Permit Trading

SPN LESSON #42

TEACHER INFORMATION

LEARNING OUTCOME
Students participate in a simulation that involves infusing renewable energy resources into the "mix" for electricity generation by employing a "renewable portfolio standard." As a result, students are able to explain market-oriented regulation and its impact on the transition to alternative energy sources.

LESSON OVERVIEW: One way to achieve a goal related to energy and the environment is *market-oriented regulation*, which has already succeeded in reducing sulfur dioxide emissions from power plants and carbon monoxide emissions from automobiles at less than anticipated cost. It works this way: after a goal is set, let's say, for sulfur dioxide emissions by power plants or carbon monoxide emissions by vehicles, permits are apportioned equitably among electricity generators or auto manufacturers to "allow" emissions within the overall goal. Producers who reduce their emissions below the level allowed by their permits may sell their permits to other producers, thus entitling the other producers to emit more carbon monoxide or sulfur dioxide.

This activity employs the same approach to infuse renewable energy resources into the mix for electricity generation: it employs a renewable portfolio standard (RPS).

GRADE-LEVEL APPROPRIATENESS
This Level III interdisciplinary lesson is intended for students enrolled in high school environmental or social science classes.

MATERIALS: student handouts, plus cutout pieces of money and deeds for conventional and photovoltaic power plants

SAFETY: There are no specific safety precautions for this lesson.

TEACHING THE LESSON: Introduce the concept of market-oriented regulation as presented in the above overview and background information below, and point out to students that they will be experiencing the process via a simulation. Review the "rules" of the simulation as they are presented in the student handout, and have students begin the first round of the simulation. Note that each student group needs to complete a summary form at the end of each round of the simulation. An additional feature of technological innovation is that it becomes less costly when it becomes more widely used. Therefore, if and when more than half of the total electricity is generated by photovoltaic plants (as reflected in the summary form at the end of a given round), the cost of photovoltaic plants is cut in half—and you will need to announce this to your students at the appropriate time (i.e., whenever the number of photovoltaic plants becomes large enough to generate half the total electricity). As noted in the student handout, the simulation should achieve its goal of generating all electricity renewably by the end of ten rounds, but it can be terminated after any number of rounds. However, it should go at least three to five rounds in order to realize the main learning points.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION
Responses are expected to vary, according to how much students choose to invest in generating electricity by photovoltaic plants and how early in the simulation they choose to invest it. A group pursuing the strategy of investing all their money in photovoltaic plants will purchase four in round 1, thus receiving a permit to compensate for generation of 600 million kilowatt-hours per year by a conventional power plant. The income from the electricity generated by these four photovoltaic plants would be 4 x $.04B x 5 = $.8B, added to .84 x $.4B x 5 from the conventional power plant, for a total of $2.48B. This would allow purchase of two more photovoltaic plants in round 2, entitling a permit to generate 400 million kilowatt-hours per year by a conventional power plant, an income of 6 x $.04B x 5 = $1.2B from these photovoltaic plants and .76 x $.4B x 5 = $1.52B from the conventional plant, for a total of $2.84B. With the amount of money already on hand, this is enough to buy three more photovoltaic plants in round 3, and from there on out the income in each round will exceed $3 billion, enough to buy three more photovoltaic plants each round, which is enough to reduce the electricity generated by conventional fuels more than an additional 10%.

The strategy of buying permits to continue generating electricity from conventional fuels rather than buying photovoltaic plants will lead to an income of $.4B x 5 = $2B each round, not enough to buy enough photovoltaic plants for another 10% reduction in electricity generation by conventional fuels. Thus groups pursuing this strategy will need to hope they can obtain the necessary permits for their $2B income from each round.

If you prefer to “level the playing field” by making the income from generating electricity from conventional fuels equal to that from photovoltaic plants in the early rounds of the game, you could increase the annual income from the conventional power plant from $.4B to $.6B (this gives $3B over the course of five years, the time of each “round.”)

