Co-funded by the European Union

# EN-ROADS
# Climate Scenarios

## TEACHER'S GUIDE & REGIONAL ROLE-PLAY SCENARIOS

A classroom resource for exploring climate policy choices and visualising possible futures.

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## About EN-ROADS

EN-ROADS is an interactive climate simulator developed by Climate Interactive and MIT Sloan. It allows students and educators to explore how changes in energy, transport, buildings, industry, land use and other policies influence projected global warming. Students can adjust policy controls, observe the model's results and discuss the trade-offs between different approaches.

Simulator: https://enroads.climateinteractive.org

The following materials reproduce the supplied teacher instructions, five scenarios and student worksheets. Scenario outcomes and numerical examples are retained as provided; they are illustrative and may differ from current simulator results.

# TEACHER INSTRUCTIONS

### 1. Introduction (10 minutes)

As the teacher, explain:

- Today, students will explore what the world might look like in the future if we change (or do not change) how we produce and use energy.
- You will use the EN-ROADS simulator, a simple interactive website: https://enroads.climateinteractive.org.

You might say:

"This tool shows what happens to the climate if we continue living as we do today, or if we begin investing more in renewable energy."

### 2. Students Choose (or Are Assigned) a Scenario

For example, your group is assigned Scenario 1 – Business as Usual (BAU).

This means:

- Nothing changes – we continue using large amounts of coal, oil and gas.
- Governments do not introduce new environmental protection laws.
- There is no investment in renewable energy.

Students hardly move any controls in the simulator – everything stays at its initial settings.

### 3. Observe the Results in EN-ROADS (15 minutes)

When students open EN-ROADS, the simulator already displays the baseline ("Business as Usual") scenario. The graphs may show, for example:

- A temperature increase of approximately +3.3°C by 2100.
- Increasing $CO_2$ concentration.
- Continuously increasing emissions.

You can ask:

- "How much has the temperature increased?"
- "What is happening to $CO_2$ emissions?"
- "How could this affect people and nature?"

### 4. Create a Map of the Future (30–40 minutes)

Students now use paper or a digital tool (e.g., Canva, Google Jamboard or a poster board).

Their task is to draw what the world might look like in 2100 if nothing changes.

On their maps, they should mark the climate consequences of the scenario:

| Element | Examples of what students can draw or mark |
|---|---|
| Temperature | Mark the hottest areas in red (Africa, the Middle East, Southern Europe). |
| Water | Areas that may be flooded (e.g., parts of coastlines and islands). |
| Agriculture | Droughts and failed crops. |
| Extreme weather | Symbols for hurricanes and floods. |
| Animals | Species disappearing in the Arctic and changing habitats. |
| People | Migration, overcrowded cities and poverty. |

### 5. Presentation (10–15 minutes)

Each group (if there are several) presents its scenario and explains:

1. What they changed in the simulator.
2. How they used the results to predict what might happen.
3. What they showed on their map and why.

Questions you can ask:

1. “What would life be like in your scenario?”
2. “What would happen if we changed just one factor – for example, switched to renewable energy?”

### 6. Discussion and Reflection (5–10 minutes)

Together, discuss:

1. Which scenario is the worst (e.g., BAU).
2. Which offers hope (e.g., Global Cooperation).
3. What can be done today to move closer to the best outcome.

### In Brief: What Students Do in "Business as Usual"

1. Open EN-ROADS (without making changes).
2. Observe the results (temperature, emissions, $CO_2$).
3. Record the numbers and effects.
4. Draw a map of the future world (2100).
5. Present their scenario.

## Step 1: The Teacher Shows the Results in EN-ROADS

When students open EN-ROADS, the tool automatically displays the baseline ("Business as Usual") scenario. They see graphs at the bottom of the screen, but the numbers (°C, $GtCO_2$...) can feel abstract.

As the teacher, explain what these results mean in everyday life using the table below:

| EN-ROADS Data | What It Means for the World (Explain to Students) |
|---|---|
| +3.3°C global warming by 2100 | Many more heatwaves, wildfires, droughts and floods. |
| $CO_2$ continues to rise | Air becomes more polluted; oceans become more acidic. |
| Loss of ice and snow | Glaciers disappear; polar bears lose their habitat. |
| Sea level rise | Coastal cities (e.g., Venice, Rotterdam, Dhaka) are flooded. |
| Less food | Droughts reduce crop yields and food prices rise. |
| Climate migration | People move away from affected areas (Africa, Asia). |

### Example for the "Business as Usual" Scenario (What You Can Say)

"If we change nothing, Earth's temperature will rise by more than three and a half degrees by the end of the century. This means some parts of Africa and Asia will turn into deserts, the Mediterranean will experience many more wildfires, and sea levels will rise enough to submerge parts of coasts and islands. In northern areas (Canada and Russia), there may be more arable land – but globally many people will lose their homes."

