

ME-420

Advanced design for sustainable future

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Definition of Sustainability

- Meeting current societal, environmental, humanity, and governmental needs without harming future generations.

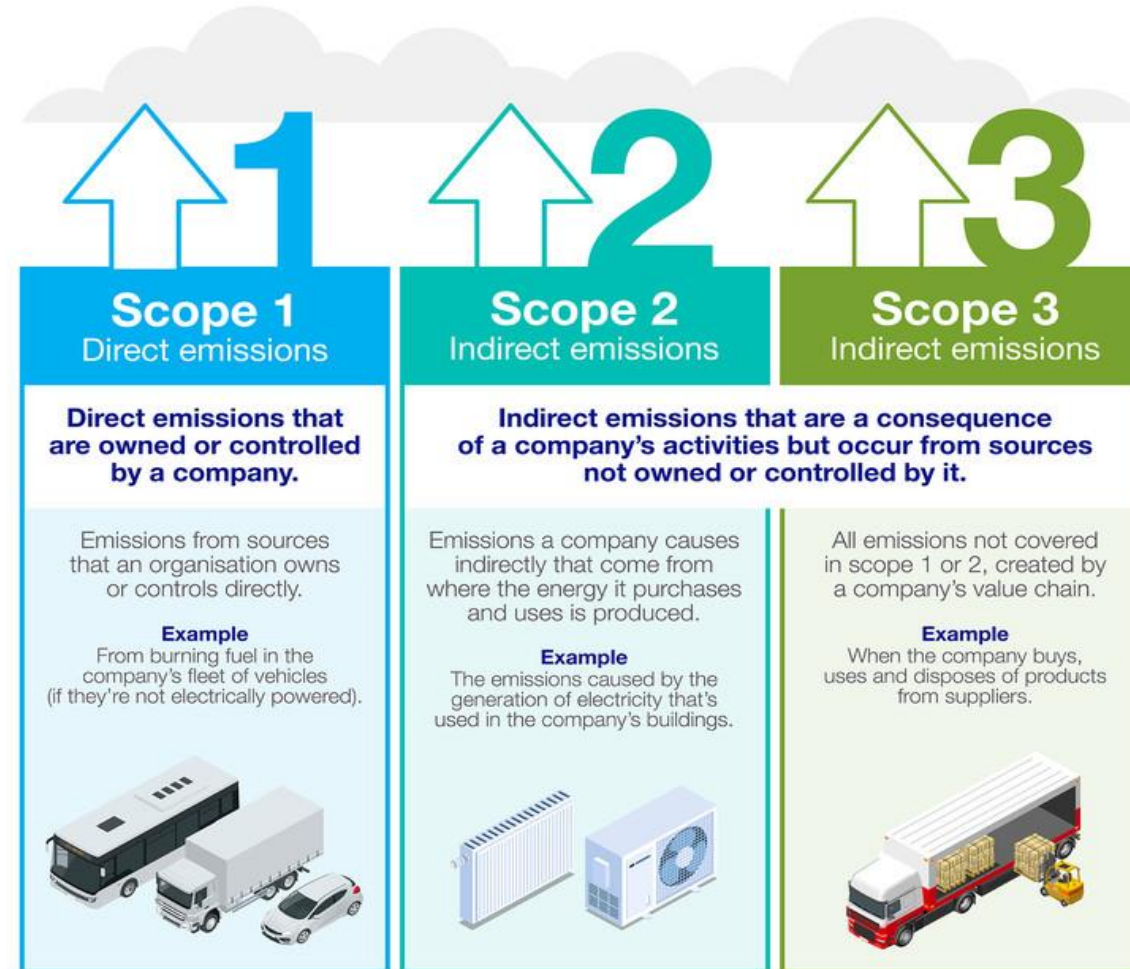
The Importance of Sustainability in Mechanical Design

- **Environmental Responsibility:** Engineers play a crucial role in reducing environmental impacts by designing resource-efficient products
- **Innovations and new technologies:** modular robots, energy-harvesting devices, and more durable mechanical components.
- **Trend in industry:** Stricter environmental regulations, Consumers and clients increasingly favor sustainable products.

Benefit your future career: Prepare you for your future career with skills, vocabularies, and experience on sustainability technologies.

What are Scope 1, 2 and 3 carbon emissions?

