Innovation and the Future of Climate-Tech

Teacher Manual: Lesson 9

Essential Question (AKA "The Big Question")

How do innovation and creative thinking help us reach our climate goals in Massachusetts?

Learning Objectives. Students will be able to:

1. Identify examples of how innovation has advanced Massachusetts's climate solutions
2. Identify and describe innovations that will accelerate the creation of new solutions to climate change
3. Describe how research and design contribute to innovation in climate solutions.

Lesson Summary

Today's lesson will explore real-world examples of creative solutions to climate challenges and how innovation drives the development of climate solutions, especially here in Massachusetts. Students will begin thinking about how technological innovation shapes the future of clean energy. Notably, innovation isn't always about creating something new. Often, it's about adapting something in a new way.

Technology referenced in this lesson

- High-Performance Buildings
- Electric Vehicles
- Offshore Wind Power
- Low-Carbon Steel & Cement
- Long-Duration Batteries

Careers referenced in this lesson:

[No careers are specifically referenced in this lesson.]

Agenda	Timing	PPT Slide	
Opening Activity	5 minutes	2–4	**Pre-lesson**
Present Agenda & learning objectives	5 minutes	5–7	
Direct Instruction Video Technology introduced Careers introduced	20 minutes	8–14	
Primary Learning Activity Partner or small group work Reinforce what was learned	20 minutes	15	
Closing Review learning objectives Closing activity Reflection	5 minutes	16-18	
Extension			
Handouts			
TOTAL TIME	**55 mins**		

Preparation

- Read Student Presentation Deck (PPT)
- Watch video(s) included in Student Presentation Deck (Most are available on the MassCEC YouTube channel)
- Print worksheets and handouts prior to 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 make sure they work as intended, and then review the content below.

Where to learn more about the lesson's content

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

- MassCEC / Funding / Technology to Market
  A look at how MassCEC incentivizes and funds new greenhouse gas reduction technologies and the innovative companies that bring them to market.
- U.S. DOE / Office of Energy Efficiency & Renewable Energy / Clean Energy Innovation
  How the federal government directly supports and inspires climate-tech innovation.

- Top Climate Tech Trends & Innovations in 2024 and Beyond
  Business news article published on climateinsider.com

Overview and Opening Activity (10 mins)

Materials & Resources

- Slide Deck
- Worksheets

Opening Activity. Get students thinking and talking right away.

Activity Objective: Highlight how innovation drives progress and adaptability; emphasize that innovation extends beyond its original purpose.

ANIMATED - Wait to click to reveal the image as an additional clue. Then wait to reveal the answer.

Background: Often, great innovations come from applying existing ideas in new ways. Many technologies we use today may have first been invented for something entirely different. Give students the chance to identify three of these essential technological innovations based on their origins.

Instructions

- Read the clues for the first innovation and ask students to call out their guesses.
- Click to reveal the image as the final clue.
- After students share their final guesses and their explanations for their thinking, click again to reveal the answer.

Answer 1 of 3: The steam engine

- The steam engine was one of the earliest machines to convert energy to mechanical power.
- Over time, it has been used to power factories, trains, ships, etc.
- The steam engine made the Industrial Revolution possible
- The turbine design is still used today in modern steam-based power plants, including biomass and geothermal energy plants, which are a type of renewable energy power plant.

Answer 2 of 3: The LED, or Light Emitting Diode

- LEDs were invented to be an indicator light for electronics like tvs and radios; they were energy-efficient and didn't use much power themselves, so they could be incorporated into a device's design without requiring lots of additional power
- Today, LEDs are used everywhere. We use LED light bulbs, grow lights in greenhouses, and computer monitors or tv screens
- Because they are more energy-efficient than traditional light bulbs, they are an important part of lowering our electricity use in homes and buildings

Answer 3 of 3: The fuel cell (Specifically, the PEM (proton exchange membrane) fuel cell

- The basic concept was invented in the 19th century, but practical fuel cells weren't invented until NASA needed a reliable source of clean electricity and water in space.
- PEM fuel cells were used by astronauts on spacecraft like Gemini and Apollo.
- These fuel cells worked in space because they produced only water and electricity as by-products, with no other emissions.
- Today, these fuel cells are used in hydrogen-powered vehicles, such as fuel-cell electric cars, buses, and trains.
- They also provide reliable backup power for data centers, hospitals, and emergency services.

These technologies were created for a specific use but have been adapted over time for other applications, including clean energy uses.

Present the Agenda. Students should be gaining familiarity with the format:

- After the opening activity, students will learn new information. The main activity will ask students to work in groups to create an "Innovation Impact Map." The closing activity asks individual students to identify an unsolved, climate-related problem and a specific innovation that has propelled the Massachusetts energy transition.