Now students have concrete ideas about what to illustrate:

1. Red zones = very hot areas
2. Blue = flooded coastlines
3. Yellow = drought-affected areas
4. Green = areas with more vegetation

### What the Students' Map Looks Like

Students can use:

1. A paper world map template (e.g., a printed outline map).
2. A digital tool (Google Drawings, Canva, Jamboard).

On the map, they mark:

1. Areas most affected by heat – e.g., North Africa and South Asia.
2. Areas affected by flooding – e.g., the coasts of Bangladesh and the Netherlands.
3. Areas with wildfires and droughts – Southern Europe and Australia.
4. Migration flows – arrows showing how people move.

Finally, they write a short text:

"In our Business as Usual world, the temperature is +3.6 °C higher. Many coastal cities are flooded, and droughts cause food shortages."

### The Order of Activities Is:

1. Show students what their scenario means in EN-ROADS.
2. Together, translate the numbers into real-world consequences (using the table above).
3. Students record their findings on the worksheet.
4. They draw a map using that information.
5. They present their scenario.

## WORKSHEET – MAP OF THE FUTURE: CLIMATE CHANGE SCENARIOS

Activity Goal:

Using EN-ROADS, we will explore how different decisions about energy, forests and the economy affect the future of our planet. Each group represents one scenario and creates a world map of 2100 showing the climate consequences.

### 1. Scenario Information

| Scenario Name | Short Description (What Happens in the World) | Global Temperature Rise by 2100 | Changes in $CO_2$ Emissions | Main Changes in Nature and Society |
|---|---|---|---|---|
| 1. Business as Usual | The world continues using coal, oil and gas. No new environmental protection laws. | +3.6°C | $CO_2$ continues rising | Frequent droughts, wildfires, heatwaves, floods, glacier loss and migration. |
| 2. Renewable Revolution | Solar and wind power increase; coal and oil use decreases. | +2.2°C | $CO_2$ slowly declines | Cleaner air, slower ice melt and partial ecosystem recovery. |
| 3. Technology and Efficiency | Electric vehicles, more efficient buildings and carbon capture are introduced. | +1.8°C | $CO_2$ is significantly reduced | Less pollution, smart cities and more stable weather. |
| 4. Global Cooperation (Paris Goal) | All countries cooperate to reduce emissions and plant forests. | +1.5°C | $CO_2$ falls dramatically | Healthier ecosystems, a more stable climate and fewer disasters. |
| 5. Delayed Action | Measures begin only after 2040. | +2.8°C | $CO_2$ rises and then slowly declines | Chaotic changes, energy shortages and population displacement. |

### 2. Analyse Your Scenario (Complete as a Group)

| Question | Answer |
|---|---|
| Which scenario did you choose? | |
| What is the temperature increase in your scenario? | |
| How does the amount of $CO_2$ in the atmosphere change? | |
| What are the three most important consequences for nature? | |

| Question | Answer |
|---|---|
| What are two consequences for people and society? | |
| Which regions of the world are most affected? | |
| Is there anything positive in your scenario? | |
| What could we change to improve the future? | |

### 3. Create a Map of the Future

1. On a world map outline, mark the areas most affected by change: very hot regions, flooded coastlines, drought areas, hurricanes and new forests.
2. Add symbols or colours to show the consequences.
3. Write a short description (2–3 sentences):

“In our scenario (‘Business as Usual’), the temperature rises by +3.6°C. Many coastal areas are submerged, and droughts destroy crops in Africa and Asia.”

### 4. Group Presentation

1. Show your map.
2. Explain which data you used.
3. Answer the question: Would you like to live in this world? If not, what would you change?

### Conclusion

All scenarios together show that our decisions today shape tomorrow’s world. The goal is to understand that small changes in energy, consumption and behaviour can have a major impact on our planet’s future.

