BEST
Bioenergy and
Sustainable Technologies

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Energy System Perspectives for Net Zero

BOKU
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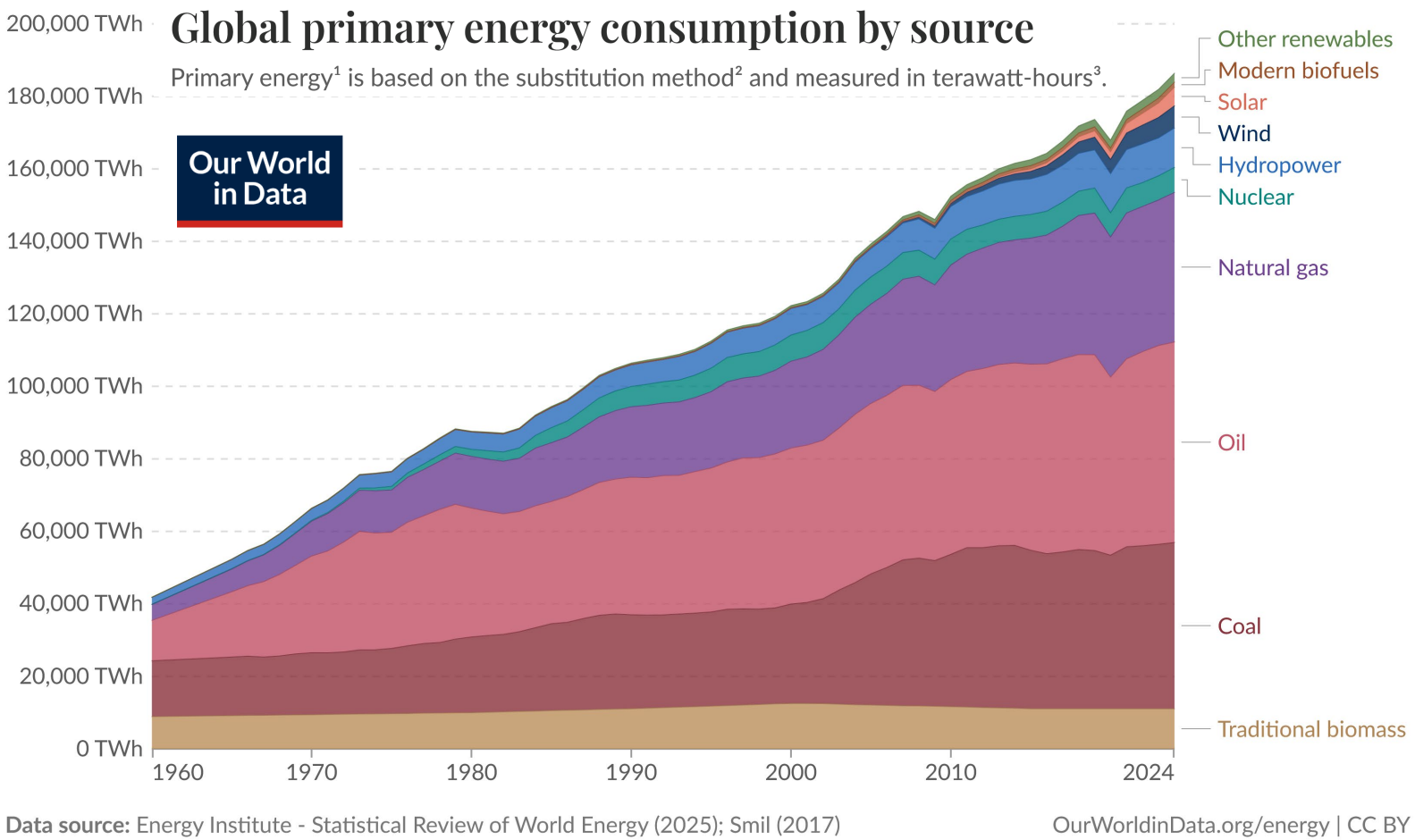
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Learnings from 35 Years of Climate Politics

- **Hope for global governance is shattered by reality.**
- **Poorly designed policies shift emissions**, not reduce them globally.
- **Subsidies** are politically popular, but **often inefficient** in practice.
- **Carbon taxes are effective but widely unpopular**, even when accompanied by dividends.
- **Voters tend to move away** from parties advertising climate policies.

Why do we utterly fail to steer toward net zero?

It’s the energy, stupid!



- > 80% fossil (globally)
- Fossil consumption still growing
- Growing renewables still do not cover increasing demand
- ¾ of all greenhouse gas emissions from fossil fuels

Why are fossil fuels so attractive?

