ENERGY for the COMMON GOOD

ENERGY 101: SUPPLY & DEMAND BASICS

This overview provides definitions for a basic understanding of the energy sector in order to empower you, the reader, to make estimates about humanity's future energy needs.

Energy Sector 101

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Prepared by Tourmaline Group LLC for
exclusive use of Energy for the Common Good.

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Who is Energy for the Common Good?

Energy for the Common Good (ECG) is a not-for-profit organization that advocates for the widespread acceptance and adoption of fusion energy as an integral part of a clean energy economy, in time to make a difference in battling climate change.

What is our fusion mission?

ECG is building a voice for fusion energy within the existing climate and clean energy community of NGOs, policymakers, activists and investors.

Our mission is to prepare leaders in energy, environmental regulation, and policy to be ready to implement safe, non-carbon innovations as soon as they are available.

Through coalitions, forums, and small groups, we encourage evaluation of fusion's potential to replace our electric grid's fossil baseload; to find confidence in its waste footprint; and to see the many industrial applications available from the various device types and output ranges under development.

Through education, communication, and strategic partnerships, ECG seeks to ensure demand and market support for fusion energy as soon as the industry can deliver it.

WHY DO WE NEED FUSION ENERGY?

Renewable energy largely comes in the form of electricity, and it cannot significantly grow without a fix for intermittency.

Electricity must become the majority of energy consumed globally.

Fusion can step in when the sun does not shine, and the wind does not blow.

WHY THIS BROCHURE?

BECAUSE THE BASIC STRUCTURE OF ENERGY MARKETS ARE POORLY UNDERSTOOD

If you tried to look for basic information about the energy market, such as what percentage of our energy is electricity, chances are you faced several failed attempts before discovering that only 38% of energy is in the form of electricity.

- *Global electricity consumed in 2019 = 23,845 billion kwh*
- *Global total energy consumption in 2019 = 601 quadrillion BTU (quads)*
- *… converting kwh into quads unfortunately will not yield the full answer because of the energy accounting methods employed by the U.S. Energy Information Administration (EIA).*

Numbers and percentages of energy output are published using a variety of accounting methods. This brochure is meant to give you some basic definitions to empower you and your work toward a cleaner future for us all.

We also hope that the reader will come away with a better understanding of why fusion energy is needed, and how it can open the way for more clean, renewable energy.

WHAT YOU WILL LEARN…

This brochure is meant to empower the reader to make her or his own analysis with the available data on the energy and electricity sector.

To that end, this quick guide covers the following basic terms and unit conversions:

- Power vs. energy
- Gigawatt capacity vs. Kilowatt-hours
- Primary Energy & Final Energy
- Kwh & BTU conversions

Energy Market Basics: Making sense of units in supply and demand

Getting a basic overview is not straight forward because demand and supply are multi-faceted in the energy market. Energy accounting uses labels that often require unit conversions, and to boot there is the concept of primary energy and final energy.

Primary vs Final Energy

When reports in the industry reference energy consumption, they will base their calculations on either primary energy, or final energy.

The US Energy Information Administration (EIA) for instance bases their graphs and reports on primary energy consumption.

Bloomberg's New Energy reports on the other hand, are based on final energy used.

While **used** and **consumed** are synonymous, consumed tends to be the verb associated with primary energy, and *used* the verb associated with *final energy*.

BTU vs KJ / EJ … and kwh

If primary/consumed vs. final/used terms were not sufficient to confuse, some will use British Thermal Units (BTU), others will use joules (KJ or EJ).

Then there is the electricity/power sector nomenclature. When referring to electricity production/generation or consumption, the unit generally used is kilowatt-hours (kwh).

This makes it impossible to compare the electricity sector data with the primary or final energy data – that is, unless you take the time to convert the units yourself.

Power or Energy?