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY: Thomas B. Johansson and José Goldemberg (eds.), *Energy for Sustainable Development* (United Nations Development Programme, 2002).

BACKGROUND INFORMATION: Market-oriented regulation sets a goal, let’s say, for sulfur dioxide emissions by power plants or carbon monoxide emissions by vehicles, and apportions permits equitably among electricity generators or auto manufacturers to “allow” emissions within the aggregate goal. Producers who reduce their emissions below the level allowed by their permits may sell their permits. Both sulfur dioxide and auto emissions have been reduced at less than anticipated cost in this way. The success has been attributed to the flexibility it allows producers, the incentive it provides to advertise products that are environmentally sound, and the way it allows manufacturers to introduce these products into the market (with a gradually increasing market share) with minimal effect on consumer prices or consumption patterns. In short, given point A (where we are now) and point B (where we'd like to be), we can make the transition if we set a series of interim goals and use market-oriented regulation to address each one. This approach, which employs a renewable portfolio standard, has been used successfully to infuse renewable energy sources into the "energy mix."

REFERENCES FOR BACKGROUND INFORMATION: Thomas B. Johansson and José Goldemberg (eds.), *Energy for Sustainable Development* (United Nations Development Programme, 2002), pp. 68–74.

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA: 1: M2.1; 6: 1.1, 2.2, 6.1; 7: 1.3, 2.1

Standard 1—Analysis, Inquiry, and Design: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Mathematics Key Idea 2: Deductive and inductive reasoning are used to reach mathematical conclusions.

M2.1: Use deductive reasoning to construct and evaluate conjectures and arguments, recognizing that patterns and relationships in mathematics assist them in arriving at these conjectures and arguments.

Standard 6—Interconnectedness: Common Themes: Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

1.1: Explain how positive feedback and negative feedback have opposite effects on system outputs.

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

2.2: Collect information about the behavior of a system and use modeling tools to represent the operation of the system.

Key Idea 6: In order to arrive at the best solution that meets criteria within constraints, it is often necessary to make trade-offs.

6.1: Use optimization techniques, such as linear programming, to determine optimum solutions to problems that can be solved using quantitative models.

Standard 7—Interdisciplinary Problem Solving: Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Key Idea 1: The knowledge and skills of mathematics, science, and technology are used together to make informed decisions and solve problems, especially those relating to issues of science/technology/society, consumer decision making, design, and inquiry into phenomena.

1.3: Design solutions to real-world problems on a community, national, or global scale using a technological design process that integrates scientific investigation and rigorous mathematical analysis of the problem and of the solution.

Key Idea 2: Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; making connections among the common themes of mathematics, science, and technology; and presenting results.

2.1: Students participate in an extended, culminating mathematics, science, and technology project.

SOCIAL STUDIES LEARNING STANDARDS

Standard 4—Economics: Students use a variety of intellectual skills to demonstrate their understanding of how the United States and other societies develop economic systems and associated institutions to allocate scarce resources, how major decision-making units function in the U.S. and other national economies, and how an economy solves the scarcity problem through market and nonmarket mechanisms.

Key Idea 1: The study of economics requires an understanding of major economic concepts and systems, the principles of economic decision making, and the interdependence of economies and economic systems throughout the world.

Students will analyze the effectiveness of varying ways societies, nations, and regions of the world attempt to satisfy their basic needs and wants by utilizing scarce resources.

- Students will define and apply basic economic concepts such as scarcity, supply/demand, opportunity costs, production, resources, money and banking, economic growth, markets, costs, competition, and world economic systems.
- Students will understand the nature of scarcity and how nations of the world make choices which involve economic and social costs and benefits.
- Students will understand the roles in the economic system of consumers, producers, workers, investors, and voters.

Key Idea 2: Economics requires the development and application of the skills needed to make informed and well-reasoned economic decisions in daily and national life.