Cost of oil production

- Middle East and Iran: **10 USD/bbl** (**6 USD/MWh**, **20 USD/t_{CO2}**)
- Russia, Northern Africa: **20 USD/bbl**
- Kazakhstan, Mexico, Nigeria: **30 USD/bbl**
- Norway, Canada, US: **40 USD/bbl**
- Brazil, UK: **50 USD/bbl**

www.statista.com/statistics/597669/cost-breakdown-of-producing-one-barrel-of-oil-in-the-worlds-leading-oil-producing-countries/

- Global oil market price: 20-120 USD/bbl **(mostly around 60 USD/bbl)**

→ Unabated fossil fuels are relatively cheap to produce (<1 ct./kWh).

→ A carbon tax of **100 USD/t_{CO2}** adds **50 USD/bbl** to oil costs.

1st key question of this talk

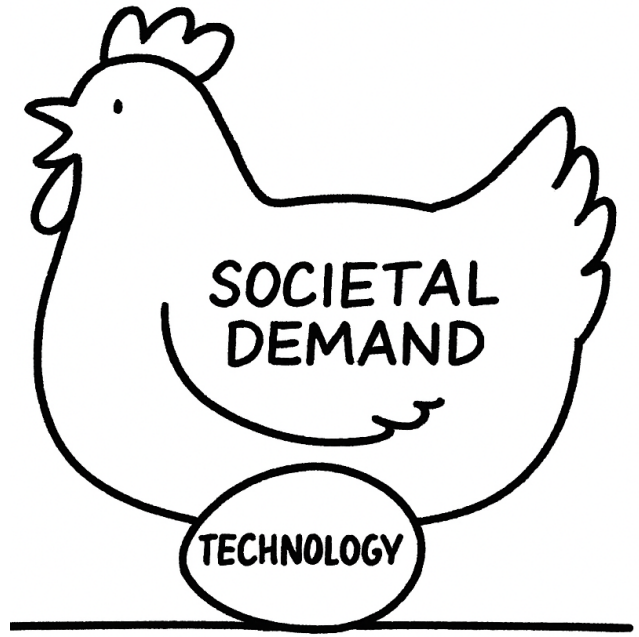
Why is there so little breakthrough in renewable energy generation and other net zero technologies?

→ Because **unabated fossil** solutions (without accounting for environmental damage) are still **more profitable** in many cases.

→ Could we effectively do something about this?

Learnings from Recent Crises (A Glimmer of Hope)

1. **COVID-19 Pandemic**
   - **Politicians can act decisively when needed** — even if measures are unpopular or costly.
   - **Technological development accelerated dramatically** when demand created business cases.



2. **2022 European Energy Crisis**
   - **Price signals do work** — high energy prices triggered rapid adaptation and efficiency gains, thus (temporarily) decreasing greenhouse gas emissions.

Any use in this for fighting climate crisis?

In Theory, Our Approach Should Be…

a) **Effective** → Capable of reducing emissions deeply and quickly

b) **Locally Applicable** → Economically work without global governance

c) **Legally Feasible** → Align with established legal standards

d) **Technologically Open** → Cost-efficient solutions evolve naturally

e) **Socially & Globally Fair** → Contribute to improving income equality

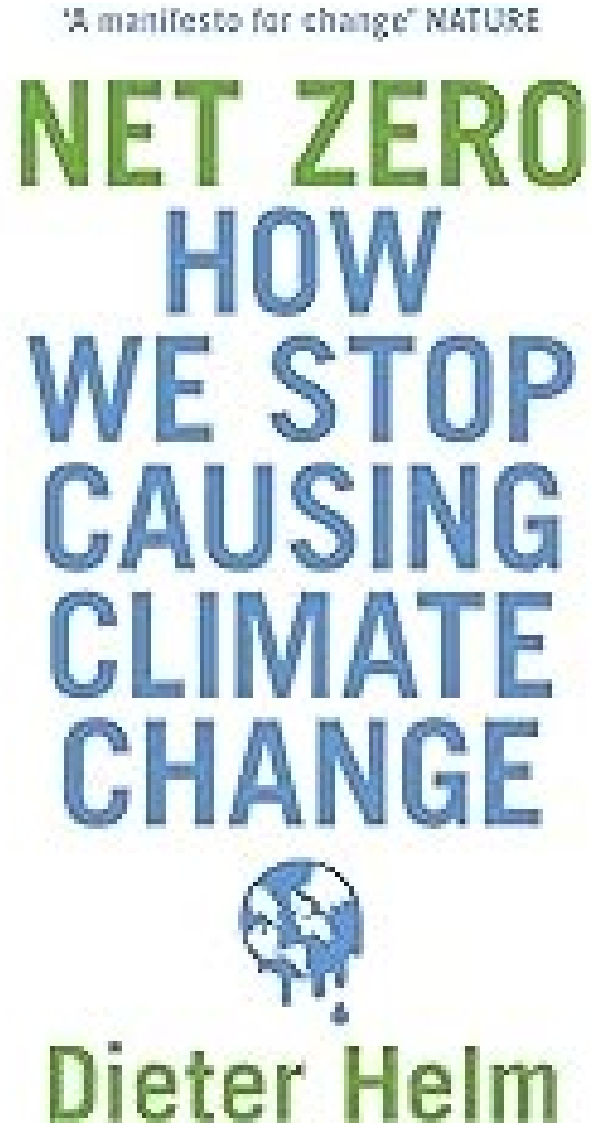
f) **Democratically Supported** → Win and maintain majority support

Could such a „*eierlegende Wollmilchsau*“ exist?

