# LP 7 Climate Change Mitigation

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| # of Days | 4 | | |
| Prior Knowledge | | California English-Language Arts Content Standards | Reading 2.4<br>Writing 1.2, 1.4 |
| Lesson Objective | Students will be able to compare and contrast climate change mitigation strategies (macro and micro) in light of environmental, economic, political, and ethical impact. | Language Goals/Demands | Some expert groups may receive more than 3 wedge strategies or some home groups may have more than one individual from an expert group. |
| Lesson Assessment | Mitigation Performance Assessment: Group & Individual Products | Changes for Next Time | |
| California State Science Standard | | | |
| Materials Needed | Mitigation Diagram, Wedge Activity Packets including task cards, resource cards, and graphic organizers. Individual assessment prompt | What Worked Well | |

| Time | Learning Task or Activity | Method & Notes |
|---|---|---|
| **Day 1** | | |
| 15 min | Mitigation Strategies Introduction<br>- Define & illustrate mitigation wedges using diagrams<br>- Introduce the activity goals and procedures | LECTURE<br>See in 7.1.0 Mitigation Wedge Images |
| 35 min | Expert Group Jigsaw<br>- Students analyze 3-4 strategies to take back to their groups. | GROUP WORK<br>Use 7.1.1 Expert Groups Task Card #1<br>Use 7.1.2 Graphic Organizer<br>Use 7.1.3 Resource Cards<br>Use 7.1.4 Wedge Strategies Table |
| HW | Students review their organize to present to their home groups tomorrow | |
| | | |
| **Day 2** | | |
| 25 min | Home Group Sharing<br>- Experts divide into their home groups and give an overview from their graphic organizer about their particular strategies | GROUP WORK |

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|---|---|---|
| 25 min | Home Group Discussion<br>- Home groups choose 10 strategies based on the given parameters.<br>- Students discuss the rationale of picking specific strategies. | GROUP WORK<br>Use 7.2.1 Home Group Assignment (Task Card #2)<br>Use 7.2.2Band 7.2.2A Mitigation Wedge Pieces<br>Use 7.2.3 Mitigation Plan Worksheet |
| | | |
| **Day 3** | | |
| 15 min | Home Group Wedges Finalization<br>- Groups label the wedge strategies on their workseet that will be turned in and check over their group summary sheet | GROUP WORK<br><br>- Have extra worksheets available in case students need a blank sheet |
| 35 min | Mitigation Plan Analysis<br>- Teacher models how to analyze the perspective of a 'teacher' with the transportation conservation strategy. (Use 7.3.2)<br>- Students analyze their choices in light of two different perspectives on the Mitigation Plan Group Analysis. | GROUP WORK<br>Use 7.3.1 Mitigation Plan Group Analysis<br>See 7.3.2 Mitigation Plan Answers<br>- Groups should turn in a consensus analysis of their plan by the end of the period. |
| | | |
| **Day 4** | | |
| 20 min | Class Discussion of Plans<br>- Ask different groups to talk about how one wedge they chose affected one of the perspectives in each of the categories. | TEACHER-LED DISCUSSION |
| 30 min | Individual Assessment<br>- Given a standard mitigation plan, students will analyze the plan's consequences from two perspectives. | SUMMATIVE ASSESSMENT<br>Use 7.4 Mitigation Plan Individual Analysis |

Lesson Plan 7
Climate Change Mitigation

Teacher Guides/Student Worksheets:
7.0 Mitigation Activity Instructions and Teacher Guide
7.1.0 Mitigation Wedge Images
7.1.1 Expert Groups Task Card #1
7.1.2 Graphic Organizer
7.1.3 Resource Cards
7.1.4 Strategy Wedge Table
7.2.1 Home Group Assignment Task Card #2
7.2.2B Mitigation Wedge Pieces
7.2.2A Mitigation Wedge Pieces
7.2.3 Mitigation Plan Board
7.3.1 Mitigation Plan Group Assignment
7.3.2 Mitigation Plan Answers
7.4 Individual Assignment

## 7.0 Climate Change Mitigation Teacher Guide

### Activity Instructions and Teacher Guide

This activity was adapted from the Princeton University Environmental Institute's *Stabilization Wedge Game*, 2007. http://cmi.princeton.edu/wedges/

**Activity Goal**:
Students will be able to work in groups to create, analyze, and justify global mitigation plans in response to global warming. Students will learn about technologies currently available that can substantially cut carbon emissions.

Students will individually analyze a standardized plan as the final performance assessment.

**Materials:**
Group Activity:

Day 1: Task #1 Card, 1 set of Resource Cards, Graphic Organizer/student
Day 2: Task #2 Card, 1 set of colored wedges/group, 1 mitigation plan worksheet,
Day 3: scissor, tape or glue

Individual Assessment: 1 standardized mitigation plan/student, 1 analysis template/student

**Timeframe:**
3-4 50-minute periods

**Lesson Plan Overview:**

| Time | Task |
|---|---|
| Day 1:<br>25 min | Teacher-led Activity Introduction<br>- Connect to previous days' lesson plans<br>- Define and illustrate Mitigation Wedges<br>- Outline the Activity Goals & Procedures |
| 25 min | Student Jigsaw for Wedges – Expert Groups<br>- Students are divided into groups of 5. Each member is responsible for becoming an expert on 3 wedges. (Graphic Organizer) |
| Day 2:<br>25 min | Home Group Sharing<br>- Experts divide into their home groups and give an overview from their graphic organizer about their particular wedges |
| 25 min | Home Group Discussion<br>- Home groups choose 10 wedges based on the given parameters.<br>- Students discuss the rationale of picking specific wedges |

| | |
|---|---|
| Day 3:<br>15 min | Home Group Wedges Finalization<br>- Groups label the wedges on their final diagram that will be turned in and check over their group summary sheet |
| 35 min | Mitigation Plan Analysis<br>- Teacher models how to analyze the perspective of a teacher with the transportation conservation strategy.<br>- Students analyze their choices in light of two different perspectives on the Mitigation Plan Group Analysis. |
| Day 4:<br>20 min | Class Discussion of Plans |
| 30 min | Individual Assessment<br>- Given a standard mitigation plan, students will analyze the plan's consequences for a new perspective |

**Detailed Lesson Plan**

**Day 1**

Teacher's Notes for the Introduction

The following provides a general outline of information and figures that may be helpful in preparation for the group activity. This information should not be read directly, but rather linked to previous material learned through questioning and class discussion.

**Of greatest importance,** at the end of the introduction, students understand the purpose of the group activity, what a wedge represents, why they will choose 10 wedges, and the sequence of tasks that groups will use to accomplish the goal.

Activity Introduction

As we have learned, the Earth's climate is changing due mostly to human actions. In previous lessons, we examined the possible consequences of climate change and know that while humans must adapt their behavior to deal with the changes that are occurring, humans must also take active steps to mitigate future emissions.

Human-based greenhouse gas emissions are the major source for climate change. Unfortunately, worldwide greenhouse gas emissions, specifically carbon dioxide, increase each year. If this continues, with the same emission rate over the next 50 years, levels of carbon dioxide concentration would probably triple, reaching extremely dangerous levels.

As we know, carbon emissions result from many activities that help us work, travel, grow crops, and relax. Cutting emissions requires difficult choices that will inevitably have significant consequences for large groups of people. Difficult choices must be made.

The following diagram shows the carbon emission rate (tons of carbon emitted per year) (Figure 1 The orange line from 1955 to 2005 shows the actual emission rate for that time period. The slope of the line indicates that emission rates increased over this period. The black dashed line shows that if this trend continues, then by 2055, carbon dioxide concentration will be on a path to tripling the preindustrial level.

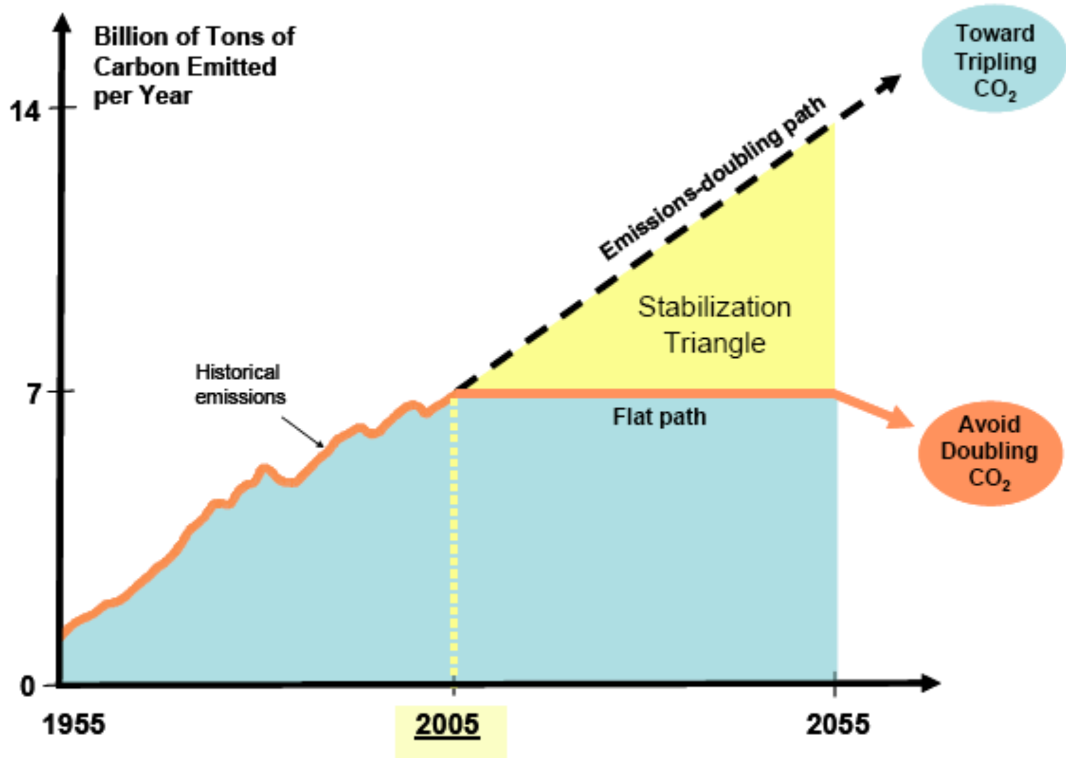



**Figure 1**

The flat orange line starting in 2005 shows the carbon emission rate for each year remaining at 7 billion tons per year over the next 50 years. However, this requires sacrifices to be made in terms of future growth in carbon emissions. That is represented by the yellow stabilization triangle. If the carbon emission rate stays constant, the amount of carbon equal to the yellow triangle <u>cannot</u> be emitted. Difficult choices must be made.

