DISCOVER E PRESENTS

Waste-Free Future Project Challenge

Grades: 9 to 12

Topics: Green & Climate, Technology & Materials

Engineering Disciplines: Project Management, Environmental, Industrial & Manufacturing

Project Challenge: Waste-Free Future

Redesign the life cycle of a material or product so that nothing is wasted, no pollution is generated, and natural systems are protected or regenerated.

This project asks students to learn about the three principles of the circular economy:

1. **Design out waste and pollution from materials.**
2. **Keep products and materials in use.**
3. **Regenerate natural systems.**

It requires them to focus on a current material, construction process, or manufacturing system, apply one or more of these principles, and transform it into a waste-free contributor to the circular economy.

Throughout the project, they will use the Engineering Design Process (a series of steps that helps solve a problem) and Project Management (the use of knowledge, skills, tools, and techniques to deliver a product or result) to develop their solution.

Materials and Resources

Included with this module:

- *Waste-Free Future Challenge Student Handbook*
- *Glossary of Project Management Terms*
- *Project Rubric*
- *Appendix of Project Management Templates*

Included separately:

- *Introduction to Project Management module*

Before starting the Rain Challenge, ask students to review the introductory module to get familiar with project management and key tools. discovere.org/stem-activities/introduction-to-project-management/

Before Students Begin

The Waste-Free Future Challenge has been written as an open-ended challenge where local needs and conditions will drive the students' solutions. With this in mind, there are some things you (the educator or STEM leader) will need to consider before the students start.

Who is the client?

A project's scope is determined by the client, who sets the deliverables, deadline, and resources. This challenge assumes the educator or STEM leader will serve as the client, but you can also ask leaders of local sustainability initiatives, faculty of environmental or engineering programs at local colleges, engineers or city planners specializing in achieving zero waste, or another entity with relevant expertise to be the client.

Project Scope

Well-defined project deliverables and outcomes are key to your students' success. While they are responsible for identifying the problem they want to address, you should determine how they will present their solution.

This project lends itself to developing a proposal for a prototype or proof of concept rather than building a model. The scope of the proposal needs to be specified. Will they:

- Produce drawings or videos?
- Include suggestions for funding the prototype?
- Present their solution to classmates, local experts, or public officials?
- Publish their proposal in an online publication?
- Submit their proposal or proof of concept to a relevant local organization for consideration?

As you think through these options, how will the final product be assessed? An assessment rubric is available for you to customize for your students.

Constraints and Resources

An engineering constraint is any limitation on your design. A resource is anything needed to plan and build an engineering project, such as materials or people's work efforts.

- Are there any project constraints that the students need to be aware of?
- What is the time frame for the project?
- What resources are available? Do they have a budget for purchasing materials or creating multimedia presentations?
- Are there subject matter experts (SMEs) who can serve as advisors or are available during the research phase?
- Are there any permissions that need to be secured before the students begin?

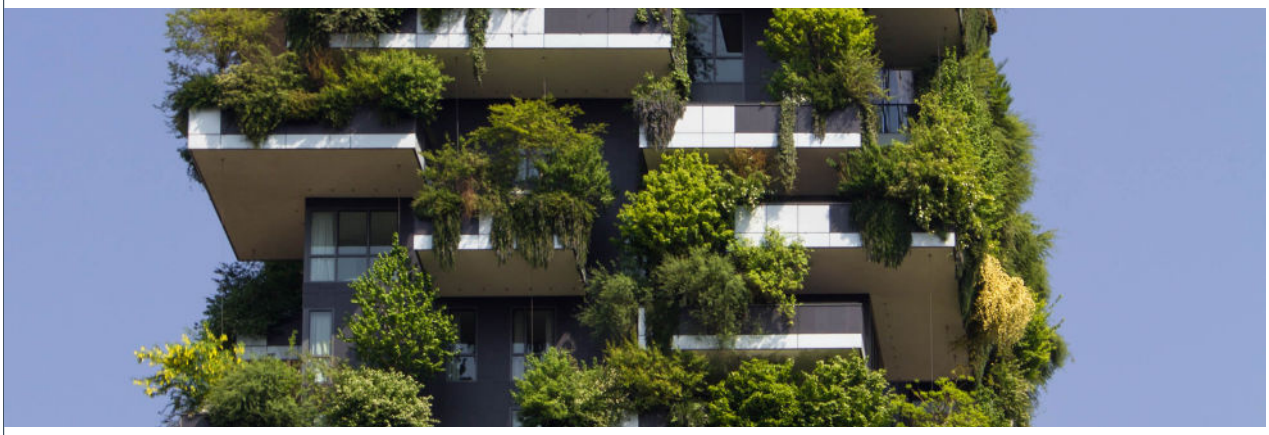
Academic Standards

This project meets the following Next Gen Science Standards:

- **HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics**
  Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

- **HS-ESS3-4 Earth and Human Activity**
  Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

- **HS-ETS1-2 Engineering Design**
  Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.



Student Handout

Creating a Waste-Free Future

Imagine a future where there is no waste and no pollution. Is this even possible? If we look to the natural world, the answer is yes! Waste does not occur in nature. One organism's waste is another organism's food. Nutrients and energy flow in a cycle of growth, decay, and reuse. This is called a circular system.

Today's world works as a linear system (think of it as a straight line rather than nature's circle). This linear system follows a path of taking natural resources, making products, using them, and then throwing away anything that is left over after we are done with it—from empty water bottles to old cars. While some things in a linear system are recycled, today's approach does not have a way to capture all the resources and materials that make up the items we throw away or the waste that's created in the original production process. This results in a lot of trash and pollution and is using up the world's natural resources.

But what if we followed nature's circular system? This is called a circular economy.

It is modeled on cycles in nature where nothing is wasted and everything feeds back into the systems that keep life in balance. The circular economy is complex and necessarily involves many elements, but it is based on three principles:

1. Design Out Waste and Pollution
   Waste and pollution are not accidents but the consequences of decisions made at the design stage. What if we looked at waste as a design flaw? How can we use new materials and technologies to ensure that waste and pollution are not created in the first place?

2. Keep Products and Materials in Use
   We can design some products and components so they can be reused, repaired, and remanufactured. But making things last forever is not the only solution. We should be able to get the materials back so they don't end up in landfills.

3. Regenerate Natural Systems
   In nature, there is no concept of waste. Everything is food for something else; a leaf that falls from a tree feeds the forest. By returning valuable nutrients to the soil and other ecosystems, we can enhance our natural resources.

All around the world, engineers, city planners, and government leaders are using the principles of a circular economy to develop methods, systems, production practices, and materials that don't generate waste or pollution and allow nature to recover. Materials are continuously reused, consumption is sustainable, energy sources are renewable—and people, animals, and plants thrive.

Your challenge: *Redesign the life cycle of a material or product so that nothing is wasted, no pollution is generated, and natural systems are protected or regenerated.*

This project asks you to develop an innovative idea and write a proposal about how it can be made into a reality. Your solution could help engineers with a problem they've been trying to solve around waste, pollution, reuse, or regeneration. You'll be using the Engineering Design Process (a series of steps that is helpful to solve a problem) and Project Management (the use of knowledge, skills, tools, and techniques to deliver a product or result.)

Initiating Your Project

Successful projects require much forethought as well as flexibility along the way. The first step in project management is to initiate your project with your client (this may be your teacher, a volunteer leader, or an outside community member) to learn the project parameters and scope.

If you haven't already, now's the time to review the **Introduction to Project Management** module. It takes you through an example project and shows you how to use a set of project management tools that are useful in any project, including this one: discovere.org/stem-activities/introduction-to-project-management/

Here are a few questions to get your Waste-Free Future Challenge started:

- What is the project deliverable (e.g., a prototype, presentation, or video), and how will your team be assessed?
- What is the scope of your project?
- Who is on your team?
- What is the deadline for completing the project?
- What resources are available to you, is there a project budget, and are you allowed to access additional resources beyond what is being provided?
- Are there any project constraints? Limitations or conditions must be considered as you design the life cycle of your material or product.
- Will you have access to subject matter experts?

