ME-420

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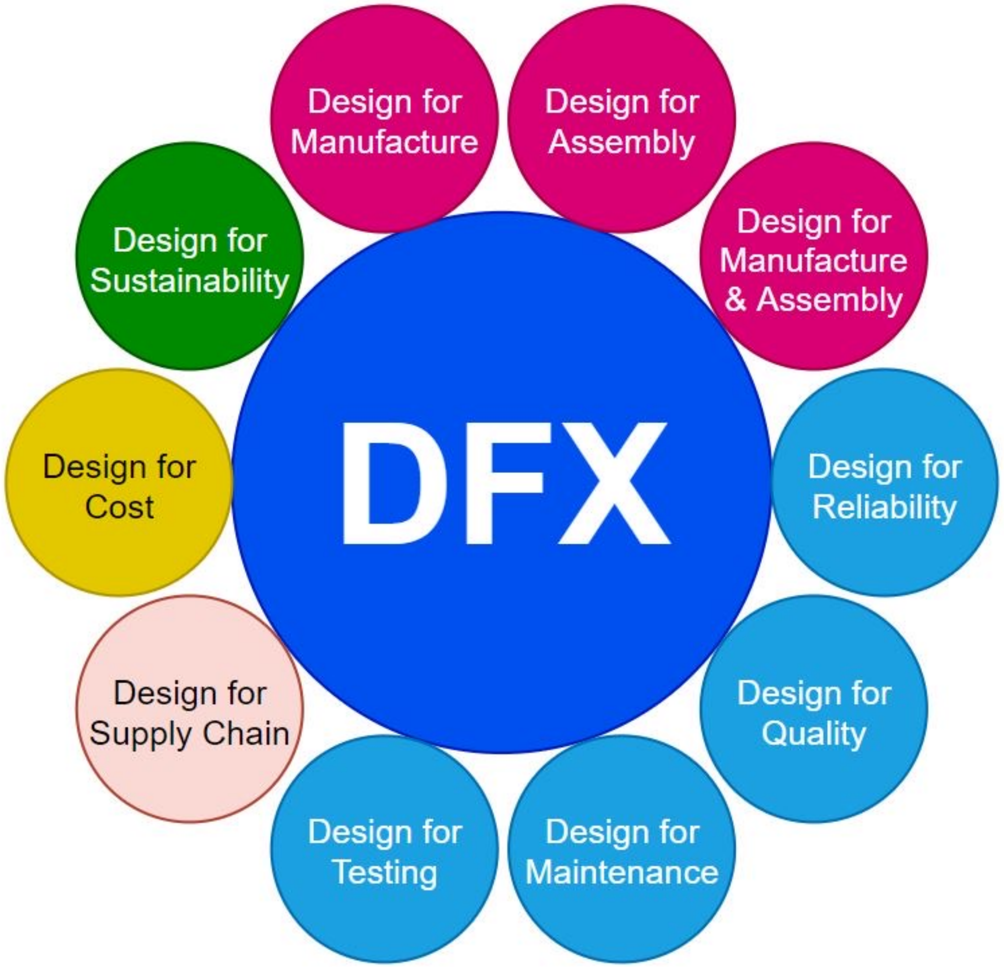

Design for Manufacture
Design for Assembly
Design for Sustainability
Design for Manufacture & Assembly
DFX
Design for Cost
Design for Reliability
Design for Supply Chain
Design for Quality
Design for Testing
Design for Maintenance

Definition of Sustainability

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

Why Sustainability Matters in Technology?