# SCENARIO 1 · BUSINESS AS USUAL

When students open EN-Roads, the tool automatically shows the baseline scenario ("Business as Usual"). At the bottom of the screen, they see graphs — but the numbers are abstract to them (°C, $GtCO_2$, etc.). That's why, as the teacher, you translate the results into everyday consequences using this table:

| EN-Roads Data | What It Means for the World (Explain to Students) |
|---|---|
| 🌡️ +3.3 °C global warming by 2100 | Many more heating waves, wildfires, droughts, and floods. |
| 📈 $CO_2$ continues to rise | Air becomes more polluted, oceans acidify. |
| 🧊 Loss of ice and snow | Glaciers disappear; polar bears lose their habitat. |
| 🌊 Sea level rise | Coastal cities (e.g., Venice, Rotterdam, Dhaka) are flooded. |
| 🌾 Less food | Droughts reduce yields, food prices rise. |
| 👥 Climate migration | People move from affected regions (Africa, Asia). |

## Example of the Business-as-Usual Scenario

The Earth continues to use coal, oil, and gas as it does today. There are no major changes in behavior or policy. If nothing changes, the planet's temperature will rise by more than 3.5°C by the end of the century. $CO_2$ emissions keep increasing (over 60 Gt per year by 2070). Sea level rise: 0.7–1 m by the end of the century. Ice and snow: The Arctic could be ice-free in summer by around 2050. Climate patterns: extreme heatwaves, powerful floods, and long droughts.

This means that some parts of Africa and Asia will turn into deserts, the Mediterranean will experience many more wildfires, and sea levels will rise enough to submerge parts of coastlines and islands. In northern regions (Canada, Russia), there might be more arable land — but globally, many people will lose their homes.

## What Students Can Show

- 🔴 Red zones = very hot areas
- 💧 Blue = flooded coastlines
- 🌾 Yellow = drought-stricken regions
- 🌲 Green = areas with more vegetation

## What the Map Looks Like

Students can use a paper world map template.

On the map, they mark:

**Europe** – Southern Europe (Spain, Italy, Croatia, Greece) suffers from long droughts and wildfires. Northern Europe has more rain and floods.

**Africa** – Sub-Saharan areas turn into deserts; food and water shortages occur.

**Asia** – South and Southeast Asia face floods and hurricanes; Bangladesh and Indonesia lose coastal cities.

**North America** – Wildfires in California and Canada; destructive storms on the East Coast.

**South America** – The Amazon turns into savanna.

**Oceans and islands** – Small island nations (Kiribati, Maldives) disappear under the sea.

**Migration flows** – Arrows showing the movement of people.

## Consequences

- Loss of agricultural land
- Millions of climate refugees
- Rising prices of food and water
- Extinction of numerous plant and animal species

# SCENARIO 2 · RENEWABLE REVOLUTION

When students open EN-Roads, the tool automatically shows the baseline scenario ("Business as Usual"). At the bottom of the screen, they see graphs — but the numbers are abstract to them (°C, $GtCO_2$, etc.). That's why, as the teacher, you translate the results into everyday consequences using this table:

| EN-Roads Data | What It Means for the World (Explain to Students) |
|---|---|
| 🌡️ +3.3 °C global warming by 2100 | Many more heat waves, wildfires, droughts, and floods. |
| 📈 $CO_2$ continues to rise | Air becomes more polluted, oceans acidify. |
| 🧊 Loss of ice and snow | Glaciers disappear, polar bears lose their habitat. |
| 🌊 Sea level rise | Coastal cities (e.g., Venice, Rotterdam, Dhaka) are flooded. |
| 🌾 Less food | Droughts reduce yields, food prices rise. |
| 👥 Climate migration | People move from affected regions (Africa, Asia). |

## Example of the Scenario: Renewable Revolution

The world shifts to renewable energy sources (wind, solar, hydro), but oil is still partially used.

The world is shifting to renewable energy sources such as solar, wind, and hydro power, but oil is still partly in use.
Thanks to greater investment in clean technologies and changes in behavior, $CO_2$ emissions begin to decline after 2040.
Global warming slows down, and the temperature rises by about 2.2 °C by the end of the century.
Sea levels rise by around 0.5 m, while air quality gradually improves, and forests partially recover.