Research Resources

- Comprehensive discussion of the circular economy: https://ellenmacarthurfoundation.org/
- Ann Arbor, Michigan's plan for a circular economy: https://www.researchgate.net/publication/350067492_Envisioning_a_Circular_Economy_The_Journey_of_One_Mid-Sized_Midwestern_City
- Engineers, industrial ecology, and the circular economy: https://cozero.io/blog/industrial-ecology/ https://www.csis.org/analysis/industrial-ecology-closing-loop-circularity
- Plastic, fossil fuels, and climate change: https://www.ecowatch.com/fossil-fuels-single-use-plastics-2565595371.html

Identifying the Problem

Step one of the Engineering Design Process is to identify the problem. Start by learning how manufacturing, waste, and recycling are typically handled. Then focus on how your community currently makes products and handles waste and recycling.

Making Stuff

Pick something ordinary, like a pair of pants, a car, your phone, or even your favorite store-bought cookies, and research how it is made. Find out:

- What natural resources or materials are needed to make it?
- Where do the resources or materials come from? Are they mined, grown, or manufactured? Are they locally available, or do they need to be shipped from far away?
- What is the process for making your item?
- Does making it create any waste or pollution?
- How does your item get to consumers?
- How long is it designed to last? Was it designed for a single use (a candy wrapper or bottle of water)? Or can it be used for a long period of time (a washing machine, phone, or car)?
- What happens to it when it's no longer useful? Can it be recycled or reused, or is it thrown away?
- Does it cause pollution or contamination when it's disposed of?

After you have learned about how your item is currently being made, explore with your teammates what changes you might make to the production process to design out waste and keep your item and/or the materials it is made from in use longer.

Today's Trash

When people first learn about the circular economy, they might think it is just another way to talk about recycling. But it is way more than that: it involves a range of strategies such as starting with sustainable, easily replenished manufacturing materials and rethinking packaging. It also includes reuse, sharing, repair, refurbishing, remanufacturing, and recycling.

Research how trash and recycling are handled in your city or town:

- What waste streams (types of trash) are typically found in the trash?
- What happens after trash is collected?

- What role do the 4 Rs (reduce, reuse, recycle, and rot) play in today's waste management system?
- Are the current systems effectively using the 4 Rs?
- Are there innovative examples of how cities or companies are rethinking or reusing waste?

Diving into the Circular Economy

There are a lot of great resources. We recommend starting with the Ellen MacArthur Foundation. But don't stop there! Do an internet search looking for examples of the circular economy in action. Ask:

- What does it mean to design out waste?
- What is regenerative agriculture?
- How are cities using the principles of a circular economy?

Then start exploring the circular economy in your community:

- What energy sources power your community? Are there opportunities to apply a principle of the circular economy to local power generation and distribution?
- Does your community practice regenerative agriculture? If so, what does that look like?
- How does your community handle agricultural by-products?
- What materials are used in construction in your community? In what ways are they sustainable, and how are they contributing to pollution or waste?
- Is public transit powered by renewable sources or by gasoline and diesel?
- What incentives do residents have to choose sustainable, reusable products?
- What are your community's policies around single-use plastic, plastic bags, Styrofoam, and petroleum-based forms of packaging?

List the ways you've learned that your community is working toward becoming waste-free, carbon-negative, and regenerative. What's working? What could use improvement?

Zero in on one of the three principles of a circular economy. Can you identify one or two problems you'd like to design a solution for that would push your community closer to joining the circular economy?

Planning Your Project

Now that you've learned more about the issue and the project scope and parameters, your team is ready to make your project plan.

Choosing Roles

Dividing up all of the work means that nobody carries the whole load and everyone has an important part to play in the project. It also means that each person does what they feel ready and able to do. They can use their skills and do the part that interests them.

Here's a list of typical project roles. You'll need to determine which of these are needed for your project, as well as any other roles that make sense to you. Also, be sure to plan which team members will need to take on multiple roles.

- Project manager
- Researcher
- Scheduler
- Designer
- Builder
- Tester
- Note taker
- Presenter

Capture all the people affected by your project by filling out a Stakeholder Register.

Building Your Schedule

The schedule tells each team member what the deadline is for their particular responsibilities. It may also mean that not everyone is working on the project at the same time; for example, if your role is to create a CAD drawing, you need to hit your deadline in the schedule so that the presenter(s) have time to prepare for the presentation.