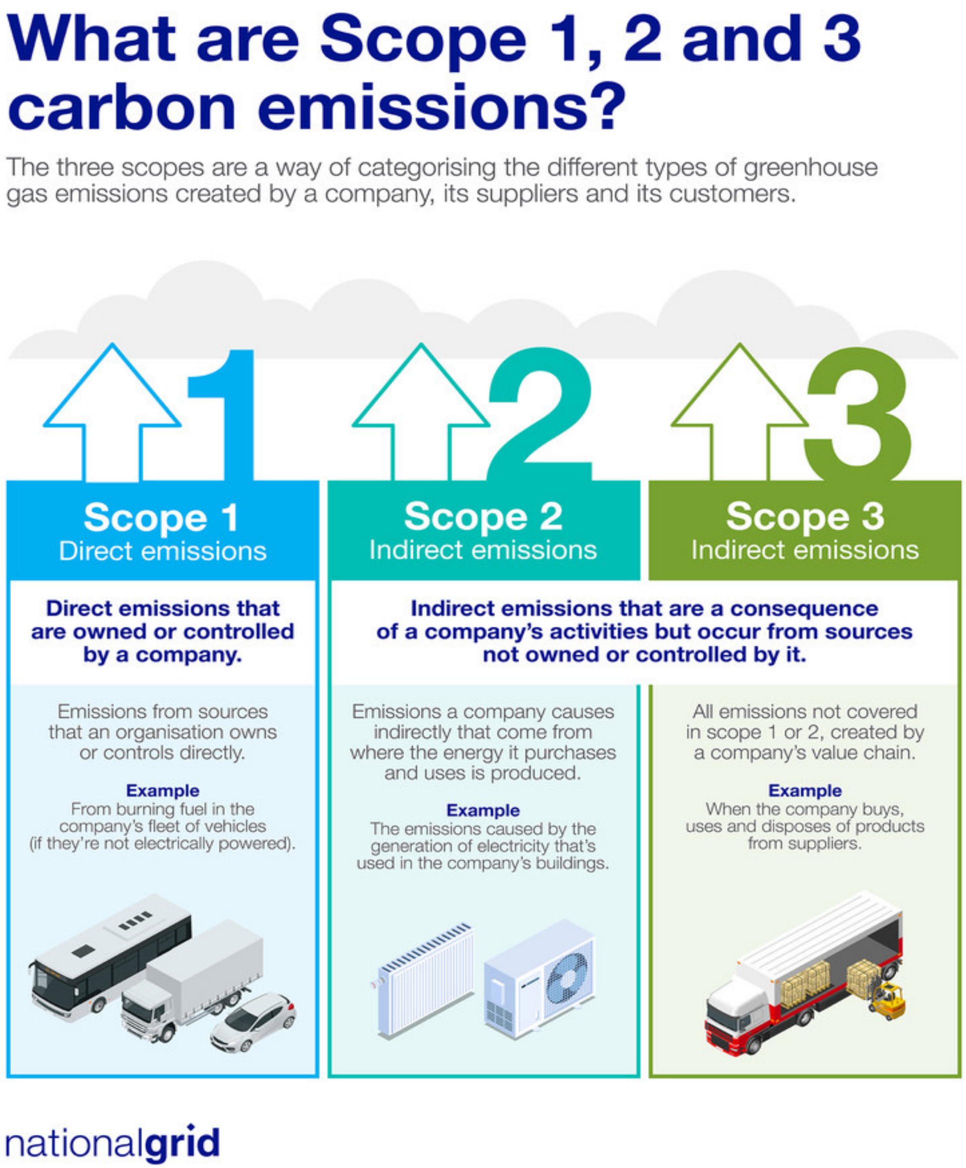
- **Global Context**: Technology manufacturing contributes to significant environmental impacts through resource consumption, waste generation, and energy use.
- **The Need for Sustainability**: The shift toward sustainable production is driven by global environmental concerns, consumer demands, and regulatory pressures.
- **6 Rs Framework**: A roadmap to sustainability focusing on Refuse, Reduce, Rethink, Reuse, Repair, and Recycle. These strategies help us to align “success” with environmental responsibility

The Importance of Sustainability in Mechanical Design

- Environmental Responsibility: Engineers play a crucial role in reducing environmental impacts by designing resource-efficient products
- 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.

The Six Rs

The 6 Rs of Sustainability
Rethink
Refuse
Reduce
Reuse
Repair
Recycle
Priority level


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.
1
2
3
Scope 1
Direct emissions
Scope 2
Indirect emissions
Scope 3
Indirect emissions
Direct emissions that are owned or controlled by a company.
Indirect emissions that are a consequence of a company's activities but occur from sources not owned or controlled by it.
Emissions from sources that an organisation owns or controls directly.
Example
From burning fuel in the company's fleet of vehicles (if they're not electrically powered).
Emissions a company causes indirectly that come from where the energy it purchases and uses is produced.
Example
The emissions caused by the generation of electricity that's used in the company's buildings.
All emissions not covered in scope 1 or 2, created by a company's value chain.
Example
When the company buys, uses and disposes of products from suppliers.
nationalgrid

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RRL

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ME 420
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Indirect emissions
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nationalgrid

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., NOx, particulate matter).
- Noise Pollution: Mechanical systems can be designed to minimize noise emissions by using damping materials or optimizing vibrations in mechanical components.

Lifecycle Impact

- 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.

TPs and Demos

- Equip you with the latest sensor and actuator options in theory and practical use
- “Softness” may not necessarily the main solution for the project but useful tools and knowledge.

Arduino and electronics

- Simple electronics to build your own motor circuit
- Use Arduino kit to program your sensor and actuator feedback loop for controlling your wearable
- You will be given a complete kit before the lecture and TP

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
  - Existing concurrent products / patens (Pros and Cons) that are less / unsustainable
  - Functionality – how does it move/ function ? Based on which information?

Upload by the end of the 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

NEXT WEEK: Homework: TinkerCAD

Create account in tinkerCAD and learning its basics

- Creating account:
  - Youtube tutorial
    - https://www.youtube.com/watch?v=4L8ViGqaZbE
  - TinkerCad website
    - https://www.tinkercad.com/
- Basics of tinkercad:
  - How to make a basic LED circuit in Tinkercad Circuits
    - https://www.youtube.com/watch?v=LrOM2GABK1g
  - Controlling LED brightness using a potentiometer in Tinkercad Circuits
    - https://www.youtube.com/watch?v=A7HpLRWm81Q