Title: Energy Stored in Ocean When It Is 1ºC Warmer

Subject: Physics / Chemistry

Grade Level: 10^{th} – 12^{th}

Rational or Purpose: This lesson will help students visualize how small changes in temperature are due to large amounts of energy. Students should understand the causes of energy accumulation on Earth. This lesson will reinforce students' concepts of unit conversion.

Lesson Duration: 90 minutes

Materials:
Home utility bill
Calculator

Science TEKS:

§112.45. Chemistry.
(c) Knowledge and skills.
(5) Science concepts. The student knows that energy transformations occur during physical or chemical changes in matter. The student is expected to:
(A) identify changes in matter, determine the nature of the change, and examine the forms of energy involved;
(B) identify and measure energy transformations and exchanges involved in chemical reactions; and
(C) measure the effects of the gain or loss of heat energy on the properties of solids, liquids, and gases.

§112.47. Physics.
(c) Knowledge and skills.
(7) Science concepts. The student knows the laws of thermodynamics. The student is expected to:
(A) analyze and explain everyday examples that illustrate the laws of thermodynamics.

Background Information:
Daily temperature changes about 10-20ºF (5-11ºC) on an average, sunny day. The air becomes warmer when it absorbs solar energy during the daytime. Air warms much faster than water because water has a higher heat capacity. This is why the ocean temperature tends to stay constant throughout a day. Since we experience a 5-11ºC temperature change everyday, we may not feel "warmer" or "hotter" when the temperature increases by 1ºC.

In the ocean, however, a 1ºC increase may be enough to cause the extinction of some species and have profound effects on oceanic habitat. The ocean is a tremendously large body of water. It must store huge amounts of heat for it to increase its temperature significantly. In recent decades, oceans have warmed at a rapid pace. Before looking at the consequences of the global warming of oceans, students should understand how ocean temperature increases.

Water has a higher *specific heat capacity* than most other substances. What exactly is specific heat capacity? Specific heat capacity is the energy required to raise certain amount of substance with a certain temperature. The unit is J/g•K (Joules per gram per Kelvin). Water has a specific heat capacity of 4.181 J/g•K, meaning 4.184 Joules of energy is needed to raise 1 gram of water with 1ºC. The following chart lists some specific heat capacities of common substances:

Water	4.18 J/g•K
Ice	2.05 J/g•K
Air	1.01 J/g•K
Ethanol	2.44 J/g•K
Mercury	0.14 J/g•K
Copper	0.39 J/g•K

The SI (International System of Units) unit for energy is a Joule. However, while reading an electrical appliance label or home utility bill, energy is shown in kWh. What is kWh? It means **k**ilo-**W**att **h**our. The ultimate unit of kWh is still Joule. Here is the explanation: Watt is the unit for power, the amount of energy used per second. kWh is used to represent energy in our daily life because it is more conventional (similar to using mph instead of ft/s in driving).

Activity:
Temperature increase is caused by the storage of solar energy in oceans. Since the energy absorption is huge, it is difficult for students to make sense of it. This activity will help students understand the amount of energy by comparing it to their monthly energy usage.

Students will use "$Q = m\ c\ \Delta T$" to calculate the net energy stored by oceans in a year, where Q, m, and c stand for energy (in Joule), mass (in gram), and specific heat capacity (in J/g•K). ΔT stands for the change of temperature, which is calculated by subtracting the initial temperature by the final temperature. A positive value of Q indicates that the energy is gained by the substance, and *vice versa*.

After computing the net energy stored in the ocean, students will determine how many years it takes for the energy gained by the ocean to support Austin, Texas' usage.

Procedure:
Students are given one week to ask their parents to make a photocopy of their utility bill for any month. (If parents do not feel comfortable in sharing their utility bill, students can write down the amount of electricity used in one particular month – the number circled in the following diagram.)

Electric Service	Meter # Read Date		Reading
	01/03/2007		32034.00
	12/03/2006		31732.00
	Read Difference		302.00
	Total Consumption in KWH		302
	Billing Rate: Residential Service Winter		
	Customer Charge		$6.00
	Energy Charge	302.00 @ $ .0355000 per KWH	$10.72
	Fuel Charge	302.00 @ $ .0334300 per KWH	$10.10
	Sales Tax		$0.27
	TOTAL CURRENT CHARGES - Electric		$27.09
Solid Waste Service	Anti-Litter Residential		$2.60
	TOTAL CURRENT CHARGES - Solid Waste		$2.60
Drainage/ Street Service	Comprehensive Drainage Fee		$7.15
	Transportation User Fee		$2.79
	TOTAL CURRENT CHARGES - Drainage/Street Service		$9.94

Students are divided into groups of five. They will share their energy usage among the group. They need to calculate an average energy usage for their group. The value will be written on the blackboard. The whole class will average these numbers and obtain the "Average energy usage per household per month of your class."