Remember that your schedule has to be flexible. Some parts of this project might take longer than anticipated, so know ahead of time that you will probably need to adjust as you go. That's what engineers and project managers have to do all the time—be ready for plans to change!

There are many ways to keep track of what needs doing, when, and in what order.

- With scheduling programs on a computer include Excel spreadsheets, Google Sheets, and Apple Numbers
- On smartphones: Trello, Asana
- Or use the templates in the Appendix

Research

Now's the time to go deeper into the research and find potential solutions.

As you research, jot down any ideas that emerge for your particular problem and how they might be solved. Keep careful track of where you get your information so you can go back to the source as needed.

Consulting a subject matter expert (SME) is a great idea to bolster your online research. SMEs are professionals with expertise in a particular subject who can give you important information that will affect your understanding of the problem, how the problem plays out in your community, and what solutions are already being considered. You can find SMEs at your local college or university, engineering firms, and relevant government organizations.

Brainstorm Solutions

Come together with your group and talk about what you've learned from your research. Let the ideas for solutions flow. Don't shoot any down; just gather a bunch and see where they lead. Eventually, choose one idea for a solution to work with (but keep your list in case the first idea doesn't work out).

As you are brainstorming, check in with your client to make sure you can deliver your solution on time and on budget. Make sure you understand how they'd like you to deliver your solution and how your solution will be assessed. If there are any new details or misunderstandings, now is the time to resolve them. For instance, maybe your potential solution doesn't fit within the scope of the project, or it would be better suited to a different presentation method. Talk with your client and see if the project specifications can be adapted.

Check the Project Management Templates in the Appendix and see which ones would be helpful for your project. Everyone needs a budget and a way to track expenses; what about listing the resources you need, troubleshooting risks, and creating a system for communicating often and effectively?

Executing & Monitoring Your Project

Now's the time to develop your deliverable or project outcome. If you are making a prototype or a model, build one now. If you are developing a design that could be built in the future, think through every step of how you would build it. Look for trouble spots and think about how to handle them. Do a rough draft or sketch before designing the final version.

Test your prototype or model. If it worked, how could it work better? If it didn't, redesign and try again. Engineers recognize that their first prototypes are rarely their best. They go back to the drawing board, however many times it takes.

If you are doing a presentation as part of your project deliverable, consider what you want to present and any supporting materials you may need to develop (e.g., background information, models, prototypes). Consider the following questions when producing your presentation:

- How much time will you have for your presentation?
- Who will the audience be?
- Will there be a Q&A session?
- How will your work be assessed?

As you work, a few things to consider in this phase are:

- **Your Schedule:** Go back to your schedule and see what tasks you are assigned. You may need to switch roles or change dates at this point.
- **Scope Creep:** This common phenomenon happens when your idea for a project deliverable keeps growing until it is way bigger than you can actually do. If you have a client, are you being asked to do more than you're able? Now is the time to renegotiate.
- **Group Check-ins:** Check in with the team and see how all of the pieces are moving along. Check in regularly!
- **Status Reports:** Your client will want assurances that the project is going as planned—or that change is required. Remember to keep your client posted by providing a status report like the one in the Appendix.

Close

Share your results! Be prepared for some questions and feedback from your client.

At this stage, take some time to reflect on your experience and the work of others. This is a critical phase in the Engineering Design Process as well as Project Management. Part of your reflection includes thinking about what you did well and what you'd like to do better; it's also important to look as objectively as possible at the work of your teammates.

Write a Lessons Learned Report and a Self- and Peer Assessment by using the forms in the Appendix or creating your own.

We want to see what you and your teammates develop!

Share your project results with us at Social@DiscoverE.org or tag us @DiscoverEorg

Glossary of Project Management Terms

Acceptance criteria: A set of conditions that must be met before deliverables are accepted.

Activity: A distinct, scheduled portion of work performed during the course of a project to meet a project milestone.

Budget: The estimated amount the project will cost, including labor, supplies, and overhead (office space and equipment).

Closing process: The process(es) performed to formally complete or close a project.

Constraint: A limiting factor that affects the execution of a project, such as time or money.

