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.

WEDGE STRATEGY: 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.

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

COST: $

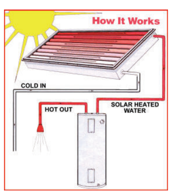
Resource Card #3
Strategy: BUILDING EFFICIENCY

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

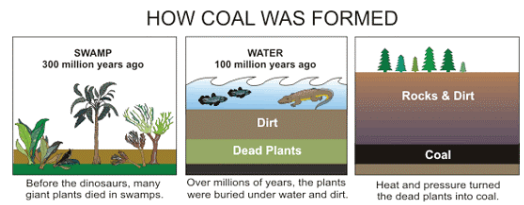
WEDGE STRATEGY: A wedge would be achieved if we cut emissions by 25% in all new and existing residential and commercial buildings.

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.

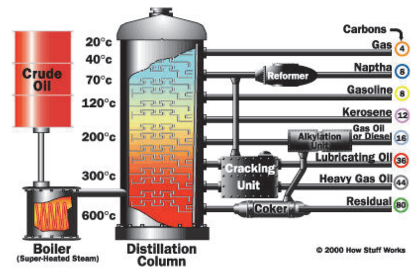
COST: $$

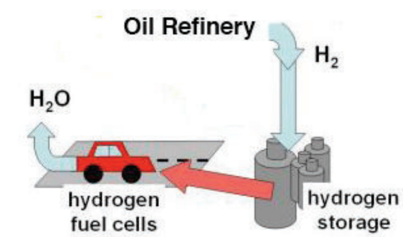
Resource Card #6
Strategy: CARBON CAPTURE AND STORAGE (CCS) and HYDROGEN

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.

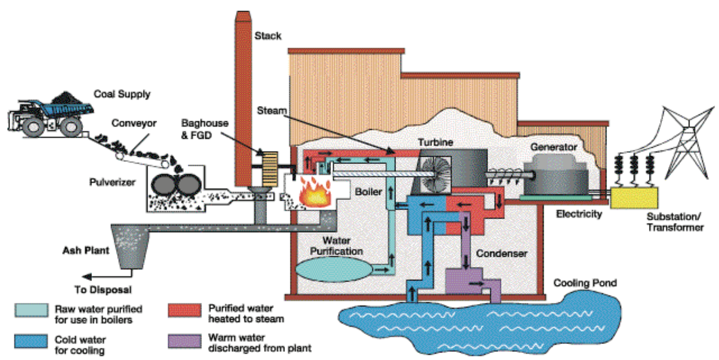


Illustration of A Coal Power Plant
How does the coal get turned into energy and electricity? Coal is burned producing large amounts of heat and energy that will be used to heat water. Once the water begins to heat up and boil, it begins to release steam. This high pressured steam gets pumped down a tube 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.

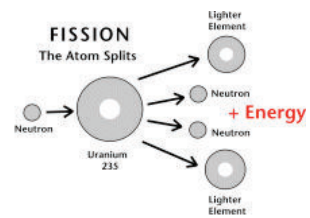


Figure 1: Fission splits the uranium atom, producing energy.
Source: EIA Energy Kids

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.)

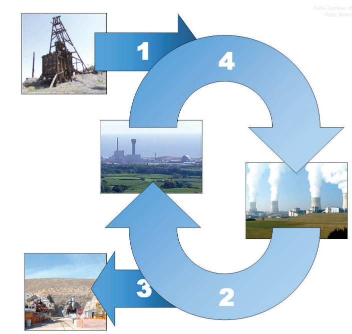


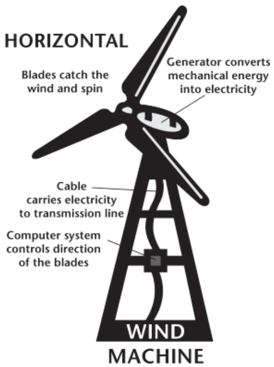
Figure 2: This diagram demonstrates the nuclear fuel cycle. Uranium is mined, enriched and manufactured to nuclear fuel (1) which is delivered to a nuclear power plant. After usage in the power plant the spent fuel is delivered to a reprocessing plant (2) or to final repository (3) for permanent storage 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.

WEDGE STRATEGY: 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.

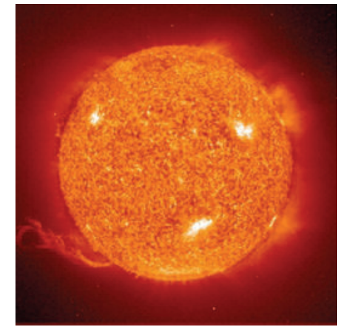


Figure 1: The Sun. Radiant heat from the Sun has powered life on the Earth for many millions of years. Source: NASA

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

WEDGE STRATEGY: 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.

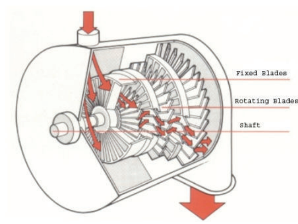


Figure 2: The Inside of a Turbine.
When water is heated it turns to steam. The steam pushes on the blades and turns the turbine which creates electricity.

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.

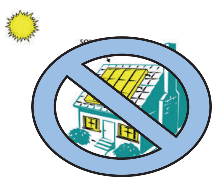


Figure 3: CSPs cannot be placed on rooftops.

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

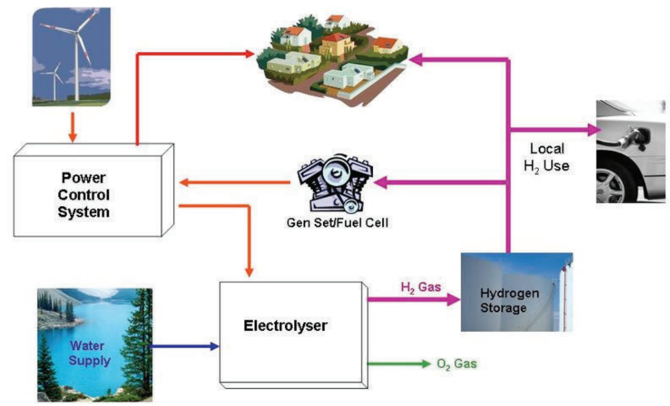
<u>WEDGE STRATEGY</u>: A wedge of emissions savings would require thermal collectors and plants to cover an area 1/6th the size of the state of California.

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.

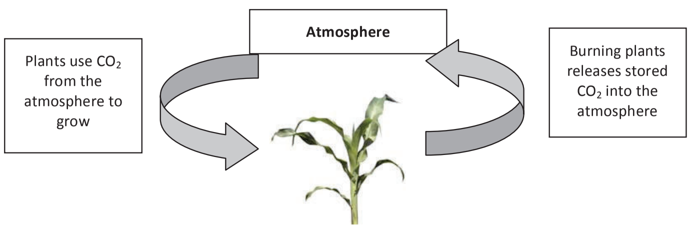


Figure 2: Burning biofuels does not increase the net concentration of CO_2

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."

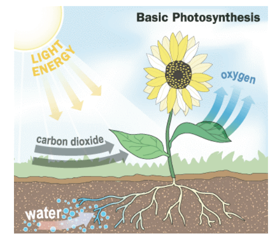


Figure 1: Photosynthesis takes carbon dioxide out of the air, stores it, and helps plants grow.

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.

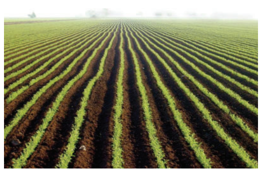


Figure 3: Tilled Field. Here farmers dig deep into the soil releasing trapped carbon.

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: $