promising and innovative research and projects in this space, which we encourage you to consider as well. The Summit and this accompanying report are the beginning of a set of conversations about the sustainability roadmaps that ASME's EGD team will develop and implement in the years to come, and we hope that you will find a role for yourself in this work.

LETTER FROM STEPHANIE VIOLA, EXECUTIVE DIRECTOR OF THE ASME FOUNDATION

Dear Colleagues,

Engineers at heart are problem solvers. Overcoming technical challenges is what engineers do. But in a fast-warming world with finite resources, where systemic inequities hold so many back, there is no such thing as a purely technical challenge. Successful solutions must also be environmentally, socially, and economically sustainable even as they solve technical problems.

That is the overarching goal of ASME's Engineering Global Development initiatives, and it was the central topic of our EGD Stakeholder Summit 2022.

Activating the engineering community to address the wider impacts of technical innovation is more than an academic discussion; it's an existential imperative, not only for the engineering profession, but for the future of people everywhere and the planet we all share. So EGD convened representatives of industry, academia, NGOs, the public sector, and individual innovators to explore avenues of collaboration that can lead to measurable progress in service of both technological progress and the greater good.

The recommendations contained in the EGD Stakeholder Summit 2022 Report aren't the final word on this topic. In fact, they're just a beginning. A promising, hopeful, optimistic start on a journey we must all take together. I hope you'll join us for the next step—bringing these recommendations to life!

Sincerely,

Stephanie Viola

ACKNOWLEDGMENTS

ASME expresses its deepest gratitude to EGD and E4C staff and leadership, as well as to Summit design leads, volunteers, contributors, attendees and other stakeholders for their technical support and additional contributions to the event's success. Special thanks go to the Summit's Design Leads and the ASME EGD Committee for their role as Summit facilitators.

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EXECUTIVE SUMMARY

At the 2022 Engineering Global Development Stakeholder Summit, ASME's EGD group convened industry leaders, innovators, academics, NGOs, and other leading voices in engineering whose work advances sustainable development for a high-level exploration of the emerging factors that are impacting (and will ultimately shape) the future of the engineering profession. This substantive, solutions-based conversation addressed topics such as how best to equip future talent to practice technological stewardship and how to strengthen the pathways to achieving and promoting sustainable development through engineering.

Key themes emerged during the Summit, including the far-reaching impact of challenges such as global resource inequality, climate change, and the COVID-19 pandemic, with participants exploring tactics to strengthen connections between policymakers, academia, and industry, towards the ultimate goal of amplifying the impact that the engineering workforce can make in sustainable development. The Summit focused on interdisciplinary perspectives, recognizing that the future of engineering lies in establishing and developing bridges across professions.

During the Summit, stakeholders were divided into small groups where facilitators guided participants through discussion-based activities. This report provides a synthesis the data collected during this Summit by notetakers in each group, which were subsequently thematically analyzed. Among the key insights that emerged are:

(1) The **climate crisis, COVID-19 pandemic, and broader global social justice movements** have amplified concerns of social and environmental impacts within the field of engineering.

(2) Consumers are **demanding more sustainable and socially responsible products**. While many companies are responding by investing in social and/or environmental metrics and reporting, these initiatives are not widespread or standardized.

(3) There is increasing advocacy for the engineering field to continue to move away from a Eurocentric approach, towards a more **equitable and inclusive workforce**, one that prioritizes community perspectives and the social and environmental impact of engineered solutions. While there have been some substantiated efforts in the engineering community to develop tools for designing and measuring such impacts, there exists a great opportunity to develop and distribute wide-spread methods and tools for improving the field's impact on community and environmental outcomes within their specific contexts.

(4) While there are increasing career opportunities for engineers to advance sustainable development, these can be difficult to find and are often not directly connected with the outcomes of engineering educational programs. Some programs within universities exist, for example Development Engineering at UC-Berkeley, Global Engineering at Colorado University-Boulder, and Humanitarian Engineering at University of Sydney. However, **findings from this Summit highlight a disconnect between industry and academia in preparing graduates for successful employment in sustainable development careers**. Existing career pathways include, but are not limited to, technology and design, product and project management, finance and funding decision-making, supply chain management, social entrepreneurship, impact reporting, and academic career pathways.

(5) To be successful in sustainability-focused roles, **engineers must demonstrate non-technical skills directed towards ethical, inclusive, and equitable ends**. Skills such as socio-technical competencies, improvisation, communication, and teamwork, alongside mindsets of humility and empathy are critical for engineers aiming to contribute to sustainable development.

The findings presented in this report highlight the increasing interest and need within the engineering community to invest in and advance efforts towards sustainable development, including but not limited to: environmental sustainability, social equity, diversity, and inclusion. Notably, the analysis identified six emerging cultural shifts required to advance engineering and sustainable development efforts. This report recommends that engineers who are addressing such challenges should:

1. **Take an interdisciplinary & multi-stakeholder approach**
2. **Consider dynamic & interconnected systems**
3. **Prioritize diversity & inclusion**
4. **Challenge the perception that engineering is neutral**
5. **Increase humility & center community perspectives**
6. **Broaden engineering goals to include environmental & social outcomes**

Based on Summit findings, **the Summit organizers propose the use of the term "Engineering for Sustainable Development"** as an umbrella term to refer to the broad interdisciplinary practice of engineering to improve the quality of life of society and the environment worldwide, which aims to be inclusive of all sub-disciplines and philosophies of engineering and design (e.g., global engineering, humanitarian engineering, design justice, community-engagement, participatory engineering etc.). This broadening affords affinity among distinct functions which nonetheless collectively seek “sustainable development” ends. We suggest that Engineering for Sustainable Development (ESD) is integrated into the engineering profession broadly. Aspects of ESD can and should be incorporated into all professional pathways to achieve the systemic change necessary for engineering to support sustainable development.

In addition to recommendations for the broader engineering community, this report also acknowledges the existing ASME infrastructure and provides actionable recommendations for ASME, including how:

(1) ASME must champion the aforementioned key mindsets and cultural shifts through its programs; many specific examples are presented in this report.

(2) ASME should continue and grow its efforts to create the proper scaffolding for engineering for sustainable development to thrive by continuing to invest in engaging the active community, professionalizing the practice, and encouraging engineering educational institutions to develop clear pathways for the next generation of the engineering workforce to support sustainable development efforts.

(3) Given its credibility and resources, ASME should increasingly invest in work with policymakers and industry decision makers to design and implement sustainability metrics and incentive structures such that the broader engineering community becomes more encouraged to support these broader initiatives.

Through these strategies, ASME and its affiliates can position themselves as leading voices to ensure the field of engineering is equipped to tackle pressing challenges related to sustainable development. The cultural shifts described in this report, including interdisciplinarity, systems-thinking, diversity, challenging apoliticality, increasing humility, and broadening engineering goals are critical for advancement towards social equity and sustainability.

ASME is poised to build on more than a decade of learning and successful sustainable development programs and platforms to establish a unified strategy ensuring that sustainability is integrated across the enterprise. The collective potential of this unified front is transformative to the profession and society at large and inherent to ASME’s mission to advance engineering for the benefit of humanity.

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1 INTRODUCTION

Engineers play a pivotal role in reducing the progression of climate change, mitigating the impact of global emergencies, and advancing towards the United Nations' 2030 Agenda for Sustainable Development. Now, more than ever, the engineering field is front and center in large-scale issues that directly impact daily life around the globe. During the COVID-19 pandemic, rapid innovation of health technologies, such as ventilators, vaccines, and protective equipment, improved access to life-saving resources.[1] These and many other breakthrough technologies are essential to helping solve some of the most critical human development challenges, such as monitoring, adapting, and mitigating changing climates in agricultural and residential contexts, providing access to clean water, and developing affordable and accessible solutions to combat diseases, e.g., HIV/AIDs, malaria, and coronavirus.[2]

However, the global engineering profession, including academic, industrial, and public systems, is not currently equipped to tackle these large socio-technical challenges. First, engineering itself must undergo transformative developments to be more inclusive, cooperative, and socially and environmentally responsible.[3] Globally, representation within the engineering field remains inequitable. In the United States, Black engineers make up only 5% of the engineering workforce, while women make up just 15%; these groups are well below their total respective workforce shares of 11% and 47%.[4] Second, most engineering curricula do not adequately prepare technical talent to address what some call "wicked sustainability problems," e.g., climate change, poverty, resource scarcity,[5] rather, curricula emphasize technical skills, training students to reduce large complex systems to simpler quantitative models. While modeling is a critical component of large-scale problem solving, many curricula emphasize the technical at the expense of other necessary skills, such as interdisciplinarity, ethics, and cross-cultural competence.[6] Third, the engineering industry lacks guiding principles, incentives, and tools to make sustainably focused decisions. While the UN Sustainable Development Goals (SDGs) provide a "North Star," the framework lacks a specific roadmap or set of operating instructions. Many enterprises are striving to meet market demand and decrease their carbon footprint but encounter operating and business roadblocks; among many other socially, environmentally, and economically difficult decisions.

While the global engineering workforce requires much-needed transformation, there has been incredible progress across various sectors and industries. Many academic institutions are establishing interdisciplinary departments and schools focused on sustainability and responsible innovation, and prior work has identified over 85 academic institutions worldwide that provide learning opportunities for engineers interested in sustainable development.[7] Examples include Arizona State University's School for the Future of Innovation in Society and Stanford University's Doeer School of Sustainability, the latter of which was established with investments of $1.1 billion. In 2021, a large interdisciplinary working group co-developed 15 learning objectives for global engineering graduate programs that emphasized ethics, cross-cultural humility, complex systems analysis, and climate resilience, among others.[8] Moreover, approaches such as the Environmental, Social, and Corporate Governance framework (ESG) provide metrics for evaluating the extent of which an organization works on behalf of social and environmental goals. While these efforts are formidable, they remain dispersed and not widely adopted by the global engineering community.

