Spotlight: Engineers

Teacher Manual: Lesson 12

Essential Question (AKA "The Big Question")
How do engineers play a critical role in designing climate solutions?

Learning objectives. Students will be able to:

1. Describe how engineers contribute to climate-critical projects
2. Identify the skills and training needed for engineering careers
3. Describe the aspects of an engineering career that align with your skills and interests.

Lesson summary
This lesson is all about engineers and their diverse roles in climate solutions. Students will explore how engineers design solutions that help build a sustainable future and the typical skills and interests that result in a successful engineering career.

11. Electricians
12. Engineers
13. Lineworkers
14. Managers and analysts
15. Construction, installation, and maintenance workers
16. Wind turbine technicians
17. Sales and customer service workers

Technology referenced in this lesson:

- Solar electricity
- Wind turbines
- Geothermal systems
- High-performance buildings

Careers referenced in this lesson:

- Solar engineer
- Wind turbine engineer
- Building systems engineer

- Engineering technician
- Scientist

Agenda	Timing	PPT Slide	
Opening Activity	5 minutes	2	**Pre-lesson**
Present agenda and learning objectives	5 minutes	3–5	
Direct Instruction Video Technology introduced Careers introduced	20 minutes	6–12	
Primary Learning Activity Partner or small group work Reinforce what was learned	20 minutes	13–14	
Closing Review learning objectives Closing activity Reflection	5 minutes	15–17	
Extension			
Handouts			
TOTAL TIME	**55 mins**		

Preparation

- Read the Student Presentation Deck (PPT).
- Watch the video(s) included in the Student Presentation Deck (Most are available on the MassCEC YouTube channel).
- Print worksheets and handouts before class.
- Verify that the computer hosting the presentation deck is connected to the internet for video and hyperlink viewing.
- Check any links in the slide deck to ensure they work as intended, then review the content below.

Where to learn more about the lesson's content

If extra preparation time is available, these resources will provide additional background on the topics covered in this lesson.

- Unity Environmental University/How to Become an Energy Engineer
  Web article detailing job descriptions, requirements, and salary information for a variety of renewable energy engineering roles

- What Does a Renewable Energy Engineer Do?
  Cousera.com article detailing types of jobs, required skills, salary estimates, and career path description
- Wind Technology Testing Center. One of the only testing centers of its kind in the world is right in Boston. Four-minute video tour.

Overview and Opening Activity (10 mins)

Materials and resources

- Worksheets
- Index Cards (10 per pair or group)

Opening activity: Get students thinking and talking right away.

Activity objective: Introduce students to the engineering design thinking process in a fun, engaging, and relevant way by having them brainstorm and plan an invention that addresses a classroom-related challenge.

Background: Clean energy projects often begin with a problem that needs to be solved. Today, you'll practice design thinking and get creative!

Instructions

- This activity can be done in pairs or small groups. Students should use their worksheets to follow the design thinking process.
- Present the challenge: Students are to design a bookstand for student desks.
- Each pair may only use ten index cards (total) and two objects currently found on their person (per person).
- Students have five minutes—encourage them to move quickly, and don't let perfectionism slow them down!
- After five minutes, ask one or two groups to share their reactions to the activity and whether they would be excited to build and test their ideas.*

*This is an optional extension activity if you split this lesson over two days.

Extension Activity: Create and Test Your Invention

Activity Objective: Allow students to implement their design thinking by building and testing their inventions from the earlier Opening Activity, simulating the real-world iterative engineering process.

Activity Overview (20 Minutes)
Build Phase (10 Minutes): Students construct their inventions using the materials identified in the opening activity (e.g., index cards + personal items). Encourage them to follow their design plan but allow room for improvisation if challenges arise.
Testing Phase (5 Minutes): Each group tests their invention based on their defined success criteria. For example:

- Does it solve the problem they identified?
- How effective or efficient is it?
- What feedback might the stakeholders (teacher or classmates) give?