Deliverable: What is delivered to the client as a result of the project. Deliverables can be products or completed activities; projects usually create deliverables during the project, such as progress reports, as well as the final deliverable.

Executing process: The doing phase of a project; work is completed until the project goals are achieved.

Goals: The main purposes of the project; the general outcomes you want to achieve.

Initiating process: The first steps of a project. These include coming up with a project idea, vetting it, identifying stakeholders, choosing the project manager and team, and getting the project authorized.

Milestone: A significant point or event in a project that marks progress toward the project's completion.

Monitoring/controlling process: The processes of tracking, reviewing, and regulating the progress and performance of the project. During this phase, any needed changes are identified, and the team prepares to make those changes.

Objectives: The specific and measurable outcomes that need to be achieved to fulfill project goals.

Planning process: The phase of a project set in motion after it has been approved, during which many key decisions are made. These include writing the scope statement, project schedule, and budget. It also includes deciding how to monitor the project's progress, who will do what, how to obtain resources, how and when to communicate with project stakeholders, and thinking ahead about handling potential risks and pitfalls.

Project: A temporary endeavor undertaken to create a unique product, service, or result that has value to people.

Glossary of Project Management Terms (continued)

Project management: The use of specific knowledge, tools, and techniques to ensure that a project comes to successful fruition.

Project manager: The person chosen to lead the team who is responsible for completing the project.

Project portfolio: A collection of all the documents generated over the course of a project.

Project schedule: A detailed layout of a project's timeline that provides a start date and a due date for all project milestones, activities, and tasks.

Project scope: Description of the project's limits in terms of its cost, time frame, and objectives.

Project team: A set of individuals who support the project manager in performing the work of the project to achieve its objectives.

Resource: Anything needed to complete the project—people, tools, money, time, and facilities, for example.

Risk: A potential event or condition that can have a negative effect on the project.

Scope creep: The uncontrolled expansion of the project scope without adjustments to time, cost, and resources; when goals get added that weren't part of the original scope.

Scope statement: The formal description of a project's scope. The scope statement describes the work that will be done as well as what won't be done to create the project's unique outcome.

Sign off: Approve or agree with a decision.

Sponsor: A person or group who provides resources and support for the project. A project sponsor is responsible for enabling success.

Stakeholder: A person, group, or organization that has something to gain or lose from a project's outcome; anyone with an interest or investment in a project.

Stakeholder register: A project document that lists project stakeholders and relevant information about them.

Status report: The document that details progress toward completion of the project.

Task: The discrete steps that must be accomplished to complete a project activity. **Dependent tasks** are steps that can only be taken if the previous steps are done; **independent tasks** are not contingent on other tasks and can be done within a more flexible time frame.

Project Rubric

Student Names:_____ Date:_____

Project Title: _____

	Exemplary	Solid	Developing	Needs Attention
Comprehension of Subject Matter	All content is accurate and complete and communicates a full understanding of the topic.	Most of the content is accurate and shows mastery of the topic.	Content shows some flaws and omissions and illustrates only partial knowledge of the topic.	Much of the content is inaccurate and confusing and communicates very little understanding of the topic.
Quality of Research	Research includes multiple, varied sources that are cited at appropriate points and that contribute valuable information to the project.	Research includes several sources that are cited at some point in the project and that contribute relevant information.	Research includes at least a few sources that are cited, but the information contributed is only partially relevant and useful.	Research is inadequate or does not contribute relevant information to the project. Research sources cannot be checked.
EDP & Engineering-based Solutions	The Engineering Design Process has been followed, and engineers could implement the solutions.	Most elements of the Engineering Design Process have been followed, and engineers could implement the solutions.	Only some elements of the Engineering Design Process have been followed, and not all solutions are engineering-based.	The Engineering Design Process was not followed, and the solutions are not engineering-based.
Problem/Solution	The problem has been clearly defined, and the proposed solution is innovative and well considered.	The problem has been adequately defined, and the proposed solution is sensible.	The problem has not been well defined, and the solution is not necessarily actionable.	The problem is defined confusingly, and the solution does not make sense.

Project Rubric (continued)

	Exemplary	Solid	Developing	Needs Attention
Project Management Implementation	The team makes effective use of all appropriate project management principles and tools.	The team makes use of most appropriate project management principles and tools.	The team makes use of some appropriate project management principles and tools.	The team does not make good use of appropriate project management principles or tools.
Group Work	All of the group members participated completely and enthusiastically, exceeding expectations for the assignment tasks.	All of the group members participated completely, meeting all of the requirements for the assignment tasks.	Most of the group members participated, completing most of the requirements for the assignment tasks.	Some of the group members did not participate, causing the group to miss some of the requirements for the assignment tasks.
Risk Management	The team's response to problems or setbacks demonstrated flexibility, resourcefulness, and practicality.	The team's response to problems or setbacks demonstrated flexibility and willingness to ask for help when needed.	The team's response to problems or setbacks was somewhat disorganized, or the team did not ask for help when needed.	The team's response to problems or setbacks was chaotic or inappropriate.
Presentation Characteristics (if applicable)	Presentation is logically organized, complete, and persuasive.	Presentation is logically organized and complete.	Presentation is not well organized or is missing a few important elements.	Presentation is disorganized and obviously incomplete.

Additional Comments:

Appendix of Project Management Templates

Templates are a type of tool that give you a basic layout for creating your own versions of documents. You may use the templates in this Appendix to guide your Project Management Processes. Either print the PDFs in this appendix or download editable Word documents at this URL: discovere.org/stem-activities/introduction-to-project-management/

Initiating Process

- Stakeholder Register

Planning Process

- Project Schedule
- Responsibility Assignments
- Plan for Acquiring Resources
- Create a Budget
- Communication Plan
- Managing Project Risk

Executing Process

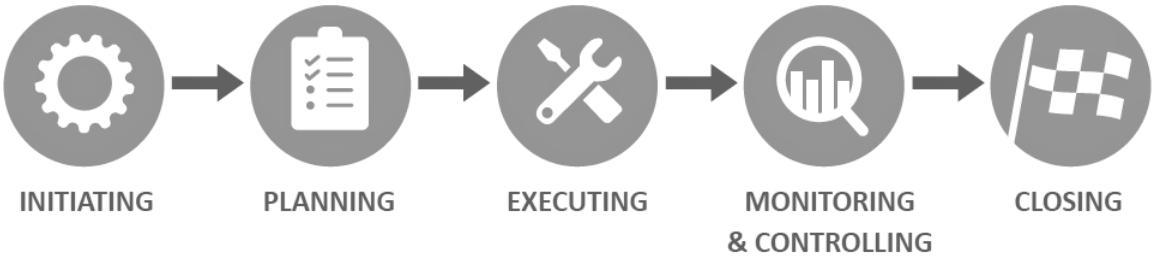
no templates necessary

Monitoring and Controlling Process

- Status Report

Closing Process

- Lessons Learned



Stakeholder Register Project Title: _____

Name	Role in Project	Contact Information

Schedule

Project Title: _____

Task	Estimate Work Time										

Responsibility Assignments

Project Title: _____

	Person				
Activity					

Plan for Acquiring Resources

Project Title: _____

Resource Needed	When will you need it?	How you will acquire it

Create a Budget

Project Title: _____

Estimate the cost of supplies and other resources for each activity.

Activity	Supplies Cost	Other Resources Cost

Communication Plan Project Title: _____

Who to contact	What to communicate	How? (Method)	When?

Managing Project Risk

Project Title: _____

What might go wrong?	Risk Level L = Low M = Medium H = High	Area of Impact R = Resources T = Timing S = Scope Q = Quality	How to prevent it or fix it

Project Status Report

Project Title_____

Team Name:

Date:

Project Status:

- ☐ In good shape
- ☐ At risk of going off track
- ☐ Out of control

Tasks Accomplished:
What work have you completed?

Tasks in Progress:
What are you currently working on?

Planned Tasks:
What work do you still need to start?

Issues:
What challenges have you experienced? What steps did you (or will you) take to solve them?

Questions for Discussion:
What do you need to talk with your project manager about?

Lessons Learned

Project Title_____

Team Name:

What did we do right?

What could we have done better?

What should we continue to do?

What significant issues did we encounter during the project, and how were these issues handled?

What lessons did we learn from this project that will help us when doing projects in the future?