



Energy Use

Renewable Energy Integration in the Energy System

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Recap

Energy is the ability to do work.

Energy can neither be created nor destroyed. Energy can only be transferred from one place to another or converted from one form to another.

Units of Energy

Joule [J]
Calorie [cal]
Kilowatt hour [kWh]
Cubic meter of gas [m³ gas]
Tonne of oil equivalent [toe]

Efficiency

$$\eta = \text{Efficiency} = \frac{\text{useable output}}{\text{input}}$$

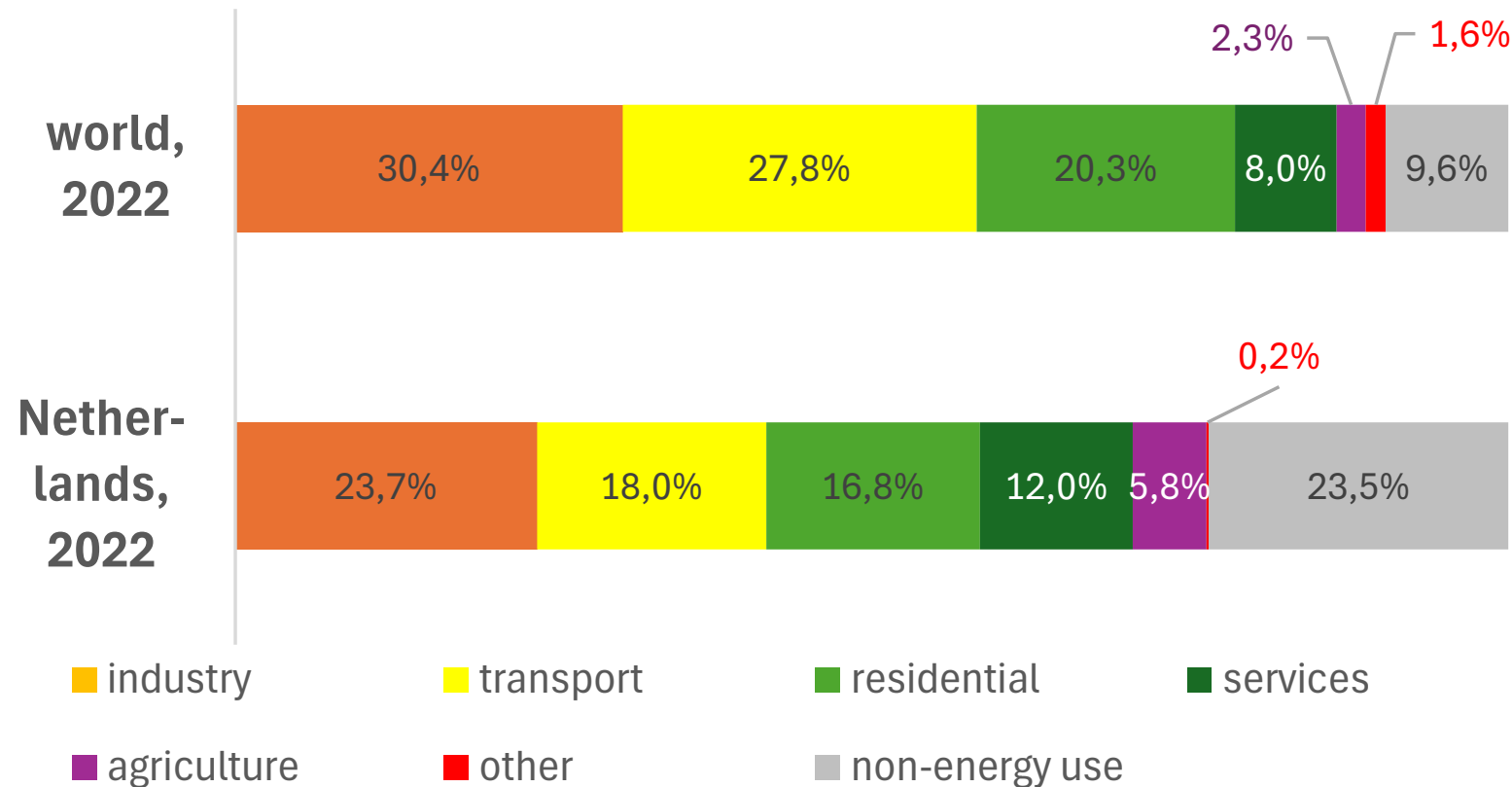
Power

$$P = \text{Power [W]} = \frac{\text{Energy [J]}}{\text{time [s]}}$$



Energy Use

Total Energy Consumption



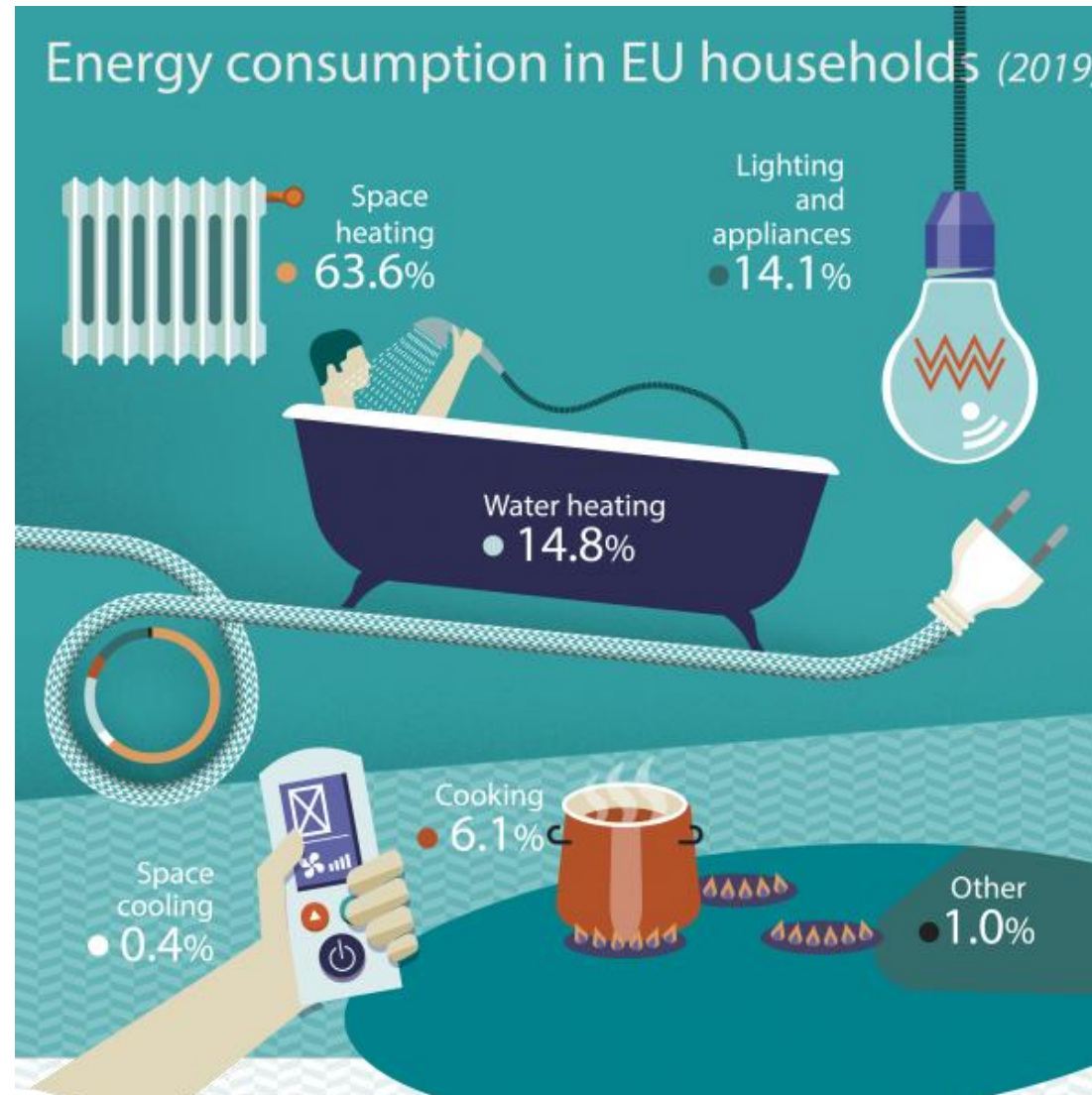
In numbers:

620 EJ (= $620 \cdot 10^{18}$ J)

2713 PJ (= 2,713 EJ)



Energy Use Household



Yearly energy per household (EU):

1.26 toe =
50.6 GJ



Energy Use



heating (and cooling)

heating = 88.72 GJ



electrical appliances

appliance = 131.4 MJ



Energy Efficiency

$$\text{energy input} = \frac{\text{useful energy output}}{\text{efficiency}}$$

heating = 88.72 GJ

electrical appliance = 131.4 MJ

central heating efficiency = 90%

electrical efficiency $\approx$ 100%

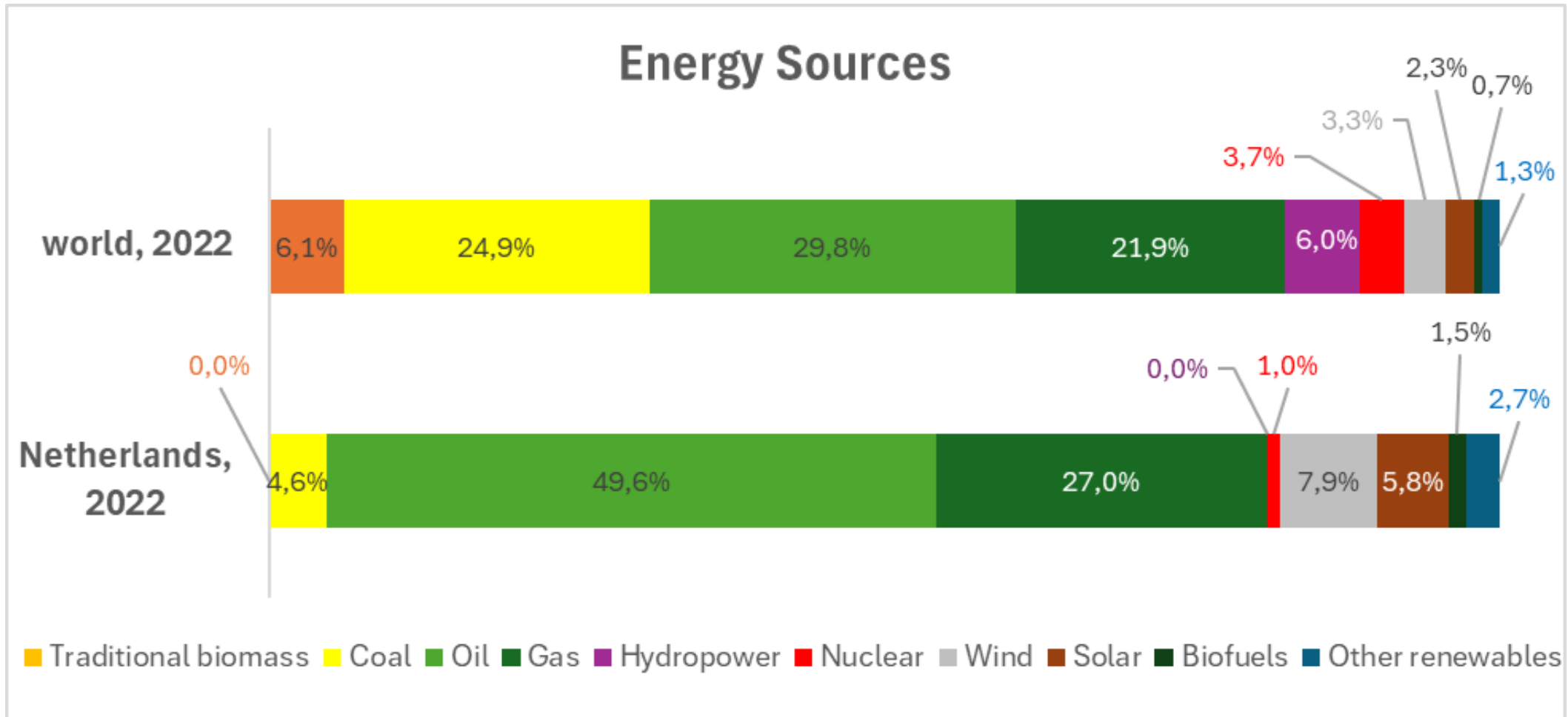
$$\text{energy input} = \frac{88.72}{0,9} = 98.56 \text{ GJ}$$