Reflection and Iteration Phase (5 Minutes): Groups reflect on their results and consider:

- What worked well?
- What didn't work as expected?
- What changes or improvements could be made in a second version of the invention?

Debrief Discussion

- What was the most challenging part of translating your invention from an idea to a prototype that could be tested?
- How did your design thinking process help you during the building and testing phases?
- What would you do differently if you had more time or resources?

Present the agenda. Students should be getting familiar with the format:

- After the opening activity, students will learn new information. The main activity asks students to use the engineering design process to develop a solution to improve solar efficiency in a small fictional town. The closing activity asks students to answer three questions about the engineering vocation before sharing one answer aloud.

Present the Big Question and lesson objectives (See top of page 1)

- By the end of the lesson, students will better understand how different engineering roles work together to make clean energy projects possible and successful.

Key points to emphasize:

- Encourage students to keep the big question in mind throughout the lesson.
- By integrating technical knowledge with a focus on sustainability, creativity, and collaboration, engineers are indispensable in addressing the complexities of climate change and building a sustainable future.

Possible discussion questions:

- If you know anyone currently working as an engineer, what work do they do?
- Name some school subjects you think aspiring engineers would be required to study when earning their engineering degree.

Direct Instruction (20 mins)

Provide information to help the students achieve the learning objectives and prepare them to actively engage with the activity.

- Use inquiry-based learning strategies to engage learners where possible.
- Highlight careers related to the technologies.
- Help the learners to relate the learning to themselves and their communities.

Show the MassCEC engineering video *[Title TBD]* (three to five minutes) and follow it with a brief check-in to hear what students took away.

The video features a young mechanical engineer at the Wind Technology Testing Center in Charlestown, Boston.

Video debrief

- What happens at the Wind Technology Testing Center?
- What things did Carly enjoy growing up that made her think engineering might be interesting to pursue?

What do engineers do?

Discussion guidance

- Engineers figure out how technology or creations can be used to solve real-world problems.
- Engineers are educated to design, analyze, innovate, and communicate.
- Studying engineering gives you a well-rounded science, math, design skills, communication, and entrepreneurship education.
- Engineers usually specialize in a focused field or discipline. Let's look at some engineering specialties closely related to clean energy industries, technologies, climate goals, and innovation.
    - Solar engineers
    - Wind turbine engineers
    - Building systems engineers

Key points to emphasize:

- Engineers use math and science to solve problems by designing, building, and improving systems and products in technology, energy, and construction.
- There are several different types of engineers.
- These are some of the most common career paths for engineers who work in the clean energy field.
- Engineers tackle projects that make life safer, easier, and, ideally, more efficient.
- Engineers play an essential role in developing technologies that combat climate change, such as solar and wind power products, systems, electric vehicles, and high-performance buildings.

Anticipated student questions:

Why does some engineering work require the engineer to be licensed or certified?

- Answer: Not all engineers need a license, but licensure is essential for those working on public-facing projects or in regulated industries, mainly where public safety is a concern.

When working at a project site, what color helmet do engineers wear? Why?

- Answer: White. Helmet colors help to define the various job roles that are present on a project site.

Engineering skills and interests

Discussion guidance:

- Engineering skills are highly transferable across different fields or disciplines. As a result, engineers can easily switch fields or collaborate on projects outside their usual area of expertise.
- Depending on what specific type of engineering one goes into, there are lots of skills you might need, but the top five skill sets that are shared across the board are:
    - **Problem-solving**. Critical thinking and innovative approaches apply to all engineering fields.
    - **Mathematics**. This is essential for design, analysis, and modeling in every branch

of engineering.
    - **Project management**. This involves coordinating timelines, budgets, and teams.
    - **Software literacy**. Engineers use tools such as CAD, modeling, and simulation software. It's helpful for an engineer to understand new software quickly and use different software tools on various aspects of the project.
    - **Communication**. Engineers need to explain complex ideas and collaborate with cross-functional teams.
- Most engineering roles do require an undergraduate degree.
- Many schools will separate engineering programs based on the specific type of science behind them, but not all.
- You can pursue advanced degrees in engineering and advanced certifications or licensing.
- Some, but not all, engineering roles require further licensing specific to the branch of engineering you're pursuing.
- Some roles are similar to engineers but different.
    - Engineering technicians work closely with engineers but are often more hands-on than computer-based.
    - Scientists start by asking a question, conducting background research, formulating a hypothesis, testing it through an experiment, analyzing the data, and documenting and communicating their results.