Unfortunately, just leveling off the carbon emission rate will not stop some warming. Figure 2 is the same nearly the same as figure 1 except for the declining blue line from 2005 to 2055. Maintaining a stable emissions rate at the 2005 level does not mean that the temperature will not change. In order to stop warming we must eliminate an even larger wedge as shown by the triangle that occupies the area between the solid orange line and the solid blue line.

Carbon emissions equal to the 2005 rate will still lead to increasing carbon dioxide concentrations in the atmosphere and further temperature increase. Atmospheric concentrations, not just emissions, need to be stabilized to stop temperature increase. That is why many people argue not for just maintaining the current level of emissions, but for decreasing them.  The dark blue line on the figure 2 represents decreased carbon emission rate.  To decrease emissions, even more carbon emissions must be eliminated represented by the larger yellow wedge.

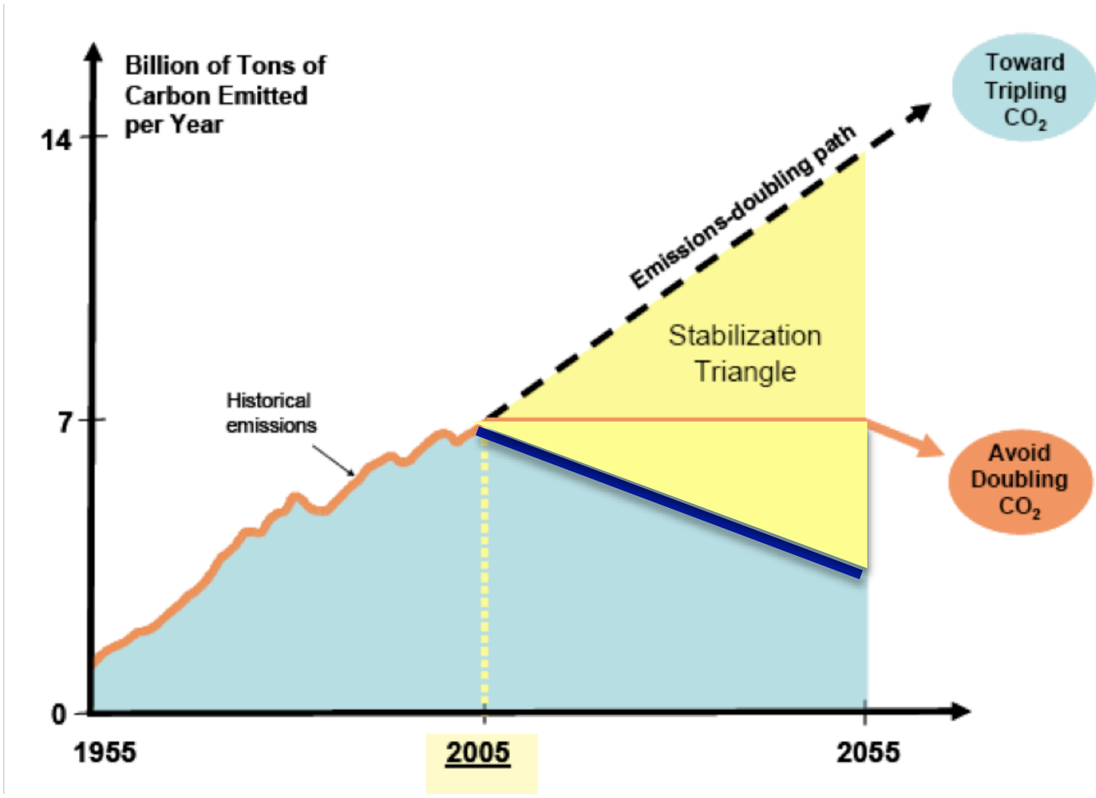



**Figure 2**

For this scenario, even more difficult decisions must be made.  And you will all have the opportunity to make some of those decisions in this class.

**Activity Procedures**

(Keep Figure 2 projected for students to see while describing the goals and procedures for the activity.

This class will divide up into groups of 5 that represent policymakers.  Your goal is to make decisions about what carbon emissions should be cut to reach the goal of reducing emissions equal to the yellow triangle in Figure 2.  To make it easier, this yellow triangle can be divided into 10 wedges (Figure 3).

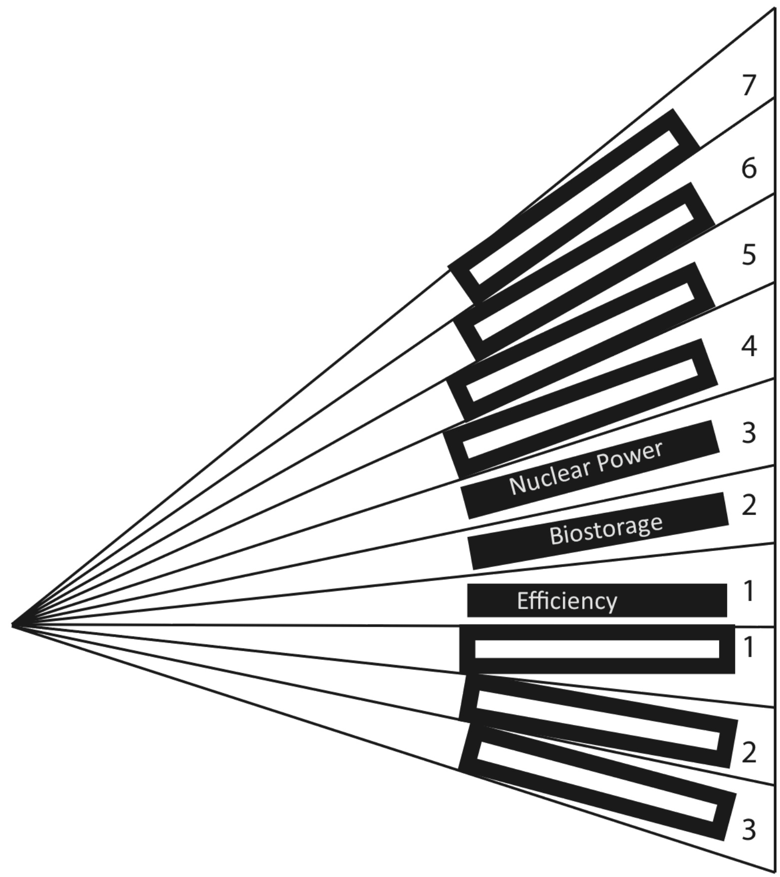



**Figure 3**

Each wedge represents 1 billion tons of carbon that will not be emitted.  Your group will receive information about 15 different ways to save a “wedge” of carbon emissions.  You may use some wedges twice.  Others you may choose not use at all, but in the end you must decide as a group what 10 wedges (10 billion tons of carbon emissions) are your mitigation plan.  Then you will justify your decisions on why you chose this group of wedges and the impact it will have on the human behavior, the economy, and life styles.  **There is no easy or “right” solution to the carbon and climate problem!**

## Mitigation Strategies Activity Instructions

**Activity Goal**: As a group, construct a mitigation triangle using 10 wedge strategies keeping in mind the economic (cost) and social (how does it affect people) impact.

**Guidelines**

The mitigation triangle can comprise any 10 wedge strategies and strategies can be used more than once. However, each of the strategies is labeled according to three categories: Heat, Electricity, and Transportation. Your group's mitigation triangle can only have a maximum of:

a. 6 Heat
b. 6 Electricity
c. 5 Transportation
d. 3 Biostorage

**Procedures**

1. Meet in Expert Jigsaw

Each group is comprised of 5 members. Each member of the groups is responsible for becoming an expert about 3 of the possible strategies. You will first meet in your "expert" groups to learn more about your 3 wedge strategies. You will make a chart listing positive and negative aspects of each strategy.

2. Meet in Home Groups

Next you will meet with your group members who learned about the other strategies. You will take turns briefly describing the wedge strategy and its positive and negative attributes.

3. Develop the Mitigation Plan

A. Your group will develop the mitigation plan. You will start by going around the group. Each member gets to suggest one strategy to for the plan that they would like to discuss. The group then discusses the wedge strategy and either includes it or does not include it in the plan. This continues until all 10 wedges are chosen.

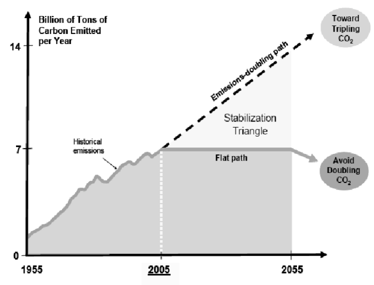
B. Strategies can be used for more than one wedge. Prior to pasting and labeling the wedges on the Mitigation Plan, the group should look at the plan as a whole and see if any changes need to be made.

4. Analyze the Mitigation Plan

Each group will receive a graphic organizer with which to analyze the Mitigation Plan. The group will discuss the questions and turn in only one copy of the analysis.