This means that floods and droughts become less frequent, though they still occur in some regions.
In Africa and Asia, living conditions improve due to the expansion of solar energy, while Europe and North America experience cleaner air and reduced dependence on fossil fuels.
However, climate change is not completely stopped, and some areas of the world still face extreme weather events.

🔥 Global warming: +2.2 °C
⚪ $CO_2$ emissions: decrease after 2040
🌊 Sea level rise: around 0.5 m
🌳 Green growth: forests recover and air pollution decreases.

## What Students Can Show

🔴 Red zones = very hot areas
💧 Blue = flooded coastlines
🌾 Yellow = drought-stricken regions
🌲 Green = areas with more vegetation

## What the Map Looks Like

Students can use a paper world map template.

On the map, they mark:

| Region | Change |
|---|---|
| Europe | Less air pollution, but droughts remain a problem in southern countries. |
| Africa | Increased use of solar energy, but droughts still threaten the Sahel. |
| Asia | China and India invest in renewables, reducing smog. |
| North America | More wind and solar farms; less air pollution. |
| Oceans | Rising temperatures continue to threaten coral reefs. |

## Consequences

- Fewer respiratory diseases due to cleaner air
- Greater energy independence for countries
- Partial recovery of forests and ecosystems
- Occasional floods and droughts still occur

# SCENARIO 3 · TECHNOLOGY AND EFFICIENCY

When students open EN-Roads, the tool automatically shows the baseline scenario ("Business as Usual"). At the bottom of the screen, they see graphs — but the numbers are abstract to them (°C, $GtCO_2$, etc.). That's why, as the teacher, you translate the results into everyday consequences using this table:

| EN-Roads Data | What It Means for the World (Explain to Students) |
|---|---|
| 🌡️ +3.3 °C global warming by 2100 | Many more heating waves, wildfires, droughts, and floods. |
| 📈 $CO_2$ continues to rise | Air becomes more polluted, oceans acidify. |
| 🧊 Loss of ice and snow | Glaciers disappear; polar bears lose their habitat. |
| 🌊 Sea level rise | Coastal cities (e.g., Venice, Rotterdam, Dhaka) are flooded. |
| 🌾 Less food | Droughts reduce yields, food prices rise. |
| 👥 Climate migration | People move from affected regions (Africa, Asia). |

## Example of the Scenario: Technology and Efficiency

Countries invest in new technologies – electric vehicles, smart buildings, carbon capture, and waste reduction.

Countries invest in new technologies — electric vehicles, smart buildings, carbon capture systems, and waste reduction.
Thanks to these investments, greenhouse gas emissions drop sharply by 2050, and global warming slows to about 1.8 °C.
Sea levels rise between 0.3 and 0.5 m, while ice and snow begin to stabilize after 2060.
Air quality in cities improves, and energy production becomes more efficient and cleaner.

This means that floods, droughts, and wildfires become rarer, and cities grow greener and more livable.
In Europe and North America, the number of energy-efficient buildings increases, while Africa and Asia gain access to modern technologies.
However, the high costs of technological development remain a challenge for less wealthy countries.

🔥 Global warming: +1.8 °C
💨 $CO_2$ emissions: significantly reduced by 2050
🌊 Sea level rise: 0.3–0.5 m
🧊 Ice and snow: stabilize after 2060.

## What Students Can Show

🔴 Red zones = very hot areas
💧 Blue = flooded coastlines
🌾 Yellow = drought-stricken regions
🌲 Green = areas with more vegetation

## What the Map Looks Like

Students can use a paper world map template.

On the map, they mark:

| Region | Change |
|---|---|
| Europe | Cities become energy-efficient, more green spaces. |
| Africa | Better access to clean energy, but heat remains a problem. |
| Asia | Tech hubs reduce emissions, but climate risks remain high in river deltas. |
| North America | Electric transport and carbon capture; emission decline. |
| Oceans | Slower temperature rise, reduced acidification. |

## Consequences

- More stable weather patterns
- Fewer floods and wildfires
- Better air quality and urban living conditions
- High technology costs