The three scopes are a way of categorising the different types of greenhouse gas emissions created by a company, its suppliers and its customers.



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Rethink: Design with the End in Mind

- Key Consideration: Rethink how products are designed to reduce environmental impacts over their lifecycle while integrating quantifiable metrics.
- Designer Focus:
 - Optimize the number of components to reduce complexity and improve repairability.
 - Track energy consumption during manufacturing to identify areas for improvement.
 - Plan for product end-of-life with trackable disassembly time and material lifecycle impacts.
- Example: In mechanical design, modularity and fewer components can simplify maintenance tracking and improve sustainability through data-based optimization (e.g., reducing assembly time by 15%).

Refuse: Eliminate Unsustainable Components

- Design Principle: Avoid harmful materials and prioritize those with known environmental impacts and traceable lifecycle metrics.
 - Considerations for you:
 - Choose based components that demonstrate functionality, durability and performance efficiency to ensure longer product life / various usages
 - Track the reduction in components across multiple product designs.
- *Example: Track the percentage reduction of the number of mechanical components to demonstrate improved sustainability, e.g., reducing total number and weight of components by 30% across projects.

Reduce: Minimize Material and Energy Usage

- Focus Area: Reduce environmental footprint by minimizing material usage, energy consumption, and waste, with quantifiable goals.
- Strategies for Designers:
 - Track and reduce the number of parts used in assemblies.
 - Measure and optimize energy consumption during the product's operation, aiming for a specific reduction percentage.
 - Track reductions in material usage/wastage during manufacturing
- Example: Optimize material usage, showing quantifiable improvements, such as a 20% reduction in material use compared to previous designs

Reuse: Design for Reusability and Remanufacturing

- Objective: Ensure products and components can be reused with trackable metrics on component longevity and reusability.
- Design parts with standardized dimensions to track and extend their number of reuse cycles.
 - Measure and improve time between refurbishments to ensure durability.
 - Use data to track the reduction in new raw materials through part reuse.
 - Count how many parts are using mass produced components / replaceable components.

Repair: Prioritize Repairability in Design

- Design Focus: Enable products to be easily repaired with trackable repair metrics.
- Key Considerations:
 - Track the average repair time for key components and optimize designs to reduce it.
 - Use predictive maintenance data to track the maintenance period of parts, designing products to extend this interval.
 - Provide list of accessible parts to ensure repairability is quantifiable and easy to manage.
- Example: By designing a product with a modular architecture, track and reduce repair time by 20%, thus extending product lifespan and minimizing waste

Recycle: Design for End-of-Life Processing

- End-of-Life Planning: Design products that are easy to process at the end of their life, with trackable metrics.
- Design Strategies:
 - Use components that can be easily disassembled and repurposed.
 - Track the disassembly time and ease of processing for each component, aiming for quantifiable improvements.
 - Track the percentage of components that can be repurposed or reused from each product to the next.
- Example: Track the lifecycle of components used in the product, with a focus on extending component life or reassigning parts to new applications.
- Quantifying easy assembly: count not in arbitrary seconds, but in operation steps, number of movements, points of operations, etc

Measurable metrics in sustainable engineering design

- Energy Efficiency:
 - Energy Intensity: Mechanical designs can improve the energy efficiency of machines and systems (e.g., more efficient motors, optimized mechanical layouts).
 - Energy Return on Investment (EROI): By designing energy-efficient systems (e.g., heat recovery systems, advanced thermodynamic cycles), we can increase the energy return from processes

Water Usage and Conservation:

- **Water Intensity:** Mechanical engineering can optimize water usage in processes (e.g., water-efficient cooling systems or machinery that requires less water for operation).
- **Water Reuse Ratio:** Mechanical systems (e.g., water recycling systems or closed-loop cooling) can be designed to increase the reuse of water within a process.

Material Efficiency

- **Material Intensity:** Mechanical design can reduce material use through lightweighting (e.g., using advanced materials or optimized structures) while maintaining performance.
- **Recycling Rate:** Mechanical engineers can design products for easier disassembly, repair, and recycling, improving the overall recyclability of materials.
- **Waste Generation:** Through precise manufacturing techniques (e.g., additive manufacturing, CNC machining), mechanical design can minimize material waste in production.