A list of states and land area might be helpful in land use comparisons.
http://www.worldatlas.com/aatlas/populations/usaareal.htm

## Carbon Emissions & Stabilization

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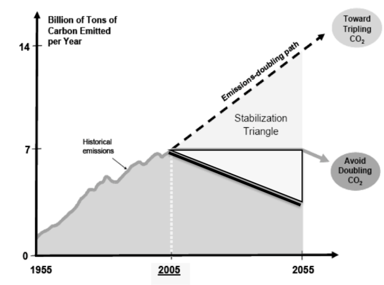
## Carbon Emissions & Stabilization

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**7.1.2**

**EXPERT GROUP TASK CARD #1**

Activity Goal: Become an expert on the mitigation strategies provided to your group.

Discuss the following questions and summarize your discussion on the chart provided.

- This particular strategy addresses one kind of problem that causes carbon dioxide ($CO_2$) emissions. Describe the problem.
- How can this strategy be implemented?
- What are the effects and consequences of implementing this strategy? Think about social, political and economic effects both positive and negative.

Each person must complete their own chart. You will become an expert on the strategies explored in your group. You will share your expertise in your next group.

7.1.2 Graphic Organizer Name

| Strategy and Category | Problems Addressed | Implementation | Effects (social, economic, political)<br>positive, negative, unintended consequences |
| --- | --- | --- | --- |
| | | | |
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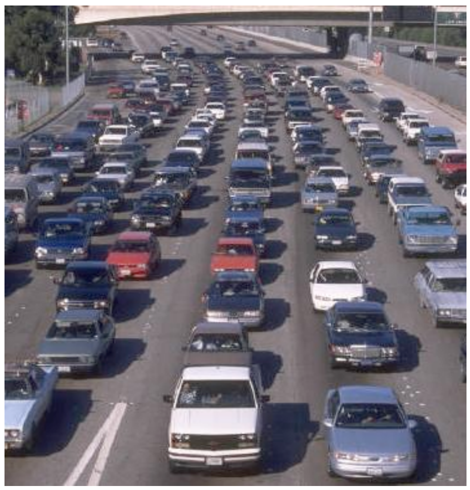
| | | | |

**Resource Card #1**
**Strategy: TRANSPORT EFFICIENCY**

**Category: Transportation**

Today there are nearly 600 million cars in the world. A typical car getting 30 miles per gallon (mpg) releases 1 ton of carbon into the air for every 10,000 miles of driving. It's predicted that there will be about 2 billion cars on the road in 50 years.



Cars that get more miles per gallon are considered fuel-efficient. Improved efficiency could come from using hybrid and diesel engine technologies, as well as making vehicles out of strong but lighter materials. The heavier a car is, the more fuel it needs to run. Lightweight cars require less energy.

2009 Toyota Prius which has a hybrid gas - electric engine gets 50 mpg.

**<u>WEDGE STRATEGY</u>: A wedge of emissions savings would require increasing the fuel efficiency of all cars from 30 mpg to 60 mpg by the year 2055**

COST: $

**Resource Card #2**
**Strategy: TRANSPORT CONSERVATION**

**Category: Transportation**

On average, Americans drive 10,000 miles per year.  In a one year period, a car that gets 30 miles per gallon (mpg) releases 1 ton of carbon into the air. The number of cars on the road is expected to increase from 600 million to 2 billion over the next 50 years.

Reducing the amount of time traveled by cars would greatly reduce the amount of carbon released into the air. Increasing the use of mass transit such as buses, trains, and subways would greatly reduce the amount of driving.

Another way to reduce the amount of driving is for people to use more electronic communication such as video conferencing and email instead of face-to-face meetings.

**<u>WEDGE STRATEGY</u>: A wedge of emissions savings would be achieved if we decreased the number of miles traveled by cars in half.**

COST: $

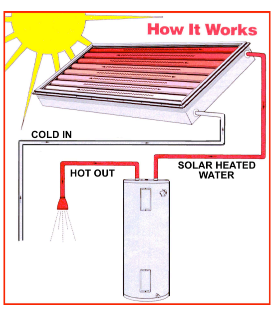
**Resource Card #3**
**Strategy: BUILDING EFFICIENCY**

**Category: Electricity and Heat and Fuel**

Movie theaters, malls, apartments, houses, and even cars use a significant amount of heat and electricity. This energy use releases a large amount of carbon into the atmosphere.

Almost equal amounts of carbon emissions come from providing electricity, transportation, and heat for industry and buildings. The largest potential savings in the buildings sector are in space heating and cooling, water heating, lighting, and electric appliances.

Reducing the amount of space heating, air conditioning, water heating, lighting, and electric appliance use could help us cut emissions overall. Carbon savings will come from efficiency strategies, like increasing insulation, and using renewable energy strategies, like solar water heaters.



An example of solar water heating


Building insulation

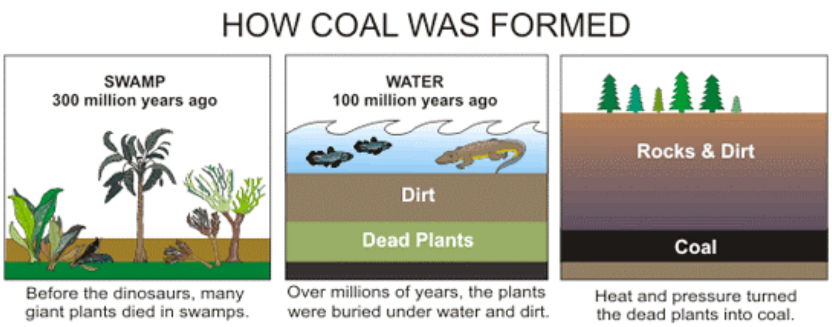
**<u>WEDGE STRATEGY</u>: A wedge would be achieved if we cut emissions by 25% in all new and existing residential and commercial buildings.**

COST: $

**Resource Card #4**
**Strategy: EFFICIENCY IN ELECTRICITY PRODUCTION**

**Category: Electricity**

A significant amount of the electricity we use is produced by burning coal. Coal is used to generate more than half of all electricity in the United States. Power plants burn coal to make steam, which turns turbines (large machines that generate power) that help generate electricity.




The combustion (heating/burning) of coal releases several types of emissions including carbon dioxide ($CO_2$) into the atmosphere. Today's coal-power plants produce about one-fourth of the world's carbon emissions.


A coal power plant

Since coal plants will continue to be an important source of energy, we must find ways to increase their efficiency. One way this can be accomplished is by reducing the amount of emissions in the conversion of coal to generate energy. This means finding alternative ways to generate energy such as better turbines and fuel cells. Fuel cells allow us to produce electricity from coal without burning it. A more even distribution of the energy demand would also increase conversion efficiency.

**WEDGE STRATEGY: A wedge would of saving would be achieved by doubling the efficiency of the world's current coal burning power plants.**

COST: $

**Resource Card #5**
**Strategy: CARBON CAPTURE AND STORAGE (CCS) and ELECTRICITY**

**Category: Electricity**

We can directly trace 25% of the world's carbon emissions directly to coal-burning power plants. This makes them large sources of carbon dioxide ($CO_2$) in the atmosphere.


The Mountaineer Power Plant in West Virginia

Carbon Capture and Storage (CCS) is a strategy where carbon dioxide ($CO_2$) is captured at large electricity and fuel plants, then stored underground. Capturing and storing the $CO_2$ emissions rather than releasing the emissions into the atmosphere would allow us to continue using coal, oil, and natural gas with less harmful impact on the environment.


The Mountaineer Power plant is also the world's first power facility to capture and store a portion of its carbon dioxide

Right now, there are 3 pilot storage projects in the world. Each one stores about 1 million tons of carbon underground per year. With all CCS strategies, the captured carbon dioxide would need to be stored for centuries.

**<u>WEDGE STRATEGY</u>: A wedge would be achieved if we applied Carbon Capture and Storage (CCS) to 800 large coal power plants or 1600 large natural gas power plants over the next 50 years.**

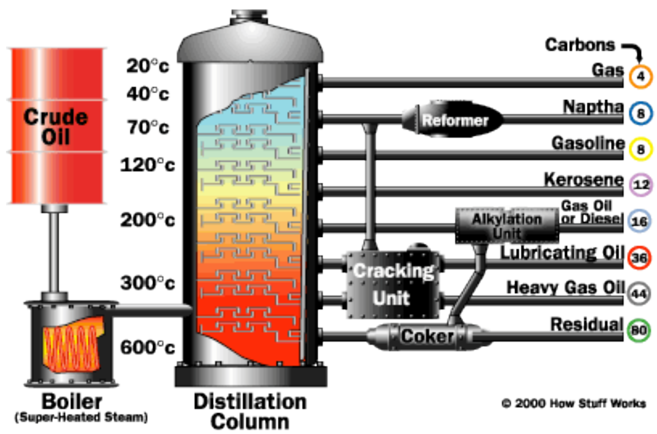
COST: $$

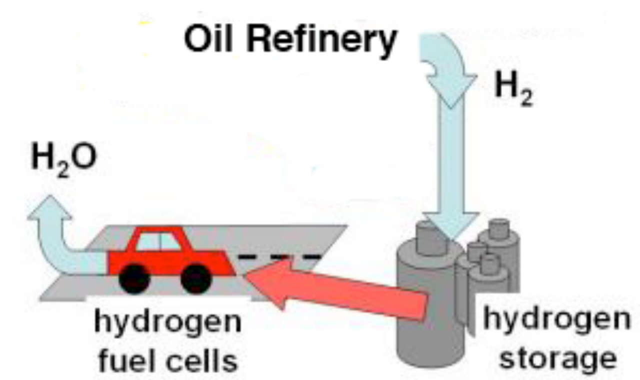
**Resource Card #6**
**Strategy: CARBON CAPTURE AND STORAGE (CCS) and HYDROGEN**

**Category: Transportation and Heat and Fuel**  

Because fossil fuels are composed mainly of carbon and hydrogen, they are potential sources of hydrogen fuel. Hydrogen is a good fuel because when burned, it only emits water vapor. But to have a climate benefit of using hydrogen fuel, the excess carbon must be captured and stored out of the atmosphere.

Oil refineries are where the fossil fuel called crude oil is separated into gasoline, diesel fuel, and other-petroleum based products. Oil refining is one of two industries that produce pure hydrogen. Hydrogen producing plants generate nearly 100 million tons of carbon in the process. By modifying oil refineries, this carbon can be captured and stored where it will not enter the atmosphere.




The figure on the left shows the process of changing crude oil to the different forms of petroleum products listed on the right. In the figure on the right, the Hydrogen gas that also produced at the oil refinery is stored and used in hydrogen fuel cells. (images from HowStuffWorks.com and http://am35.files.wordpress.com/2009/02/hydrogen_cycle.jpg)

The current number of plants that produce hydrogen is about one-tenth what is needed to achieve a wedge through capturing the carbon produced during this process.

**<u>WEDGE STRATEGY</u>: A wedge would be achieved if we increased pure hydrogen production with carbon capture by ten times the current rate.**

COST: $$$

**Resource Card #7**
**Strategy: FUEL-SWITCHING FOR ELECTRICITY**

**Category: Electricity**

Coal-electric plants release billions of tons of carbon per year into the atmosphere when coal is combusted (burned) to help generate electricity.

Producing electricity at natural gas plants results in ½ the carbon emission of coal-based plants. Natural gas has a lower carbon content than coal. Generating four times more electricity from natural gas instead of coal over the next 50 years would significantly reduce the level of carbon emissions.

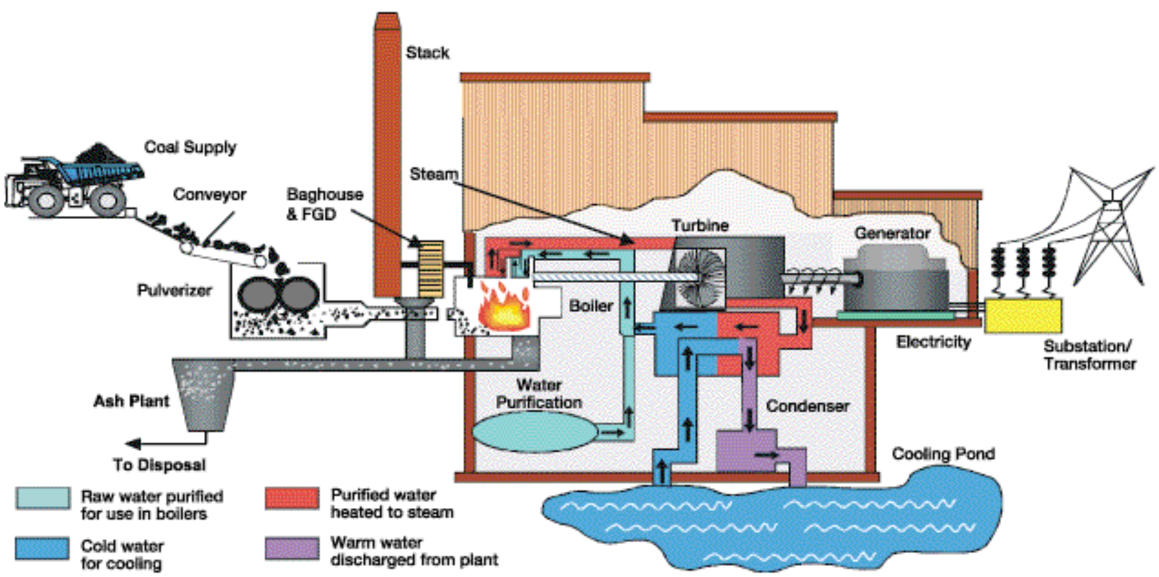



**Illustration of A Coal Power Plant**
How does the coal get turned into energy and electricity? Coal is burned producing large amounts of heat and energy that will be used to heat water. Once the water begins to heat up and boil, it begins to release steam. This high pressured steam gets pumped down a tube which leads to a massive turbine. The turbine begins to spin because of the fast moving, high energy steam. When the turbine begins to spin it powers the electrical generator which then produces electricity.

**WEDGE STRATEGY: A wedge would be achieved by replacing 1400 coal plants with 1400 natural gas plants.**

COST: $

**Resource Card #8:**
**Strategy: NUCLEAR ENERGY**

**Category: Electricity**

Nuclear power accounted for about 20% of the total electricity generated in the United States in 2008. This is equal to the amount of electricity used in California, New York and Texas, the states with the most people.

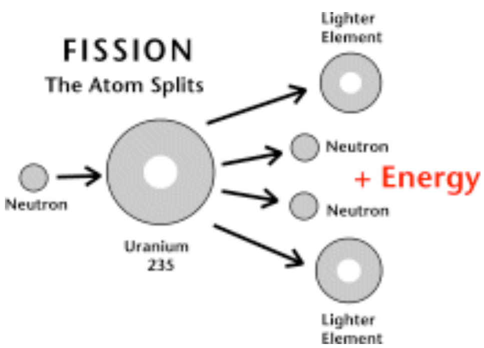
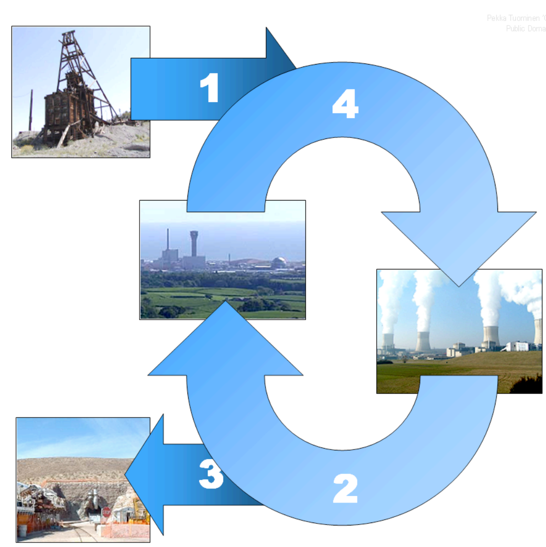



Figure 1: Fission splits the uranium atom, producing energy.
Source: EIA Energy Kids

Nuclear power plants use heat, given off when atoms break apart (fission), to produce electricity. Uranium is the chemical element used to fuel a nuclear power plant. The fuel is formed into ceramic pellets. These pellets are only the size of your fingertip, but each single pellet produces about the same amount of energy as 150 gallons of oil.

Nuclear power produces no carbon dioxide emissions. However, it does create radioactive waste, which must be stored and protected. It also creates waste called plutonium. Plutonium is used to make nuclear weapons. The new reactors required for one wedge would add several thousand tons of plutonium to the worlds' current stockpile of reactor plutonium (roughly 1000 tons.)

Figure 2: This diagram demonstrates the nuclear fuel cycle. Uranium is mined, enriched and manufactured to nuclear fuel (1) which is delivered to a nuclear power plant. After usage in the power plant the spent fuel is delivered to a reprocessing plant (2) or to final repository (3) for permanent storage in a safe place, such as inside rock. Through reprocessing, 95% of spent fuel can be recycled to be returned to usage in a power plant (4).

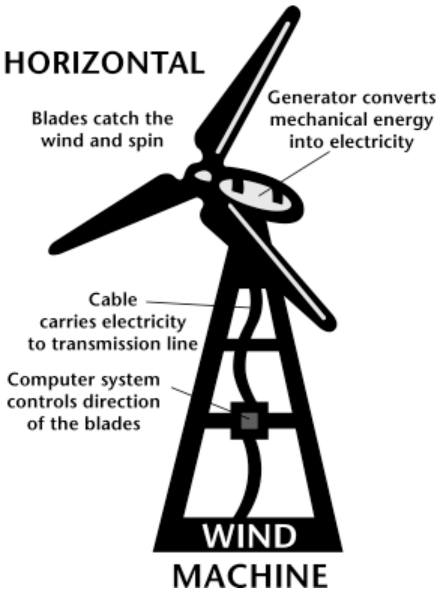



**WEDGE STRATEGY: Building new nuclear power plants to replace coal-burning power plants will cut carbon emissions by one wedge if we build 3 times our current capacity.**

COST: $$

**Resource Card #9**
**Strategy: WIND ELECTRICITY**

**Category: Electricity**




Wind currently creates only about 1% of global electricity. Technologies are getting less expensive and electricity produced by wind farms is increasing by about 30% per year. Wind is a clean and renewable source of electricity. It produces no carbon dioxide ($CO_2$).

Wind machines generally are built tall and wide to collect the most wind. Typically they are 20 stories tall and have blades 200 ft across. The largest wind machines in the world have blades as long as a football field. The height and size can cause trouble for some migrating bird populations.

Based on current turbine spacing on wind farms, wind power for one wedge would require a combined area slightly smaller than the size of the state of California. However, land with wind machines can also be used for other purposes, mostly for crops or pasture.

Figure 1: Horizontal access wind machine.
Source: National Energy Education Development Project

Figure 2: A person standing near modern size wind turbine.

Figure 3: Wind turbines on the horizon.

**<u>WEDGE STRATEGY</u>: To gain a wedge of emissions savings from wind displacing coal-based electricity, current wind capacity would need to be scaled up by a factor of 30.**

COST: $$

**Resource Card #10**
**Strategy: SOLAR ELECTRICITY**

**Category: Electricity**

Photovoltaic (PV) cells in solar panels convert solar energy from the Sun into electricity, providing a carbon dioxide-free source of renewable energy. Solar panels currently create less than 1% of the total electricity used in the United States.

Solar power systems can be small enough to charge your cell phone or house, or large enough to be a whole power plant.