$$\text{energy input} = \frac{131.4}{1} = 131.4 \text{ MJ}$$

In the EU, 16% of energy is “lost” in conversions



Energy Sources

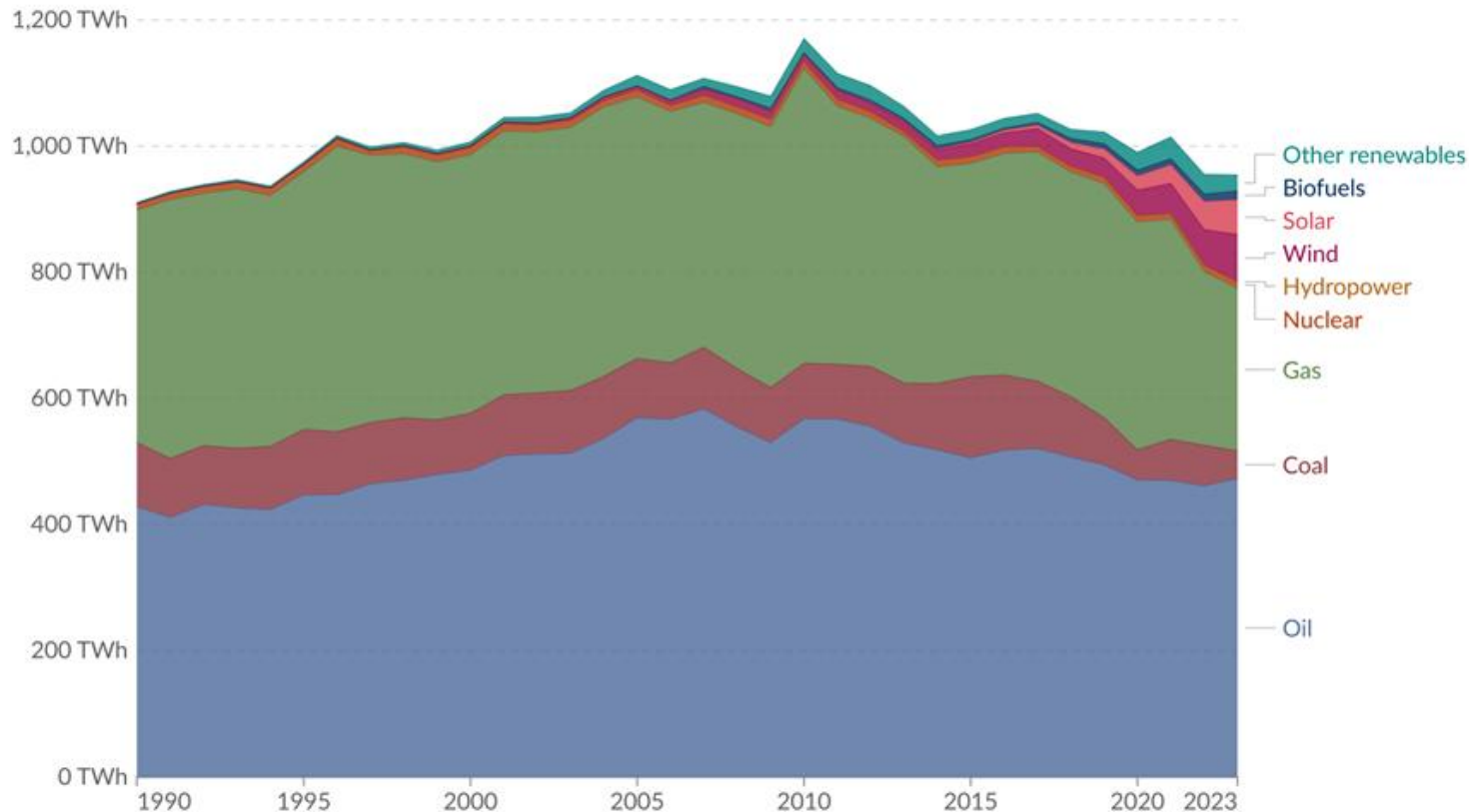


Energy Sources; Changes

Energy consumption by source, Netherlands

Measured in terms of primary energy¹ using the substitution method².

Our World
in Data



Goal for shift to renewables:

- Global warming!
- Limit temperature rise to 1.5 °C.