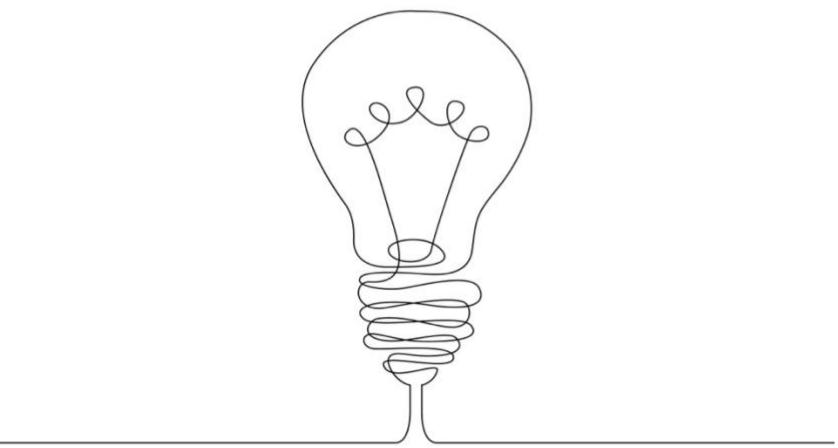
Piling on, the electricity/power sector has its own set of measures.

References to installed capacity are made in gigawatts (GW), which is a unit of *power* not *energy.*

In this report we deal only with energy units, which are a function of power * time, so they will be shown in kwh or billion kwh, or trillion kwh.

What's a watt?

A watt is a unit/measure of power, or force – NOT energy.



When you couple watts with time, it becomes a unit of *energy.*

It is important to keep the concept of power and energy separate.

For example, looking at the power and total output statistics on an indoor cycling machine, or on an app linked to your bicycle, you likely will see both watts and kilojoules.

How hard you are peddling is registered in watts, and the accumulated output you exert is measured in kilojoules.

KILOWATT-HOUR, OR KWH

A kilowatt hour is a measure of energy

A kilowatt is 1000 watts of power. When a kilowatt is sustained for a full hour of time, it is called a kilowatt-hour.

The average home in the US consumes 10,000 kilowatt-hours annually.

WHAT DOES *INSTALLED CAPACITY* MEAN?

Capacity refers to the maximum power an electricity generator can produce under ideal conditions.

At the end of 2020, the US had 1,117 gigawatts of installed capacity.

You may think if you just multiply the installed capacity times 24 hours per day, times 365 days per year I have the total amount of electricity generated, right?

Wrong.

This does *not* mean that the US supplied – or even could supply – 1,117 * 365 days * 24 hours, or 9,784,920 gigawatt-hours of electricity.

Instead, US electricity generators produced 4,009,000 gigawatt-hours of electricity.

That is because *capacity* refers to maximum power output under ideal conditions, and the plants are not always operating under ideal conditions… and rarely at maximum capacity.

WHAT DOES PRIMARY ENERGY MEAN?

"Primary energy" is the term the EIA uses in reference to the energy density of the *feedstock* used in generating the energy.

"Source" or "source energy" are names also used and are synonymous with primary energy.

You may come across different terms. We use *primary energy* in this report, in keeping with the naming conventions of the EIA dataset.

Generally speaking, *primary energy* refers to fossil fuels. That is because green or renewable energy is not combustion based and has minimal efficiency losses.

But that's getting ahead of things… and actually the EIA converts renewable electricity into fossil fuel equivalents in accounting for total energy.

The examples below will provide some clarity.

EXAMPLE A: GASOLINE POWERED CAR

When you fill up your tank with gasoline, the engine combusts the fuel turning it into energy, and moving the car.

In transportation, the primary energy consumed is straightforward to calculate: it is equal to the energy density of fuel types combusted times the quantity used.

Energy density gasoline[1]** number of gallons combusted = total primary energy consumed (kj or BTU)*

[1] 5.25 million BTU / barrel of motor gasoline

Example B: An electric vehicle

However, if you were to power up your car with electricity instead of gasoline, the primary energy consumed is more complicated to calculate because you must consider the energy density of the feedstock that the power company used to generate the electricity you consumed.