Paradigm Shift

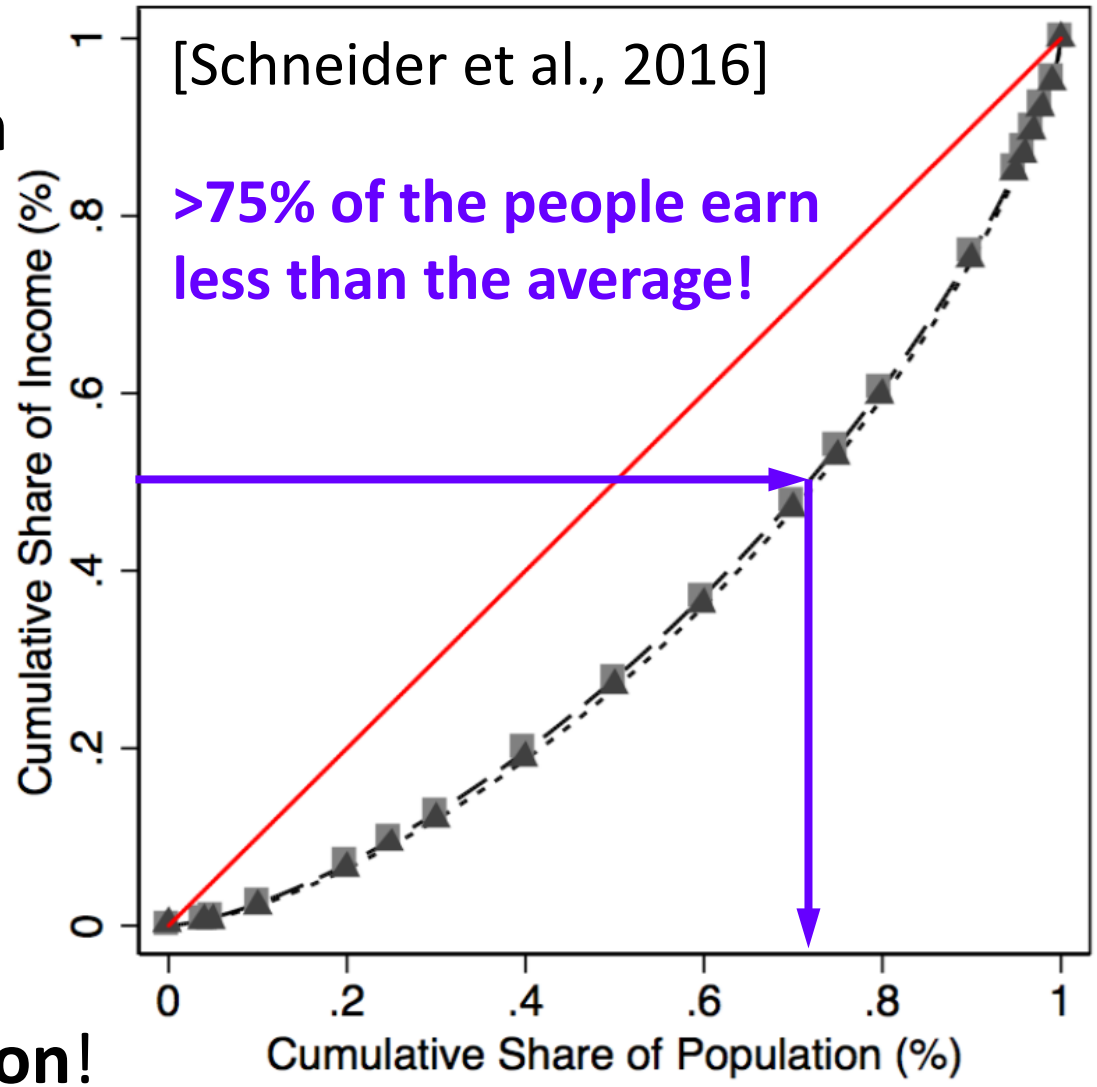
- The **polluters** are ***NOT*** **"the industry"** or **"China".**
- The **responsible** polluters are **YOU and ME** –
  WE who BUY carbon-intensive goods and services.
- Dieter Helm: "**Make the Polluter Pay!**"
- Consequence: **Act on consumption directly!**
- Through a **tax on carbon consumption.**

BUT: How to get the democratic consent
to such a measure?



The Option of Carbon Dividends

- **Aim:** Fair **redistribution** to **maintain purchasing power** and to **secure democratic backing**.
- **However:** Emissions **concentrate at the top** of the income pyramid.
- A majority of the electorate rationally benefits from equal per-capita re-distribution.
- Remaining challenge: **Communication**!



How Could It Look Like?



- Efficiently **assess footprints for product categories**
- **Consumer-level carbon footprint tax** alongside VAT
- **Fair Redistribution**
  - E.g. tax revenue redistributed equally per capita → the **majority benefits**
- **Competitive advantages for decarbonized supply chains**
  - Companies can claim reduced footprints if produced with lower emissions
  - Verified and approved by authority → competitive advantage
- **No production/import charges** or direct taxing of smokestack emissions
- Transparent, gradual but **ambitious tariff increase** toward net-zero levels

→ The overall purchasing power is not affected. → High tariffs possible

Expected Results

- **Consumers pushed** toward **climate-friendly consumption behavior**
  - **Including sufficiency**! Mechanism works **based on simple emotions**.
  - No reliance on individual goodwill!
- **Market demand for low-carbon** products and **supply chains**
  - Low-carbon **business cases without subsidies**
  - **Industry** transforms **without incentive to relocate**
- Economic redistribution while **maintaining overall purchasing power**
  - **Ambitious carbon pricing possible – €500/t_{CO2}** levels required for net zero
  - Improved societal resilience through **reduced income inequality**

→ Democratic support possible *IF* adequately *COMMUNICATED*.

2nd key question of this talk

If such a framework could be established –
which technologies can we expect to see?

- Steering in uncertainty

  → Priority for more cost-effective measures

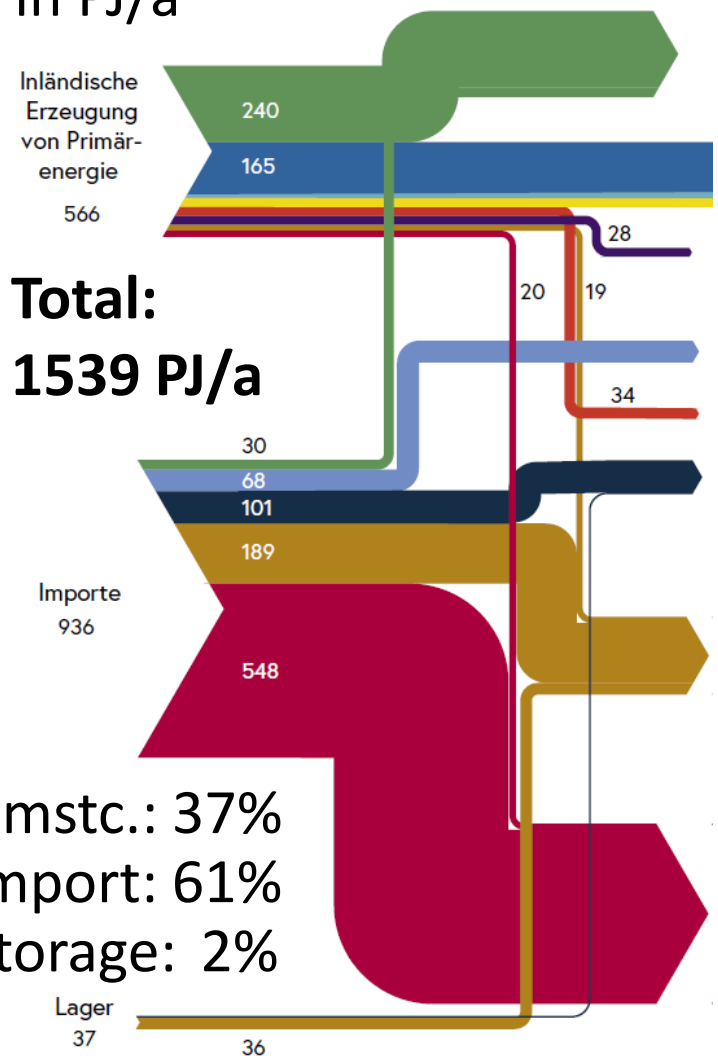
- Mid- and long-term predictions highly questionable

→ Short-term focus on **no regret measures**

→ High climate change mitigation effect per EUR

Present energy supply in Austria – Data 2024

in PJ/a



Total:
1539 PJ/a

Dmstc.: 37%
Import: 61%
Storage: 2%

Biomass: 17.5%

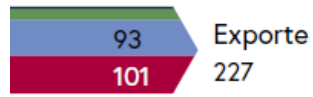
Hydropower: 10.7%
Wind: 2.1%, PV: 1.8%
Waste to energy: 1.8%

El. import: 4.4%
Environm. heat: 2.2%
Coal: 6.6%

Natural gas: 15.9%

Petroleum: 36.9%

Minus exported energy 227 PJ/a



Yields Gross-National Energy Consumption of **1312 PJ/a**.

Energy supply Austria

60% fossil

40% renewable

1 PJ = 3.6 TWh

→ **How to phase out the 60%?**

[Energieflussbild Österreich 2024 – Austrian Energy Agency, Statistik Austria]

What is the energy for? – Final energy – Data 2024

in PJ/a

Biomass: 156 PJ

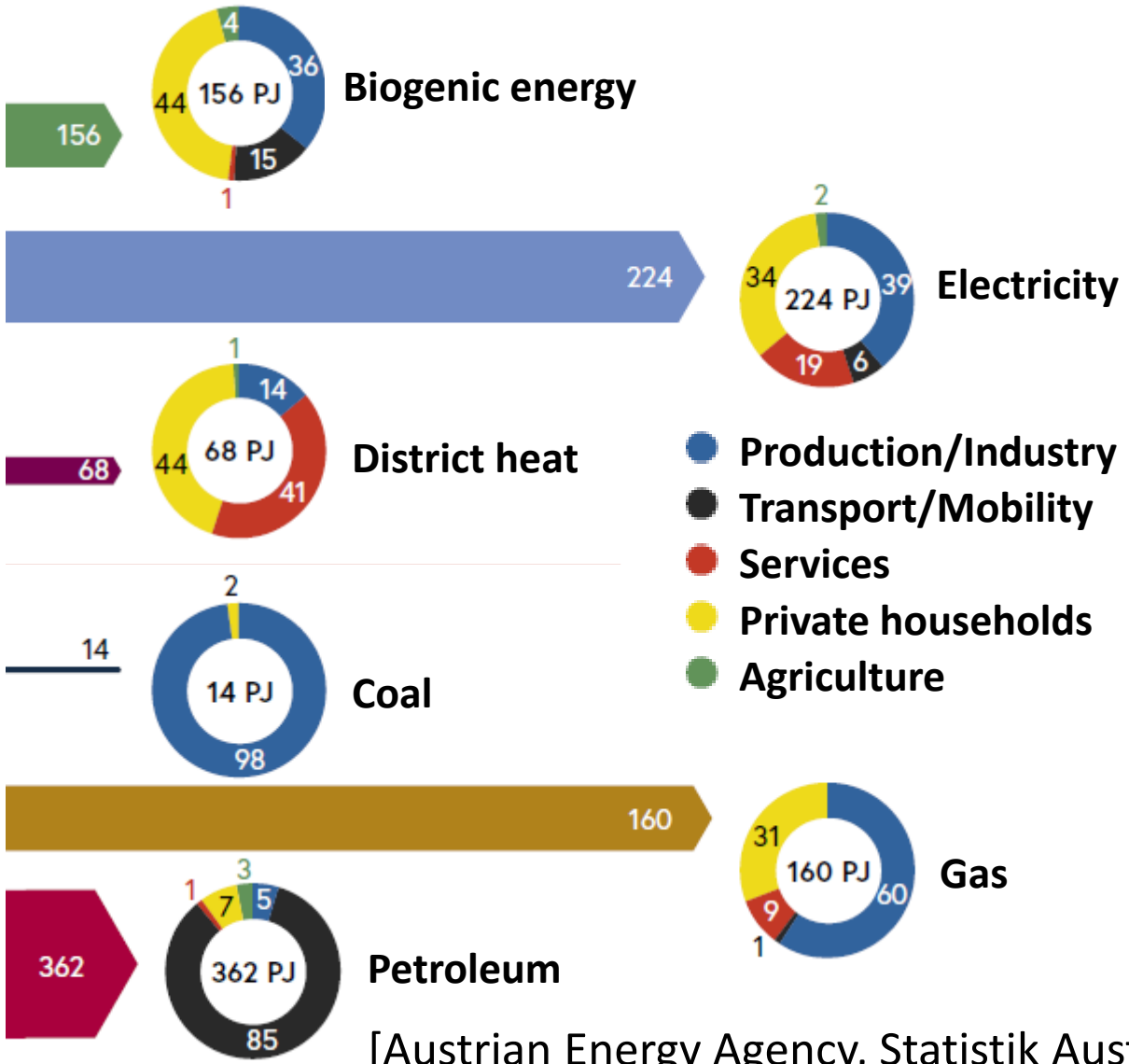
Electricity: 224 PJ

District heat: 68 PJ

Coal: 14 PJ

Natural gas: 160 PJ

Petroleum: 362 PJ



[Austrian Energy Agency, Statistik Austria]