Pollutant Emissions

- **Toxic Emissions:** Mechanical designs that incorporate cleaner combustion systems or filtration technologies can reduce the release of harmful pollutants (e.g., NO_x, particulate matter).
- **Noise Pollution:** Mechanical systems can be designed to minimize noise emissions by using damping materials or optimizing vibrations in mechanical components.

- Embodied Energy: Mechanical engineers can design products with lower embodied energy by selecting energy-efficient manufacturing methods and materials.
- Lifecycle Assessment (LCA): Design choices such as durability, ease of repair, and modularity can reduce the environmental impact across a product's lifecycle. (but for ME 420, we will focus on the scope 2)

Ecological Impact:

- Land Use Efficiency: Mechanical engineers can design compact machinery or systems that require less physical space for operation, reducing the impact on land use.

Human and Social Metrics

- Human Health Impact: Mechanical engineers can design safer systems and machinery (e.g., ergonomic tools, improved safety features) that reduce the risk of injury and health issues.
- Fair Labor Practices: Design automation and optimization can reduce dangerous labor tasks and improve worker safety, impacting the overall quality of working conditions.

Conclusion: Sustainable Design as a Competitive Advantage

- Key Takeaway: The 6 Rs framework provides mechanical engineers with the opportunity to design more sustainable products while tracking and optimizing quantifiable aspects like material use, energy consumption, and repairability.
- By integrating sustainability and measurable metrics into the design process, engineers not only meet environmental goals but also improve product efficiency and longevity.
- Action Plans for ME 420 : Start implementing the 6 Rs and track key performance indicators like energy consumption, component count, and maintenance periods, easy of assembly, etc — to prove sustainability is a measurable and achievable goal.

How the Sustainability is Reflected in this Class

- **Quantifiable Metrics:** Tracking metrics such as material usage, energy consumption, and component lifespan is essential for sustainable design.
- **Focus on the 6 Rs:** Refuse, Reduce, Rethink, Reuse, Repair, and Recycle — a comprehensive framework that mechanical designers can adopt, supported by measurable data to gauge impact.
- **Focus on design, function, not just material**

Quick Checklist for a Good Sustainable Design

- Does the design minimize material and energy use?
- Is it easy to repair, upgrade, or recycle?
- Are emissions, waste, and pollution minimized?
- Are materials sustainable and non-toxic?
- Is it energy efficient in use?
- Does it meet safety and regulatory standards?
- Is it economically feasible over its entire lifecycle?

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About ME420

- Project based course.
- Form teams of 5–6 students.
- Create innovative concepts, and evaluate the environmental impact, and social implications
- Design and build a sustainable, automated device using the provided hardware (and any additional components you choose) to address a real-world sustainability challenge.
- A series of lectures will be given that cover the key aspects of developing a sustainable robotic device.
- Each team will have 3-min presentation every week during the class to report the status of the project.
- TA hours: Fridays 13h – 15h (in person and Zoom). Meetings outside these hours are available by appointment only.

Final Deliverables

- **Final poster, flyer, and demo video** (due 20 Nov – soft copy needs to be uploaded to Moodle)
- **Working Prototype Demo for the Public Presentation on 4th Dec at 13h.**
 - A budget of **250 CHF** + a tackle box (ESP32 + DC motor servos + essential electronic parts) are allocated toward building a prototype for each group
 - High importance on the creative solution, working concept, and a functioning prototype
 - Poster + Screen + Prototype presentation with apero (4th Dec. 17h-20h)
- **Final Presentation in class**
 - Starts at 15h15, 11th Dec.
 - Soft copy of presentation: upload to Moodle on the 11 Dec.
 - 15 min presentation followed by a Q&A session.
 - All members should be present.
 - 5-7 min question period should be answered by anyone from the group
- **Final report (format on Moodle)**
 - Due 18 December
 - Soft copy: uploaded on the OneDrive and on Moodle
 - Late submission will lose 50 % of the grade.