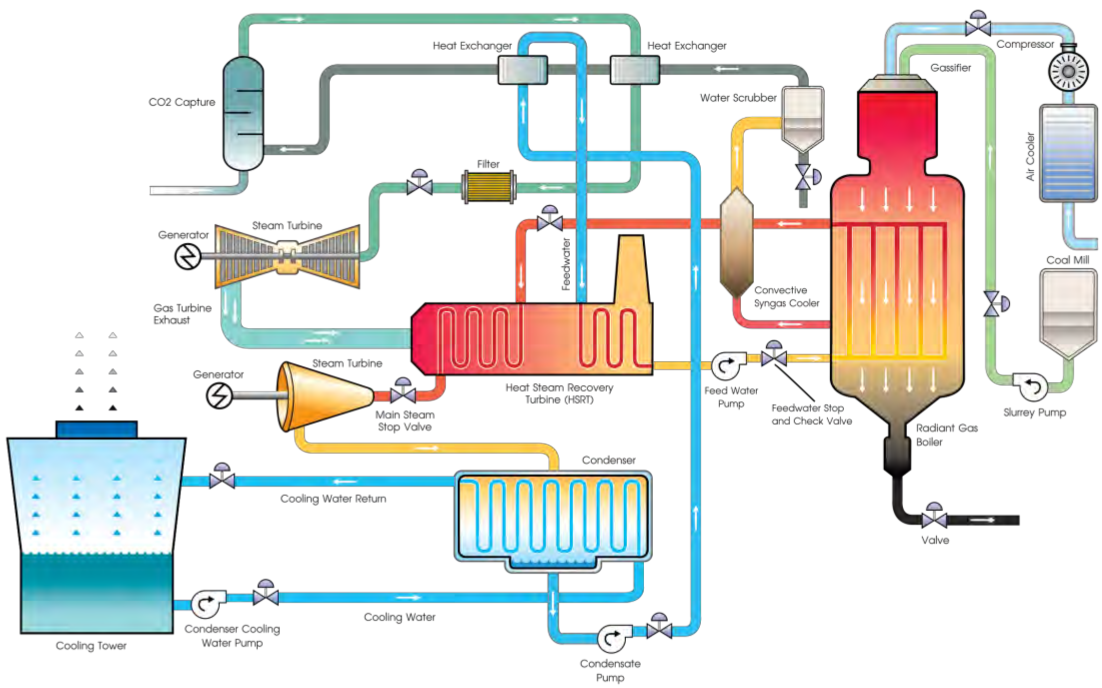
Was it powered by coal, or methane, or something else?

Each has its own energy density and will produce different results.

... AND, WAS IT A COMBINED CYCLE POWER PLANT?

Once you settle the question of the type of feedstock used by the power plant that generated electricity for your car, then you must ask whether or not it was a combined cycle power plant.

Integrated Gassification Combined Cycle Process Diagram



A combined cycle just means that the power plant "combines" or uses two plants so that they can recycle the heat generated by one plant for the other adjacent plant, thereby increasing the efficiency of electricity production.

A single cycle methane gas power plant typically has an efficiency rate of about 30%, and if it is a combined cycle plant, the efficiency is closer to 60%.

In plain language, when generating electricity in a single cycle, you lose 70% of the energy you put in. If you double up, you lose only 40%.

Transmission losses are typically 5%, but can be more

After calculating the energy density of the feedstock a power plant uses, as well as the energy lost in the production of electricity, you must also account for the energy lost in getting the electricity to a particular location.

The EIA estimates that we lose 5% of our energy during transmission. That said, larger distances mean larger losses, which is why the EIA's projection model limits the distance electricity can be transported from one area to another. In other words, given the technology we have today, it is not possible to have the Nevada desert supply the country with solar power.

Assuming you live relatively near the power plant, then you have all the data needed to calculate that electric "fill-up."

- *energy density of the feedstock used by the power plant*
- *energy generation losses*
- *energy transmission losses*
- *kwh to kj conversion factor*

Example C:
An electric vehicle that powers up with solar panels

What if, though, you have solar panels on your home rooftop that fully supplies your electricity needs during the day, and you charge your car at home, during daylight hours.

Because the electricity generated by renewables does not use combustion, it has no generation losses,[2] thus the heat content of the electricity consumed can be used to calculate the "primary energy consumed."[3]

[2] Negligible, if any

[3] Technically you can also calculate the amount of power captured from the sun, but these calculations are for economic purposes, not scientific pontifications. Since sunlight is free, we do not account for it here.

THINGS GET MESSY… TRANSLATING RENEWABLE ELECTRICITY INTO PRIMARY ENERGY TERMS

While it is perfectly acceptable to calculate the heat content of electricity generated with solar panel as the primary energy consumed, it is not what the EIA uses. This is because of intermittency issues.[4]

Those who need to ensure secure energy supply may prefer to calculate the heat content of renewable electricity by converting it into the fossil fuel equivalent. Doing so might address a question such as:

"If fires cause smoke to block the sun for several weeks, how much methane gas would we need in order to replace the electricity losses from this solar plant?"

However, this accounting significantly complicates the process for calculating electricity as a percent of total energy!

[4] Intermittency refers to inability to use electricity when the sun is not shining, or wind is not blowing

WHAT PERCENTAGE OF TOTAL ENERGY DOES ELECTRICITY REPRESENT?

As explained in the section above, because renewables are converted to primary energy using a fossil fuel conversion rate, it is not possible to simply take kwh, convert to BTU and divide by total energy.

Going back to our initial question, what percentage of the energy we consume is electricity, in energy accounting, the subtotals do not add up to the totals!

World -- Electricity Generation	Billion Kwh	Converted to Quad BTU at electricity conversion rate of 3,412 btu/kwh	EIA Nuclear heat rate for electricity conversion (2019)	Converted to Quad BTU at EIA specified conversation rate
Generation (billion kWh)	25827	88		234
Nuclear (billion kWh)	2657	9	10,442	28
Fossil fuels (billion kWh)	16094	55	8905	143
Renewables (billion kWh)	7112	24	8905	63
Hydroelectricity (billion kWh)	4205	14		
Non-hydroelectric renewables (billion kWh)	2907	10		
Geothermal (billion kWh)	88	0		
Solar, tide, wave, fuel cell (billion kWh)	741	3		
Tide and wave (billion kWh)	41	0		
Solar (billion kWh)	700	2		
Wind (billion kWh)	1428	5		
Biomass and waste (billion kWh)	651	2		

Sum of parts does not equal the total!

28+143+63 = 234

234 > 88

Thus, while the topline kwh to BTU conversion yields an answer of 14%, it does not reflect what is actually happening.

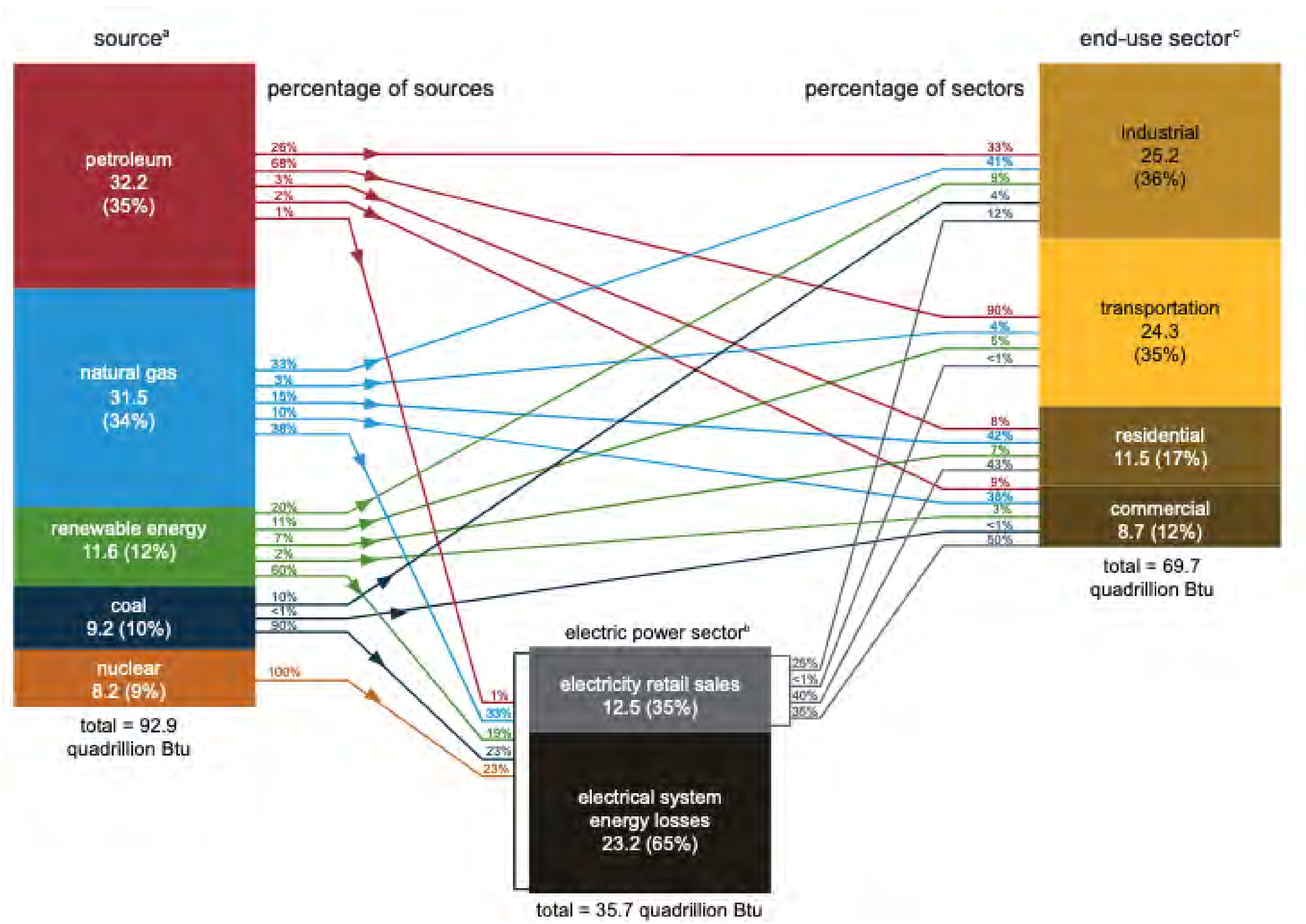
In reality, electricity represents 38% of total energy.

You can read more about renewable energy conversion at the EIA website.

The graph below was taken from the EIA website may help to illustrate the points made earlier.

It depicts the flow of energy from primary sources to final use – or said differently, from sources to uses.

FIGURE 1: US ENERGY BY SOURCE AND SECTOR, 2020



Source: EIA -- U.S. energy consumption by source and sector, 2020

The left-hand stack refers to "primary energy," which here is labeled "source." The right-hand stack is a depiction of "final energy used," which here is labeled "end-use sector."

In the middle is the power sector that consumes the primary, and transforms it into electricity for industry, buildings and homes (…losing a lot in the process).

Conclusion – We need to grow the electricity grid, and fusion can help

Renewable energy comes in the form of electricity, and it is intermittent, meaning it requires sun or wind. Understanding what percentage of our energy use comes from electricity, and how the intermittency problem can be resolved is useful for activists, investors and others working toward a greener future.

Currently, electricity represents only 38% of final energy used. In order to increase use of renewable energy, we need more of our global economy to be powered by electricity.

For the renewable electricity market to grow, we will also need a solution for the renewable energy intermittency problem. Energy for the Common Good believes that fusion is the best available solution.

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