Total final energy consumption: 1044 PJ/a

Largest potential for transformation:

- **Petroleum in transport 308 PJ**
- **Fossil fuels in buildings 93 PJ**
- **Natural gas in production/ industry 96 PJ**

Petroleum in transport

Currently **308 PJ/a fossil fuels** plus **24 PJ/a biofuels** = 332 PJ/a total in transport sector

Assumptions: Conversion of all internal combustion engines to **electric motors**
Same number of vehicles, same benhavior, no rebound, no sufficiency
Efficiency-gains: Electric 80% versus combustion engine 30%
Same (Austrian) electricity mix: 152 kg CO_{2e}/MWh_{el} (Consumption mix)

Parameter	Now	Then	Rel. change
Petroleum in final energy	362 PJ/a	54 PJ/a	- 85%
Electric final energy	224 PJ/a	349 PJ/a	+ 56%
GHG emissions* transport	27.4 Mt/a	6.3 Mt/a	- 80%
Total final energy consumption	1044 PJ/a	861 PJ/a	- 18%

*) Including indirect emissions of energy carriers: Diesel fuel ≈ 320 kg CO_{2e}/MWh_{LHV}

[CO_{2e}-Monitor UBA: secure.umweltbundesamt.at/co2mon/co2mon.html]

Fossil fuels in buildings (heating and hot water)

29 PJ/a fuel oil extra light and **64 PJ/a natural gas** in households and in services

Assumptions: Conversion of all fossil boilers to **to heat pumps**
Efficiency-gains: Heat pump COP 3.0 versus boiler-efficiency 95%
Same (Austrian) electricity mix: 152 kg CO_{2e}/MWh_{el}

Parameter	Now	Then	Rel. change
Petroleum in final energy	362 PJ/a	333 PJ/a	- 8%
Natural gas in final energy	160 PJ/a	96 PJ/a	- 40%
Electric final energy	224 PJ/a	253 PJ/a	+ 13%
GHG emissions* heating	7.2 Mt/a	1.5 Mt/a	- 83%
Total final energy consumption	1044 PJ/a	980 PJ/a	- 9%

*) Including indirect emissions: Fuel oil ≈ 340 kgCO_{2e}/MWh_{LHV}; Nat. gas ≈ 250 kgCO_{2e}/MWh_{LHV}

Fossil fuels in production / industry (process heat)

Different options, depending mainly on temperature level:

- Low temperature heat up to 60°C: Heat pumps from environmental heat
- Medium temperatures up to 160°C: Active heat recovery and biomass
- High temperatures above 160°C: Biomass, direct electricity, renewable gases or continued fossil with carbon capture and storage (CCS)

Quantification difficult, currently **128 PJ/a fossil final energy in the production sector**

(14 PJ/a Kohle, 18 PJ/a Öl und 96 PJ/J Erdgas)

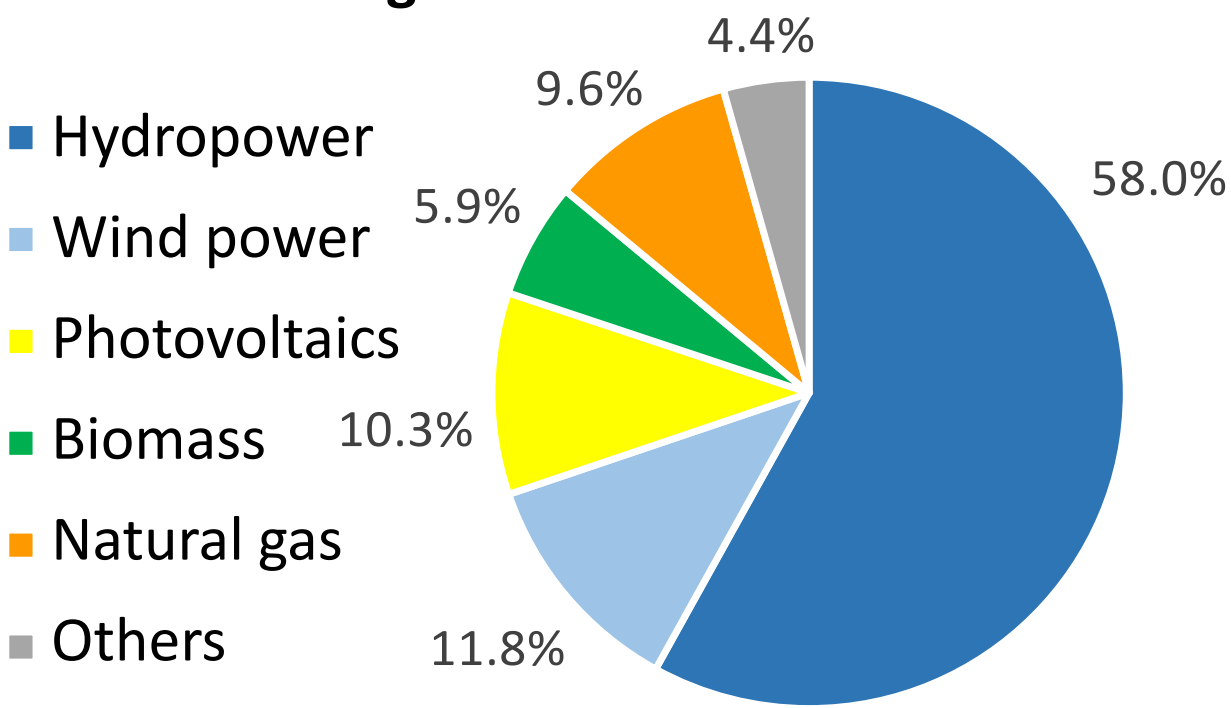
Economic sustainability of the solution is key for industrial players.