Grading

- 70% Project (20 % Final Report, 20 % Final Presentation, and 30 % Working Prototype Demo)
- 30% Participation (Weekly presentations + participation, mandatory!)
- Bonus (+10 on prototype): recycle at least 3 key parts (controller, motor, sensor, etc.) from previous projects

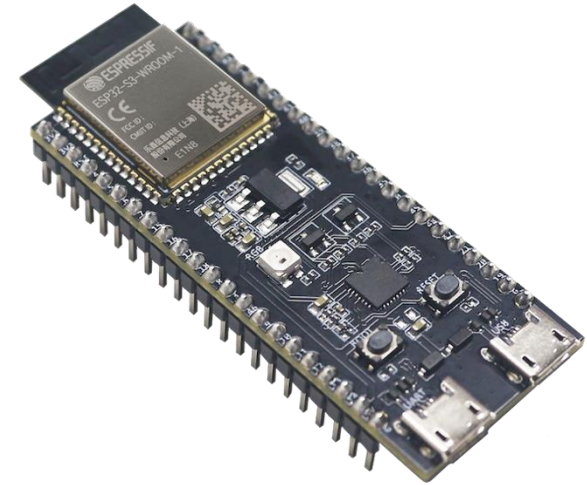
| Demo Day Grading Scales |
|--|
| Cohesive Scenario (10%) |
| Clear motivation and communication for the need of the product (10%) |
| Concept novelty (20%) |
| Maturity of the prototype (20%) |
| Application of novel technology (20%) |
| Poster (content and design) (10%) |
| Videos and other visual aids to communicate better the concept and working principle (10%) |

| Final Presentation Grading Scale |
|--|
| Organization (20%) Clear goal Clear engineering approach Clear solution selection Timing |
| Presentation (30%) Audible and confident presentation Cohesive and coherent slides Visually and content-wise illustrative slides Well-practiced talk |
| Technical Quality (40%) Clear engineering specifications and approach methods Good solution with clear justification Clear presentation of pros and cons of the suggested solutions Analytical and engineering approach to the solution Present and defend the design options during Q&A |
| Project Participation (10%) Active weekly TP participation Team effort Quality improvement over the semester |

- This is a 5-credit course—but it's much more than that.
- It can be very intense, but also highly rewarding.
- Reach out to the TAs frequently for support.
- Choose your teammates carefully; diverse skills and experience make a stronger team.
- Be responsible and accountable to your teammates.
- In-person participation in class sessions and team activities is **mandatory**.
- Check the program and syllabus carefully (in Moodle).
- Lecture recordings available online (links on Moodle).

Hardware provided in the class

- **Hardware list**
 - **Already Provided**
 - Microcontroller: ESP32
 - Support Arduino ecosystem;
 - Bluetooth + WIFI communication;
 - Duo-core CPU;
 - Servo: 5V DC motor servo x 2
 - Power supply
 - 5V USB power supply
 - Battery optional
 - **To be selected**
 - Sensors

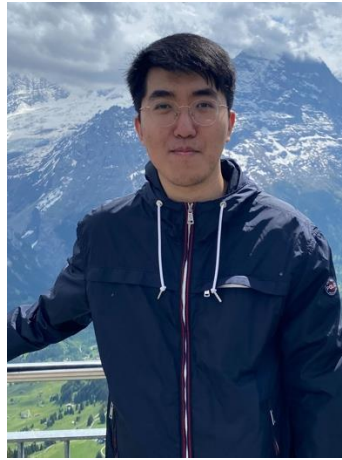




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Ekrem Yüksel
(Ekrem)



Hugo René Bordereaux
(Hugo)

Ordering materials

- SPOT use (3D-Printing, assemblies, testing, etc.)
 - Cabinet of essential parts available
 - Workbenches
 - Thursdays 3PM – 6PM
 - Fridays 11AM - 5PM
 - Training required
- Ordering happens only on three dates (week 4, 6, and 9)

Brainstorming

- Brainstorm 3 potential “sustainable” product idea → using materials around you such as straps, fasteners, micro actuations, pumps, are also viable options.
- Prepare a 3 slides for 3 ideas that describes
 - **The need (challenge?)**
 - Existing concurrent products / patents (Pros and Cons) that are less / unsustainable
 - **Functionality** – how does it move/ function ? Based on which information?

By this week

- Make a group of 5-6 (put group member names and number on the moodle)
- Brainstorm 3 examples of sustainable technology and make 3 slides
- Upload the slides with your group number

By next week

- Finalize 3 solutions about the Brainstorm 3 examples of sustainable technology and make 3 slides
- Upload the slides with your group number