Because the Sun does not shine all the time, there needs to be a way to collect and store solar energy.
A large amount of space is required to install solar panels.
Current solar energy technology is fairly expensive, at least 2-5 times more expensive than fossil fuel-based electricity.

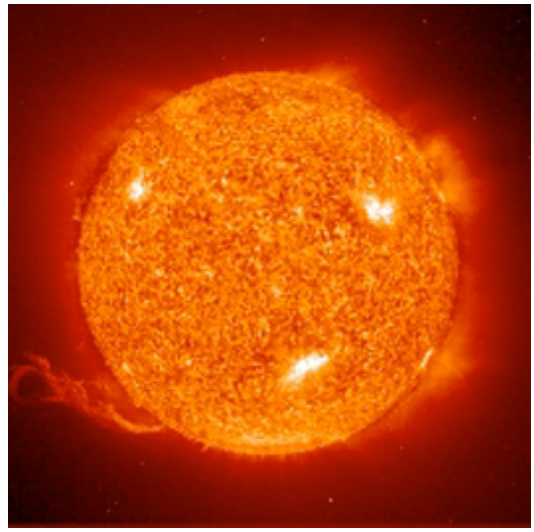


Figure 1: The Sun. Radiant heat from the Sun has powered life on the Earth for many millions of years. Source: NASA

Figure 2: Solar Panels are grouped in large arrays in order to collect more sunlight and produce more energy. These are placed along a cornfield. Source: NASA

Solar PV cells can be placed on roofs and the sides of buildings in order to increase the surface area available for panels.

Figure 3: A small solar panel shown powering a toy waterwheel. Small arrays can charge cell phones or computers. Source: NASA

**<u>WEDGE STRATEGY</u>: A wedge of emissions savings could be achieved installing arrays equal to the size of the state of New Jersey (about 9000 square miles).**

COST: $$$

**Resource Card #11**
**Strategy: CONCENTRATED SOLAR POWER (CSP)**

**Category: Electricity**

Concentrated Solar Power (CSP) takes energy from the Sun and turns it into electricity. CSP requires several more steps than photovoltaic (PV) solar power that turns solar energy directly into electricity (Strategy #10). First, thermal collectors catch solar energy (Figure 1). Second, the thermal collectors use mirrors to concentrate the solar energy and heat a fluid, like water. This water turns into steam and turns a turbine (Figure 2). Finally, the spinning of the turbine creates useable electricity.

**Figure 1: Rows of Thermal Collectors.**

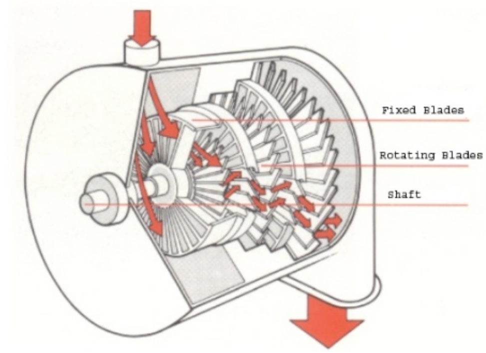



**Figure 2: The Inside of a Turbine.**
**When water is heated it turns to steam. The steam pushes on the blades and turns the turbine which creates electricity.**

CSP is very clean. It creates very little carbon dioxide ($CO_2$) and may be one of the lowest emitters of $CO_2$ that is currently available. CSP plants are expensive to build, but are generally cheaper than building the same amount of PV capacity. Once they are built, CSP plants last up to 40 years and produce fairly cheap electricity – but only when the sun is shining.

Unlike PV cells, CSP thermal collectors cannot be attached to the tops of buildings or houses (Figure 3). They take up a lot of space and that's why most of the 11 current CSP plants are located in deserts or open spaces (Figure 4). In creating CSP plants, some animal habitats have been destroyed and animals that run or fly near the CSP plant could die from the intense heat reflected by the mirrors.

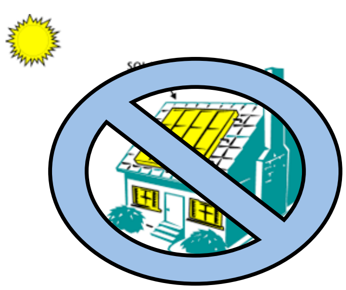


**Figure 3: CSPs cannot be placed on rooftops.**

**Figure 4: CSP Station in the Desert.**
**Thermal Collectors take up a lot of space and can destroy animal habitats.**

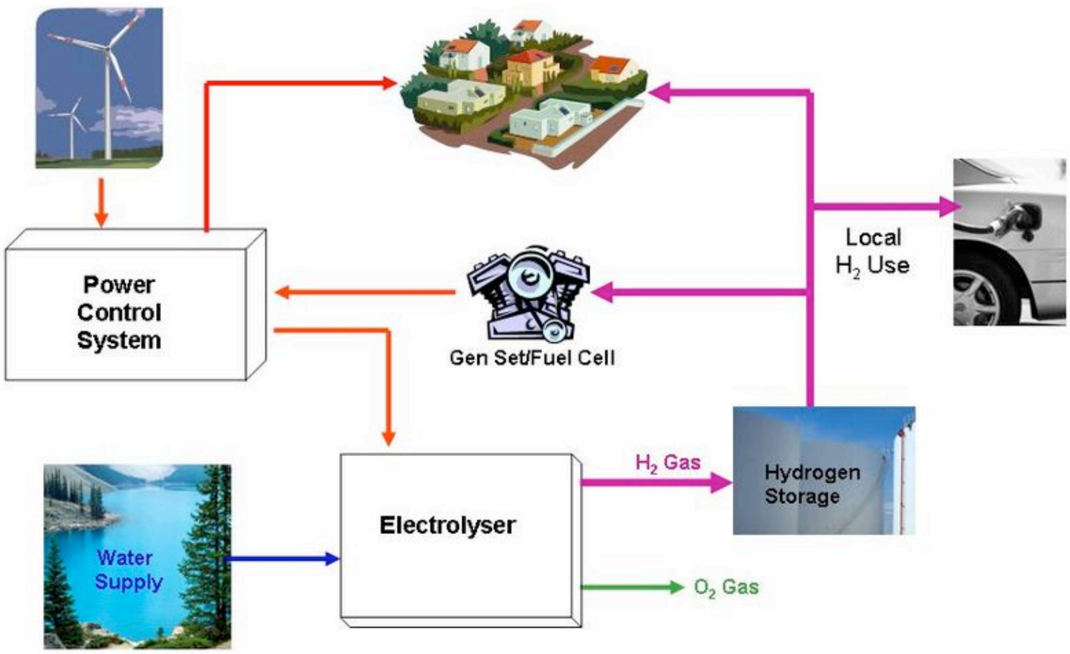
**<u>WEDGE STRATEGY</u>: A wedge of emissions savings would require thermal collectors and plants to cover an area 1/6$^{th}$ the size of the state of California.**

COST: $$$

**Resource Card #12**
**Strategy: WIND HYDROGEN**

**Category: Transportation** 

Hydrogen is a desirable fuel for a low-carbon society because when it is burned the only emission is water vapor. To make hydrogen fuel from wind energy, electricity splits hydrogen from water. Wind hydrogen is only about half as efficient as reducing carbon emissions through replacing electricity generation from coal with wind electricity.




Unlike hydrogen produced from fossil fuels with Carbon Capture and Storage (CCS) (Strategy #6), wind hydrogen could be produced at small scales where it is needed. Wind turbines will create electricity. The electricity produced will be sent to hydrogen filling stations where the electric current will be applied to water. The water will be split it into hydrogen and oxygen. Then, the hydrogen can be used as a fuel for a car.

Wind hydrogen requires less investment in infrastructure for fuel distribution to homes and vehicles because it is produced where it is needed. It is the electricity that is distributed across the established power lines.

Figure 1: Sequel, a hydrogen fuel powered vehicle from General Motors. Source: Wikipedia

**<u>WEDGE STRATEGY</u>: It will require scaling up current wind capacity by about 80 times, a land area slightly smaller than Texas, to create one wedge of emissions reduction.**

COST: $$

**Resource Card #13**
**Strategy: BIOFUELS**

**Categories: Transportation and Heat and Fuel**

Carbon dioxide ($CO_2$) is released into the atmosphere from many sources, especially burning of petroleum in cars. Some living plants, like corn or sugar cane, can be used to create the same fuels that normally require petroleum. Fuels from living plants are called "biofuels."

Corn

Sugar Cane

Coal

**Figure 1: Plants can be used to produce energy just like coal.**

Burning biofuels releases carbon dioxide ($CO_2$) into the environment, but living plants already took this carbon dioxide ($CO_2$) out of the atmosphere for photosynthesis. Thus, there is no overall (net) change in carbon dioxide ($CO_2$) in the atmosphere. The U.S. and Brazil currently produce over 9.75 billion gallons of biofuel per year. That is enough fuel to run 10% of all the cars in the U.S. each year.

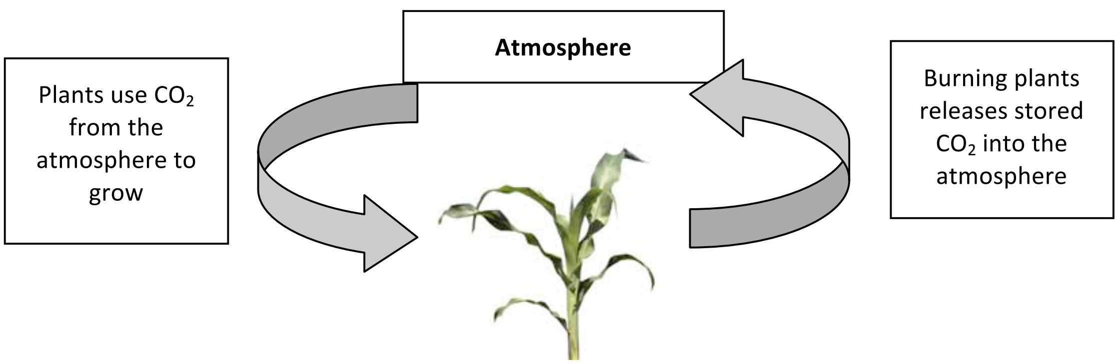



**Figure 2: Burning biofuels does not increase the net concentration of $CO_2$**

Biofuels require a great deal of land. One wedge worth of biofuels would require an area of farmland roughly 1/3 the size of the United States. One-sixth of the world's crops would have to be used for biofuels rather than food supplies.