In an effort to develop tactics for advancing engineering for sustainable development, supporting the engineering workforce to address these "wicked sustainability problems", and strengthening

[1] Agarwal, N., Floryan, M., Lyu, J. H., Lindsay, H., Rojas, C., Soyars, C. (2021, February 15). Engineers respond to COVID-19: Case Studies from around the globe. *Engineering for Change*. (link)
[2] ITT (2019). *50 Breakthroughs: Critical Scientific and Technological Advances Needed for Sustainable Global Development*. (link)
[3] UNESCO (2021). *UNESCO Engineering Report. Engineering for Sustainable Development: Delivering on the Sustainable Development Goals*. (link)
[4] Kennedy, B., Fry, R., Funk, C. (2021, April 14). 6 facts about America's STEM workforce and those training for it. *Pew Research Center*. (link)
[5] Lönngren, J., & Svanström, M. (2016). Systems thinking for dealing with wicked sustainability problems: Beyond functionalist approaches. In *New developments in engineering education for sustainable development* (pp. 151-160). Springer, Cham. (link)
[6] Lattuca, L., Terenzini, P., Knight, D., & Ro, H. K. (2014). *2020 Vision: Progress in preparing the engineer of the future.* (link)
[7] Burleson, G., Machado, M., & Aranda, I. (2021). 'Engineering for Global Development' in Academic Institutions: An Initial Review of Learning Opportunities Across Four Global Regions. 2021 *World Engineering Education Forum/Global Engineering Deans Council,* 153–158. (link)
[8] MacDonald, L., Thomas, E., Javernick-Will, A., Austin-Breneman, J., Aranda, I., Salvinelli, C., Klees, R., Walters, J., Parmentier, M. J., Schaad, D., Shahi, A., Bedell, E., Platais, G., Brown, J., Gershenson, J., Watkins, D., Obonyo, E., Oyanedel-Craver, V., Olson, M., … Linden, K. (2022). Aligning learning objectives and approaches in global engineering graduate programs: Review and recommendations by an interdisciplinary working group. Development Engineering, 7, 100095. (link)

pathways between engineering education, industry and policy, the 2022 Engineering for Global Development Stakeholder Summit brought together industry leaders, innovators, academics, NGOs, and other sustainable development leaders. The following objectives guided the design and operation of the summit and analysis of its outcomes:

1. To describe primary graduate and professional competencies for engineers which are valued by employers pursuing sustainable global development.
2. To describe the professional pathways currently available for engineers trained in sustainable global development.
3. To understand the current and shifting global drivers on the professional pathways (e.g., inequity, poverty, pandemic, social justice, climate change).
4. To identify opportunities for the engineering for sustainable development sector to increase its positive impact on society while increasing the availability of long-term and en masse professional pathways within engineering for sustainable development.
5. To suggest opportunities for ASME to advance sustainable economic, social, and environmental global development objectives.

Among many recommendations presented, a key finding from this work is **the recommendation of an umbrella term, "Engineering for Sustainable Development" (ESD),** which allows for the identification of various subfields underneath it, e.g., Engineering for Global Development, Global Engineering, Humanitarian Engineering, and Social Innovation; among many others. As such, for the majority of this report, we use the umbrella term 'ESD' to refer to the broad interdisciplinary practice of engineering to improve the quality of life of society and the environment worldwide, particularly as it relates to the UN Sustainable Development Goals (SDGs). When other terminology is used in this report, we are referring to specific sub-fields within this broader international ESD effort.

2 METHODS

2.1 Stakeholder recruitment

To ensure a diverse and wide range of expertise and perspectives, ASME recruited stakeholders across private industrial, academic, and public sectors. Stakeholders attended from engineering organizations and employers with existing sustainability strategies or ESD practices in place. The ultimate goal was to generate groups of individuals with diverse, cross-sector, and multidisciplinary experience in ESD.

Overall, 55 stakeholders were involved in the summit (50 in focus group sessions and 5 in post-summit individual semi-structured interviews). Most of the participants represented the public and private sector, with just under 20 from academia, and over 35 from industry. Participants joined from all over the world, including Canada, India, Italy, Kenya, and the U.K., with the majority participating from the U.S.

2.2 Summit design & data collection

Before the summit, we conducted two surveys: one for stakeholders affiliated with academic institutions and one for industry more broadly. Both surveys focused on individual perspectives and values of engineering skills, training, and career pathways related to ESD.

During the summit, we conducted two focus-group sessions. Each session involved seven groups, each with 5-8 stakeholders, a facilitator, and 1-2 notetakers. Survey results were presented to encourage reflection and solicit interpretation of the results. Using the virtual white board platform, "Miro," stakeholders were led through a series of discussion-based activities driven by the various session goals shown below.

SESSION 1

Topic 1.1: Engineering in the global landscape: To elicit participants' key priorities related to their sustainability agenda

Topic 1.2: Skills desired in future engineers: To elicit top skills industry participants require in engineers working in sustainable fields; and compare this with what academics train to prepare students.

Topic 1.3: Value of EGD-trained engineers. To elicit participants' experiences with engineers trained in sustainability.

SESSION 2

Topic 2.1: Emerging pathways. To elicit ESD-related career pathways available for engineers (current and future-casting).

Topic 2.2: Enablers and barriers to future pathways. To identify and describe existing and potential barriers to thriving ESD careers, as well as existing and potential enablers.

Data were collected in two ways: virtual sticky notes and comments written by participants on the Miro Boards and conversations transcribed by notetakers. After the summit, we conducted five interviews with key stakeholders who were unable to attend the summit. Early results from the summit and survey were included in the interviews for initial member checking, as a way to assess resonance and transferability of results.

2.3 Data synthesis & analysis

Our data synthesis and analysis was grounded in our five objectives presented in the introduction. First, transcripts from the Summit and Miro Boards were examined independently by two individual evaluators and participants' responses were grouped (i.e., deductively coded) into seven categories that mapped emergent themes driven by our objectives: (1) Barriers for ESD careers, (2) Enablers for ESD careers, (3) Career pathway opportunities, (4) Skill development in ESD-trained engineers, (5) Shifting career pathways, (6) Changing mindsets, and (7) Other. Second, the themes from the two evaluators were consolidated. Next, the full set of clustered data were evaluated and synthesized into three key findings, presented in the following section: "Global drivers leading to mindset shifts," "Increased availability of professional pathways for ESD engineers," and "Broader skill sets for ESD engineers are valued." Thematic clustering was then completed to identify key findings including current trends, potential pathways forward, and, ultimately, recommendations for the field of engineering as well as within ASME. We also conducted member checking (i.e., participant validation) with facilitators and some summit participants. In the following sections, the findings are presented along with relevant literature and resources.

3 KEY TRENDS IN ESD

3.1 Global drivers lead to mindset shifts

During the summit, participants affirmed the increasing awareness of social and environmental impacts of innovation across the field of engineering. **The climate crisis, COVID-19 pandemic, and broader global social justice movements have amplified concerns in engineering sectors around the world.** What used to be considered "problems" in primarily emerging markets, such as social impact of technology, resource allocation, and supply chain issues, are now front-and-center priorities for all markets. As evident in the way that the UN Millennium Development Goals (the predecessors to the SDGs) were only for "developing nations" while the SDGs are now for all member nations, participants described the lines between so-called "developed", "developing", and "underdeveloped" as blurred, as the field grows in its awareness and mitigation of historical colonial approaches, "parachute aid" and "voluntourism". There was **palpable advocacy for the engineering field to continue to move away from the globalization of Eurocentric engineering** towards a more localized global engineering, e.g., building local capacity and respecting local expertise and knowledge, in order to attend to social justice considerations and historical inequities.

Participants stressed how the awareness of environmental and social consideration is rapidly growing in the public eye, particularly among younger generations. **Consumers are demanding more sustainable and socially responsible products,** as evidenced by a study by Forrester that found that more than half of U.S. respondents aged 18 to 23 will ensure that a brand's corporate social responsibility (CSR) aligns with their values before making a purchase.[9] Summit participants described that this demand has led to increased CSR initiatives as well as standards and certifications, such as B Corp, Cradle to Cradle Certified, and other various fair trade and responsibly sourced certifications. While there exists more certifications and metrics for environmental impacts, participants emphasized that consumers are increasingly interested in social considerations, such as Diversity, Equity, and Inclusion (DEI). As such, **many engineering companies are investing in DEI metrics and reporting, but participants stressed that these initiatives are not widespread or standardized,** which some participants claimed can result in "impact washing," i.e., claims of social or economic impact without sufficient evidence.[10] In addition to consumers, the engineering workforce has been challenging much of the status quo–particularly Millennials and Generation Z, who are more motivated by meaningful work and social change compared to previous generations.[11] More broadly, the Institute for Corporate Productivity, determined that 93% of Generation Z (persons born between 1996 and 2012) employees in the U.S. said that a

[9] Kelly, Chris. January 20, 2021. 'Post-truth' climate impacts Gen Z's conflicting brand perceptions, Forrester says. *Marketing Dive*. (link)
[10] ISO (2021, November). *Impact Washing: What it is and how to spot it.* (link)
[11] Moore, K., & Frazier, R. S. (2017). Engineering education for generation Z. *American Journal of Engineering Education (AJEE)*, 8(2), 111-126. (link)

company's impact on society affects their decision to work there.[12]

These shifts have enabled an increasing number of initiatives in public-interest technology, including the Design Justice Network, Data Science for Social Good, and Technology Stewardship, among others referenced by stakeholder participants. There has also been significant investment by industry leaders and scholars to research and operationalize robust ethics for advanced technology, such as AI and automation.[13] **These public-interest initiatives advocate for the consideration of social, historical, and political factors in the creation of new, inclusive, equitable solutions.** Participants also referenced advancements in engineering product and service design methodologies, such as inclusive design, participatory design, and contextual design, which provide recommendations for engaging stakeholders ethically and effectively throughout design and innovation processes.