Key points to emphasize:
- There are a variety of engineering roles in climate solutions.
- Engineers require a wide range of skills, but five essential ones (described above).
- Engineering is not just numbers and science. Engineers are curious, creative, and skilled at simplifying and communicating complex topics.
- Engineers have a considerable impact on sustainable development and drive innovation.

Anticipated student questions:

How do the roles of designers and engineers differ when they collaborate to solve problems?
- Answer: Designers think creatively to solve user-focused problems, considering how the solution fits into the broader context. Engineers apply technical knowledge to address structural, mechanical, or electrical challenges and ensure the solution is durable and efficient.

At which Massachusetts colleges and universities are engineering degrees available?
- Answer: Engineering is a popular area of study. Programs are available at many schools, including MIT, Northeastern, Worcester Polytechnic, Harvard, Tufts, UMass Amherst/Lowell/Dartmouth, Boston University, Olin College, Smith College, Wentworth Institute of Technology, Western New England University.

Primary Learning Activity (20 mins)

Materials
- Worksheets

Activity objective: Allow students to use the engineering design process to develop a solution to improve solar efficiency in a small fictional town, Sunnyville. Students will also practice evaluating plans against criteria and constraints to select the most viable solution.

Background: Sunnyville is a small town in coastal Massachusetts that wants to increase its climate resiliency and reduce reliance on fossil fuels by improving solar efficiency. They've hired you as a team of engineers to design a solution that meets their criteria and fits within their constraints.

Instructions
- Divide students into groups of an appropriate size for collaborative work and direct them to their worksheets, which will guide them through the engineering design process: defining the problem, identifying criteria and constraints, researching, brainstorming and planning, and selecting the best solution (as a class).
- In these groups, students will examine
    - details about Sunnyville, including project constraints and criteria for a successful solution
    - specifications for available types of solar panels and battery storage options
    - solar placement strategies.
    - Encourage students to focus on information relevant to their design, such as budget and the town's energy goals.
- Students will then design a solution for Sunnyville that they believe best meets the criteria laid out by the town.
- Groups will present their plans to the rest of the class, and together we will decide which of the plans is the one that best meets the town's needs.

Presentations and debrief
- Invite each group to present their solution to the class, including their chosen solar panel type, storage method, and placement strategy. Each group should specify why their solution best meets Sunnyville's needs based on the criteria provided.
- After all presentations, ask the class to compare the three proposed solutions against each criterion. Ask students which plan best fits Sunnyville's needs and why. Hold a simple vote or discussion to decide which plan the class feels would work best.
- If there's no clear winner, encourage students to reflect on how engineers must balance multiple factors when designing solutions and there often isn't a single obvious best way forward.

Differentiations and Adaptations—Learning Activity (If available)

For students who enjoy role-playing or need specific task delegation for focus, assign specialized roles within groups.
Adaptation: Divide each group into specialized roles, such as “Data Analyst,” “Budget Planner,” “Community Liaison,” and “Presentation Leader.” Provide role-specific prompts and tasks to guide each student’s focus. For example:

- Data Analyst: Focuses on identifying issues and inefficiencies in the current system data.
- Budget Planner: Evaluates costs and prioritizes upgrades within the $150,000 budget.
- Community Liaison: Considers community goals and environmental impacts of proposed upgrades.
- Presentation Leader: Organizes the group’s findings into a cohesive summary and prepares for the presentation.

Goal: This structure allows students to work within their strengths while ensuring every group member has a clear, manageable role contributing to the solution.