**<u>WEDGE STRATEGY</u>: A wedge of emissions savings would require increasing today's biofuel production by 30 times and making it sustainable.**

COST: $$

**Resource Card #14**
**Strategy: FOREST STORAGE**

**Category: Biostorage** 

Land plants and soil contain large amounts of carbon. Plants use photosynthesis to change carbon dioxide ($CO_2$) in a way that helps plants grow. Plants trap and store carbon dioxide ($CO_2$) and they are called "carbon sinks." Cars and other things that release carbon dioxide ($CO_2$) are called "carbon sources."

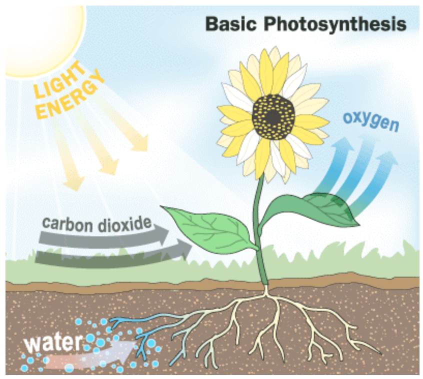



**Figure 1:** Photosynthesis takes carbon dioxide out of the air, stores it, and helps plants grow.

Each year the destruction of forests releases 1 to 2 billion tons of trapped carbon back into the atmosphere. This happens because many trees that are chopped down either decay and release carbon or are eventually burned and release carbon dioxide ($CO_2$). More carbon could be stored if deforestation stopped and new forests were planted.

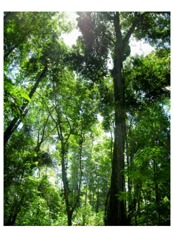


**Figure 2:** *Left*: An intact forest. *Right*: A forest that has been destroyed.

**Figure 3:** A Map of the USA

Unfortunately, to achieve a wedge through planting only new forests would have to be planted around the world that covered an area the size of the United States (Figure 3).

**<u>WEDGE STRATEGY</u>: A wedge of emissions savings could be achieved by stopping global deforestation in the next 50 years.**

COST: $

**Resource Card #15**
**Strategy: SOIL STORAGE**

**Category: Biostorage**

Conversion of natural vegetation to cropland reduces the carbon trapped in the soil by one-half to one-third of the original amount.

**Figure 1:** Prairies or native grasses double the amount of carbon capture

**Figure 2:** Corn or other food crops decrease the carbon capture by one-half.

Soil carbon loss can be reversed by farming practices that build up the carbon in soils. These include:
1. Planting cover crops – Farmers can plant specific crops between growing seasons to help keep carbon in the ground and provide nutrients to the field.
2. Reducing aeration - Farmers release carbon into the atmosphere when they aerate, or dig up, the fields prior to planting crops. Farmers can use other practices such as no-till farming.

**Figure 3:** Tilled Field. Here farmers dig deep into the soil releasing trapped carbon.

**Figure 4:** No-Tilled Field. Remains of previous crops remain next to rows of planted crops.

**<u>WEDGE STRATEGY:</u> A wedge of emissions savings could be achieved by applying carbon management strategies to all of the world's existing agricultural soils.**

COST: $

**Wedge Strategies Table**

Electricy Production  Heating and Direct Fuel Use =  Transportation =  Biostorage = 

| Strategy | Category | Description | 1 wedge could come from… | Cost | Challenges |
|---|---|---|---|---|---|
| 1. Transportation Efficiency |  | Increase automobile fuel efficiency (2 billion cars) | … doubling the efficiency of all the world's cars from 30 to 60 mpg | $ | Car size and power |
| 2. Transportation Conservation |  | Reduce miles traveled by passenger cars and trucks | … cutting miles traveled by all passenger vehicles in half | $ | Increased public transportation, urban design |
| 3. Building Efficiency |  | Increase insulation, furnace and lighting efficiency | … using best available technology in all new and existing buildings | $ | House size, consumer demand for appliances |
| 4. Electricity Efficiency |  | Increase efficiency of power generation | … raising plant efficiency from 40% to 60% | $ | Increased plant costs |
| 5. CCS Electricity |  | $CO_2$ from fossil fuel power plants captured then stored underground (700 large coal plants ) | … injecting a volume of $CO_2$ every year equal to the volume of oil extracted | $$ | Possibility of $CO_2$ leakage |
| 6. CCS Hydrogen |  | Hydrogen fuel from fossil sources with CCS traps carbon dioxide | … producing hydrogen at a 10 times the current rate | $$$ | New infrastructure needed, hydrogen safety issues |
| 7. Fuel Switching - Electricity |  | Replacing coal-burning electric plants with natural gas plants | . . . using an amount of natural gas equal to that used for all purposes today | $ | Natural gas availability |
| 8. Nuclear Electricity |  | Displace coal-burning electricity plants with nuclear plants (2 x current capacity) | … ~ 3 times the effort France put into expanding nuclear power in the to 1980's, sustained for 50 years | $$ | Weapons proliferation, nuclear waste, local opposition |
| 9. Wind Electricity |  | Wind displaces coal-based electric (30 x current capacity) | … using area equal to ~3% of U.S. Land area for wind farms | $$ | competing land use, location disputes |
| 10. Solar Electricity |  | Solar PV displaces coal-based electricity (700 x current capacity) | . . . using the equivalent of a 100 km x 200 km PV array | $$$ | PV cell materials |
| 11. Concentrated Solar Power (CSP) |  | Solar power displaces coal-based electricity | … CSP collectors and plants covering an area the size of 1/6 of California | $$$ | Requires lots of land, endangers some animals |
| 12. Wind Hydrogen |  | Produce hydrogen with wind electricity | … powering half the world's cars with hydrogen | $$ | infrastructure, safety, location disputes |
| 13. Biofuels |  | Biomass fuels from plantations, replace petroleum fuels | … scaling up world ethanol production by a factor of 30 | $$ | Biodiversity, competing land use |
| 14 Forest Storage |  | Carbon stored in new forests | … halting deforestation in 50 years | $ | competing land use, biodiversity |
| 15. Soil Storage |  | Farming techniques increase carbon retention or storage in soils | … using conservation tillage on all agricultural soils | $ | Reversed if land is deep-plowed later |

CCS = Carbon Capture and Storage PV = Photovoltaic mpg = miles per gallon

**7.2.2**

**Home Group Task Card #2**

Policymaking Groups

Activity Goal: As a group, construct a mitigation triangle using 10 wedge strategies, keeping in mind the economic (cost) and social (how does it affect people) impact.

1. One at a time, share the strategies you researched in your first group. For each strategy give at least one positive and one negative aspect.

2. Take turns going around the group. Each member should suggest a strategy they would like to include on the mitigation plan. You can suggest any strategy, not only those you researched.

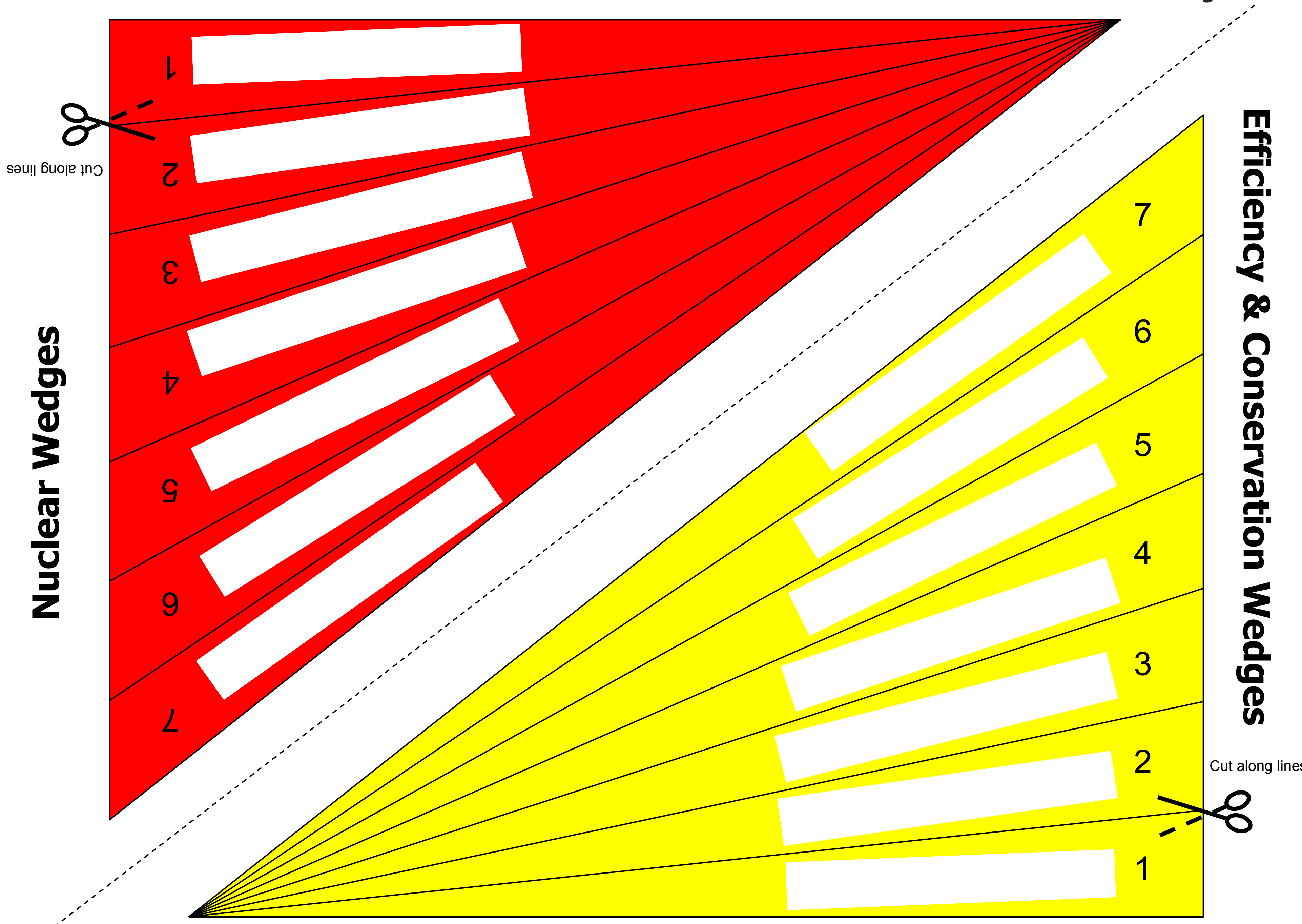
3. Discuss each possible strategy that is suggested and whether or not your group would like to include it on your plan. Continue until you have decided all 10 wedges.