Possibilities (cost-efficient first): Heat pumps where applicable, direct electric heating (high temperature), bio-fuels (z.B. 24 PJ/a from the electrified transport sector), biogenic gases, CCS, chemically stored electricity (e-fuels)

Transformation effect on the Austrian energy system

- Complete electrification of the transport sector + 56% electric energy
- Electrification of (fossil) building heating systems + 13% electric energy
- Electrification/decarbonsiation of production + 50% electric energy
- **Total** **+ 120% electric demand**

Domestic electric generation 2024: 283 PJ



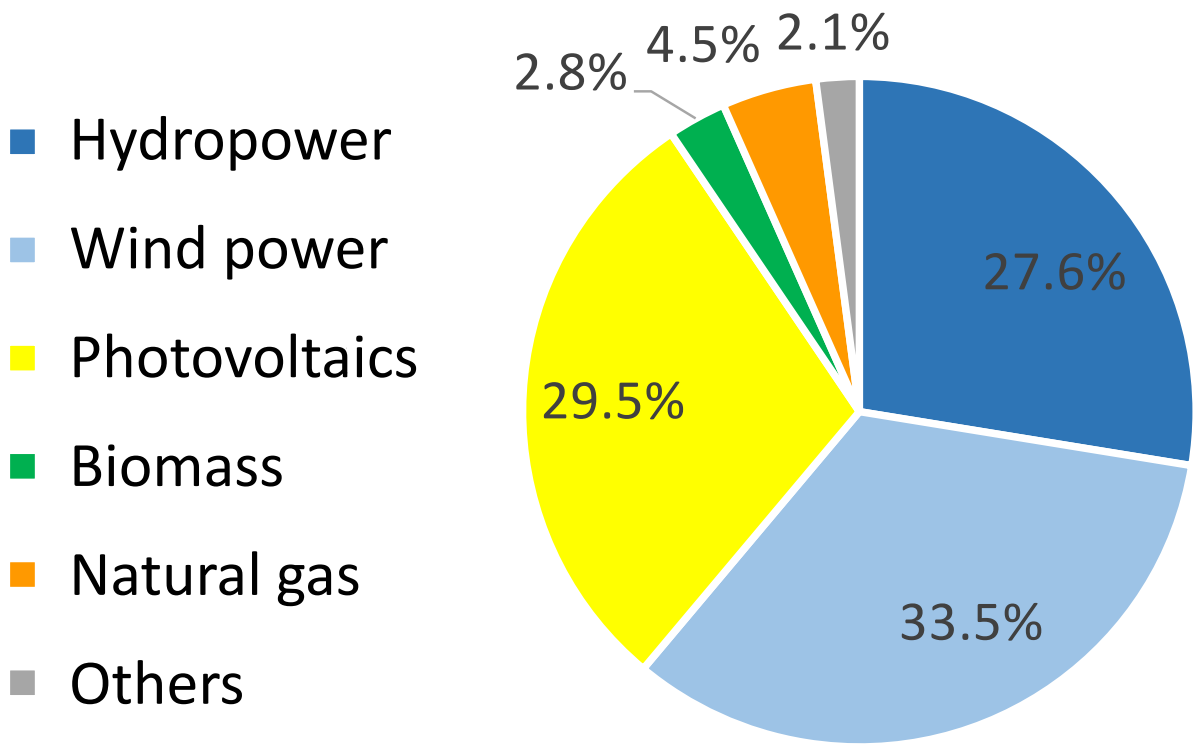
2024: 224 PJ/a electric final energy
283 PJ/a domestic generation
of which 86% renewable

After transformation:
500 PJ/a electric final energy
600 PJ/a domestic generation
Goal: 100% renewable

Assumption: only **Wind and PV grow**
→ each **x 6 for Wind and PV**

Future electric energy system

Domestic electricity generation: 600 PJ/a
(Wind and PV grow x 6, others at 2024 level)



→ Wind and PV reach today‘s share of hydropower in annual generation.