# SCENARIO 4 · GLOBAL COOPERATION

When students open EN-Roads, the tool automatically displays the default scenario ("Business as Usual"). At the bottom of the screen, they can see graphs — but the numbers are abstract to them (°C, $CO_2$...). That's why, as a teacher, you translate these results into everyday consequences using this table:

| EN-Roads Data | What It Means for the World (explain to students) |
|---|---|
| 🌡️ +3.3 °C global warming by 2100 | Many more heating waves, wildfires, droughts, and floods. |
| 📈 $CO_2$ keeps rising | The air becomes more polluted, oceans acidify. |
| 🧊 Loss of ice and snow | Glaciers disappear; polar bears lose their habitat. |
| 🌊 Rising sea levels | Coastal cities (e.g. Venice, Rotterdam, Dhaka) are flooded. |
| 🌾 Less food | Droughts reduce crop yields, food prices increase. |
| 👥 Climate migration | People move away from affected areas (Africa, Asia). |

## Example Scenario: Global Cooperation

All countries work together and fully implement the Paris Agreement — reducing emissions, planting trees, and switching to clean and renewable energy sources.
Governments, businesses, and citizens cooperate to protect the environment and promote sustainable development.
As a result, $CO_2$ emissions drop rapidly, reaching almost zero by 2050.

🔥 Global warming: limited to about +1.5 °C by 2100
🌫️ $CO_2$ emissions: fall close to zero by 2050
🌊 Sea level rise: around 0.2–0.3 m
🌳 Ecosystems: many recovers and become more resilient

Because of strong global action, the number of floods, wildfires, and droughts decreases significantly.
Europe and North America see cleaner air and stable weather conditions.
In Africa and Asia, large reforestation projects and investments in solar energy help reduce poverty and improve quality of life.
South America restores the Amazon rainforest and protects biodiversity.

Thanks to global cooperation, the world becomes safer, healthier, and more sustainable — with more renewable energy, green jobs, and stable food production.

## What Students Can Show

- 🔴 Red zones = very hot areas
- 💧 Blue = flooded coasts
- 🌾 Yellow = dry regions
- 🌲 Green = areas with more vegetation

## What the map looks like

Students can use a **paper template of the world map**.
On the map, they mark:

| Region | Change |
|---|---|
| **Europe** | Reforestation and sustainable agriculture; milder winters, stable weather. |
| **Africa** | Solar farms, reforestation projects, poverty reduction. |
| **Asia** | Cleaner rivers and air; less pollution. |
| **North America** | Fewer extreme weather events. |
| **South America** | Amazon restoration and biodiversity protection. |

## Consequences

- Stable food production
- More renewable energy and green jobs
- Healthier living conditions
- Fewer ecological disasters

# SCENARIO 5 · DELAYED ACTION

When students open EN-Roads, the tool automatically displays the default scenario ("Business as Usual"). At the bottom of the screen, they can see graphs — but for many students, the numbers are abstract (°C, $GtCO_2$...). That's why you, as the teacher, translate the results into everyday consequences using this table:

| EN-Roads Data | What It Means for the World (explain to students) |
|---|---|
| 🌡️ +3.3 °C global warming by 2100 | Many more heating waves, wildfires, droughts, and floods. |
| 📈 $CO_2$ keeps rising | Air becomes more polluted, oceans acidify. |
| 🧊 Loss of ice and snow | Glaciers disappear; polar bears lose their habitat. |
| 🌊 Rising sea levels | Coastal cities (e.g. Venice, Rotterdam, Dhaka) are flooded. |
| 🌾 Less food | Droughts reduce crop yields, food prices increase. |
| 👥 Climate migration | People move away from affected regions (Africa, Asia). |

## Example Scenario: Delayed Action

Countries take no real action until 2040, and then suddenly try to reduce emissions as fast as possible. However, it is too late to prevent major changes to the climate system.

- 🔥 Global warming: +2.8 °C by 2100
- 🏭 $CO_2$ emissions: rise until 2040, then fall sharply
- 🌊 Sea level rise: around 0.6 m
- 🧊 Ice: lost before partial recovery begins

As a result, sea levels continue to rise, and ice sheets and glaciers shrink drastically.
Floods, heatwaves, and wildfires become more frequent and destructive, especially in coastal and tropical regions.

By the second half of the century, air quality improves slightly, and some ecosystems begin to recover — but many areas have already suffered irreversible damage.

In Europe, southern regions face wildfires and droughts, while the north experiences more floods.
Africa struggles with food shortages and migration caused by desertification and heat.
Asia faces stronger monsoons, deadly heatwaves, and habitat loss.
North America experiences violent storms and rising temperatures, while the oceans continue to acidify, leading to coral reef decline.