Present the Big Question and Lesson Objectives (See top of page 1)

- After today's lesson, students should be able to discuss how different types of innovations can drive cleaner, more sustainable communities across Massachusetts and elsewhere.
- Keep this question in mind throughout today's lesson.

Possible discussion questions:

- What types of careers are closely related to or responsible for climate-tech innovation?
- Name another recent technological innovation that has helped propel Massachusetts toward its climate-related goals.

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 video *[TBD/Adept Materials]* (3-5 minutes) and follow it with a brief check-in to hear what students took away.

Video Debrief

- What does DQ like about her career?
- What does the specialized paint do?

Show the video *[TBD/Sublime Systems]* (3-5 minutes) and follow it with a brief check-in to hear what students took away.

Video Debrief

- What stood out to you?
- What part of the video inspired you the most?
- Is there anything you want to learn more about or try at your school?

Climate-Tech Innovation Showcase

Discussion Guidance

- This direct instruction section showcases four different examples of climate-tech innovation. Vehicle-to-Grid (V2G), Floating Wind Turbines, Low-Carbon Steel & Cement, and Long-Duration Batteries
- One goal should be to contrast the benefits of each innovation against the shortfalls of the technology it seeks to replace or improve upon.

Key points to emphasize:

- Vehicle-to-Grid (V2G)
    - V2G Technology allows EVs to store energy and send it back to the grid.
    - This can help stabilize the electricity supply.
    - Imagine if your car could power your home during a blackout!
    - In Massachusetts, V2G can support renewable energy because electric vehicles can store excess solar or wind power.
- Floating Wind Turbines
    - About two-thirds of the United States' offshore wind potential exists over bodies of water too deep for "fixed-bottom" wind turbine foundations secured to the sea floor.
    - Harnessing power over waters hundreds to thousands of feet deep requires floating offshore wind technology—turbines mounted to a floating foundation or platform moored to the seabed.
    - Floating offshore wind turbines can be placed in deep waters with more wind.
    - Because there is more wind, these turbines create more energy than traditional wind turbines on land or closer to shore.

    - This also allows them to be placed in more locations because they have more space.
    - In Massachusetts, offshore wind power projects like Vineyard Wind use fixed-bottom foundations. The development of floating foundation wind turbines will open additional areas for wind farm development, creating new options for offshore wind farms.
- Low-Carbon Steel & Cement
    - Cement and steel are essential for building almost anything—roads, buildings, bridges.
    - Their production generates a lot of carbon emissions.
    - New processes can make these necessary materials cleaner and more sustainable.
    - Companies in Massachusetts are pioneering these materials, helping to lower the carbon footprint of construction
    - Massachusetts-based Sublime Systems has developed a low-carbon alternative to typical building cement that reduces kiln emissions by 50 percent without changing the properties or chemistry of the cement.
- Long-Duration Batteries
    - Today, most battery systems designed to support the utility grid are sized to produce power for about four hours.
    - Long-duration batteries can store clean energy for extended periods, ensuring a reliable power supply.
    - This makes renewable energy more consistent and reliable

Anticipated student questions:

Does V2G shorten the life of an EV battery?

- Answer: With proper system controls and battery design, V2G technology has a relatively small effect on EV battery life. In many cases, V2G participation offers financial incentives from utilities or energy programs, potentially offsetting the minor battery wear. This trade-off makes V2G appealing for some EV owners despite the added battery usage.

Do floating wind turbines produce less electricity than other wind turbines?

- Answer: While floating wind turbines can face stability challenges, they are usually located in optimal, far-offshore wind zones, allowing them to produce electricity levels comparable to or higher than other types of wind turbines.

Primary Learning Activity (20 mins)

Materials

- Worksheets

Activity Objective: Imagine how climate innovations relate to challenges and questions and how they affect communities.

Students will work in groups to create an "Innovation Impact Map" or tree.

- We start with a question or a climate challenge. Students will select one challenge to focus on.
- Then comes the innovation that addresses that challenge, followed by its impacts, including benefits, challenges, and further innovations or technologies.

Instructions

- Divide students into groups. The worksheets provide guidance for completing this activity. Student groups should be small since this is a creative collaboration activity.
- In their groups, students will:
    - Identify the question or climate challenge they want to focus on as a group. Students should be prepared to share their innovation and three ways it will impact their community with the rest of the class.
    - Come up with an innovation to address that challenge. Students may select an existing innovation discussed or create something of their own!
    - Fill in the branches with the many ways this innovation could affect the community when implemented. Include benefits, but also consider things that could be disruptive or difficult. And include ideas you have about other ways this innovation could be applied, like with the steam engine or LED bulbs.
- Groups will have 12 minutes to work before presenting their maps/trees to the class. They will focus on 2-3 impacts they found most exciting or unexpected.