For students who struggle to process verbal information quickly, provide scenario cards with visual aids
Adaptation: Provide each group with “Scenario Cards” highlighting key issues for each solar array or battery system. For example, a card for Array A could include a photo of shaded panels and text summarizing its reduced output and potential solutions (e.g., “Shading reduces output by 10-15%. Options: Replace panels for $75,000 or reduce shading for $15,000”).
Goal: The visual aids make the data more accessible and help students quickly grasp the key challenges and options without feeling overwhelmed by large amounts of text.
Extension: Include color-coded icons or symbols to emphasize urgency (e.g., red for critical issues, yellow for moderate issues) and guide prioritization.

Takeaways and Closing Activity (5 mins)

Key lesson points

- Engineers are crucial in designing and implementing clean energy solutions, from renewable energy systems to energy-efficient buildings.
- Different types of engineers contribute to the clean energy sector, including environmental, mechanical, electrical, and civil engineers. Each role requires specialized skills to tackle different climate challenges.

- Engineering careers in clean energy require strong problem-solving abilities, technical skills, and an innovative mindset to develop sustainable technologies.
- Engineers help to build a sustainable future by creating systems and infrastructure that reduce emissions, improve efficiency, and support environmental resilience.
- There are various pathways to becoming an engineer, including higher education, technical skills, and real-world engineering applications in clean energy. This is an excellent path for students who love math and science to explore.

Closing activity objective: This activity encourages students to reflect individually on the value engineers bring to meeting Massachusetts's climate goals by answering three questions.

Give students two minutes to reflect on these questions in their worksheet/career guide, and ask volunteers to share responses aloud:

- What can we learn from how engineers approach problem-solving?
- What is one question you still have about how engineers support climate solutions?
- What interests you about becoming an engineer?

Instructional steps

1. Review the learning objectives so that learners can summarize what they have learned.
2. Present the closing activity.
3. Allow time for reflection in the career journal.

Extensions—if learners are loving this topic and want more…

Engineer profile research and presentation

Prompt: Research a specific type of clean energy engineer, such as a wind energy engineer, energy efficiency engineer, or geothermal systems engineer. Create a profile that includes their job responsibilities, required skills and education, and how their work contributes to clean energy solutions. Present your findings creatively, such as a poster, infographic, or job advertisement.

Goal: help students explore the diverse roles within clean energy engineering and understand the skills and knowledge required for these careers.

Design a clean energy engineering challenge

Prompt: Imagine you are an engineer tasked with solving a specific clean energy challenge, such as reducing energy waste in a building or improving the efficiency of a wind turbine. Design a solution and create a sketch or prototype of your idea. Include an explanation of the problem, your solution, and how it works.

Goal: foster creative problem-solving and introduce students to the process of designing solutions to real-world engineering problems.

Interview a clean energy engineer (virtually or in-person)
Prompt: Identify a clean energy engineer (or watch a video interview of one) and learn about their career path, daily responsibilities, and the projects they've worked on. Write a reflection sharing what you learned, including any advice they gave for pursuing a similar career.
Goal: provide students real-world insights into the profession and inspire interest in clean energy engineering careers.

Explore engineering ethics in clean energy
Prompt: Research an ethical dilemma faced by engineers in the clean energy industry, such as balancing environmental impacts with community needs or addressing equity in clean energy access. Make a short presentation or hold a class discussion on your ideas for how engineers can navigate these challenges.
Goal: introduce students to the ethical considerations in engineering and encourage critical thinking about the social implications of clean energy projects.

Handouts—Opening and Group Activity

Opening Activity: Design Thinking

Practice using the design thinking process to plan how to create a bookstand for a student desk. For this challenge, you may only use ten index cards and two objects currently on your person (per person in your pair or small group). You have five minutes to complete the steps below, so think quickly!