- Mainly by limiting CO₂ emission.
- Renewables emit no (nett) CO₂.



Renewable Energy

Renewable energy is defined as energy derived from natural sources that are replenished at a higher rate than they are consumed.

Recognised Sources

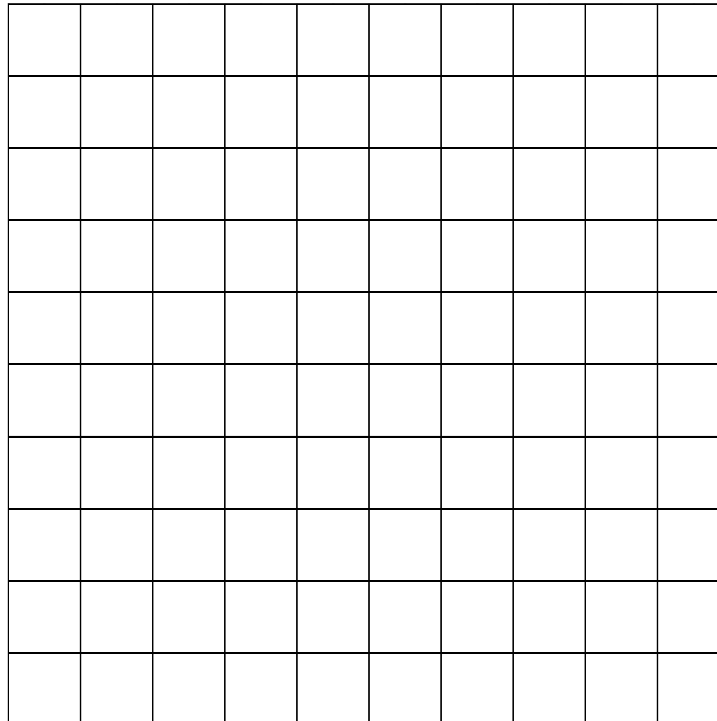
Solar
Wind
Geothermal
Hydropower
Ocean
Bio(mass)



RE Potential; Challenges

1st step is always trying to reduce energy use!