This delayed global response leads to hunger, poverty, and climate-related conflicts in the most affected areas.
Although some recovery begins toward the end of the century, the world faces a long and difficult path to restore balance in nature and society.

## What students can show

- 🔴 **Red zones** = very hot areas
- 💧 **Blue** = flooded coasts
- 🌾 **Yellow** = dry, drought-affected regions
- 🌲 **Green** = areas with more vegetation

## What their map looks like

Students can use a paper map template.

On the map, they mark the following:

| Region | Change |
|---|---|
| **Europe** | Wildfires in the south, floods in the north. |
| **Africa** | Crop loss and migration toward Europe. |
| **Asia** | Floods and heatwaves; loss of habitats. |
| **North America** | Strong storms and higher temperatures. |
| **Oceans** | Acidification; coral reefs dying. |

## Consequences

- Hunger and poverty in affected regions
- Loss of homes and infrastructure along the coasts
- Chaotic migration and social conflicts
- Slow and incomplete recovery of nature

# STUDENT WORKSHEET

## WORKSHEET – TESTING CLIMATE SCENARIOS IN THE EN-ROADS SIMULATOR

### Activity Goal

Using the EN-Roads simulator, we will explore how different decisions in energy, transport, and environmental protection can change the future of our planet.
At the end, we will compare the actual results with those we predicted on our *map of the future*.

### 1. Group Information

| **Group / Student Name:** | |
|---|---|
| **Selected Scenario:** | ☐ Business as Usual<br>☐ Renewable Revolution<br>☐ Technology and Efficiency<br>☐ Global Cooperation<br>☐ Delayed Action |
| **Short Description of the Scenario:** | |

## 2. EN-Roads Simulator Settings

Fill in the table to show how you would change each factor in the simulator (by moving the sliders)

| | EN-Roads Factor | Change<br>Use these symbols:<br>decreased<br>increased<br>unchanged | Explanation<br>(What did you want to achieve?) |
|---|---|---|---|
| **Energy Supply** | **Coal** – Discourage or encourage coal mining and its use in power plants.<br>Coal is the most harmful fossil fuel in terms of carbon emissions and air pollution, causing serious health problems.<br>However, it remains a dominant global energy source because it is relatively cheap to extract and transport.<br>Carbon Capture and Storage (CCS) technology can retain some of the emissions from coal burning, but it is not yet widely used and faces implementation challenges | | |
| | **Oil** – Discourage or encourage drilling, refining, and use of oil for energy.<br>Oil is a fossil fuel widely used in cars, ships, and airplanes, as well as in industry, heating, and electricity generation.<br>Access to oil has been a cause of many conflicts, and oil spills threaten ecosystems and water resources. | | |
| | **Renewable Energy Sources** – Encourage or discourage the construction of solar panels, geothermal systems, and wind turbines.<br>Renewable energy includes wind, solar, geothermal, hydro, and other technologies that produce energy with little or no $CO_2$ or air pollution.<br>Note that nuclear energy and bioenergy are treated separately.<br>Hydrogen production from renewable sources and energy storage systems should also be supported to balance variable energy output. | | |
| | **Natural Gas** – Discourage or encourage drilling and burning of natural gas for energy.<br>Natural gas is a fossil fuel used for electricity | | |

| | | | |
|---|---|---|---|
| | generation, heating, and industry.<br>It releases carbon dioxide when burned (less than coal or oil), but methane leaks contribute heavily to warming.<br>Drilling requires large amounts of water and can cause environmental pollution.<br>CCS technology can reduce emissions but is not yet widely applied. | | |
| | **New Zero-Emission Energy Source** – Discover a completely new, cheap source of electricity that emits no greenhouse gases. This could include nuclear fusion, thorium-based fission, or small modular reactors (SMR).<br>However, every new energy source comes with unknown risks.<br>You must decide when this discovery occurs, its starting price compared to coal, and how quickly it becomes available worldwide. | | |
| | **Bioenergy** – Encourage or discourage the use of wood, waste, and crops to produce energy. These feedstocks produce energy when burned as solids (wood), liquids (ethanol), or gases (methane).<br>Some feedstocks can be sustainable, while others may be more harmful than coal.<br>Bioenergy combined with CCS (BECCS) could remove $CO_2$ from the atmosphere, but the technology is not yet widely used. | | |
| | **Carbon Price** – Set a global carbon price, making energy sources more expensive based on their $CO_2$ emissions, or introduce clean energy or emission efficiency standards.<br>Energy producers might pass these extra costs to consumers, so policies must be designed to minimize impacts on the poorest populations. | | |
| **Transport** | **Energy Efficiency** – Increase or decrease the energy efficiency of vehicles, ships, airplanes, and transport systems.<br>Efficiency measures include hybrid vehicles, expanded public transport, and low-energy travel options.<br>Improved efficiency can save money and improve public health. | | |