Insights from the broader community

EXAMPLES OF PRINCIPLES FROM THE DESIGN JUSTICE NETWORK

Principle 1: We use design to sustain, health, and empower our communities, as well as to seek liberation from exploitative and oppressive systems.

Principle 3: We prioritize design's impact on the community over the intentions of the designer.

Principle 8: We work towards sustainable, community-led and -controlled outcomes.

To see more principles, view their webpage.

Participants described how increased public incentives and awareness of the social and environmental impacts of innovation has led to **efforts to establish methods to develop and measure these impacts.** Metrics, such as the Environmental, Social, and Governance (ESG) criteria, enable investors to screen initiatives and make socially conscious decisions. These metrics are also crucial for recruiting and retaining the ESD workforce; a recent survey found that an employer's ESG activity and rating influences 61% of engineers' decision to remain at their company.[14] Participants also referenced government-enacted regulations, such as the Corporate Average Fuel Economy (CAFE) in the U.S. and the Directive on Single-Use Plastics in the European Union, which are pushing companies to reduce their environmental impact. Discussing the case of a governmental ban on sulfur-rich coal in Mongolia in 2019, one participant emphasized how government regulation helped subsidize the development of green energy. "You need both guidance and enforcement for the uptake of sustainability to work well," he explained. "Where there's obvious financial benefit, like waste to energy, that can drive itself forward, and the more of that the better. On the other side, where what you're doing is, say, creating an absence of pollution, that's harder for the market to drive, and that's where we need someone to come in and regulate." How best to balance regulation and guidance was a recurring topic, with regulation seen as useful in some contexts and guidance in others. One participant found that successful regulations occurred when powerful organizations "made rules that are outcome rather than process based. Not 'do x, y, z' but 'achieve x, y, z'." When it comes to navigating the "minefield" of accreditation and certification, another participant felt that "rather than regulatory, there is a need for a guidance role" to help companies.

For social factors, there exists even less unification of performance metrics, and many Summit participants highlighted this existing gap. While some assessment tools exist for community-level impact assessment, e.g., Social Impact Assessments and Social Return on Investment (SROI), their application and use is varied. A review by Rainock et al. (2018)[15] characterized eleven types of social impacts (e.g., population change, gender, human rights), but standardized metrics for these specific social characteristics remain lacking. Within product development, scholars have proposed social performance indicators related to employment, health, and standard of living, among others[16,17] and there have been recent advancements in the

[12] Samdahl, Erik. December 16, 2015. New I4CP Research: 93% of Gen Z Says Society Impact Affects Where they Work. The Institute for Corporate Productivity. (link)

[13] Blackman, Reid. October 15, 2020. A Practical Guide to Building Ethical AI. *Harvard Business Review.* (link)

[14] GETI (2022). Global Energy Talent Index Report. (link)

[15] Rainock, M., Everett, D., Pack, A., Dahlin, E.C., & Mattson, C.A. (2018). The social impacts of products: A review. *Impact Assessment and Project Appraisal*, 36(3), 230-241. (link)

[16] Stevenson, P.D., Mattson, C.A., Bryden, K.M., & MacCarty, N.A. (2018). Toward a universal social impact metric for engineered products that alleviate poverty. *Journal of Mechanical Design*, 140(4), 041404. (link)

[17] Fontes, J., Tarne, P., Traverso, M., & Bernstein, P. (2018). Product social impact assessment. *The International Journal of Life Cycle Assessment*, 23(3), 547-555. (link)

modeling and prediction of social impacts of engineered solutions.[18,19] However, there remains ample opportunity to advance and operationalize socially driven engineering impacts and goals.

Insights from the Summit
EXAMPLES OF ESD CAREERS:

Sustainability Manager: Individuals in these positions manage various sustainability programs and environmental impact reporting, including managing and implementing institutional climate action plans.

Consultants: Individuals work directly with companies to develop climate action plans, reporting structures, and programs to enhance sustainability outcomes.

Technical Associates: Individuals provide technical expertise on projects, particularly for non-profit organizations.

Social Innovators & Start-ups: Individuals undertake entrepreneurial projects to develop a scalable business model focused on improving environmental and/or social wellbeing

3.2 Professional pathways are becoming more available to ESD engineers

At the summit, participants described a variety of ESD career opportunities, including (1) technology and design, (2) product and project management, (3) supply chain management, (4) financing and funding decision-making, (5) social entrepreneurship, (6) impact reporting, and (7) academic pathways. **Design and development of sustainable processes, products, and programs were the most commonly mentioned ESD career opportunities currently available.** Next, participants cited opportunities in measuring progress and outcomes in sustainable development, as well as project management. Many career paths for sustainability-focused engineers are available within a variety of organizations, such as consulting firms, social enterprises, non-government organizations, educational institutions, product manufacturers, international development organizations, government agencies, disaster response organizations, and corporate responsibility divisions.[20]

Participants also emphasized an **increasing presence of engineers in historically non-traditional career pathways, such as those in finance and policy.** Engineers with technical and contextual expertise have roles to play in funding decision-making and regulation development and application. For example, in the U.S., the White House Fellows Program offers individuals first-hand experience in national affairs. Additionally, participants highlighted the role of engineers applying existing metrics, such as ESG, into company financial and design models. As an example, one participant described their role in developing funding requirements to ensure that their organization selected proposals aligned with recommended practices and social and environmental goals. Specifically, by developing funding requirements, she was able to provide incentives for development organizations to incorporate specific equity considerations. Within academia, although relatively small, there has been an increase in the number of engineering faculty positions for researchers with a focus on sustainability and social impact. For example, within the last two years, the Mechanical Engineering Department at the University of Michigan hired four tenure-track faculty members whose research focused on "engineering for social justice."

Participants highlighted the wide **variation in epistemologies and prioritizations of their vision of ESD across various career paths and institutions,** which include different influences from humanities and social sciences, applications of empathy and humility, social justice principles, and disciplinary standards of work,[21] and differences in engineering-specific technical expertise and knowledge domains.[22,23] It is clear that there are expansive and diverse opportunities for engineers

[18] Mabey, C.S., Armstrong, A.G., Mattson, C.A., Salmon, J.L., Hatch, N.W., & Dahlin, E.C. (2021). A computational simulation-based framework for estimating potential product impact during product design. *Design Science*, 7. (link)

[19] Stevenson, P.D., Mattson, C.A., & Dahlin, E.C. (2020). A method for creating product social impact of engineered products. *Journal of Mechanical Design*, 142(4). (link)

[20] Geiger, R., West, S., Peiffer, E., Kleine, M. S., & Lucena, J. (2021). Mapping Engineering For Good Career Pathways: Examples From North America. *Engineering for Change, ASME, Colorado School of Mines*. (link)

[21] Lucena, J., Schneider, J., & Leydens, J. (2010). Engineering And Sustainable Community Development: Critical Pedagogy In *Education For "Engineering To Help."* (link)

[22] Riley, D. (2008). Engineering and Social Justice. Synthesis Lectures on Engineers, Technology and Society, 3(1), 1–152. (link)

[23] Kleine, M. S., & Lucena, J. C. (2021). The World of "Engineering for Good": Towards A Mapping of Research, Teaching, and Practice of Engineers Doing Good. *ASEE Annual Conference & Exposition.* (link)

interested in global sustainability career paths, which many scholars are actively investigating (e.g., Juan Lucena, Marie Stettler Kleine, Amy Javernick-Will, and others).

There are **increasing educational and training opportunities for engineers to pursue ESD careers.** Academics participating in the Summit reported an increase in students interested in ESD, which is increasingly taught through extracurricular, certificate, minor, major, and graduate degree programs. ESD-focused programs are quickly expanding across the globe through a wide range of pedagogy as well as curriculum approaches, with a focus on experience- and project-based learning.[24] However, Summit participants highlighted the wide ranges of philosophies and vocabulary,[25] which have led to endeavors to create cohesion across ESD-focused programs. For example, the Humanitarian Engineering Community of Practice (HECoP) aims to provide explanations of the boundaries, concepts, and practices within the field of Humanitarian Engineering in Australia. In another example, a 2021 conference convened 55 universities and companies (primarily U.S-based) to develop a list of priority learning objectives for graduates of global engineering programs.[26] Additionally, Summit participants described ways in which ESD programs are working to improve their training by incorporating frameworks to increase social responsibility in students[27] as well as fostering project-based learning without disempowering communities or promoting neo-colonialism.[28]

However, participants highlighted **a gap between industry and academia in preparing graduates for successful ESD employment.** For example, participants discussed how many students and early-career engineers have a misconception that ESD work only engages in Low- and Middle-Income Countries. Participants instead highlighted the immense opportunities for ESD work across all countries and contexts, regardless of national income level. As such, many participants claimed that the framing of ESD and examples used in ESD teaching should expand students' understanding of ESD career opportunities. To better connect engineering students to ESD careers, organizations are offering fellowships for students to get valuable work experience in the field, such as the ASME Engineering for Change Fellowship and AAAS Science & Technology Policy Fellowship Program.

At the Summit, there was discussion of developing and retaining a diverse engineering workforce. A prior ASME Summit called "Increasing Women in Mechanical Engineering" identified that the retention of female engineers across the mechanical engineering profession is a critical problem. While prior literature has found that ESD-related work attracts women and minorities to engineering,[29] other studies have found that **women pursuing community development engineering were especially at risk of leaving the engineering profession** due to discontent with their experiences.[30] Other studies have found that ESD students particularly worry about the difficulty of securing an ESD career as opposed to a career in other engineering fields.[31] During the Summit, many participants highlighted that many engineers from disadvantaged backgrounds are drawn away from ESD career paths due to the lack of high-paying positions compared to traditional engineering roles. Indeed, while ESD-related work attracts diverse talent due to its breadth of applications, there are many opportunities to improve retention through clearer, more inclusive career pathways and paid opportunities.

Summit participants highlighted the importance of **recognizing power dynamics, cultural differences, implicit biases, and privilege within engineering work,** and dismantling the historical divide between "international" staff and "local" staff in ESD. Individuals among the "international" staff, who carry sets of privileged social constructs, were called to reflect on their identity and motivations for working in the sector, e.g., increase humility, learn and prioritize Indigenous knowledge, develop goals

[24] Burleson, G., Machado, M., & Aranda, I. (2021). 'Engineering for Global Development' in Academic Institutions: An Initial Review of Learning Opportunities Across Four Global Regions. 2021 *World Engineering Education Forum/Global Engineering Deans Council,* 153–158. (link)
[25] Smith, J., Tran, A. L. H., & Compston, P. (2020). Review of humanitarian action and development engineering education programmes. European Journal of Engineering Education, 45(2), 249–272. (link)
[26] Ibid 8.
[27] Canney, N., & Bielefeldt, A. (2015). A Framework for the Development of Social Responsibility in Engineers. *International Journal of Engineering Education*, 31, 11. (link)
[28] Birzer, C. H., & Hamilton, J. (2019). Humanitarian engineering education fieldwork and the risk of doing more harm than good. *Australasian Journal of Engineering Education*, 24(2), 51–60. (link)
[29] Jayakumar, A., & Nozaki, S. (2020, June). Impact of Humanitarianism on Female Student Participation in Engineering. In *2020 ASEE Virtual Annual Conference Content Access*. (link)
[30] Litchfield, K., & Javernick-Will, A. (2017). Socially Engaged Engineers' Career Interests and Experiences: A Miner's Canary. *Journal of Professional Issues in Engineering Education and Practice*, 143(1), 04016018. (link)
[31] Smith, J. (2019). Impacts of a humanitarian engineering education pathway on student learning and graduate outcomes. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 14(1), 1–20. (link)

without tokenizing, and assist in rebalancing salaries, benefits and power.[32] Individuals in the "local" pathway, who carry variations of historically marginalized identities, hold social, navigational, technical, linguistic, and cultural capacities that are instrumental in leading global reform efforts and reaching sustainable development targets should be fairly compensated and hold roles of power.[33,34] **Many international ESD organizations aim to address this need by hiring regional directors who are experienced local leaders and experts in their country's context**. Organizations with this model include Habitat for Humanity Terwilliger Center for Innovation in Shelter and Water for People, amongst an increasing number of others.

In addition to formalized career pathways, Summit participants argued that engineers specialized in ESD should increase their political participation to advocate for social and environmental accountability of the technology and engineering industry at large. Coalitions, such as the Engaging Scientists & Engineers in Policy (ESEP), the IEEE European Public Policy Committee (EPPC), and the African Technology Policy Studies Network (ATPS) aim to bring engineering expertise into policy and governance discussions.

Insights from the literature

15 LEARNING OBJECTIVES FOR GLOBAL ENGINEERING GRADUATES:[8]

- Contextual comprehension & analysis
- Cross-cultural humility
- Global engineering ethics
- Stakeholder analysis & engagement
- Complex systems analysis
- Data collection & analysis
- Data-driven decision making
- Applied engineering knowledge
- Project design
- Project management
- Multidisciplinary teamwork & leadership
- Communication
- Climate change, sustainability, & resilience
- Global health
- Development economics

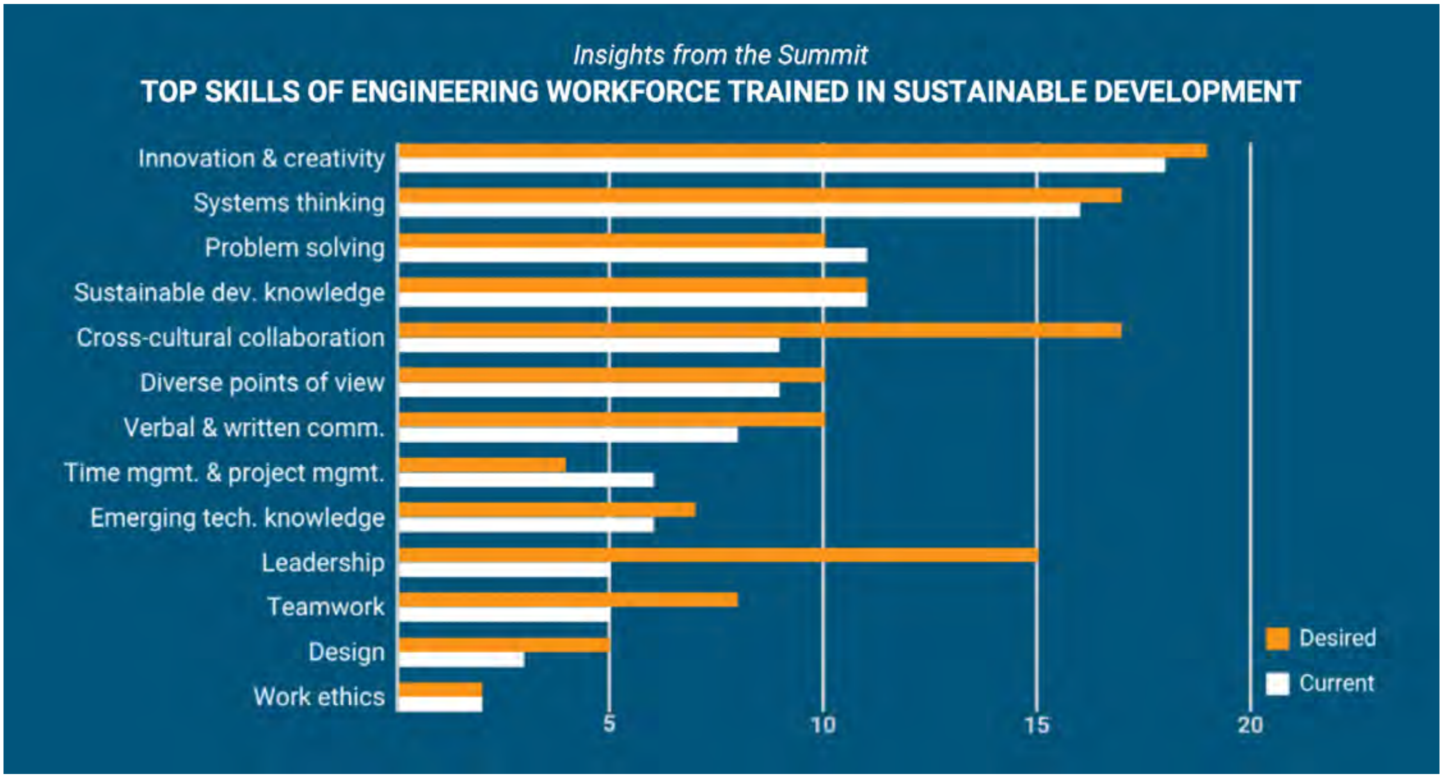
There are also many opportunities for the political participation of engineers associated with political advocacy groups, such as those defending digital rights (e.g., Center for Digital Democracy, Accountable Tech, Fight for the Future), promoting water, energy, and technology access (e.g., International Energy Agency, Clean Water Action, First Nations Technology Council) and climate action (e.g., Climate Action Network, Natural Resources Defense Council). These advocacy groups, along with many others around the globe, offer engineers opportunities to inform, educate, and drive sound policymaking that reduces inequalities.

3.3 Broader skill sets for ESD engineers are valued

Given the rigors, technical content, and responsibilities of the profession, engineers are widely recognized for their technical competencies, however, Summit participants emphasized the **need to grow engineers' interpersonal and reflexive skills.** This imperative aligns with a recent Deloitte report that stressed the need to "prioritiz[e] enduring human capabilities" to ensure long-term success of employees and organizations, which includes fundamental skills like communication and teamwork, as well as personal attributes like empathy and humility.[35] Traditionally, these skills have been treated as adjacent to technical competencies, but increasing importance is placed on teaching that inculcates fundamental skills and technical competencies as complementary to one another and co-constitutive of professional engineering practice. Participants suggested that infusing broader personal and professional skills within existing technical education, especially in ways that seek to resolve traditionally imposed demarcations between them, would also allow engineering educators to inject these competencies while still meeting the specific credit demands of engineering degrees.

Summit participants highlighted ways in which ESD skills and competencies are increasingly directed towards ethical, inclusive, and equitable ends. Terms like "global competency," described by Downey et al. (2006)[36] as the "knowledge, ability, and predisposition to work effectively with people who define problems differently than they do," underpin a

[32] Peace Direct, Adesco, Alliance for Peace Building, & WCAPS. (2021). Time to Decolonize Aid: Insights and lessons from a global consultation. *Peace Direct*. (link)
[33] Stine, E., Javernick-Will, A., & Tanksley, T. (2022). Passing along experimental and learned understandings of inequality: Marginalized communities are shapers of humanitarian engineers. 2022 ASEE Annual Conference & Exposition. (link)
[34] Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, 8(1), 69–91. (link)
[35] Radin, J., Hatfield, S., Schwartz, J., Bordeaux, C. (2020, January 28). Closing the employability skills gap: The answer is simpler than you may think. *Deloitte Insights*. (link)
[36] Downey, G. L., Lucena, J. C., Moskal, B. M., Parkhurst, R., Bigley, T., Hays, C., ... & Nichols-Belo, A. (2006). The globally competent engineer: Working effectively with people who define problems differently. *Journal of Engineering Education*, *95*(2), 107-122. (link)



growing push for socio-technical competencies among engineers, conceived primarily as the ability to develop ethical engineering solutions attentive to the diverse cultures in which they are embedded.[37] Indeed, there is a growing move away from a traditional "save the poor" model towards interactions that ensure community empowerment.[38] Participants suggested that engineers draw from fields like Science and Technology Studies (STS), Philosophy of Technology, and other social sciences, to strengthen ethical approaches to engineering solutions and critical decision-making skills.[39] Although there have been recent notable efforts to address variations in learning objectives through working groups[40] and coalitions (e.g., the Humanitarian Engineering Community of Practice), Summit participants expressed that university education efforts require more unification and incentives for more robust ESD training. For example, some participants suggested that curricula recommendations through the Accreditation Board for Engineering and Technology (ABET) in the U.S. and the Engineers Australia Stage 1 Competencies in Australia could provide guidelines and incentives for educators to incorporate ESD training.

To better prepare for the collaborative and connected nature of Industry 4.0, which is characterized by rapid changes to technology, industry, and society due to increasing interconnectivity and smart automation, engineers must also be equipped with broader systems-thinking skills, such as defining problems systematically to better devise appropriate technical solutions. Our survey results showed that within industry, there is a gap between the current and desired skills of engineers trained in sustainable development when it comes to Leadership and Cross-cultural collaboration. Interestingly, while cross-cultural collaboration was ranked highly by educators as among the top three skills they train in students, only one academic respondent cited leadership as a top-three skill, which is likely because opportunities for students to gain leadership experience is primarily found in extracurricular activities. This result suggests a mismatch between the degree of leadership instruction in engineering programs and its demonstration among early career engineers. Future research could explore this question of leadership in ESD-related careers, and how it can be imbibed by students and demonstrated, especially within

[37] Jesiek, B. K., Zhu, Q., Woo, S. E., Thompson, J., & Mazzurco, A. (2014). Global engineering competency in context: Situations and behaviors. *Online Journal for Global Engineering Education*, *8*(1), 1. (link)
[38] Ibid 21.
[39] Hess, J. L., Beever, J., Zoltowski, C. B., Kisselburgh, L., & Brightman, A. O. (2019). Enhancing engineering students' ethical reasoning: Situating reflexive principlism within the SIRA framework. *Journal of Engineering Education*, *108*(1), 82-102. (link)
[40] Ibid 8.

programs focused on fostering collaboration and humility.

Participants highlighted the importance of ESD education with respect to the training and preparation of all future engineers. The skills highlighted above are critical for any practitioner working on technological solutions, since these require consideration of resource allocation, product lifecycle, and social impacts, and are increasingly developed on dispersed global teams. Notably, other investigations have identified that all fields of engineering (not just ESD) increasingly value sustainability and systems-engineering skills.[41] Understanding key drivers of innovation and development is especially critical for developing this holistic approach in which engineers can analyze problems and then develop sustainable and equitable solutions that consider the broader sociocultural and environmental contexts in which they will be embedded.

4 RECOMMENDATIONS FOR THE ENGINEERING AND ESD FIELD AT LARGE

4.1 Emerging & recommended cultural shifts

The challenges that ESD efforts seek to address are wide-ranging and intertwined. Complex problems cannot, by definition, be solved by discrete solutions or processes. Based on the findings from the Summit, ESD thought leaders are adopting the following mindset and cultural shifts (i.e., reconstruction of concepts and definitions within engineering) to address challenges of this magnitude, urgency, and complexity:

(1) Take an interdisciplinary and multi-stakeholder approach. The most effective solutions will be those that (1) cross existing sector silos,[42,43] (2) bridge the distinctions between public and private; that bring industry, academia, NGOs, and the public sector together, (3) cross borders and advance international collaboration, and (4) borrow from multiple perspectives and schools of thought. No single group or school of thought can even begin to approach the scale of impact that is needed; engineers must recognize that multiple sectors have roles to play, and the field must find ways to reckon with authentic critiques and effectively manage the tensions between seemingly discordant approaches.

(2) Consider dynamic and interconnected systems. Engineers must develop systems-thinking capability, as it relates to broader historical, socio-technical, and environmental considerations. Ignoring the broader dimensions of systems (e.g., socio-economic, environmental, political, cultural, historical) leads to failures and negative impacts within ESD.[44] COVID-19 forced the engineering field to reckon with the larger systems that drive our world, which are dynamic and deeply interconnected. The pandemic contributed to, among countless other effects, deep disruption in healthcare, labor markets, education, supply chains, and policymaking processes. Both ESD challenges and potential solutions operate within dynamic and interconnected systems, and it will be critical to adopt socio-technical thinking[45] and flexible approaches that act on multiple levers simultaneously, incorporate feedback quickly, and attempt to manage for primary as well as secondary and tertiary effects.

(3) Prioritize diversity and inclusion. A homogenous field is a limited field. Engineering as a whole, and particularly ESD efforts, needs a broad range of social identities,[46] perspectives, backgrounds, skill sets, and knowledge domains, which can only be achieved by ensuring that the decision-makers and stakeholders involved are diverse and are capable of breaking out of groupthink. Engineering firms and institutions must work to cultivate inclusive environments, rather than ones that instill workplace trauma on women, people of color, and other minorities in engineering.[47] Many institutions have been working on improving diversity and equity in engineering for decades; aligning with and supporting existing societies, such as the National Society of Black Engineers (see its 2025 Strategic Plan), the Society of Hispanic Professional Engineers, the American Indian Science and Engineering Society (AISES), and the Federation of African Engineering Organizations, can help advance existing efforts. We need an engineering workforce that reflects the compositional diversity

[41] ASME & Autodesk. (2022). Future of Manufacturing: New Workflows, Roles & Skills to Achieve Industry 4.0 Business Outcomes. (link)
[42] Li, N., Kramer, J., Gordon, P., & Agogino, A. (2018). Co-author network analysis of human-centered design for development. *Design Science*, 4. (link)
[43] Burleson, G., & Austin-Breneman, J. (2020). Engineering for Global Development: Characterizing the Discipline Through a Systematic Literature Review. In *International Design Engineering Technical Conferences*. (link)
[44] Wood, A. E., & Mattson, C. A. (2016). Design for the developing world: Common pitfalls and how to avoid them. *Journal of Mechanical Design*, 138(3). (link)
[45] Mazzurco, A., & Daniel, S. (2020). Socio-technical thinking of students and practitioners in the context of humanitarian engineering. *Journal of Engineering Education*, 109(2), 243-261. (link)
[46] Hogg, M.A. (2016). Social Identity Theory. In: McKeown, S., Haji, R., Ferguson, N. (eds) Understanding Peace and Conflict Through Social Identity Theory. *Peace Psychology Book Series*. Springer, Cham. (link)
[47] Aye, G. (2021, May 24). Surviving IDEO. *Medium*. (link)

of the world around it, and we need members of that diverse workforce to feel included and supported in their positions, and who are competent and confident in including others, so that all can thrive.

Insights from the Summit

SIX EMERGENT & RECOMMENDED MINDSETS

- Take an interdisciplinary and multi-stakeholder approach
- Consider dynamic and interconnected systems
- Prioritize diversity and inclusion
- Challenge the perception that engineering is neutral
- Increase humility, increase localization, and center community perspectives
- Broaden the goals of engineering

(4) Challenge the perception that engineering is neutral. Our values shape technology, and technology shapes our values. Being cognizant of this, engineers should deliberate personal and cultural values to help design and implement technology that is beneficial for all. Historically, engineering has been framed as apolitical and divorced from historical and social contexts, phenomena that Cech calls the "culture of disengagement"[48] and the "ideology of depoliticization."[49] Engineers should broaden their definition of "politics" to consider the affordances of power or exclusion on society, including their own power to influence outcomes.[50] Summit participants, as well as scholars, highlight the salient role of individual and collective identities and their relation to design and engineering outcomes; groups can be marginalized, harmed, and erased.[51,52] Engineers should be critical of their data sources since data generation is not inherently neutral: sampling protocols, categories, and measurement scales are all designed and debated.[53] Some resources exist to help engineers reflect and explore the social, environmental, economic, and peace implications of their work,[54] however much work must be done to increase awareness and consideration of values among engineers, particularly those in ESD who aim to improve social equities.

(5) Increase humility, increase localization, and center community perspectives. Engineering, and particularly the Eurocentric voices that dominate the field, must embrace a sense of humility, including open-mindedness, collaborative communication, emotional intelligence, and empathy.[55] Here, the term "Eurocentric" describes a focus on the values, experiences, and culture of Europeans and their descendants (i.e., "the West").[56] A sense of humility is particularly needed as a means of breaking down the false notion of Eurocentric superiority. For years, western innovators have been developing solutions that they believe will be well-suited for low-resource environments in the "developing world" and then handing them off to local communities. By and large, the result has been low rates of uptake, technology that fails to fully consider the local context, and an underdeveloped engineering workforce in these environments. In some cases, these negative impacts have been devastating, resulting in detrimental health impacts (e.g., arsenic crisis in Bangladesh due to implementation of groundwater wells[57]), human rights violations (e.g., PlayPump[58]), and loss of millions of dollars in investments (e.g., One Laptop Per Child[59]). Instead, greater effort should be dedicated to increasing localization, including two-way skill-sharing, know-how transfer, capacity building, targeted support, and locally controlled long-term investments in infrastructure and services.

The engineering field, for obvious reasons, is predisposed to propose technological solutions to challenges, even when other forms of innovation

[48] Cech, E. A. (2014). Culture of disengagement in engineering education?. *Science, Technology, & Human Values*, 39(1), 42-72. (link)
[49] Cech, E. A. (2013). The (mis) framing of social justice: Why ideologies of depoliticization and meritocracy hinder engineers' ability to think about social injustices. In *Engineering education for social justice* (pp. 67-84). Springer, Dordrecht. (link)
[50] Aye, G. (2017, June 2). Design Education's Big Gap: Understanding the Role of Power. *Medium*. (link)
[51] Costanza-Chock, S. (2020). *Design justice: Community-led practices to build the worlds we need*. The MIT Press. (link)
[52] Holly Jr, J. S. (2020). A Critical Autoethnography of a Black Man Teaching Engineering to Black Boys. *Journal of African American Males in Education*, 11(2). (link)
[53] Bowker, G. & Star S.L. (2000). *Sorting things out: Classification an its consequences,* The MIT Press. (link)
[54] Karwat, D. (2020). Self-reflection for activist engineering. *Science and Engineering Ethics*, 26(3), 1329-1352. (link)
[55] Lynch, E., McLennan, A., & Smith, J. (2020). Humble Practice in Engineering: What does it look like?. *Proceedings of the Canadian Engineering Education Association (CEEA)*. (link)
[56] Pokhrel, A.K. (2011). Eurocentrism. In: Chatterjee, D.K. (eds) *Encyclopedia of Global Justice*. Springer, Dordrecht. (link)
[57] Raessler, M. (2018). The Arsenic Contamination of Drinking and Groundwaters in Bangladesh: Featuring Biogeochemical Aspects and Implications on Public Health. *Archives of Environmental Contamination and Toxicology*. 75, 1–7. (link)
[58] Chambers, A. (2009) Africa's not-so-magic roundabout. *The Guardian*. (link)
[59] Ames, M. G. (2019). *The charisma machine: The life, death, and legacy of One Laptop per Child*. Mit Press. (link)

and knowledge may be better suited to addressing them. Building relationships with fields outside of engineering, and taking their perspectives seriously, must become a regular practice within this work.

(6) Broaden the goals of engineering. Following the lead of organizations such as the Tech Stewardship Network and Design Justice Network, the field should reconsider what engineering is, what it includes, and what it is for. Historically, there has been a perception that engineering serves solely to produce systems and products, often with primary goals of technical performance, efficiency, and profitability. However, in order to fully step into ESD applications, engineering must also allow for other metrics and goals (e.g., poverty reduction, climate, sustainability, social justice), and it must reckon with the ways that it has contributed to the challenges it is seeking to solve (e.g., the relationship between fossil fuel-burning technology and climate change; the creation of technology that makes warfare more deadly). It has been and continues to be tempting to treat technology as a set of apolitical tools that impact the world only through the intentions of their users and to believe that improvements in technology are always positive. Such a perspective is ahistorical, as many of the most pressing challenges the world faces can be directly traced to changes in technology; and greater initial consideration of what that technology might have been used for could have prevented these challenges from arising. More specifically, engineers should adopt a "complete lifecycle" approach to address the full range of impacts their technology may have - from "cradle to grave."

4.2 Terminology recommendations

Organizations committed to ESD should use agreed upon and codified terminology to enable more coordination across ESD-related efforts and increase its recognition within engineering at large. Engineering and related sectors have multiple terms for work focused on ESD. It is critical to note that different terminology for ESD-related fields of study, such as Global Engineering,[60] Humanitarian Engineering,[61] and Activist Engineering[62] (among many others), cannot necessarily be used interchangeably, as these represent different schools of thought and academic ancestry (e.g., "Humanitarian Engineering" has received official sanction in Australia). However, a single umbrella term and accompanying lexicon or set of terminology that is acceptable to and adopted by the field as a whole will reduce confusion, facilitate coordination, and lay the groundwork for sustainable efforts.

Another critical terminology is the term "systems," which was discussed at length during the Summit. In engineering, the term "systems" can have a precise definition (e.g., related to the boundary drawn to model a mechanical, chemical, or thermal system), a wide-ranging definition (e.g., the broad socio-technical considerations surrounding a problem or solution), or a definition somewhere in between these two poles. Based on the findings from the Summit, as well as recent literature, we recommend the use of "systems" within ESD to consider the broader socio-technical considerations[63] as well declarations of its purpose, elements, and interconnections.[64]

Insights from the Summit
QUOTE FROM A SUMMIT PARTICIPANT

"Companies take the concept of risk very seriously, so without the science about technical performance characteristics of sustainable materials, and how to integrate these materials into their offerings –like there already are with concrete or steel—then actually making more sustainable choices can be difficult, especially to stand up and justify to the client and rest of the team, so you fall back on the familiar. But, if there are examples that challenge that perception, and show that it's not going to cost more money in the long run to be inclusive and sustainable, then companies are more open to adopting them."

[60] Thomas, E. (2020). What Is Global Engineering?. *In The Global Engineers* (pp. 1-19). Springer, Cham. (link)
[61] Smith, J., Anderson, B., Brown, N., Colley, A., Stoakley, A., & Turner, J. (2017). The rise of Humanitarian Engineering education in Australasia. *Australasian Association for Engineering Education*. 312-320. (link)
[62] Karwat, D., Eagle, W. E., Wooldridge, M. S., & Princen, T. E. (2015). Activist engineering: Changing engineering practice by deploying praxis. *Science and engineering ethics*, 21(1), 227-239. (link)
[63] Ibid 45.
[64] Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: A systems approach. *Procedia computer science*, 44, 669-678. (link)

4.3 Incentives, metrics, and decision-making frameworks

These big-picture shifts in thinking must be accompanied by processes for implementing them, including **decision-making frameworks and regulatory frameworks.** At the highest levels, companies, academic institutions, NGOs, and political actors must find a way to not only decide to prioritize ethics and sustainability, but to decide what ethics and sustainability mean in practice, what indicators should be used for tracking progress, how trade-offs will be weighed or how competing priorities will be managed, and what levers stakeholders can use to incentivize adherence and hold each other accountable. Regulations are critical in motivating organizations to make more sustainable and ethical decisions; those with experience and training in ESD have an important role to play in advocating, operationalizing, and advancing regulatory frameworks.

Economic incentives will be particularly vital–if companies see ESD as a pure cost, rather than as an opportunity, they will be unlikely to prioritize it. Thus, the sector as a whole must find a way to align progress towards ESD goals with companies' bottom lines. When companies do find ways to do well by doing good, it will be critical to lift up success stories and create continued positive social pressure on others to learn from and replicate their approaches. However, it will be critical to incorporate measures to ensure that companies do not fall into 'impact washing,' 'ethics washing,' or 'greenwashing,' in which the evidence of their reported impact is insufficient. An increasingly important evaluation and reporting framework is the Environmental, Social, and Governance (ESG), which is being adopted by investors and shareholders who want to see improvements in sustainability of a company. In addition to metrics related to the Sustainable Development Goals, which many global development organizations employ, organizations could implement the ESG framework to align with trends in the private sector.

Importantly, once an organization commits to improving its social and environmental impact, **engineering organizations will need accompanying key performance indicators (KPIs), processes for measuring and reporting impact (including codified metrics and reliable sources of data), and access to and training on standards, assessments, and other relevant tools to make these high-level commitments real.** These tools must apply to not only big-picture decision-making, but also the day-to-day actions of individual engineers. While there exist many frameworks and metrics for ESD efforts, there remains a lack of guidance and regulation for their use. Moreover, as previously mentioned, there exists a gap in data expectations: both in terms of availability and reliability of data to make equitable and dependable design decisions.

Insights from the literature
ENGINEERING FOR PEOPLE DESIGN CHALLENGE[70]

"Engineering for People Design Challenge encourages multi-disciplinary groups of university students to broaden their awareness of the social, environmental, economic, and ethical implications of engineering alongside technical skills when developing solutions. [...] Participating universities have shown that practically embedding the design challenge as a mandatory part of the curriculum is possible and can inspire and open new avenues for transformative curriculum change."

4.4 Engineering education

With respect to bridging the gap between academia and industry, several pathways should be pursued, aiming to bridge the skills developed by students and those required for early-career engineers. including curricular, co-curricular, and extra-curricular training opportunities for engineering students. Additionally, there is a need to expose university students and early-career engineers to the wide array of possible career paths in and beyond ESD. We recommend a **reframing away from ESD-specific career paths toward a much broader philosophy that ESD principles should be embedded within all career paths.** Every engineer should constantly examine and consider both the favorable and unfavorable economic, social, and environmental local and global consequences of their work. As previously discussed, younger generations are increasingly seeking careers that reflect broader social and environmental values. These ESD values need to come to the forefront within all engineering careers, and by equipping the next generation of engineers to come to their work with the relevant tools and mindsets, we would anticipate the ESD philosophy to permeate throughout the profession.

Insights from the Summit
THE TECH STEWARDSHIP PROGRAM

"This program is open to any post-secondary student or professional who's interested in helping bend the arc of technology towards good. [...] It will help participants establish a practice that better integrates considerations of ethical and societal questions into day-to-day work."