In 2050 we should be CO₂ free and NL requires roughly 2800 PJ/year



NL:

41,500 km² land

58,000 km² sea

Population:

20 million (2050)

Energy demand:

106 kWh/(person.day)



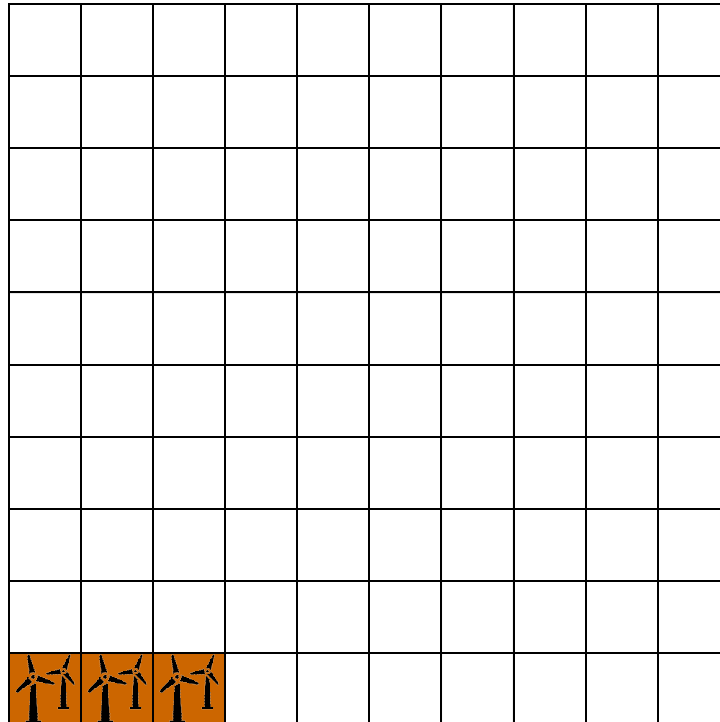
RE; Challenges

Windpower on Land

Wind generates 1 W per m² of land

Let's assume 6% of total land mass used for wind power

78.5 PJ (2.82 %)



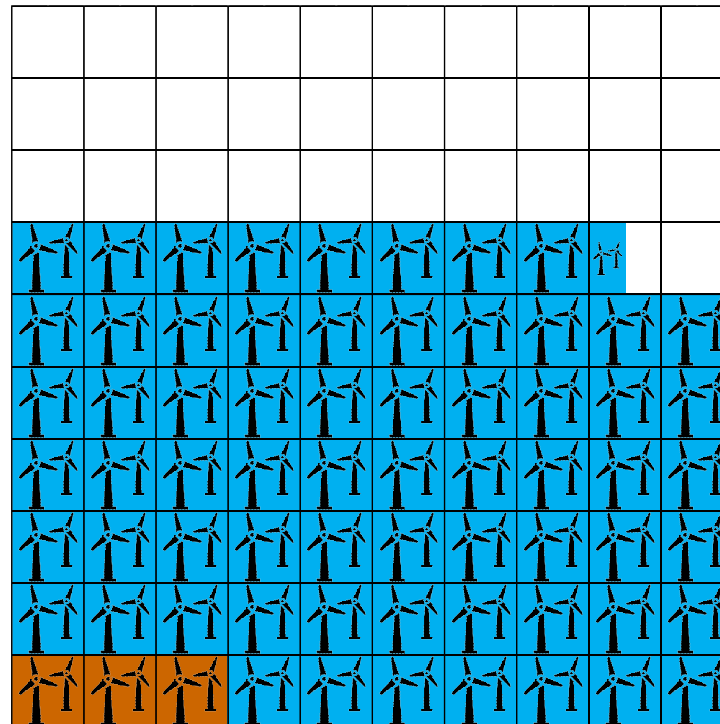
RE; Challenges

Windpower at Sea

Wind generates 5 W per m² of sea

Let's assume 20% of sea area used for wind power

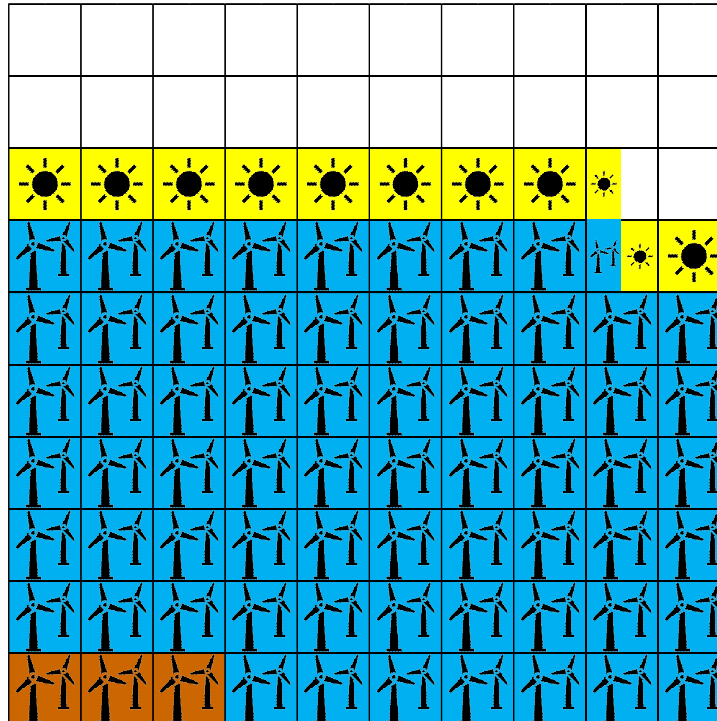
1829 PJ (65.7 %)



RE; Challenges

Solar Power, PV

Let's assume 20 m² PV panel per person available
Solar influx is 110 W/m², efficiency at 20%
278 PJ (9.96 %)