| | | | |
|---|---|---|---|
| | **Electrification** – Increase the use of electric cars, trucks, buses, and trains, as well as hydrogen-powered ships and airplanes. Using electric or hydrogen vehicles reduces greenhouse gas emissions only if the electricity or hydrogen comes from low-carbon sources such as solar and wind. | | |
| **Buildings and Industry** | **Energy Efficiency** – Increase or decrease the efficiency of buildings, appliances, and machines. This includes better insulation, reduced industrial energy use, and more efficient production systems. Improved efficiency saves money and improves health conditions indoors. | | |
| | **Electrification** – Increase the use of electricity or hydrogen instead of fuels like oil or gas in buildings, appliances, and heating systems. This reduces emissions and improves air quality only if the electricity or hydrogen comes from renewable sources. | | |
| **Growth** | **Population** – Assume higher or lower population growth. Although population trends are predictable, education for women and access to family planning can reduce fertility rates and slow population growth. | | |
| | **Economic Growth** – Assume higher or lower growth in goods production and services. Economic growth is measured by GDP per capita and drives energy consumption. Alternative models of well-being can meet human needs without continuous GDP growth. | | |
| **$CO_2$ Removal** | **Natural Methods** – Encourage reforestation, afforestation, and soil carbon storage through sustainable farming or biochar production. These methods remove $CO_2$ from the air and store it in plants and soil, but carbon can be re-released if land use changes or wildfires occur. | | |
| | **Technology** – Encourage the use of technologies that remove $CO_2$ from the atmosphere, such as direct air capture (DACCS) and enhanced mineralization. These solutions require large amounts of | | |

| | | | |
|---|---|---|---|
| | energy and funding.<br>CCS related to energy production is listed under coal, gas, and bioenergy categories. | | |
| **Other Greenhouse Gas Sources** | **Agricultural Emissions** – Change practices to reduce emissions in agriculture and food systems.<br>Methane ($CH_4$) comes from livestock and rice fields, while nitrous oxide ($N_2O$) comes from fertilizers and manure.<br>Better practices and diet shifts can lower emissions and reduce deforestation. | | |
| | **Waste and Leakage** – Change practices to reduce emissions from waste, energy, and industry.<br>Methane, nitrous oxide, $CO_2$, and fluorinated gases (HFCs, PFCs, $SF_6$) come from inefficient systems and leaks.<br>Improved waste management and industrial processes can reduce these emissions and improve efficiency. | | |
| | **Deforestation** – Encourage or discourage forest protection to change current deforestation and degradation trends.<br>Deforestation converts forest land to agriculture, while degradation is a temporary loss due to logging.<br>Both are driven by agricultural expansion and food demand. | | |

## 3. Simulator Results

| Indicator | Result (from the graph) | Comparison with Expectation |
|---|---|---|
| Global temperature increases by 2100 | | |
| $CO_2$ emissions in 2050 ($GtCO_2$) | | |
| Sea level rise (m) | | |
| Share of renewable energy (%) | | |
| Main energy source in 2100 | | |
| Impact on forests and agriculture | | |

## 4. Comparison with Your Map of the Future

| Are the simulator results similar to what you drew on your map? | |
|---|---|
| **Which world regions are more affected than you expected?** | |
| **Did you make any wrong assumptions?** | |
| **What would you change on your map after using the simulator?** | |

## 5. Discussion and Conclusions

- Which factors most effectively reduced global temperature in your experiment?
- Is there a single “magic solution,” or do we need multiple measures together?
- Which measures had the smallest impact, and why?
- What should the world do *immediately*, and what can wait?
- How does this experiment connect with your own life and habits (energy, transport, food)?

## Final Message

Our planet reacts to everything we do — from the energy we choose to the way we travel.
Every decision has consequences, but together we can create a world that is more stable, greener, and fairer for everyone