To promote inclusion of ESD training and principles, institutions could focus on incentive structures, including recognition and certification of socio-technical skills, as well as incorporation into evaluation mechanisms used for promotion and tenure for its faculty. Additionally, to increase the diversity of the graduating workforce, there should be an increase in inclusion and equity efforts among universities, primarily in their retention of minorities in engineering. Some universities have made critical declarations and commitments to equity-centered engineering[65] but these efforts require continuous resources and funding to remain sustainable.

Further **identification and definition of shared goals and language between academia and industry** would improve synergy and better support the development of practice-based learning approaches that model critical thinking and problem-solving skills. Engineers want efficient tools to make sustainable decisions and executives want to publish accurate statements, but tools to evaluate impact are lacking or complex (and often, third party experts perform this work for engineering firms); there is certainly ample career opportunities for engineering graduates to advance and perform impact assessments (e.g., life cycle assessment (LCA), stakeholder analysis, systems thinking) and research opportunities for academic institutions to support engineering decision frameworks.

Curricular. Within traditional engineering classrooms on campus, there is a perception that training socio-technical competencies and systems-thinking is difficult and time-intensive. However, there are many resources for incorporating socio-technical considerations into design prompts, classroom exercises, and case studies used in technical classrooms.[66,67] Additional frameworks, such as Engineering for One Planet, provide a menu of sustainability learning outcomes. Project-based courses (e.g., introductory design, capstone design) are great opportunities to provide ESD training through hands-on examples. Additionally, many institutions offer minors, certificates, and coursework focused on ESD,[68] many of which integrate skills and theory from the social sciences and other disciplines, allowing students to integrate relevant training without significant research into courses outside of their engineering college. During the Summit, participants highlighted that within the U.S., specifically, much work can be done to expand ABET requirements regarding broader social, political, and environmental contexts within engineering education. Moreover, we recommend further integration of International Engineering Alliance (IEA) Graduate Attributes and Professional Competencies, which were updated in 2021 to include emphasis on diversity and inclusion, sustainable development, and UN SDGs.[69]

Co-curricular and extra-curricular. Co-curricular activities can provide students with experiences outside the traditional classroom material.[70] For example, Engineers Without Borders (EWB) Challenge in Australia and New Zealand provides over 10,000 students the opportunity to engage on a team-based humanitarian engineering project. Similarly, the Siemens Design Challenge hosted by Engineering for Change to develop technology-based solutions for challenges related to the Sustainable Development Goals drew over 23,000 people from 184 countries and generated more than 220 ideas at the height of the COVID pandemic. Collaborations between universities and engineering organizations can also be expanded to offer more practical work experiences (e.g., via co-ops or internships) that model what undergraduates will experience in their careers, while also providing upskilling and reskilling training

65 McAlpine, K. (2021, June). Equity-centered engineering: A Q&A with Alec Gallimore. *Univ. of Michigan Engineering Research News.* (link)

66 Pucha, R., Newton, S., Alemdar, M., Yow, R., & Hirsch, J. (2020). Integrating Sustainability into a Freshman-Engineering Course through an Institute-Level Initiative. In *Integrating sustainable development into the curriculum*. Emerald Publishing Limited. (link)

67 Tuzun, U. (2020). Introduction to systems engineering and sustainability PART I: Student-centred learning for chemical and biological engineers. *Education for Chemical Engineers*, 31, 85-93. (link)

68 E4C. (2020). State of Engineering for Global Development: United States and Canada (link), Australia and New Zealand. (link), Latin America (link), and Asia (link)

69 IEA (2021, June 21). Graduate Attributes and Professional Competences, Version 4. (link)

70 Truslove, J., Crichton, E.., Whitehead, T., & Clark, R. (2022). Pedagogical approaches to project-based learning meeting the education needs of the globally responsible engineering workforce. Symposium for Engineering Education, University of Strathclyde, Glasgow. (link)

opportunities for employees. Participants in the summit noted the current tension that many engineering opportunities in global development are under- or unpaid, suggesting that universities help subsidize these experiences through scholarships or fellowships.

Post-educational. There is an opportunity to extend ESD education to engineers who have already completed their university education. Broader reach of ESD training opportunities, such as the Engineering for Change Fellowship and the Tech Stewardship Practice Program, can allow more engineers to gain valuable exposure and skills in this field. Moreover, with the expansion of Massive Open Online Courses (MOOCs), there is an opportunity to reach engineers with busy schedules via online educational platforms such as Coursera and edX.

Insights from ASME
THE ASME ISHOW

"ISHOW is open to individuals and organizations taking physical products to market that will have a positive social and environmental impact. [...] ISHOW defines hardware-led social innovation as taking a physical product to market to solve a social or environmental problem by utilizing a sustainable business model."

5 ASME'S ESD RECOMMENDATIONS

ASME has a unique role to play in this work, given its long-standing credibility, reputation, resources, and position within the field of engineering. Through a robust pursuit of ESD work, ASME aims to advance sustainability goals while also acting as a model for other engineering associations and stakeholders on how they can complement their participation in sector-wide efforts with their own discrete contributions. Taking on this work is deeply aligned with ASME's mission ("Advancing engineering for the benefit of humanity") and positions the organization as a leader in recognizing and helping to address the defining issues of our times.

ASME has stepped up its focus on ESD in recent years through a set of operationalized and coordinated efforts across the organization. For example, in spring of 2022, ASME signed onto the Declaration for Gender Responsive Standards and Standards Development, and the organization is working on its own Gender Action Plan to advance equity within the organization and within the field. ASME has also recently built a DEI toolkit for use by internal and industry stakeholders. Also, through the ASME Foundation, ASME has been building multiple program pathways so that traditionally underrepresented groups can gain early exposure to engineering skills and experiences, and persist within the field through their post-secondary early career experiences. With regards to climate and sustainability, ASME is a founder and key supporter of Engineering for Change (E4C), and the organization's Engineering for Global Development sector leverages engineering capacity and talent around the world to solve urgent, local and global challenges; through this work, the organization engages thousands of engineers and innovators focused on ESD across the globe every year.

This experience, coupled with a deep understanding of the social and environmental sectors, positions ASME to develop sustainable development standards and guidelines, and particularly those advancing climate action, that are ambitious while still being rooted in what is actually possible given technological and resource limitations.

The process of establishing the Gender Action Plan[71] alone has been tremendously clarifying. It has created opportunities for the organization to move from stated commitments into tangible action. This includes clarifying which elements of gender equity are highest priority and can be most immediately affected, and identifying practical short-term and long-term steps that can be taken to make progress. The presence of a concrete plan is now serving as a forcing mechanism both internally and with external stakeholders, and ASME is creating plans of action likely to yield measurable impact.

5.1 Promoting cultural shifts in engineering

To enable an engineering culture that is equipped to tackle ESD challenges, **ASME must champion the key mindset and cultural shifts identified in this report** (interdisciplinarity, systems-thinking, diversity, challenging apoliticality, increasing humility, and broadening engineering goals). To do so, ASME must take a multipronged approach that promotes and encourages these critical mindsets. Below are many examples of existing, shifting, or transformative initiatives that ASME and its stakeholders can take and advocate for ESD as the vehicle/platform enabling these critical shifts.

[71] UNECE. (2022). Declaration on Gender Responsive Standards and Standards Development. (link)

Be interdisciplinary and multistakeholder. ASME must continue to cultivate enabling ecosystems and communities of practice. As emphasized in this report, these complex issues are not exclusively an engineering problem, and part of the prior difficulty has been approaching them as such. Over the last few years, E4C has greatly expanded their research and design program, including broadening the range of partnerships across disciplines, sectors, and industries. This emphasis on interdisciplinary research, training, and practice is critical. Moreover, there is an opportunity to increase engagement across communities. For example, ASME's Public Affairs and Outreach (PAO) council in partnership with E4C can lead in reorienting the interfaces that connect groups and bridge engineering and sustainable development policy. ASME is positioned to leverage existing pathways such as the ASME Policy Impact event, ASME's Government Relations team, Federal Fellows and sessions hosted on Capitol Hill to provide opportunities for engineers to advance sustainable development by equipping participants to engage in informed policy conversations, regulations, and civic agencies. At existing ASME events, the types of invited speakers could be expanded to raise awareness on topics about Tech Assessment Frameworks, Tech Stewardship, social entrepreneurship, climate science, and other ESD-related topics, which could promote cross-disciplinary exchange and technical know-how, resulting in advancing new collaborations and innovations.

Engage in systems-thinking. Historically, ASME has focused on safety standards (i.e., the impact of technology that is the most direct on the users and individuals operating the technology). Now, ASME should continue to expand what impacts technology may have outside of the direct user-technology system. To better consider the broader system, ASME can engage with stakeholders that represent parts of that system, for example community groups, climate scientists, and social scientists, as well as stakeholders in design justice and other social movements in engineering that advocate for more equitable impacts of engineered solutions. ASME's PAO also has a role to play to promote nomenclature, methods, and metrics that consider broader impacts of engineering design. ASME can do this by leveraging its neutral-party convener status and Government Relations function to engage and advocate for these issues and communities of practice.