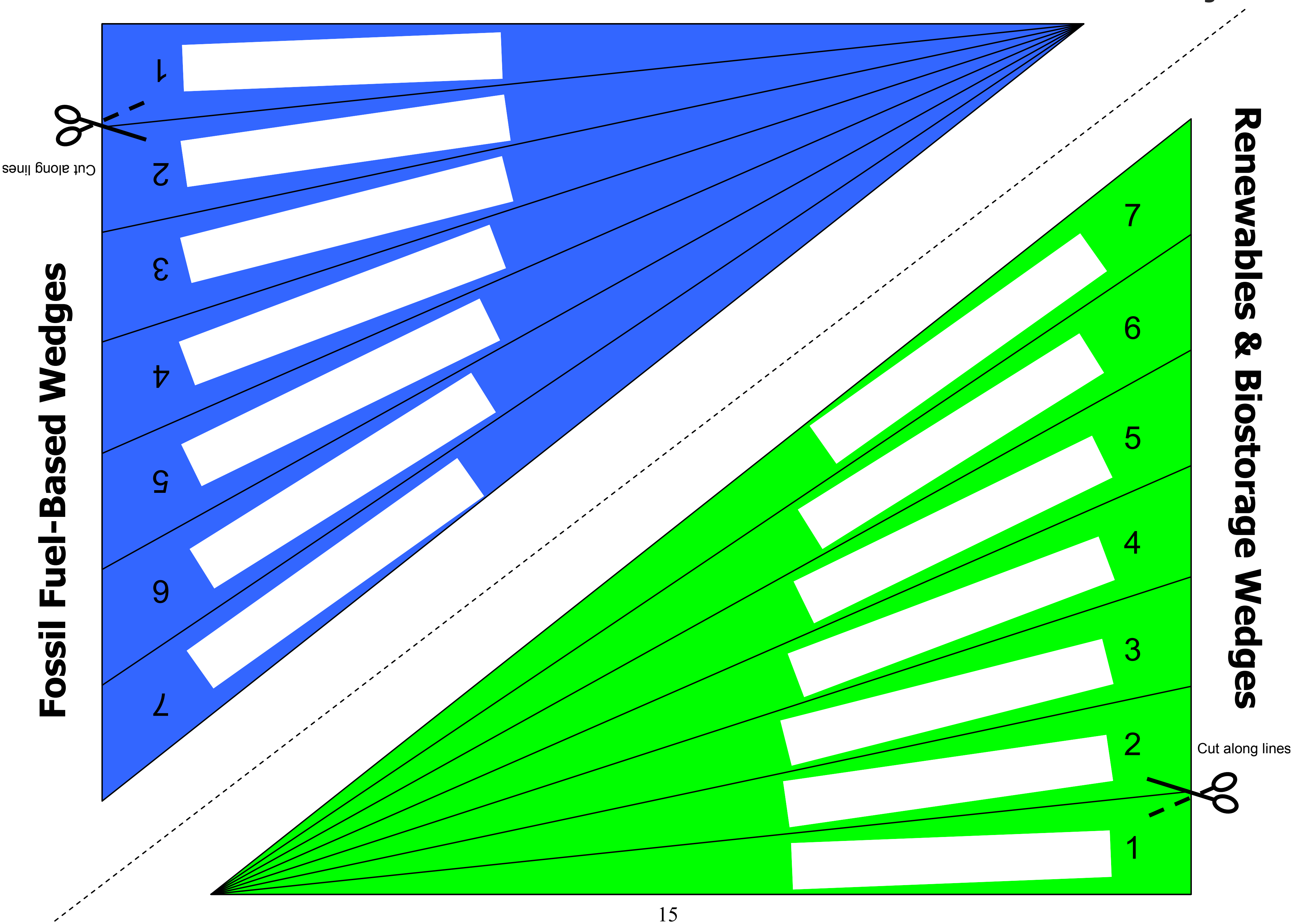
4. Some strategies can be used more than once, some do not need to be used. Before filling in your final strategy on the Mitigation Plan, the group should look at the plan as a whole and make sure it follows the guidelines.

   Guidelines:
   The mitigation triangle can be made up of any 10 wedges and each strategy can be used more than once. However, each strategy is labeled according to four categories: Heat, Electricity, Transportation and Biostorage. Each final mitigation triangle can only have the following number of categories:

   - 6 Electricity
   - 6 Heat
   - 5 Transportation
   - 3 Biostorage

5. Using the graphic organizer, analyze your mitigation plan. Discuss the questions and turn in one copy of the analysis for the entire group.


Nuclear Wedges
Cut along lines
1
2
3
4
5
6
7
Efficiency & Conservation Wedges
7
6
5
4
3
2
1
Cut along lines



Fossil Fuel-Based Wedges
1
2
3
4
5
6
7
Cut along lines
Renewables & Biostorage Wedges
7
6
5
4
3
2
1
Cut along lines

7.2.3

# Mitigation Plan Worksheet

**Record your strategies to reduce total fossil fuel emissions by 10 wedges by 2055.**
(1 “wedge” = 1 billion tons carbon per year by 2055)

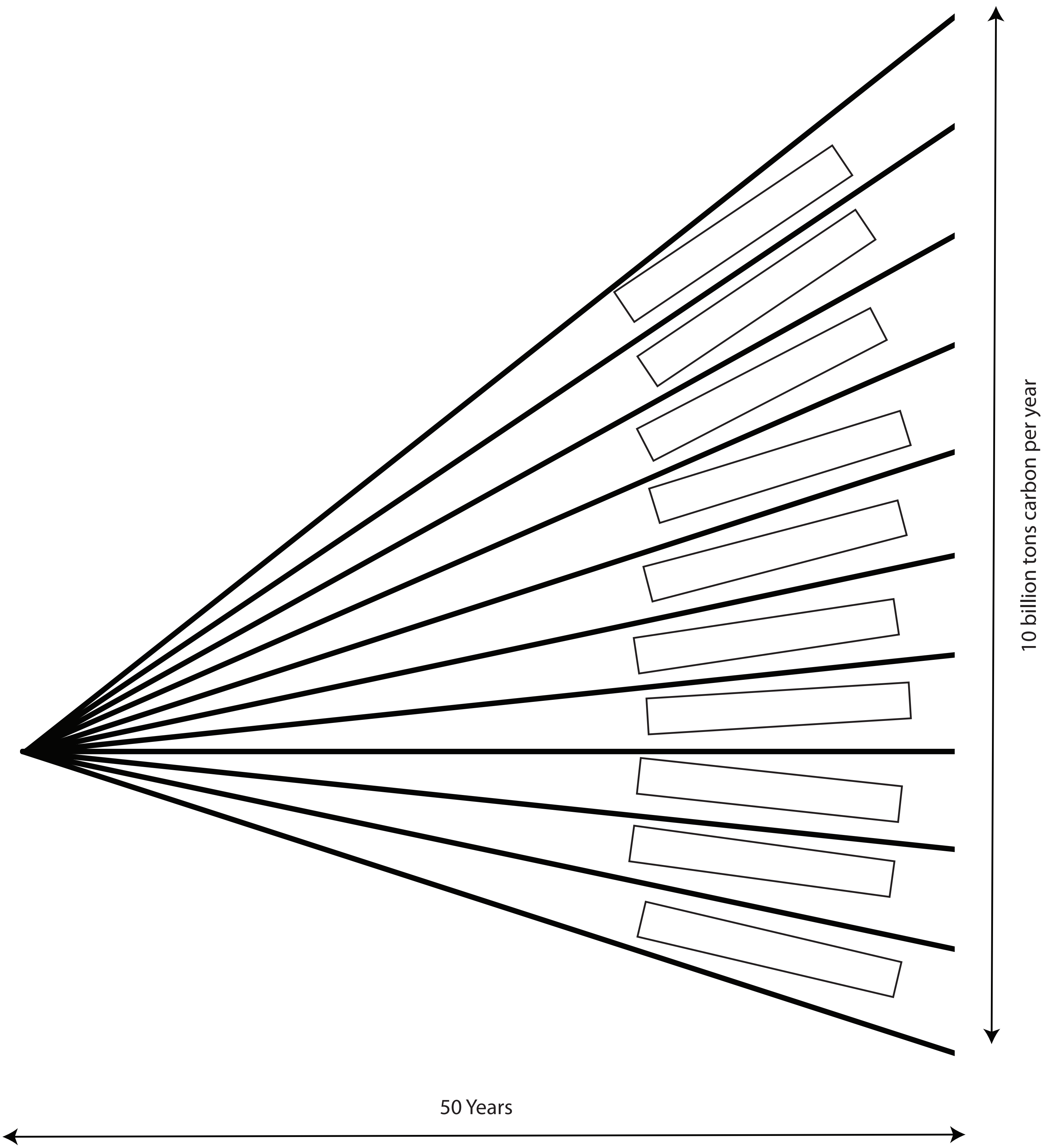
• You may use a strategy more than once
• Use only whole numbers of wedges
• You may use a maximum of
  - 6 Electricity
  - 6 Heat
  - 5 Transportation
  - 3 Biostorage

Calculate the total amount of relative money ($) and land coverage (space needed, land area). These totals may be helpful as you justify your group’s Mitigation Plan decisions.

| | Strategy | Sector (E, T, H, B) | Cost ($) | Space Needed | Comments |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| | **TOTALS** | | | | |

Stabilization Wedge Triangle

Fill in the names of the strategies that you have selected.  Each wedge represents an emission rate of 1 billion tons of carbon per year by 2055.



