EEE-102 Basic Electrical Engineering
Homework #1 Basics of Energy

Instructor: Parikshit Pareek, EE, IIT Roorkee
https://psquare-lab.github.io/teaching/

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1 Energy Losses Across the Supply Chain

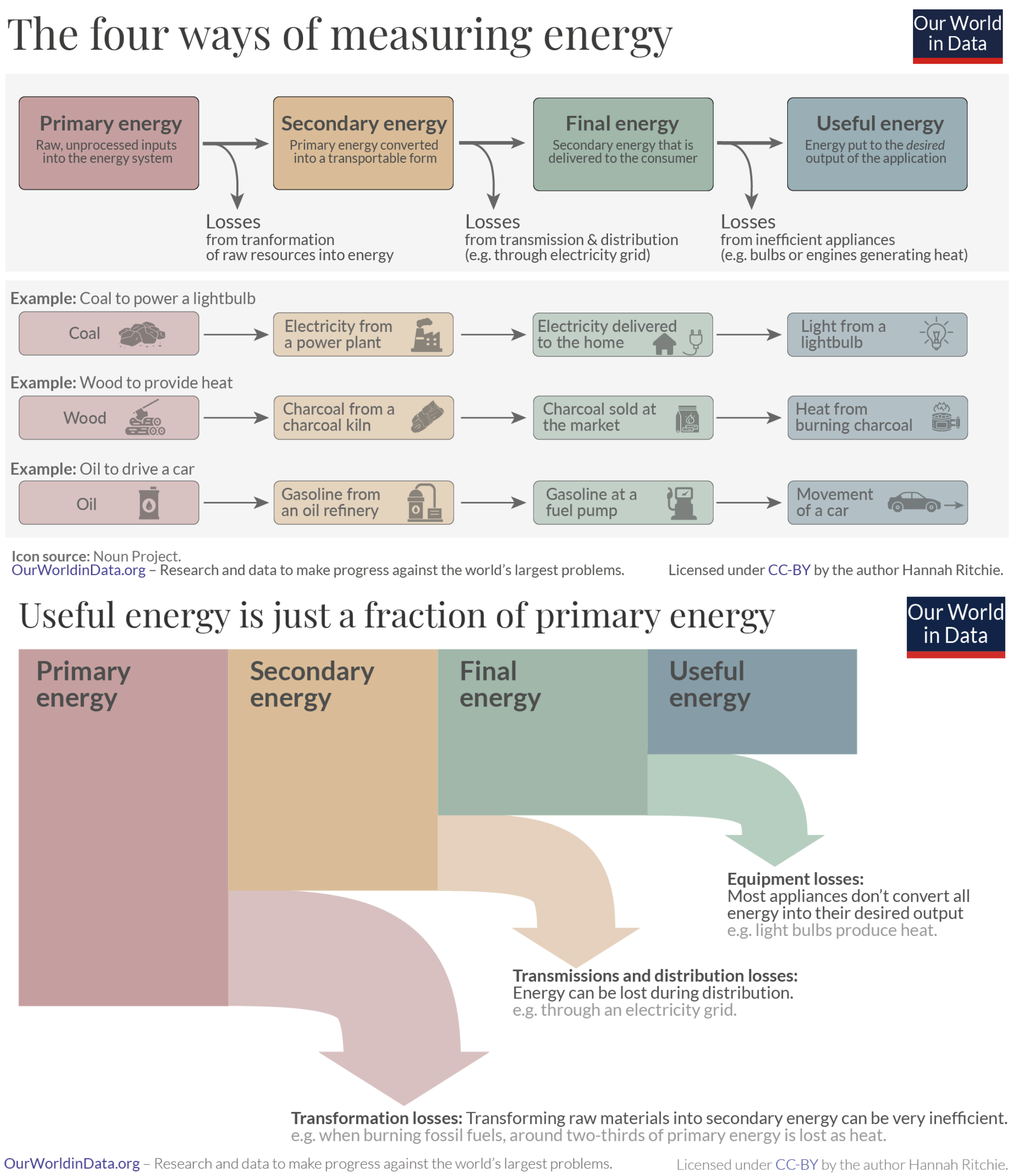

Figure 1: Energy Losses Across Supply Chain

Primary to Secondary Energy

Converting primary energy sources into secondary energy, such as electricity, is often highly inefficient. In thermal power plants, which rely on fossil fuels, biomass, or nuclear energy, up to two-thirds of the primary energy is wasted as heat. For every three units of energy input, only one unit of electricity is produced.

This inefficiency makes fossil fuels appear to contribute disproportionately to primary energy demand when compared to low-carbon sources. In primary energy terms, low-carbon energy contributions may seem smaller because they are not burdened by the significant energy losses associated with fossil fuel combustion. This can distort our perception of their true contribution.

Secondary to Final Energy

Energy losses also occur during the delivery of secondary energy to consumers, referred to as *transmission and distribution* losses. For example, when electricity is transmitted from a power plant (secondary energy) to homes (final energy), a portion of the energy is lost during transmission through power lines.

Final to Useful Energy

End-use appliances are never entirely efficient in converting final energy into the desired output. For instance:

- For lightbulbs, the useful energy is the light produced, but some energy is wasted as heat.
- For cars, the useful energy is movement, but additional energy is lost as heat and noise generated by the engine.

Any energy not directly used for the intended purpose of an appliance is considered waste.

Key Insight

The energy needed by end-users is often a small fraction of the energy entering the system at its initial stage. As shown in energy flow schematics, while the world generates a substantial amount of energy, much of it is lost across the various stages of conversion, transmission, and utilization. Each stage measures the energy available at different points along the supply chain.

2 Conversion of Primary Energy to TWh

- Energy from fossil fuels—coal, oil, and gas—is commonly measured as primary energy. This refers to the total amount of energy produced when these resources are burned in their raw state. For example, in the case of coal, it is the total energy obtained from its combustion.
- However, renewable electricity sources like solar and wind are not measured in the same way. Instead, they are reported based on the actual electricity output they generate.
- Consider the implications of this. We are comparing the energy produced by fossil fuels, which includes significant heat loss, to the efficient electricity generation of renewables, which avoids such wastage. Consequently, replacing electricity from coal and gas with renewables would significantly reduce overall energy requirements.

Substitution Method

- Non-fossil electricity generation is divided by a 'thermal efficiency factor', which is the average efficiency of fossil electricity.
- This is because thermal plants experience heat losses.
- Nuclear: In reality, nuclear does experience thermal losses in a power plant, just like fossil fuels. It has a thermal efficiency ranging from around 33% to 40%. But since it's reported in terms of electricity output, we need to do this adjustment to calculate its equivalent input value.
- Since we're adjusting renewables upwards – to assume that they're more efficient than they are – primary energy measured by the 'substitution method' overstates the amount of energy that's produced.

2.1 Numerical Example: Adjusting Non-Fossil Electricity Generation

A country has the following electricity generation data for a year:

- **Fossil Fuel Electricity Generation**: 1000 TWh
- **Non-Fossil Fuel Electricity Generation**:
  - **Nuclear Power**: 300 TWh
  - **Renewables (Solar, Wind, Hydro, etc.)**: 200 TWh
- **Thermal Efficiency Factor of Fossil Fuel Plants**: 40% or 0.4

– The task is to adjust the non-fossil fuel electricity generation to account for the losses experienced in thermal generation.

– This adjustment reflects the "primary energy equivalent" of non-fossil generation.

Solution

1. **Adjust Nuclear Generation:** Nuclear power experiences thermal losses similar to fossil fuel plants. Adjust its generation by dividing it by the thermal efficiency factor:

$$\text{Adjusted Nuclear Generation} = \frac{\text{Nuclear Generation}}{\text{Thermal Efficiency Factor}} = \frac{300}{0.4} = 750\,\text{TWh}$$

2. **Adjust Renewable Generation:** Renewables (like solar and wind) do not experience significant thermal losses. However, for comparison purposes, they are scaled similarly:

$$\text{Adjusted Renewable Generation} = \frac{\text{Renewable Generation}}{\text{Thermal Efficiency Factor}} = \frac{200}{0.4} = 500\,\text{TWh}$$

3. **Total Adjusted Non-Fossil Generation:** Add the adjusted contributions of nuclear and renewable energy:

$$\text{Total Adjusted Non-Fossil Generation} = 750 + 500 = 1250\,\text{TWh}$$

Final Adjusted Electricity Generation

The adjusted electricity generation, reflecting primary energy equivalents, is:

- **Fossil Fuel Electricity Generation**: 1000 TWh
- **Adjusted Non-Fossil Fuel Electricity Generation**: 1250 TWh

This adjustment highlights the “true” energy output when thermal losses are considered, showing non-fossil sources in an equitable framework relative to fossil fuels.