Promote diversity. ASME is committed to developing and mobilizing a diverse engineering workforce around the world. The organization recognizes diversity as a moral imperative, but also as a strategic imperative; as more people see themselves as potential engineers, the field will have access to a growing body of talent, and research consistently shows that more diverse workplaces yield new and innovative solutions to complex problems. To this end, ASME is strengthening partnerships with the major societies focused on diversifying engineering (e.g., Society of Women Engineers, National Society of Black Engineers, American Indian Science and Engineering Society (AISES), Society of Hispanic Professional Engineers, and Out To Innovate), and is creating new lines of programming with Historically Black Colleges and Universities (HBCUs), tribal colleges and universities, and community colleges. ASME is ensuring that its workforce development programs, such as E-Fests and other K-12 outreach programs, are intentionally structured to increase the diversity of participants and reach students who historically have been missed. Where standalone efforts are necessary, such as on gender equity, ASME is creating new opportunities such as the Increasing Women In Mechanical Engineering Conference, which was initiated in 2021 and has now become a regular event.

Increase political participation. While ASME works closely with local and national government agencies worldwide, the findings in this report suggest that many engineers are not engaged in broader public and social issues. However, based on conversations at the stakeholder summit, it is clear that there is a strong interest among individuals working in sustainable development and related sectors to engage more in civic society. As such, ASME has an opportunity to provide engagement opportunities through its connections and influence within policymaking circles to promote grassroots advocacy, in line with its not-for-profit, nonpartisan structure and obligations. Moreover, in the United States specifically, ASME can continue its Federal Government Fellowship Program, which provides engineers an opportunity to participate directly in the policymaking process. ASME reaffirms its non-partisan stance by engaging with policy-makers on both sides of the isle to advocate for policy that is consistent with achieving the SDGs. With the urgency of wicked sustainability challenges, federal programs could be expanded and implemented in other nations globally. Furthermore, E4C has recently launched the E4C Science Policy Interface strategy, which aims to develop a roadmap for increased engineering engagement in sustainable development policy and prepare engineers to engage effectively in the process.

Increase humility and increase localization. ASME must maintain a global scope and orientation that continues to question and challenge the role of Eurocentricity and the colonial roots of projects in international development contexts. One way ASME has worked in this area is by expanding the E4C Fellowship to include mostly Fellows from low- and middle-income countries (for example, in 2016 all Fellows were from the United States, but in 2022, 83% of Fellows were international). ASME can continue to play a leading role by expanding and evolving its portfolio of programs and development opportunities globally for its constituents. For example, ASME ISHOW events which draw global engagement and are hosted in three regions: USA, Kenya, and India annually. Overall, ASME must aim to intentionally distribute resources and investment without doing so in a colonial way. This includes continuing to focus on building capacity, building research communities, cultivating communities of practice, and creating platforms for engagement that are accessible globally and democratize opportunity to advance sustainable development.

Broaden engineering goals. ASME must champion expanding considerations of what engineering includes. ASME can continue to collaborate with existing multi-disciplinary efforts, such as Engineering for One Planet and Siemens Sustainability Network. Further, as the mechanical engineering partner of ABET accreditation, ASME's Public Affairs & Outreach can advocate for broader, more inclusive education (including case study examples, methods, practicum, etc.) in education to advance ESD and related practices. Through its journals, ASME could host special issues on emerging topics, such as ESD, responsible engineering, ethics, and social justice, among others. ASME has various programs, such as ISHOW, E4C Fellowship, but there is an opportunity for more tangible engagements that provide pathways for codifying these topics into practice, research, and curriculum. For example, micro-credentialing of practicum experience or standardization of graduate programs and electives.

5.2 Professionalizing the practice

Professionalizing the practice of Engineering for Sustainable Development is critical for its growth and future success. The most urgent role that ASME can play involves **creating the context and support structures to enable a sector-wide effort**. If ASME can build consensus around a set of clear standards and goals for the work, guidelines for how stakeholders can participate, and nomenclature for the effort, it will help reduce the fragmentation within the field, help other stakeholders understand what they are being asked to commit to, and enable potential participants to make firm commitments. Historically, ASME has focused on safety (e.g., boiler codes in the nineteenth and twentieth centuries), now ASME must continue its commitment to society by expanding beyond direct safety to include all the diverse aspects of sustainability and social equity. As an example, ASME's Gender Plan specifies metrics of equity within the organization and within the field. Additional frameworks related to ESD can ultimately support the field by operationalizing these complex socio-technical considerations.

With regards to nomenclature, **we recommend Engineering for Sustainable Development (ESD)** because it is inclusive of all disciplines within engineering and aligns with the highest-profile coordinated effort that currently exists (the UN's Sustainable Development Goals). This umbrella term allows for the identification of various subfields underneath it (e.g., Global Engineering, Humanitarian Engineering, Engineering for Climate-Adapted Building Materials, Engineering for Clean Energy), while still functioning as a broad effort that holds a role for all engineers and engineering entities.

5.3 Monitoring and evaluating

To create more wide-ranging and ambitious ESD efforts, there are a number of strategies to pursue. In particular, **ASME should continue its partnership with policymakers and/or leading companies to work at the policies and systems levels,** including designing and encouraging adherence to sustainability metrics, developing government-backed incentive structures for companies contributing to positive change, and testifying about the urgency of these issues at the U.S. and global level. Though some ASME stakeholders may be concerned about delving more deeply into work that is perceived to be political, it would be consistent with the Federal Fellows program with regards to ensuring that sociotechnical engineering expertise reaches those who are positioned to use it to make systems-level change.

ASME can build on existing commitment to data-driven impact measurement and monitoring (IMM) of its ESD workforce development programs and continue to integrate and promote the UN SDGs and, importantly, be active and involved in how these goals adapt in 2030. Additionally, ASME could integrate other influential frameworks, such as Environmental, Social, and Governance (ESG), to align with other sectors particularly focusing on the pillars of ESG for Impact and Regulation. As Horoszowski noted, 'ESG for Impact' provides metrics for making progress towards the SDGs, while 'ESG for Regulation' has the potential to help governments make and monitor policies, compliance, and standards.[72]

These frameworks, along with others, should be used to support evidence-driven decision making to encourage development, deployment and uptake of robust data for sustainable development.

5.4 Training and accreditation

Academic institutions are a key ally in this work, and ASME could partner with them to **create pathways into tenure for faculty members who are leading the way in ESD**. This could be done through direct engagement and advocacy via ASME's Engineering Education and Outreach group as well as coalitions such as the International Federation of Engineering Education Societies (IFEES) and Global Engineering Deans Council. ASME could also **leverage its role in joint curriculum accreditation efforts like ABET and the International Engineering Alliance (IEA) to drive participation in ESD** by making the claim that facilitating good practice in engineering necessarily requires dealing with the most pressing challenges of the day.

ASME can invest in various micro-credentialing to provide education on specific topics, such as case studies of ESD, frameworks and metrics, Technology Stewardship, and responsible engineering, among others. These modules could be used by ASME student chapters and engineering classrooms to expand reach to early-career engineers. Additionally, ASME early-career engineering programs, such as E-Fest, could build on existing ESD initiatives and grow integration of ESD-related topics, such as competitions focused on Sustainable Development Goals or social equity, which are already demonstrating traction among students. Additional training programs, such as the ASME ISHOW and Siemens Design Challenge could provide engineers around the globe with opportunities to apply their technical skills to pressing sustainable and social problems, while connecting them to networks of experts and resources.

Insights from the literature
ENVIRONMENTAL, SOCIAL, AND GOVERNANCE (ESG)

"While it seems like a long way away, the ESG movement can help facilitate better financial decisions, *and* progress towards the SDGs, provided we can keep the discussions from creating more divisions. After all, as former CEO of Unilever Paul Polman puts it, investing in ESG for Impact to achieve the SDGs is "the biggest business opportunity of our time," but we'll need ESG for Assurance and Regulation in order to achieve it, and to save our planet in the process." – Horoszowski (2022)[72]

Importantly, ASME is committed to investing further in the E4C Fellowship to grow the program reach and particularly to ensure expanded training, joint programs with mission-aligned organizations (such as the Association of German Engineers) and impact monitoring, evaluation, and dissemination. The E4C Fellowship specifically aims to equip engineers with the skills, knowledge, and network to contribute to these pressing challenges.

5.5 Cultivating practitioner networks

ASME must continue to invest in **creating a robust and active community in ESD**. Many institutions have a single individual or a small handful of individuals who are particularly committed to this work, and find themselves working in isolation. ASME can connect these disparate ESD champions, while positioning them to recruit their peers to participate in the joint effort. These efforts should include academic community development (e.g., faculty, graduate students, and undergraduates) and industry community (via professional chapters). Existing conferences, such as ASME technical conferences and events such as Impact.Engineered are advantageous places to increase community engagement as a starting point.

ASME could also create **a dedicated area for its programs focused on sustainable development within its existing technical divisions structure** as a means of showing the programs' importance within the organization's structure, and encourage the most active partners, including American Society of Engineering Education (ASEE) and Institute of Electrical and Electronics Engineers (IEEE), and similar organizations overseas such as European

[72] Horoszowski, M. (2022). ESG Needs a Shared Language. *Stanford Social Innovation Review*. (link)

Society for Engineering Education (SEFI) or Australasian Association for Engineering Education (AAEE), to create (or further expand) technical divisions focused on these topics.

6 CONCLUSION

Through these strategies, ASME and its affiliates can position themselves as leading voices to ensure the field of engineering is equipped to tackle pressing challenges related to sustainable development. The cultural shifts described in this report, including interdisciplinarity, systems-thinking, diversity, challenging apoliticality, increasing humility, and broadening engineering goals, are critical for advancement towards social equity and sustainability.

ASME is poised to build on more than a decade of learning and successful sustainable development programs and platforms, to establish a unified strategy ensuring that sustainability is integrated across all business units, technical divisions and sections, with robust measures of progress which will be communicated widely. The collective impact potential of this unified front is transformative to the profession and society at large and inherent to ASME's mission to advance engineering for the benefit of humanity.

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LET'S GET TO WORK

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