What problem will your solution solve?:

What are your constraints and materials?:

Who will use your solution? How will they use it? How will it help them?:

How will you know if your solution is a success? What does success look like for your solution?:

How would you test your solution to make sure it works?:

What could your solution look like? What features will it include?:

Engineering Feasibility Study

Instructions

Your group has been hired to look into the most practical changes that might be made to the existing clean energy systems in Sunnyville. You have detailed information about their system's current solar arrays and battery banks and possible upgrade and expansion options. Work with your group to recommend improvements for Sunnyville that meet their criteria and constraints. Consider each option's benefits and drawbacks and prepare to present your recommendations to the class.

Scenario Details

Sunnyville, MA

Sunnyville is a small town with a population of 5,000. It operates a community solar electric power system with multiple solar arrays and battery storage locations. The town wants to evaluate its system to ensure it operates efficiently and explore potential upgrades or improvements.

The town council has agreed on three goals:

- **Optimize energy efficiency**: Increase energy output and reduce energy loss.
- **Improve reliability**: Ensure power availability during peak demand and outages.
- **Reduce maintenance costs**: Minimize operational costs without sacrificing performance.

Constraints

- **Limited budget**: Sunnyville's budget for all upgrades is $150,000.
- **Limited installation space**: The town has no room for additional ground-based solar arrays; rooftop and tracking system improvements are feasible.

Energy Demand

- **Residential Demand**: 120,000 kWh/year
- **Commercial Demand**: 80,000 kWh/year
- **Industrial Demand**: 90,000 kWh/year

Feasibility Study Presentation

- Identify challenges or areas of underperformance within the current system.
- Recommend improvements or upgrades while considering the town's constraints.
- Explain how your plan addresses Sunnyville's goals.

Current Solar System Data

Sunnyville has three solar arrays installed in various locations throughout the town. Your team's findings on each are below.

Array A: Sunnyville's Town Hall rooftop

- **Size**: 50 kW capacity
- **Efficiency**: 18%; produces an average of 60,000 kW per year.
- **Lifespan**: Installed 5 years ago, with 20 years of useful life remaining.
- **Maintenance Cost**: Moderate; $2,500 annually for cleaning and minor repairs.
- **Issues**: Shading from nearby trees and taller buildings reduces output by 10-15%, especially in winter and late afternoon.

Array B: Ground-based system in an open field near the community park.

- **Size**: 75 kW capacity
- **Efficiency**: 15%; produces an average of 80,000 kW per year.
- **Lifespan**: Installed 10 years ago, with 15 years of useful life remaining.
- **Maintenance Cost**: Low; $1,500 annually for general upkeep.
- **Issues**: Panels are outdated, and the aging panels have decreased output by 20%.

Array C: Tracking system on the outskirts of the Industrial Zone.

- **Size**: 100 kW capacity
- **Efficiency**: 20%; produces an average of 120,000 kW per year.
- **Lifespan**: Installed 8 years ago, with 12 years of useful life remaining.
- **Maintenance Cost**: High; $7,500 annually due to mechanical repairs.
- **Issues**: Tracking system increases production by 15% compared to stationary arrays, but frequent mechanical failures disrupt optimal performance, increasing downtime.

Would improving Array A, B, or C have the most significant impact on Sunnyville's goals? Why?

Current Battery Storage Data

Sunnyville stores the clean energy generated by its solar arrays and other systems in three locations. Your team's findings on each are below.

Battery Bank 1 (Lithium-Ion): Near Array A, serving Town Hall and surrounding businesses.

- **Capacity**: 12 kWh
- **Efficiency**: 90%; Reliable storage.
- **Lifespan**: Installed 8 years ago, with 2-3 years remaining.
- **Maintenance Cost**: Low; $500 annually.
- **Issues**: System will need to be replaced soon to maintain storage capacity and reliability.

Battery Bank 2 (Lead-Acid): Adjacent to Array B, supporting residential neighborhoods and the school.

- **Capacity**: 8 kWh
- **Efficiency**: 75%; Suffers from frequent downtime during peak demand periods.
- **Lifespan**: Installed 5 years ago, with 5 years remaining.
- **Maintenance Cost**: Moderate; $1,000 annually.
- **Issues**: Insufficient capacity for high-demand periods and frequent maintenance requirements reduce cost-effectiveness.