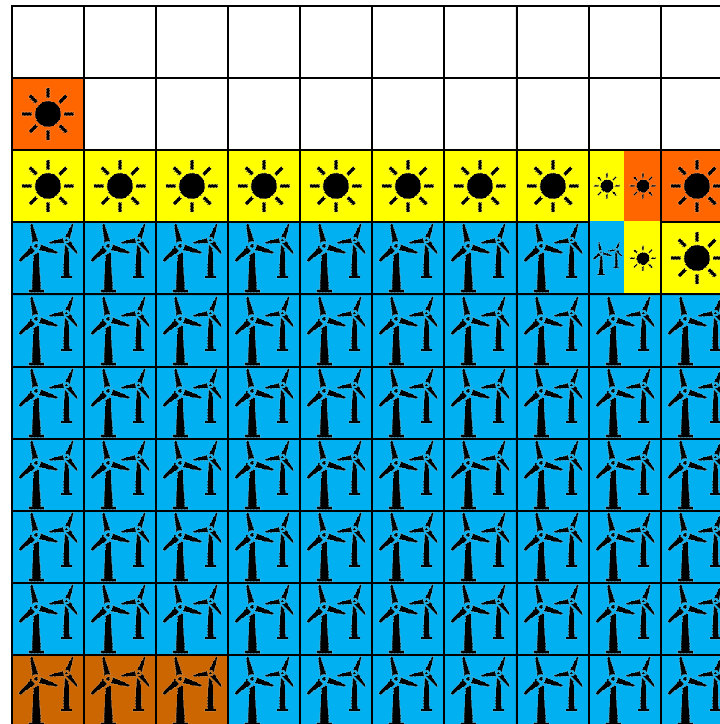
RE; Challenges

Solar Power, Heat

Let's assume 2 m² solar boiler per person available

Efficiency at 50%

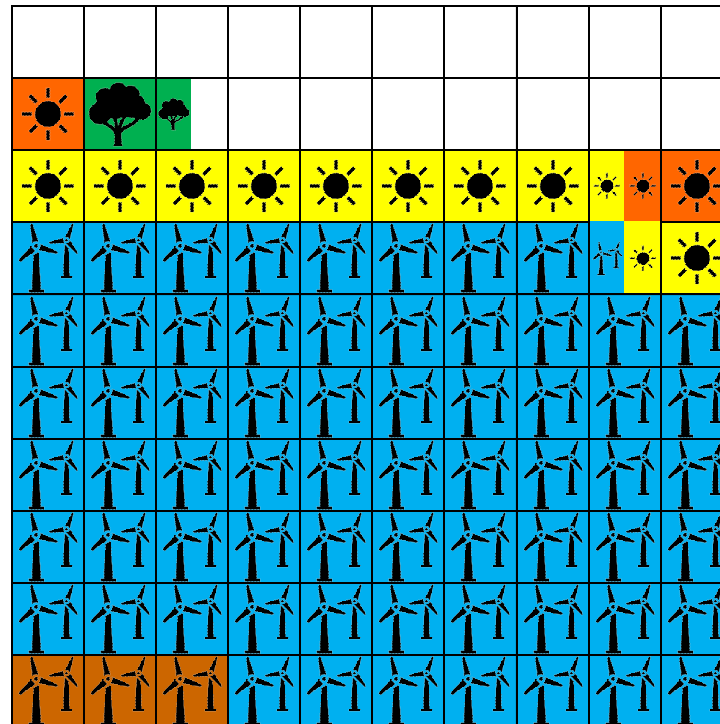
69.4 PJ (2.49 %)



RE; Challenges

Biomass

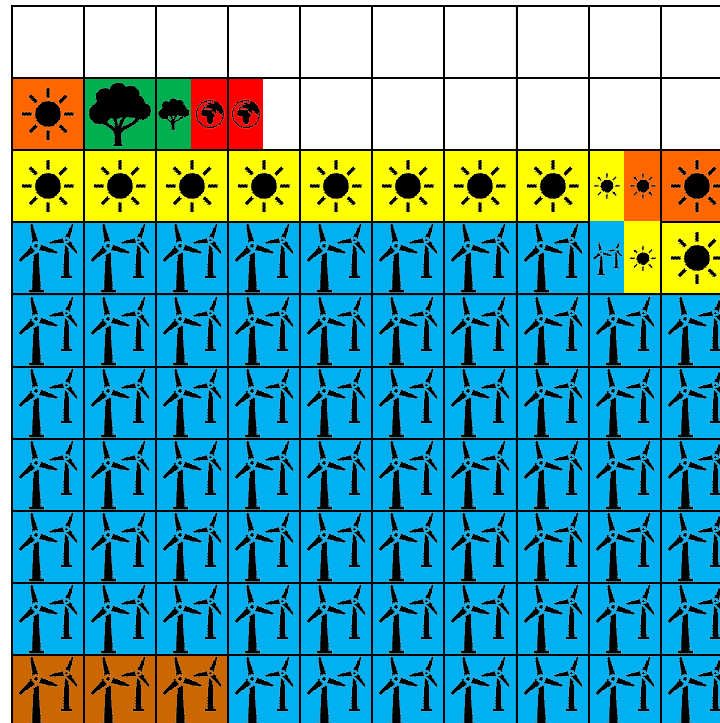
Let's assume 6% of NL with farms for biomass
Crops yield 0.5 W per m² of agricultural area
39.3 PJ (1.41 %)



RE; Challenges

Geothermal

Heat can be extracted at 0.05 W/m^2
Assuming 50% of NL used (underground)
32.7 PJ (1.17 %)



Content references

Energy Use: International Energy Agency (www.iea.org); CBS (through www.energie-nederland.nl)
Energy Use Household: [Energy in the built environment](#), book chapter from Sustainable Urban Environments by Laure Itard.
Energy sources: data from www.ourworldindata.org

Pictures:

Energy Consumption by Source, Netherlands: from www.ourworldindat.org
Fire Flames by [zdenet](#) from [Pixabay](#)

Books

Ouwehand, J., Trynke, P., Post, E., Taal, A. (2012) Toegespaste Energietechniek, Sdu, Den Haag.
Ouwehand, J., Trynke, P., Gilijamse, W., Geus, J. de (2017) Duurzame energietechniek, Boom, Amsterdam.

let's change
YOU. US. THE WORLD.