



## Integrating sustainability into robotics higher education courses

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**Topic:** Considering the SDGs at all stages of new robot creation.

**Tool type:** Guidance.

**Relevant disciplines:** Computing; Robotics; Electrical; Computer science; Information technology; Software engineering; Artificial Intelligence; Mechatronics; Manufacturing engineering; Materials engineering; Mechanical engineering; Data.

**Keywords:** SDGs; AHEP; Sustainability; Design; Life cycle; Local community; Environment; Circular economy; Recycling or recycled materials; Student support; Higher education; Learning outcomes.

**Sustainability competency:** Systems thinking; Anticipatory; Critical thinking.

**AHEP mapping:** This resource addresses two of the themes from the UK's Accreditation of Higher Education Programmes fourth edition (AHEP4): **The Engineer and Society** (acknowledging that engineering activity can have a significant societal impact) and **Engineering Practice** (the practical application of engineering concepts, tools and professional skills). To map this resource to AHEP outcomes specific to a programme under these themes, access AHEP 4 [here](#) and navigate to pages 30-31 and 35-37.

**Related SDGs:** SDG 9 (Industry, innovation, and infrastructure); SDG 12 (Responsible consumption and production).

**Reimagined Degree Map Intervention:** Adapt and repurpose learning outcomes; More real-world complexity.

**Who is this article for?** This article is for educators working at all levels of higher education who wish to integrate Sustainability into their robotics engineering and design curriculum or module design. It is also for students and professionals who want to seek practical guidance on how to integrate Sustainability considerations into their robotics engineering.



## Premise:

There is an urgent global need to address the social and economic challenges relating to our world and the environment (Raper *et al.*, 2022). The United Nations Sustainable Development Goals (SDGs) provide a framework for individuals, policy-makers and industries to work to address some of these challenges (Gutierrez-Bucheli *et al.*, 2022). These 17 goals encompass areas such as clean energy, responsible consumption, climate action, and social equity. Engineers play a pivotal role in achieving these goals by developing innovative solutions that promote sustainability and they can use these goals to work to address broader sustainability objectives.

Part of the strategy to ensure that engineers incorporate sustainability into their solution development is to ensure that engineering students are educated on these topics and taught how to incorporate considerations at all stages in the engineering process (Eidenskog *et al.*, 2022). For instance, students need not only to have a broad awareness of topics such as the SDGs, but they also need lessons on how to ensure their engineering incorporates sustainable practice. Despite the increased effort that has been demonstrated in engineering generally, there are some challenges when the sustainability paradigm needs to be integrated into robotics study programs or modules (Leifler and Dahlin, 2020). This article details one approach to incorporate considerations of the SDGs at *all stages* of new robot creation: including considerations prior to design, during creation and manufacturing and post-deployment.

## 1. During research and problem definition:

Sustainability considerations should start from the beginning of the engineering cycle for robotic systems. During this phase it is important to consider what the problem statement is for the new system, and whether the proposed solution satisfies this in a sustainable way, using Key Performance Indicators (KPIs) linked to the SDGs (United Nations, 2018), such as carbon emissions, energy efficiency and social equity (Hristov and Chirico, 2019). For instance, will the energy expended to create the robot solution be offset by the robot once it is in use? Are there long-term consequences of using a robot as a solution? It is important



to begin engagement with stakeholders, such as end-users, local communities, and subject matter experts to gain insight into these types of questions and any initial concerns. Educators can provide students with opportunities to engage in the research and development of robotics technology that can solve locally relevant problems and benefit the local community. These types of research projects allow students to gain valuable research experience and explore robotics innovations through solving problems that are relatable to the students. There are some successful examples across the globe as discussed in Dias et al., 2005.

## **2. At design and conceptualisation:**

Once it is decided that a robot works as an appropriate solution, Sustainability should be integrated into the robot system's concept and design. Considerations can include incorporating eco-design principles that prioritise resource efficiency, waste reduction, and using low-impact materials. The design should use materials with relatively low environmental footprints, assessing their complete life cycles, including extraction, production, transportation, and disposal. Powered systems should prioritise energy-efficient designs and technologies to reduce operational energy consumption, fostering sustainability from the outset.

## **3. During creation and manufacturing:**

The robotic system should be manufactured to prioritise methods that minimise, mitigate or offset waste, energy consumption, and emissions. Lean manufacturing practices can be used to optimise resource utilisation where possible. Engineers should be aware of the importance of considering sustainability in supply chain management to select suppliers with consideration of their sustainability practices, including ethical labour standards and environmentally responsible sourcing. Robotic systems should be designed in a way that is easy to assemble and disassemble, thus enabling robots to be easily recycled, or repurposed at the end of their life cycle, promoting circularity and resource conservation.



#### **4. Deployment:**

Many robotic systems are designed to run constantly day and night in working environments such as manufacturing plants and warehouses. Thus energy-efficient operation is crucial to ensure users operate the product or system efficiently, utilising energy-saving features to reduce operational impacts. Guidance and resources should be provided to users to encourage sustainable practices during the operational phase. System designers should also implement systems for continuous monitoring of performance and data collection to identify opportunities for improvement throughout the operational life.

#### **5. Disposal:**

Industrial robots have an average service life of 6-7 years. It is important to consider their end-of-life and plan for responsible disposal or recycling of product components. Designs should be prioritised that facilitate disassembly and recycling (Karastoyanov and Karastanev, 2018). Engineers should identify and safely manage hazardous materials to comply with regulations and prevent environmental harm. Designers can also explore options for product take-back and recycling as part of a circular economy strategy. There are various ways of achieving that. Designers can adopt modular design methodologies to enable upgrades and repairs, extending their useful life. Robot system manufacturers should be encouraged to develop strategies for refurbishing and reselling products, promoting reuse over disposal.

#### **Conclusion:**

Sustainability is not just an option but an imperative within the realm of engineering. Engineers must find solutions that not only meet technical and economic requirements but also align with environmental, social, and economic sustainability goals. As well as educating students on the broader topics and issues relating to Sustainability, there is a need for teaching considerations at different stages in the robot development lifecycle. Understanding the



multifaceted connections between sustainability and engineering disciplines, as well as their impact across various stages of the engineering process, is essential for engineers to meet the challenges of the 21st century responsibly.

## References:

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