**Group Names** ____________________________________________________________

**7.3.1**

# Mitigation Plan Group Analysis

**I. Using the question prompts below, please justify your group's Mitigation Plan decisions.**

1. What are the two biggest strengths (positive impacts) of your Mitigation Plan? Please explain your answer.

2. What are the two biggest drawbacks (negative impacts) of your Mitigation Plan? Please explain your answer.

3. Look at the most (or one of the most) expensive wedge strategies that your group chose. Justify why you would choose this strategy over a cheaper option.

**Group Names** ________________________________________________________

II. Choose 1 wedge strategy from your Mitigation Plan and state how that strategy will affect (A) a high school English teacher and (B) an auto mechanic in the given categories of their lives.

**Wedge Strategy Choice** __________________________________

| | **High School English Teacher** | **Auto Mechanic** |
|---|---|---|
| Job Tasks or Job Environment | | |
| Social/Personal/ Political | | |
| Economic | | |

III. Based on your comparison in the table, do you think the teacher or the auto mechanic is more negatively affected by the wedge strategy you chose? Why?

**Group Names** ______________________________________________________

**7.3.2**

# Mitigation Plan Group Analysis: ANSWERS

**I. Directions:** Using the question prompts below, please justify your group's Mitigation Plan decisions.

**1. What are the two biggest strengths (positive impacts) of your Mitigation Plan? Please explain your answer.**

**The Mitigation Plan takes a diverse approach by eliminating wedges from many different sectors. That way the impact of mitigation will be spread across citizens and the economy.**

**The Mitigation Plan will create many jobs. The new technologies will require more workers to get them set up and maintain them.**

**2. What are the two biggest drawbacks (negative impacts) of your Mitigation Plan? Please explain your answer.**

**The plan is quite expensive. Overall, a majority of the wedges are either $$ or $$$. It is unclear if these new technologies will create enough jobs to offset the start up costs. And investing in these technologies might send the nation into more debt or increase taxes significantly.**

**The reliance on nuclear power rests on the fact that the by-products of nuclear power will not be used for creating a nuclear arsenal. Given constant tensions in world relationships, this could be a permanent looming threat.**

**3. Look at the most (or one of the most) expensive wedges your group chose. Justify why you would choose this wedge over a cheaper option.**

**The Solar Energy wedge is quite expensive ($$$). Yet, it is technology that could provide a continuous supply of electricity without burning coal. The solar panels would require large plots of land in sunny areas, but over time these could be placed on the tops of buildings which is unused space. In the long-run, the start-up cost could be offset by cheaper and cleaner electricity.**

**Group Names ________________________________________________________**

**II. Choose 1 wedge from your Mitigation Plan and state how you think your group's mitigation plan will affect A) a high school English Teacher and B) an auto mechanic in the given categories of their lives.**

**Wedge Choice _______**Transport Conservation**____________________________**

| | High School English Teacher | Auto Mechanic |
|---|---|---|
| Job Tasks or Job Environment | If mass transit becomes more reliable, some teachers might actually save time in their workplace by grading papers on the train. The amount of time at school and extra-curricular activities may be affected, though by train schedules. | Fewer automobiles on the road would mean fewer cars that would need to be fixed. Demand for an auto mechanic would likely drop. |
| Social/Personal/ Political | - Taking the train may result in increased time in transit and less time at home. Having to leave at specific times may cause increased stress as a missed train could result in the teacher being late to school.<br>- Cutting transportation may also affect vacation plans.<br>- The teacher may take a greater interest in the local planning of mass transportation and look at a candidate's vision for cheap, consistent, and convenient mass transportation. | Socially, the auto mechanic would be affected similarly to other citizens. Any constraints on travel may affect travel, leisure, and social plans. The mechanic may favor politicians that support car manufacturing in order to maintain their business. Or they might support politicians who push for public transportation, but provide tax breaks to those in the auto industry for developing efficient cars. |
| Economic | Mass transit could save money by eliminating the cost of a car, the insurance, and gas money. Most likely, individuals or families would still own cars, but use them less if public transportation were a viable option. Some money would be saved, but public transportation would need to be affordable. Also, the increase in public transportation would probably raise taxes. | Annual earnings would probably decrease based on less car maintenance needed. Personally, the auto mechanic would face the same issues of other citizens – is the mass transportation affordable and convenient? Does it affect annual taxes? |

**Group Names** ____________________________________________________________

**III. Based on your comparison in the table, do you think the teacher or the auto mechanic is more negatively affected by the wedge you chose? Why?**

**The auto mechanic is more negatively affected by transportation conservation because it affects him deeply in his job. It basically will make him redefine his livelihood – perhaps forcing him to go back to school to learn how to fix other machines or modes of transportation. Also, on the personal level, he will be affected by the same issues as the high school English teacher.**

First Name ________________________ Last Name ___________________________
Teacher Name __________________ Period __________ Date _________________

## 7.4 Mitigation Plan Individual Analysis

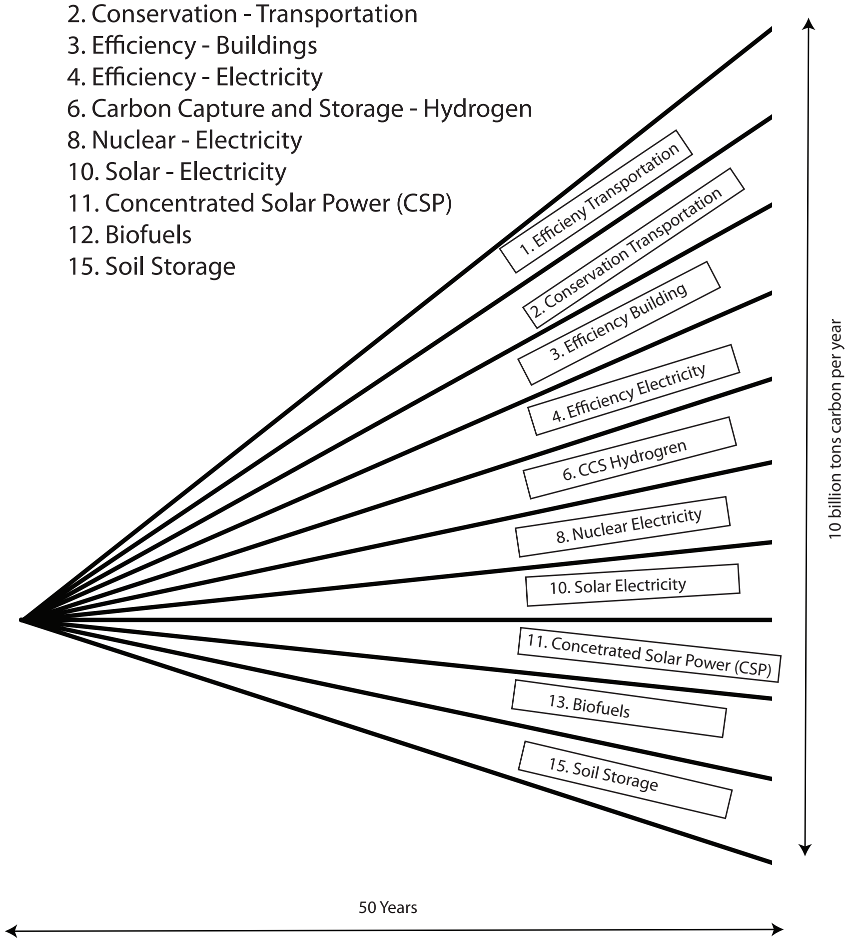
Introduction

The United Nations recently went through the exercise of creating a Mitigation Plan based on the same wedge strategies that your group used. They analyzed how their plan will affect different countries, but they did not analyze how it would affect different individuals.

Your Task

1. Read over the Mitigation Plan below.
2. Analyze the impact of the Mitigation Plan on:
    a. A Farmer
    b. A Construction Worker
3. Using the table below, provide TWO impacts (either positive or negative) for each category for each occupation. Choose the strategy or strategies from the Mitigation Plan below and indicate in your answer which strategy you are discussing. You may use your Wedge Summary Table for your analysis.

1. Efficiency - Transportation
2. Conservation - Transportation
3. Efficiency - Buildings
4. Efficiency - Electricity
6. Carbon Capture and Storage - Hydrogen
8. Nuclear - Electricity
10. Solar - Electricity
11. Concentrated Solar Power (CSP)
12. Biofuels
15. Soil Storage



First Name ________________________ Last Name __________________________
Teacher Name __________________ Period __________ Date _________________

| | **Farmer** | **Construction Worker** |
|---|---|---|
| Job Tasks or Job Environment | | |
| Social/Personal/ Political | | |
| Economic | | |

Based on your comparisons in the table, do you think the Farmer or the Construction Worker is more negatively affected by the Mitigation Plan? Why?