Challenges:

- Intermittent generation with wind and PV, seasonality of PV!
- Land demand and spacial distribution of potentials
- (Public) financing of infrastructures and business cases within market models

Opportunities:

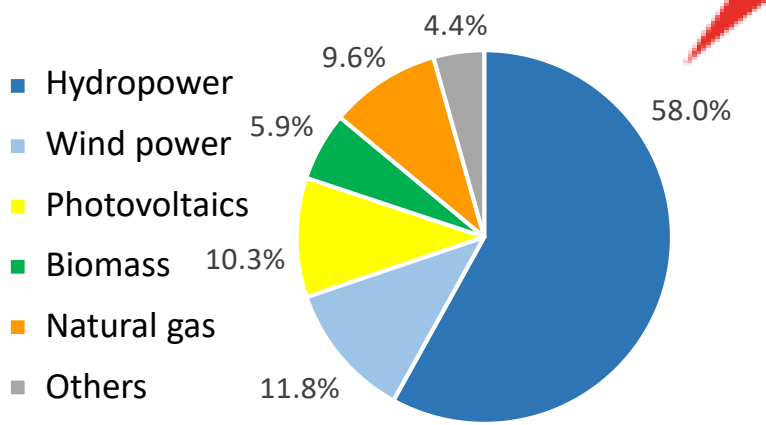
- Hybrid electricity storage
- Demand-driven grid enforcement
- Economic framework conditions for energy with low marginal costs but high system costs

Energy in Austria 2026 – 2045

2026

60% fossil in total energy mix
1000 PJ final energy consumption:
230 PJ electricity consumption
310 PJ fossil petroleum
90 PJ fossil house heating
120 PJ fossil energy in industry

280 PJ domestic el. generation



"No regrets" first:

- Refurbishment and thermal insulation, boiler substitution
- "Smartification" of distribution grid
- lifting electric storage potential
- Photovoltaics (PV) happens
- Wind power generation x 6
- Transmission grid extension

Investment in "Net Zero" infrastructures!

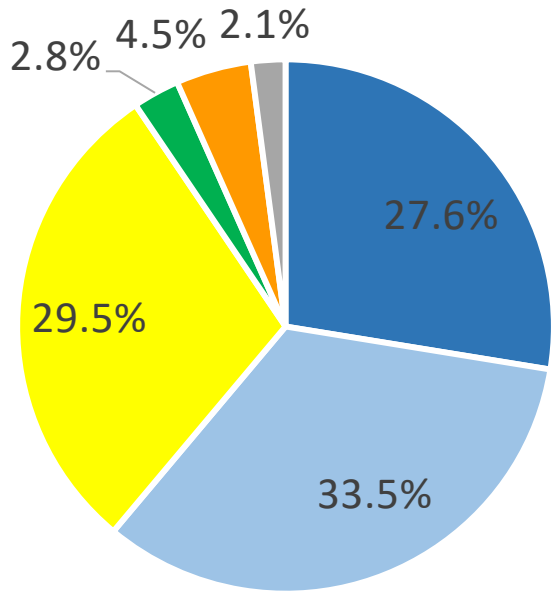
- Charging infrastructure
- Gas-fired cogeneration and CHP as backup

- **Economic policy framework for net zero**
- **Support for socially vulnerable households**
- **(Economic) participation**

2045

<10% fossil in total energy mix
700 PJ final energy consumption
500 PJ electricity consumption

600 PJ domestic el. generation



→ Wind <u>and</u> PV x 6, reach today's hydropower generation.
→ Mobility electrified (incl. road transport)
→ Heat pumps for house heating
→ Biomass and electricity in industry
→ <u>No</u> hydrogen as final energy carrier

There is a moral duty for effective Action

- **Science** needs to **take full responsibility** for solving the riddle:

  → **How** can politicians **be re-elected while driving change?**

- **Leaving the HOW to politicians** alone **means giving up**.
- **Critical Honesty** Required **for Credibility**

  → **Stop supporting pseudo-action** and **inefficient approaches** to avoid loosing public support.

- **Gather** across disciplines **to develop real, effective solutions**:

→ Build a **society so good** that **everyone will want** to live in **it**.

For reference see: **Steering toward net zero—a plea for a consumer-level carbon footprint tax**. Mitig Adapt Strateg Glob Change 30, 32 (2025). https://doi.org/10.1007/s11027-025-10222-z