

# Fusion Physics

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## A. Chapter 0: Energy and Global Income Distribution

### A.1. How is income distributed globally, and how does it relate to energy consumption?

#### Solution

If we divide the world into 4 groups  $1/7$  would earn under 2\$, another  $3/7$  between 2\$ and 8\$, another  $2/7$  between 8\$ and 32\$ and the last  $1/7$  would earn more than 32\$ a day. The energy consumption is distributed in a similar way.

In richer countries people eat more, drive more, fly more, and use more utilities, all leading to higher energy consumption.

### A.2. Compute the primary energy consumption in a fully developed country per capita and day from:

#### A.2.1. a) Estimating a person's individual consumption (heating, electricity, car, etc.)

#### Solution

I roughly pay for about 1000 Kwh of electricity per year. That is about 3 Kwh  $\Rightarrow 3 \cdot (3600 \cdot 1000) = 10.8$  MJ per day.

Heating is roughly double to triple that, so about 25 MJ per day.

1 L of gasoline has about 32 MJ of energy and I drive about 10.000 km a year:  $10.000 \text{ km} / 5 \text{ L per } 100 \text{ km} = 2000 \text{ L of gasoline per year}$ . That is 64 GJ per year or 175 MJ per day.

Clearly I'm driving a lot. With production of goods + transportation and other stuff I'd say I'm at about 300 MJ per day roughly 85 Kwh/day

**Note:**  $1 \text{ J} = 1 \text{ Ws}$ ;  $1 \text{ Kwh} = 3600 \cdot 1000 \text{ J} = 3,6 \text{ MJ}$ ;  $1 \text{ MJ} = 0,277 \text{ Kwh}$

#### A.2.2. b) From the macroeconomic perspective of a whole country

#### Solution

Primary energy consumption of Austria is about  $1,4 \cdot 10^{18} \text{ J/year}$  which is (divided by  $365 \cdot 10 \text{ Mio. [people]}$ ) about 380 MJ per person per day or about 105 Kwh per person per day.

### A.3. Explain energy intensity

#### Solution

Energy intensity is a measure of the energy inefficiency of an economy. It is calculated as units of energy per unit of GDP (Gross Domestic Product) or some other measure of economic output. High energy intensities indicate a high price or cost of converting energy into GDP. (Wikipedia)

Depends on multiple factors: climate, energy mix and sectors in the economy of the given country (e.g. industry vs. services vs. agriculture, etc.)

### A.4. How do primary energy consumption and consumer electricity differ?

#### Solution

1) Primary energy consumption is the energy contained in the fuel (e.g. coal, oil, gas, uranium, etc.)

2) Consumer electricity is the energy that is delivered to the consumer (e.g. electricity from the wall socket).

As seen in the question above, the actual electricity consumption (bill) I gave was about 10% of the primary energy consumption per person.

**Of the primary energy only about 20% are actually converted to electricity and half of that is used by consumers (rest in industry, loss etc.)**

### A.5. What's the energy mix in Austria?

**Solution**

See this [\[LINK\]](#)

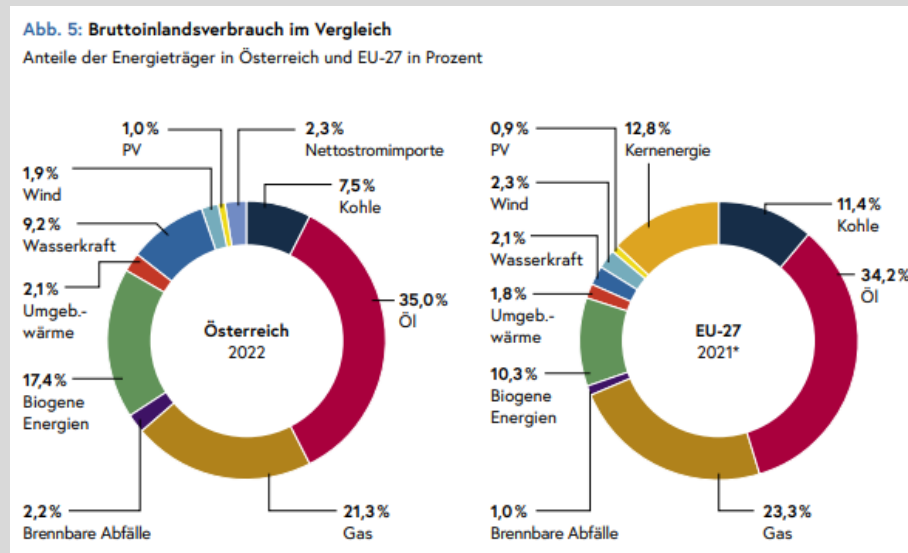


Abbildung 1: Energy mix in Austria

So we have mostly oil and gas ( 55%) and then renewable energy sources ( 35%) and coal and waste + import ( 10%).

### A.6. Given a number for reserves of a single fossil resource, compute:

A.6.1. a) What part of the energy mix it can contribute sustainably (1000 years)

**Solution**

A.6.2. b) How long would it last at current consumption levels

**Solution**

**A.7. How much  $\text{W/m}^2$  can various energy sources produce? How would you compute it?**

Solution

**A.8. Discuss whether renewables compete with arable land for food production. What about biofuels?**

Solution

**A.9. Discuss the ongoing price-drop in solar, and what it means for other alternatives, such as future fusion energy**

Solution

**A.10. Discuss the question of perceived and quantitative risk for the environment from various aspects of civilization (e.g., birds vs cats/wind turbines)**

Solution

**A.11. Are there  $\text{CO}_2$ -free energy sources? Why/why not?**

Solution

## B. Chapter 1: Nuclear Energy and Fusion

**B.1. Give a historical perspective of the controlled use of nuclear energy in general and fusion in particular.**

Solution

**B.2. Draw and explain a schematic fusion power plant.**

Solution

**B.3. Explain the difference between magnetic and inertial confinement fusion.**

Solution



## C. Chapter 2: Discoveries Leading to Fusion

**C.1. Give a historical perspective on the scientific discoveries that led to the discovery of fusion.**

**Solution**

**C.2. Explain how the mass defect of various isotopes can be used to extract energy in fission and fusion.**

**Solution**

## D. Chapter 3: Stellar Energy and Fusion

D.1. Where does the energy in stars come from, and how was it conjectured?

Solution

D.2. Write the reaction of the proton-proton cycle. Why is it important for stars?

Solution

D.3. How are stars able to generate conditions for fusion, and why do we need other ways on earth?

Solution

D.4. What's the meaning of different star stages and their composition? What stage is the Sun and elements can it produce?

Solution

D.5. Explain primordial nucleosynthesis and how it led to the current universe.

Solution

## E. Chapter 4: Fusion on Earth

**E.1. Write equations and explain similarities and differences between fusion reactions that are realistically possible to do on earth.**

[Solution](#)

**E.2. Why is tritium a scarce resource and how to produce it?**

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**E.8. Discuss from a historical perspective how close we are to reach scientific and technical break-even and ignition for various fusion technologies.**

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## G. Chapter 6: The Hydrogen Bomb

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**G.5. Discuss ideas for civil uses of nuclear bombs and why they failed.**

Solution

## H. Chapter 7: MISSING