Using the information in the student handout, answer the questions accordingly. Students may encounter mathematical challenges. Be patient to guide them to the correct answer.

Name: ______________________________ Date: ______________________

Class Section: _______________________________

Fill in the "read difference" on your utility bill in Box 1.
Fill your group members' readings in Box 2-5.

1	**2**	**3**	**4**	**5**
kWh	kWh	kWh	kWh	kWh

Average energy usage per household per month in your group: ___________________

Average energy usage per household per month in your class: ___________________

The population of Austin is about 700,000. Assuming that all people in Austin are in a household of 4 people, what is the total number of households?

___________________Households

If every household in Austin uses electricity just like in your class, what is the total energy usage of Austin in a month (in kWh)?

What is the total energy usage of Austin in a month (in Joules)?

Here is some information for you to complete your task.

1. The volume of world sea water is 1346 x 10^6 km^3.
2. The mass of world sea water is 1.4 x 10^{21} kg.
3. The specific heat capacity of sea water is assumed to the same as water.
4. The forecast temperature increase in the next 500 years is 1ºC.

Task:
1. Calculate the net energy gained by sea water in one year.
2. Calculate the number of years the energy gained by sea can support the energy usage of Austin.
3. Is there a way to make use of solar energy so that we can pay less for electricity? Explain briefly.

Extra Credit

Calculate the density of sea water in gram/mL. Is it denser or less dense than fresh water? Use an example to support your answer.

Name: KET Date: ____________

Class Section: ____________

Fill in the "read difference" on your utility bill in Box 1.
Fill your group members' readings in Box 2-5.

1	2	3	4	5
kWh	kWh	kWh	kWh	kWh

Average energy usage per household per month in your group: ____________

Average energy usage per household per month in your class: 350 kWh / HOUSEHOLD

The population of Austin is about 700,000. Assuming that all people in Austin are in a household of 4 persons, what is the total number of household?

175,000 Households

If every household in Austin use electricity just like your class, what is the total energy usage of Austin in a month (in kWh)?

$$350 \frac{kWh/Month}{HOUSEHOLD} \times 175{,}000\ HOUSEHOLD = 6.125 \times 10^7\ kWh/Month$$

What is the total energy usage of Austin in a month (in joules)?

Watt = Joule/sec

$$Q_{AUSTIN} = 6.125 \times 10^7 \frac{kWh}{month} \left(\frac{J}{s} \cdot \frac{1}{W}\right) \frac{3600 s}{1 h} = 2.205 \times 10^{11}\ kJ/month$$

$$(2.205 \times 10^{14}\ J/Month)$$

Here is some information for you to complete your task.

1. The volume of world sea water is 1346 x 10^6 km^3.
2. The mass of world sea water is 1.4 x 10^{21} kg.
3. The specific heat capacity of sea water is assumed to the same as water.
4. The forecast temperature increase in the next 500 years is 1°C.

Task:
1. Calculate the net energy gained by sea water in one year.
2. Calculate the number of years the energy gained by sea can support the usage of Austin.
3. Is it a way to make use of solar energy so that we can pay less for electricity? Explain briefly.

(1) $Q_{SEA} = mc\Delta T$

$= (1.4\times10^{21}\,kg)(4.18\,J/g\cdot{}^\circ C)(1^\circ C/500)$

$Q_{SEA} = 1.170\times10^{22}\,J$ (per year)

(2) $\frac{Q_{SEA}}{Q_{AUSTIN}} = \frac{1.170\times10^{22}\,J}{2.208\times10^{14}\,J} = 5.308\times10^{7}$ MONTHS

(or 4.423×10^{6} Years)

Extra Credit

Calculate the density of sea water in gram/mL. Is it denser or less dense than fresh water? Use an example to support your answer.

DENSITY $= \frac{MASS}{VOLUME}$

$= \frac{1.4\times10^{21}\,kg}{1346\times10^{6}\,km^3}\left(\frac{1000\,g}{1\,kg}\right)\left(\frac{1\,km}{1000\,m}\right)^3\left(\frac{1\,m}{100\,cm}\right)^3\left(\frac{1\,cm^3}{1\,mL}\right)$

$= 1.04$ g/mL