Battery Bank 3 (Saltwater): Near Array C, supporting the industrial zone.

- **Capacity**: 4 kWh
- **Efficiency**: 70%; Environmentally friendly but offers minimal storage capacity.
- **Lifespan**: Installed 6 years ago, with 4 years remaining.
- **Maintenance Cost**: Low; $250 annually.
- **Issues**: Bank's low capacity limits its usefulness during power outages or peak demand for the industrial zone.

Would improving bank 1, 2, or 3 have the most significant impact on Sunnyville's goals? Why?:

Recommendations Planning

After conducting the feasibility study and reviewing your collected data, your team has identified several possible upgrades and improvements for Sunnyville's system. Work with your group to recommend improvements for Sunnyville that will significantly impact the Town Council's goals and fit within their constraints.

Quick Reference Table for Upgrade Options

Upgrade	Cost	Considerations	Disruptions
Replace Panels on Array A (Rooftop)	$75,000	Increases overall capacity	Temporary restrictions to roof access during panel installation
Reduce shading by Array A (Rooftop)	$15,000	More cost effective than replacing panels; lower impact on efficiency	May involve tree trimming or building modifications to nearby structures
Replace Panels on Array B (Ground)	$95,000	Increases energy output	Area around the ground system will be closed during installation, potentially affecting park use
Upgrade Array B to a New Tracking System	$120,000	Improves energy production by 15-20%; better efficiency in low sunlight conditions	Short-term downtime for Array B during system upgrades
Replace Tracking System on Array C (Tracking)	$60,000	Improves efficiency and reduces maintenance costs	Short downtime for industrial area during system replacement
Switch Array C to a Fixed Ground-Based System	$75,000	Reduces maintenance costs; sacrifices some energy production efficiency	Temporary disruption to industrial zone power supply during installation
Replace Battery Bank 1 with new Lithium-Ion Batteries	$20,000	Replacement is critical to maintain backup storage	Minimal; can integrate seamlessly into existing system
Replace Battery Bank 2 with new Lead-Acid Batteries	$25,000	Would help address maintenance and reliability concerns	Short-term downtime for connected residential areas during replacement
Replace Battery Bank 3 with new Saltwater Batteries	$13,000	Eco-friendly option but with limited scalability	Minimal; replacement is a straightforward swap of components

Quick Reference Table for Expansion Options

Expansion	Cost	Considerations	Disruptions
Add a new Rooftop Solar Array (40 kW)	$80,000	Increases energy generation capacity for residential areas; requires suitable roof space	Potential temporary access restrictions to rooftop during installation
Install a new Ground-Based Array (60 kW)	$100,000	Expands renewable energy production; requires available open space	May require clearing land or reconfiguring park or open land usage
Add Battery Bank 4 (Lithium-Ion, 12 kWh)	$30,000	Increases backup capacity and reliability for emergency situations	Minimal; additional space needed for installation
Expand Battery Bank 1 with New Modules (+8 kWh)	$18,000	Cost-effective way to boost capacity with existing infrastructure	None; designed to integrate into the current system
Install Advanced Energy Management System	$50,000	Optimizes energy flow, minimizes losses, and improves overall efficiency	None; implementation is software-based with minimal physical disruptions
Add community solar subscriptions	$10,000 setup cost; 5,000/year support	Engages more community members to participate in solar energy	None; primarily an administrative and outreach effort
Install new High-Capacity Battery Bank 5 (24 kWh)	$45,000	Improve storage for peak demand; ensure reliability during outages	None; can replace one of the older banks directly

Define the Problem: What specific issues or opportunities have you identified?

Consider Constraints: What are the limits and challenges?

Which improvements align most closely with Sunnyville's goals?

What specific upgrades or improvements could address the identified issues?

Which potential solutions would you prioritize? Why?:

How would these changes improve performance and align with the town's goals?: