Name: ______________________________

Date: ____ / ____ / ____ Class Hour: ____

# Energy Conversions and Beyond

### Student Response Guide

At first glance, the language of energy is messy and difficult. Quantities of energy are expressed in many different units. These units grew out of different needs (power industry, academic needs, nutrition science, etc.), at different times, and from different places. Even today, many obscure units are still used because they fit a particular need so well. To make sense of energy, you need to be able to translate, or convert, between these different languages or units.

In **Part One** of your lesson you will learn about the two quantities of energy that are used on a typical energy bill, the KWH (kilowatt-hour) and the Therm. You'll learn to convert these energy quantities into two other practical energy units that have stood the test of time, the BTU and the Joule. Performing these conversions will help you to learn and comprehend the language of energy.

**Part Two** of **Energy Conversions and Beyond** takes you beyond just the language of energy. Here you'll go beyond what you learned in Part One to assess the real costs and benefits of energy decision making.

## Part One

The BTU (British Thermal Unit) and the Joule are the two units typically used as reference units for most energy comparisons. The scientific community does not generally favor the BTU because it is the older, English unit of measure. The definition of a BTU is probably easy for you to understand, though:

1 BTU = the quantity of energy needed to raise 1 lb. of water, 1 degree Fahrenheit*

*with water at its maximum density

The Joule is the SI unit for energy, but its definition may be harder to visualize, or comprehend:

1 Joule = energy expended in 1 sec by an electric current of 1 ampere in a circuit with a resistance of 1 ohm

To get started, we will simply learn and work with the equivalence that links these two:

| |
|---|
| $1\ BTU = 1055\ J$ |

Another way of stating this is to write this equivalence as two "conversion factors," or ratios that are equal to one (1).

| |
|---|
| $\frac{1\ BTU}{1055\ J}$ |
| $\frac{1055\ J}{1\ BTU}$ |

With this information you can now begin converting from BTU's to Joules, and vice versa.

1. Perform these conversions according to your teacher's directions:

1a. 3 BTU is equal to how many Joules?

$$\frac{\mathbf{3}\ \cancel{\boldsymbol{BTU}}}{\mathbf{1}}\ \boldsymbol{x}\ \frac{\mathbf{1055}\ \boldsymbol{J}}{\mathbf{1}\ \cancel{\boldsymbol{BTU}}} = *\ \boldsymbol{J}$$

1b. How many Joules is 14.7 BTU?

*** Answer**

1c. 7800 J is equal to how many BTU?

*** Answer**

1d. How many BTU is 28,550 J?

*** Answer**

Let's consider the energy quantities you find on an energy bill, the kilowatt-hour (KWH) and the Therm.

Energy utility companies express how much electricity a customer uses in KWH units One KWH of electricity is equal to 1000 Watts of electricity used for one hour. In other words, it is equal to the amount of energy needed to light ten 100 Watt light bulbs for one hour.

Energy utility companies express how much natural gas a customer uses in units of Therms. One Therm is equal to 100,000 BTU. One Therm is also roughly equal to 100 cubic feet of natural gas, or methane.

Following are the equivalence and conversion factors linking these two energy units to the BTU and Joule:

$$1\ KWH = 3412\ BTU = 3{,}600{,}000\ J\ (3.6\ X\ 10^{6}\ J$$

Conversion factors:

$$\frac{1\ KWH}{3412\ BTU}$$

$$\frac{1\ KWH}{3{,}600{,}000\ J}$$

$$\frac{3412\ BTU}{1\ KWH}$$

$$\frac{3{,}600{,}000\ J}{1\ KWH}$$

$$1\ Therm = 100{,}000\ BTU = 105{,}500{,}000\ J\ (1.055\ X\ 10^{8}\ J$$

Conversion factors:

$$\frac{1\ Therm}{100{,}000\ BTU}$$

$$\frac{100{,}000\ BTU}{1\ Therm}$$

$$\frac{1\ Therm}{105{,}500{,}000\ J}$$

$$\frac{105{,}500{,}000\ J}{1\ Therm}$$

2. Now perform these conversions according to your teacher's directions:

2a. 840 KWH is equal to how many Joules?

*** Answer**

2b. How many BTU is 100 KWH?

*** Answer**

2c. 100 Therms is equal to how many BTU?

*** Answer**

2d. How many J is 0.38 Therms?

*** Answer**

3. Which contains more energy, a KWH or a Therm? Explain how you know in convincing detail or show how you know mathematically in the box below.

*** Answer**

4. Consult the energy bill for a typical family home provided for this activity. Locate the KWH of electricity used and the Therms of natural gas used. Convert each quantity to BTU below.

4a. KWH to BTU:

*** Answer**

4b. Therms to BTU:

*** Answer**

5. Did this family use more energy from electricity or from natural gas? Explain how you know in convincing detail or show how you know mathematically in the box below.

| *** Answer** |
|---|

## Part Two

In this part of the lesson, you will use conversions and simple math to produce the kind of data used in making real energy management decisions. By the end of the lesson, you'll stand face to face with the real costs of using energy—and the real benefits of saving it.

6. Consult the energy bill for a typical family home provided for this activity again.

**6a.** Locate the total cost of all the electricity used (Total Electric Service Charges).

Post it into **Table 6,** box **6a.**

**6b.** Locate the total cost of all the natural gas used (Total Gas Service Charges).

Post it into **Table 6,** box **6b.**

**6c.** Locate the total KWH of electricity used (Electricity Used (KWH)).

Post it into **Table 6,** box **6c.**

**6d.** Locate the total therms of natural gas used (Gas Used (CCF) or Therms).

Post it into **Table 6,** box **6d.**

**6e.** Using data you located on the energy bill, determine the cost / KWH of Electricity. Post that cost into box **6e.** of **Table 6.** *Double-check your math! You'll be using this answer later as a conversion factor to calculate other answers.*

**6f.** Using data you located on the energy bill, determine the cost / Therm of natural gas. Post that cost into box **6f.** of **Table 6.** *Double-check your math! You'll be using this answer later as a conversion factor to calculate other answers.*

**6g. – 6j.:** Follow the **Instructions for filling in boxes 6g. – 6j.** found on separate pages to post values to **boxes 6g. – 6j.** in **Table 6.**

**Table 6**

| Electricity | Versus | Natural Gas |
|---|---|---|
| 6a. $ * [cost of electricity for the month] | **Monthly cost** | 6b. $ * [cost of natural gas for the month] |
| 6c. * KWH] [of electricity used for the month] | **Monthly use** | 6d. * therms [of natural gas use for the month] |
| **per KWH "costs"** | **Versus** | **per THERM "costs"** |
| 6e. $ * / KWH [of Electricity] | **MONEY** | 6f. $ * / Therm [of Natural Gas] |
| 6g. * lbs. of Coal / KWH [of Electricity] | **RESOURCES** | 6h. * $ft^3$ / Therm [of Natural Gas] |
| 6i. lbs. of $CO_2$ equivalent / KWH [of Electricity] | **EMISSIONS** | 6j. lbs. of $CO_2$ equivalent / Therm [of Natural Gas] |

7. Consult the energy bill for a typical family home provided for this activity again. Assume the October energy bill for this typical family home is a good average for all the energy bills for the year. Based on the monthly use for this family on the energy bill, calculate:

7a. The money this family pays per year for the electricity they use.

7b. The pounds of coal this family burns per year for the electricity they use.

7c. The pounds of carbon dioxide this family is responsible for putting into the air for the electricity they use each year.

Your answers go in the boxes to the left. Show all of your math work to the right.

| **Answer** | **Math Work** |
|---|---|
| 7a.<br>*** $ / year**<br>[for Electricity] | $\frac{* \cancel{KWH}}{1 \cancel{month}} \, x \, \frac{\$ *}{\cancel{KWH}} \, x \, \frac{12 \cancel{months}}{1 \cancel{year}} = \frac{\$ *}{year}$ |
| 7b.<br>*** lbs. Coal / year**<br>[for Electricity] | * |
| 7c.<br>*** lbs. $CO_2$ eq. / year**<br>[for Electricity] | * |

8. Using the energy bill again, calculate:

8a. The money this family pays per year for the natural gas they use.

8b. The cubic feet of natural gas this family uses per year.

8c. The pounds of carbon dioxide this family is responsible for putting into the air for the natural gas they use each year.

Your answers go in the boxes to the left. Show all of your math work to the right.

| Answer | Math Work |
|---|---|
| 8a.<br>* **$ / year**<br>[for Natural Gas] | $\frac{*\ \cancel{Therms}}{1\ \cancel{month}}\ x\ \frac{\$\ *}{\cancel{Therm}}\ x\ \frac{12\ \cancel{months}}{1\ \cancel{year}} = \frac{\$\ *}{year}$ |
| 8b.<br>* **$ft^3$ / year**<br>[for Natural Gas] | * |
| 8c.<br>* **lbs. $CO_2$ eq. / year**<br>[for Natural Gas] | * |

Let's say Patrick and Candace are heads of the household whose energy bill you have been considering. They want to save on their family's energy use.

They implement these "no cost" changes to their lifestyle and habits:

- Lower their winter heating season temperature setpoint.
- Make a deliberate effort to keep doors closed during the heating season.
- Raise their summer air conditioning temperature setpoint.
- Make a deliberate effort to keep windows and doors closed when air conditioning their home.
- Open their windows and use fans to cool their home as much as possible.
- Take shorter showers to save on hot water use.
- Remember to turn off lights and appliances whenever they are not being used.

They also implement these “low cost” changes to their lifestyle and habits:

- Install a programmable thermostat, so heat and AC are used minimally when their home is unoccupied.
- Replace the air filters in their heating and AC units every year.
- Have yearly, professional maintenance checks performed on their heating and AC systems.
- Seal cracks around windows and doors with caulk.
- Replace worn weather stripping on windows and door.
- Replace all incandescent light bulbs with energy efficient LED lamps.

These measures save an average of 8% on both their electricity and natural gas use.

9. Calculate this family’s five year savings for electricity. Your answers go in the boxes to the left. Show all of your math work to the right.

| **Answer** | **Math Work** |
|---|---|
| 9a. **$ * saved** | * |
| 9b. *** lbs. Coal saved** | * |
| 9c. *** lbs. $CO_2$ eq. saved** | * |

10. Calculate this family's five year savings for natural gas. Your answers go in the boxes to the left. Show all of your math work to the right.

| **Answers** | **Math Work** |
| --- | --- |
| 10a.<br>**$ * saved** | * |
| 10b.<br>*** $ft^3$ of Natural Gas saved** | * |
| 10c.<br>*** lbs. $CO_2$ eq. saved** | * |

11. Summarize this family's combined five year savings for electricity and natural gas. Your answers go in the boxes to the left.

| **5 year savings** |
| --- |
| 11a.<br>**$ * saved** |
| 11b. (9b.)<br>*** lbs. Coal saved** |
| 11c. (10b.)<br>*** $ft^3$ of Natural Gas saved** |
| 11d.<br>*** lbs. $CO_2$ eq. saved** |

12. Candace and Patrick decide to place a solar PV array on their roof. The entire system is large enough to generate all of the electricity the family will need in any given month.

Determine money, resources, and $CO_2$ savings for electricity use for a year, for five years, and for a 25 year period (approximate working life of a solar PV system array).

| 1 year savings | 5 year savings | 25 year savings |
|---|---|---|
| 12a. (9a.) $ * | 12b. $ * | 12c. $ * |
| 12d. (9b.) * lbs. Coal | 12e. * lbs. Coal | 12f. * lbs. Coal |
| 12g. (9c.) * lbs. $CO_2$ eq. | 12h. * lbs. $CO_2$ eq. | 12i. * lbs. $CO_2$ eq. |

13. Recreate the chart above just a little differently. Your cost answers will remain the same. But divide all of the answers you expressed in pounds (lbs.) by 2000, which will convert them to tons (2000 lbs. = 1 ton). Post your new data in tons, below.

| 1 year savings | 5 year savings | 25 year savings |
|---|---|---|
| 13a. $ * | 13b. $ * | 13c. $ * |
| 13d. * tons Coal | 13e. * tons Coal | 13f. * tons Coal |
| 13g. * tons $CO_2$ eq. | 13h. * tons $CO_2$ eq. | 13i. * tons $CO_2$ eq. |

**Lesson Summary Questions**

**1.** Candace and Patrick decide to install the solar PV array referred to earlier. It will generate all of the electricity the family will need in any given month. It costs them $18,000 to install. How many years will it take for them to pay back their investment of $18,000? Explain your answers with both words and math.

*** Answer**

**2.** You decide to place a solar PV array at or on your home. At current electric rates it will take about 10 years for the cost savings to equal your investment in the array. What is likely to happen over the years to shorten your “payback time” even more?

*** Answer**

**3.** You are considering the purchase of a solar PV system for your home. All of the installers you talk with stress this principle: Energy conservation comes first, even before renewable energy. Explain why this is such good advice to follow.

*** Answer**

**4.** Is the use of solar panels completely “green,” or “waste-free,” or “emissions-free?” Convincingly explain why it is or is not.

*** Answer**

**5.** Whenever you save or conserve energy, three things are saved at the same time. What are they?

*** Answer**

**6.** You employ many successful measures at home and work to save and conserve energy. How can it be said that you are environmental superstar?

*** Answer**

**7.** Describe the most important idea, concept, principle, or fact you learned while completing this lesson. Explain why your idea, concept, principle, or fact is important for you (and probably other people) to know and understand.

*** Answer**

**Instructions for filling in boxes 6g. – 6j.**

Follow these instructions to obtain four pieces of information from the United States Environmental Protection Agency's Greenhouse Gas Equivalency Calculator.

The four pieces of information are:

- **lbs. of Coal Burned* / KWH of Electricity** used
- **lbs. of $CO_2$ Emissions Equivalent** / KWH of Electricity** used
- **Cubic Feet of Natural Gas / Therm of Natural Gas** used
- **lbs. of $CO_2$ Emissions Equivalent** / Therm of Natural Gas** use

Following are the definitions for the lbs. of $CO_2$ Equivalent and lbs. of Coal Burned we'll use in the lesson.

***Pounds of Coal Burned** is the average mass of coal—and only coal—that would have to be burned to produce some stated quantity of energy.

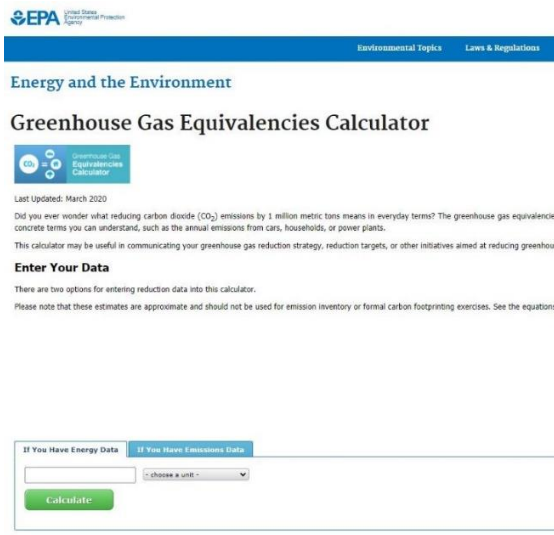
****Pounds of Carbon Dioxide Equivalent** defines the mass of $CO_2$ that would have the same warming potential as the mixture of emissions released during the use of a stated quantity of energy.

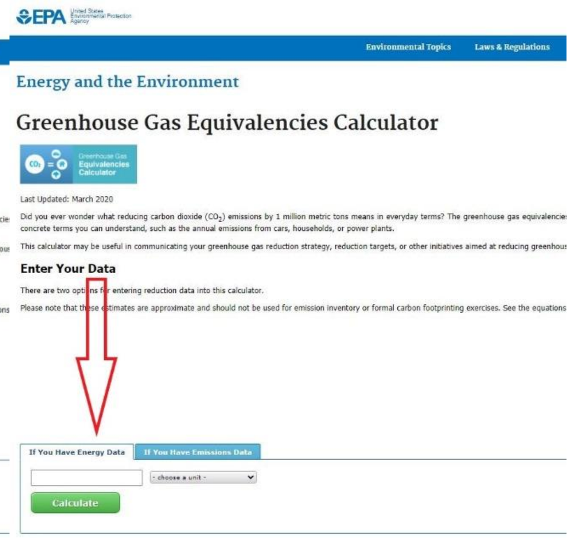
To get this information for in its most accurate and current form, navigate to the US EPA Greenhouse Gas Equivalency Calculator. Then place these values into **Table 6** back in Step 6 of your student lesson. Later, you will use these values as calculation conversions.

6-1. Follow the URL (just below) to the **United States Environmental Protection Agency's Greenhouse Gas Equivalency Calculator**:

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Their splash page will look like this. You will be entering data where indicated.

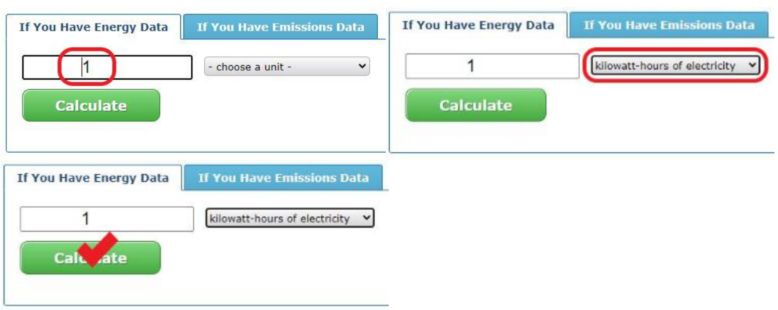


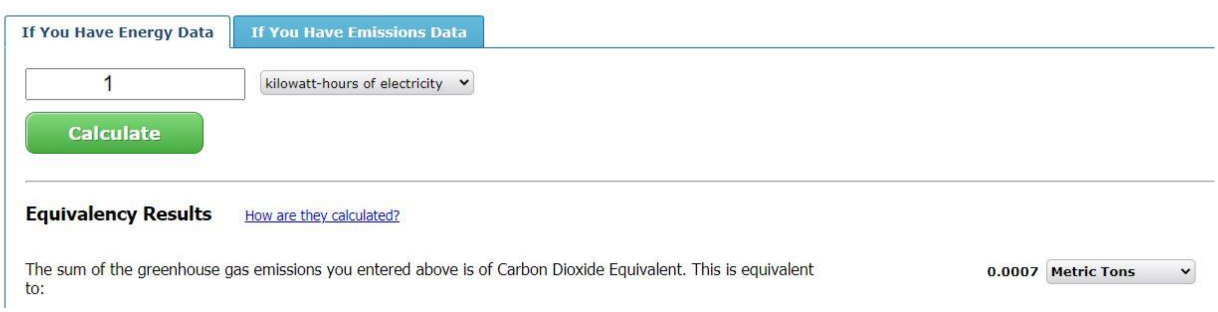




6-2. In the Energy Data section:

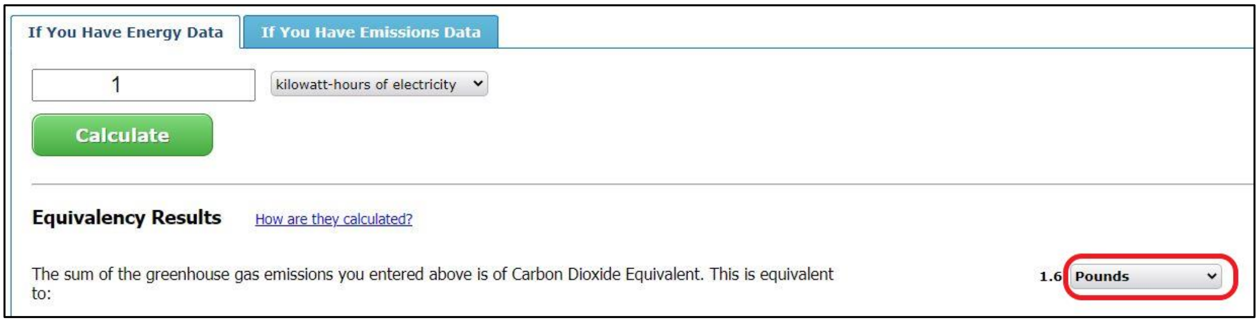
- Enter the number **1**
- Choose the unit of **kilowatt-hours of electricity**
- Click **Calculate**

After clicking, you'll arrive at a webpage displaying **Equivalency Results**.

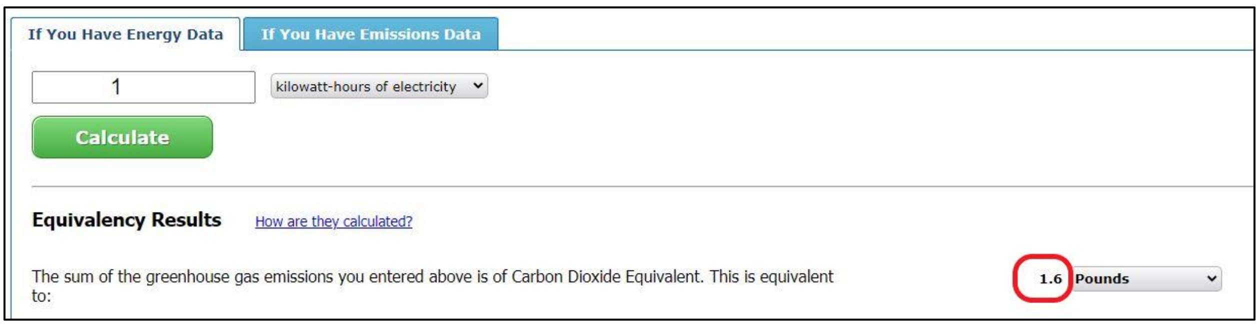


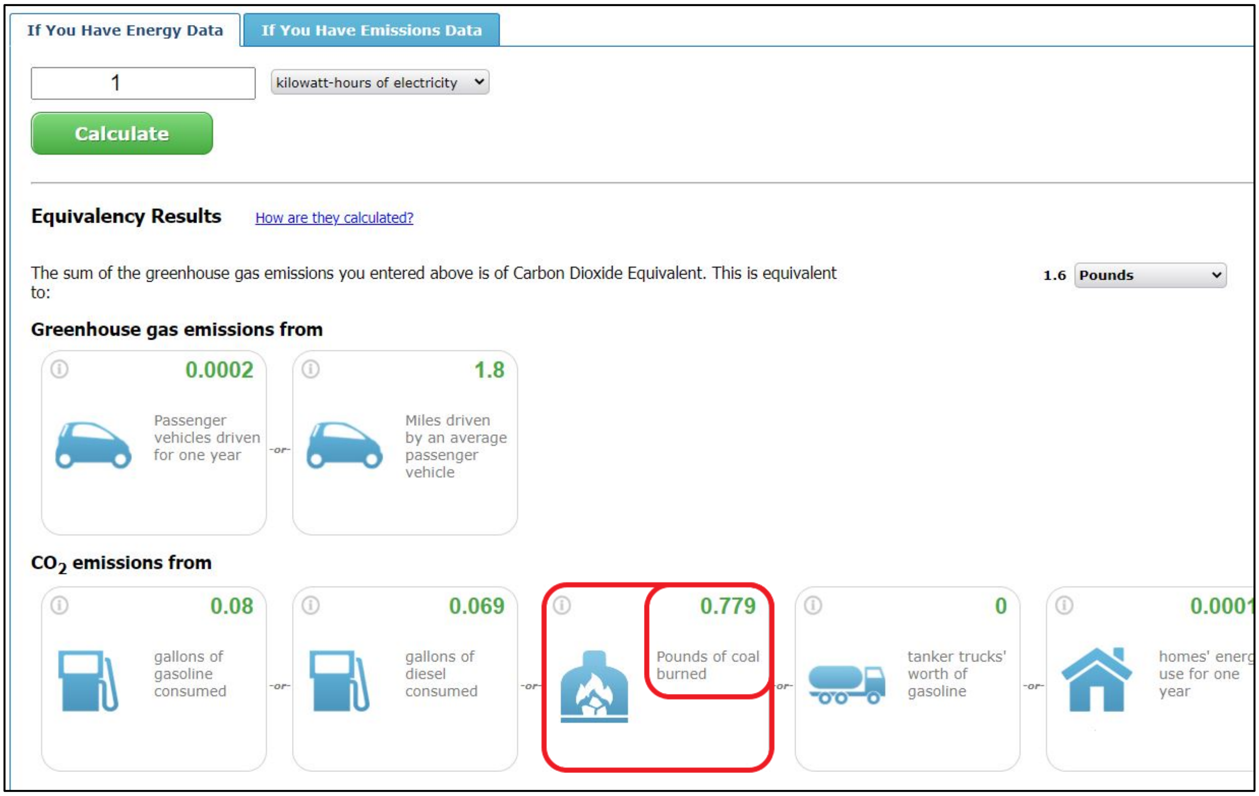
6-3. Where indicated, change the unit of **Metric Tons** to **Pounds**.




6-4. Write the **lbs. of $CO_2$ Equivalent** to produce **1 kilowatt-hour of electricity** into **Table 6 (number 6g.)** of your student lesson.

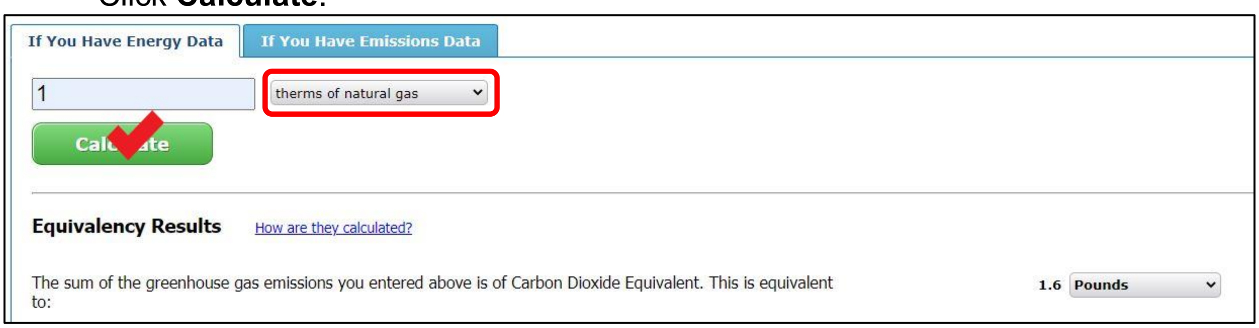


6-5. Write the **lbs. of Coal Burned** to produce **1 kilowatt-hour of electricity** into **Table 6 (number 6i.)** of your student lesson.

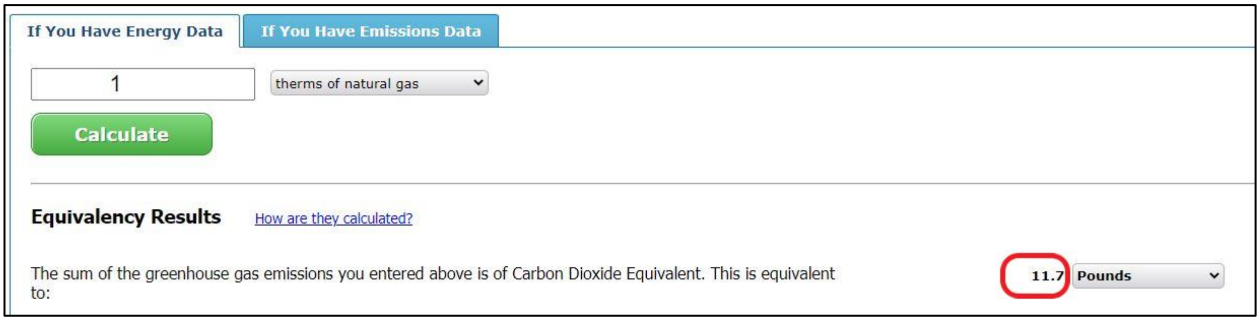



6-6. Change the unit of **kilowatt-hours of electricity** to **therms of natural gas**.

Click **Calculate**.



6-7. Write the **lbs. of $CO_2$ Equivalent** to produce **1 therm of natural gas** into **Table 6 (number 6j.)** of your student lesson.




6-8. Write the **cubic feet of natural gas** that defines **1 therm of natural gas** into **Table 6 (number 6h.)** of your student lesson. [the volume of 1 therm of natural gas varies, but it is approximately equal to 100 ft$^3$ of natural gas.]