- Students will use economic information by identifying similarities and differences in trends; inferring relationships between various elements of an economy; organizing and arranging information in charts, tables, and graphs; extrapolating and making conclusions about economic questions, issues, and problems.

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www.nyserda.org

Should you have questions about this activity or suggestions for improvement, please contact Bill Peruzzi at billperuz@aol.com

(STUDENT HANDOUT SECTION FOLLOWS)

Name ___________________________________

Date ____________________________________

Permit Trading

The generation of most electricity today derives its energy from fossil fuel combustion, nuclear fission, or hydro. Of these, only hydro is renewable. Ultimately, all of the world's electricity will have to be generated by renewable energy resources such as photovoltaic cells. The current economic situation has not been favorable for moving in this direction; thus, only limited efforts have been seen.

One way to achieve a goal related to energy and the environment is market-oriented regulation, which has already succeeded in reducing sulfur dioxide emissions from power plants and carbon monoxide emissions from automobiles at less than anticipated cost. It works this way: after a goal is set, let's say, for sulfur dioxide emissions by power plants or carbon monoxide emissions by vehicles, permits are apportioned equitably among electricity generators or auto manufacturers to "allow" emissions within the overall goal. Producers who reduce their emissions below the level allowed by their permits may sell their permits to other producers, thus entitling the other producers to emit more carbon monoxide or sulfur dioxide.

DEVELOP YOUR UNDERSTANDING

This activity uses the same approach to infuse renewable energy resources into the "mix" for electricity generation; it employs a "renewable portfolio standard." You are about to embark on a simulation based on the following information:

1. Each group of students is considered to be an electric power company, owning one conventional electric power plant generating a billion watts of electricity (the "standard" generating capacity of conventional power plants). It costs a billion dollars to build ($1 per watt) and generates about 10 billion kilowatt-hours every year. At 10¢ per kilowatt-hour, the value of this electricity is $1 billion ($1 for each watt of capacity). Suppose, however, that after payment for fuel and maintenance, this figure is reduced to $0.4 billion. Your generating plant will generate electricity for 20 years.

2. If the electricity were generated renewably, let's say, by photovoltaic cells, there would be no fuel costs, and maintenance would be minimal. But the cost of building the generating plant is more: $5 per peak-watt, and they generate electricity only 22% of the time because of nights and clouds. Photovoltaic plants come in sizes of 200 million peak-watts, thus costing $1 billion. They produce 400 million kWh per year, deriving an income of $40 million per year. Each renewable energy plant will generate electricity for 20 years.

3. In addition to the income you receive each year from the generation of electricity, you are given an initial $4 billion with which to meet the prescribed goals as follows:

a) The goal for the first round of the simulation (representing the first five years) is that each student group / electric power company is to generate 10% of its electricity by renewable means. This means that you need to generate 1 billion kilowatt-hours of electricity with a photovoltaic plant for a cost of $3 billion, or pay for a permit that allows you to continue generating all of your electricity from your conventional power plant. If you elect to buy a photovoltaic plant, indicate how many plants you want to buy on the summary form for round 1 and buy it from the "banker." If you buy or own more photovoltaic plants than you are required to have, you will receive "permits" to sell to another group/company that would allow them to continue generating that amount of electricity from their conventional power plant. If you elect to buy permits to continue generating electricity from your conventional power plant, you will need to check with other groups / electric power companies for what is available. *Permits are valid for only the round of the simulation in which they are purchased.* After you have bought your photovoltaic power plants, indicate this on the summary form for round 1, figure your income for round 1, and collect it from the "banker." (Note that your total generation of electricity is a billion watts, which is the same as 10 billion kilowatt-hours. The generation from your conventional plant is reduced by whatever is generated by your photovoltaic plants.) Mark five years' use on the deed for each of your power plants.

b) The goal for the second round of the simulation (representing another five years) is that each student group / electric power company is to generate 20% of its electricity by renewable means. This means that you need to generate 2 billion kilowatt-hours of electricity with a photovoltaic plant or buy permits that allow you to continue generating electricity with a conventional plant. Any unused permits that you have earned in a previous round are still valid, but you are allowed to sell permits only for photovoltaic generating capacity in excess of the goal for the current round. For example, if you purchased two photovoltaic plants in round 1 and received one permit, you must surrender your permit if you don't purchase an additional photovoltaic plant in round 2. At the end of round 2, fill out an additional summary form, collect your income, and mark another five years' use on the deed for each of your power plants.

c) The goal for each successive round is to increase the percentage of electricity generated by renewable means by 10%. This would lead to all the electricity generated by renewable means (or "permitted" to be generated by conventional means) by the end of ten rounds. The simulation does not need to be conducted that long, but it should go at least three to five rounds in order to realize some of the learning points. Whenever it is concluded, groups / power companies should count their total cash and add the value of their power plants, less $0.05 billion for each year of plant use (depreciation) for conventional plants and $0.02 billion for each year of plant use for photovoltaic plants.

SUMMARY FORM: Round _*n*_=___________

Goal for Round __*n*_=___________ : *n* x 1 billion kilowatt-hours generated by photovoltaic plants

Generating Capacity:

Photovoltaic plants: ________ x 0.4 billion kilowatt-hours

Conventional plants: ________ x 10 billion kilowatt-hours, less

________ x 0.4 billion kilowatt-hours
(generating capacity of photovoltaic plants)

= ________ x 10 billion kilowatt-hours

Income:

Photovoltaic plants: $0.04 billion/0.4 billion kilowatt-hours x ______ x 0.4 billion kilowatt-hours/yr x 5 years

= $________ billion

Conventional plants: $0.4 billion/10 billion kilowatt-hours x _______ x 10 billion kilowatt-hours/yr x 5 years

= $________ billion

New photovoltaic plants ordered = _________

Cost = _________ x $1 billion.

Pay “banker” for new photovoltaic plant(s) and receive “permit” for photovoltaic generation capacity above the current goal. If you have elected to continue generating electricity by conventional means instead of buying photovoltaic plants, you must obtain enough permits and attach them to this summary form.

$1 billion	$0.1 billion ($100 million)
$1 billion	$0.1 billion ($100 million)
$1 billion	$0.1 billion ($100 million)
$1 billion	$0.1 billion ($100 million)
$0.01 billion ($10 million)	$0.01 billion ($10 million)
$0.01 billion ($10 million)	$0.01 billion ($10 million)

Deed for photovoltaic power plant Generating capacity: 400 million kilowatt-hours Years of use: ___________ (mark off five years of use for each round of the simulation) Value: $1 billion – (yrs of use) x $.02 billion	Deed for photovoltaic power plant Generating capacity: 400 million kilowatt-hours Years of use: ___________ (mark off five years of use for each round of the simulation) Value: $1 billion – (yrs of use) x $.02 billion
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Deed for conventional power plant Generating capacity: 10 billion kilowatt-hours Years of use: ___________ (mark off five years of use for each round of the simulation) Value: $1 billion – (yrs of use) x $.05 billion	Deed for photovoltaic power plant Generating capacity: 400 million kilowatt-hours Years of use: ___________ (mark off five years of use for each round of the simulation) Value: $1 billion – (yrs of use) x $.02 billion

Deed for photovoltaic power plant Generating capacity: 400 million kilowatt-hours Years of use: ___________ (mark off five years of use for each round of the simulation) Value: $1 billion – (yrs of use) x $.02 billion	Deed for photovoltaic power plant Generating capacity: 400 million kilowatt-hours Years of use: ___________ (mark off five years of use for each round of the simulation) Value: $1 billion – (yrs of use) x $.02 billion
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PERMIT

to generate _00 million kilowatt-hours by a conventional power plant instead of a photovoltaic power plant.

This permit must be attached to the summary form *in lieu of* photovoltaic plant ownership if it is substituted to meet the goal for photovoltaic generation of electricity.

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