Debrief Discussion:

- Invite other groups to respond to one another's presentations with ideas for how the innovations could be combined with different technologies to have a more significant impact.
- Even small ideas can have a significant impact.
- Climate innovations are about finding solutions and discovering new ways to make our communities healthier and cleaner.

Summarize Key Takeaways:

1. Innovation drives clean energy progress
2. Historical technologies can have modern applications
3. Energy innovations create diverse career paths
4. Adaptability and curiosity fuel innovation

Differentiations & Adaptations - Learning Activity (If available)

For Students who need more examples: Provide a completed tree sample
Adaptation: Show students a fully completed innovation tree as an example. The tree could address a familiar climate challenge, like solar energy, with a challenge like fossil fuel dependency, the innovation of solar panels, and branches showing benefits like clean energy and reduced emissions.
Goal: Give students a clear model to reference, helping those who need more concrete examples to generate their own ideas and focus their thinking.

For Students who struggle with written expression: Allow for multimedia expression
Adaptation: Let students present their innovation tree ideas through multimedia formats, such as ahort video s or audio recordings rather than writing on their worksheets.
Goal: Support students who may have difficulty with written tasks, giving them an alternative way to share their creativity and understanding.

Takeaways and Closing Activity (5 mins)

Key Lesson Points

- Emphasize the role of innovation; highlight how historical and modern technologies contribute to today's clean energy solutions
- Reinforce the variety of career opportunities these innovations create and encourage students to think about the types of skills and interests that align with these roles
- Encourage curiosity; remind students that being open to learning and exploring new ideas is essential in clean energy fields where technology is continually evolving
- The energy field thrives on problem-solving and curiosity with constant advancements that respond to environmental needs and challenges

Closing Activity Materials

- Presentation/Slide Deck, slides
- Reflection journal

Closing Activity Objective: Every innovation begins with someone thinking, “there’s got to be a better way to do this.” Ask students to respond to these two prompts:

- Invite students to think of one climate-related problem or question that needs a solution. They do not need to have any idea what that solution could be!
- What is one climate-related innovation that has had a significant impact on Massachusetts’s energy transition?

Extensions - If learners are loving this topic and want more …

Design a Climate Innovation Advertisement
Prompt: Choose a real or fictional climate innovation and create an advertisement for it. Explain why this innovation is essential and how it can solve specific climate challenges. Present your ad as a poster, video, or audio ad.
Goal: Encourage students to think creatively about how to communicate the value of climate innovations to a broader audience, integrating marketing skills with climate knowledge.

Invent a Future-Focused Climate Technology
Prompt: Imagine a technology that could exist 20-50 years in the future to address a major climate challenge. Write a description of how it works, what problem it solves, and its potential benefits. Include a sketch or diagram to visualize your invention. Remember, you don’t have to be able to create the technology to envision it!
Goal: Push students to think creatively and futuristically, exploring possibilities for groundbreaking solutions to climate issues.

Host a Mini Innovation Expo
Prompt: Research an existing cutting-edge climate technology (e.g., carbon capture, algae biofuels, or energy-efficient desalination). Create a short presentation or exhibit to showcase how it works and its potential impact. Combine exhibits into a class “Climate Innovation Expo” where students can learn from each other.
Goal: Encourage deep exploration of existing technologies while fostering peer-to-peer learning in an interactive format.

Handouts - Group Activity

Climate Innovation Maps (Trees)

Instructions

Work with your group to complete your climate innovation map and identify as many potential effects of an innovation of your chosen innovation on your community as possible. You may choose an innovation discussed in class or something completely new. Consider benefits, disruptions or challenges, and additional applications. Use the prompts on the next page, and be prepared to share highlights of your map with the class.

Step 1: Identify a Climate Challenge

What is the problem you want to address?

Every innovation begins with a question or a challenge. Write a brief description of the challenge your group has selected at the top of your map. Some examples include:

- Reducing carbon emissions in transportation
- Improving energy efficiency in buildings
- Managing waste and recycling more effectively

Step 2: Choose an Innovation

What innovation will you focus on?

Write the name and a brief description of your group's chosen innovation. The innovation should somehow address the climate challenge from Step 1. Some examples include:

- Electric vehicles (EVs)
- Vertical farming
- Bio-based packaging

Step 3: Explore the Impacts

Create branches on your map or tree that explore these categories:

1. Benefits: What are the positive effects of implementing this innovation?
2. Disruptions or Challenges: What difficulties or unintended consequences might occur?
3. Other Applications: How else could this innovation be used to address related challenges?

Climate Innovation Map

Challenge and description:

Innovation and description:

Benefits	Challenges	Other Applications