

Nuclear Energy in Norway: Why everyone is suddenly talking about it

NTNU Energy Transition Week



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NTNU Team Nuclear Goals

- **Research in nuclear energy**

- Power systems
- Systems integration
- Materials
- Medicine technology
- Ethics, regulations, policy

- Engineers, scientists, and philosophers (ethics)

- **Members are politically diverse**
- Team itself is politically neutral

- **Education**

- **Nuclear Energy course**
- **Very popular**
- Prepare educational base for NTNU

- **Involvement**

- Active in **EU SMR Alliance**
(SMR=small modular reactors)

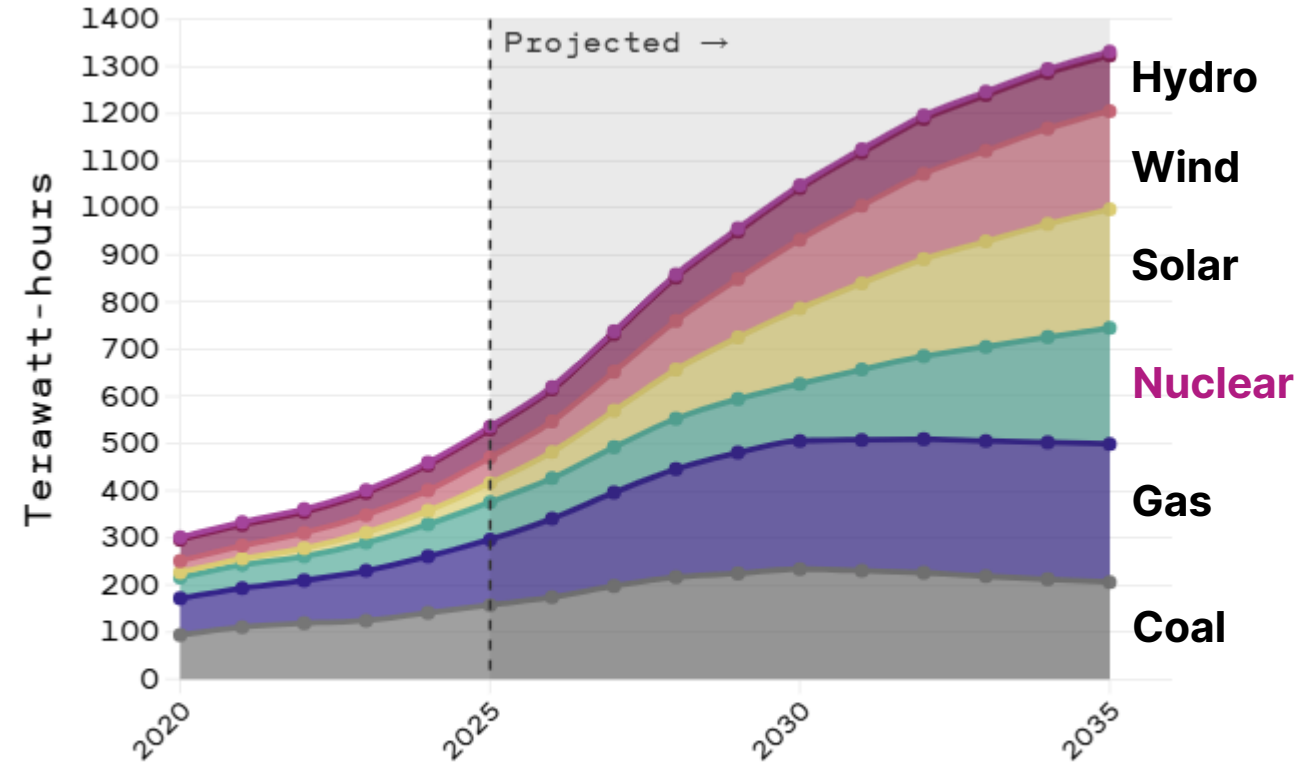
Common Goal

Establish the expertise necessary for Norway to **make informed decisions** about nuclear energy and **then act on them.**

Norway wants new electricity for:

- All ground **transportation**
- All building **heat**
- Electrification of **industry**
- Make and export **hydrogen** and ammonia
- You **don't want** to emit any **CO₂** either, and
- now you want **data centers** too...

Global Electricity Generation for Data Centers



Source: [International Energy Agency](#)
Chart by Casey Crownhart, MIT Technology Review

Source: Crownhart C. MIT Technology Review (Apr 17, 2025).

The Triple Bottom Line of Sustainability

Economical

- Capital
- Operating
- Supply Chain & Materials
- Job Creation / Losses
- Profitability
- Loans/Financing
- Stockholders
- Uncertainty and Risk

Environmental

- Greenhouse Gases
- Particulates, Smog, Acid Rain
- Deforestation/Land Transfrm.
- Resource Depletion
- Water Consumption
- Toxicity
- Wildlife Impact
- Noise

Societal

- Public Acceptance
- NIMBYs
- BANANAs
- Health Impacts
- Public/Employee Safety
- Accidents
- Public Policy
- Electoral Politics

GHG Emissions

Life Cycle Data Shown

Data for Countries are national averages for 2024 or 2025 as available

Grey = Fossil Power

Blue = Fossil with CCS

Green = Renewable / Nuke

Plant data are representative, fuzzy and uncertain.

Nearly Lowest in World!!! ----->

Electricity or Grid Source	gCO ₂ /kWh
Modern Coal Power (supercritical)	944
Mongolia	811
South Africa	717
India	705
Bangladesh	696
Saudia Arabia	692
China	555
Australia	554
World	471
Modern Nat Gas (Combined Cycle)	440
United States	384
Germany	330
Modern Coal w/CCS, all kinds	290
IGCC w/CCS	250
United Kingdom	217
Canada	185
Oxyfuels/Chem Looping w/CCS	150
Solar w/ Batteries (Canada Example)	124
NGCC w/CCS	115
Denmark	114
Coal-based SOFCs w/CCS	70
Natural-gas based SOFCs w/CCS	50
France	41
Norway	28
Nuclear (Rough, Europe)	20
Hydroelectric (Reservoir, median)	10

(Modern coal)

(Modern natural gas, baseload)

(Classic coal with CCS, modern)

(Advanced coal with CCS)

(Advanced coal with CCS)

(Modern natural gas w/CCS, baseload)

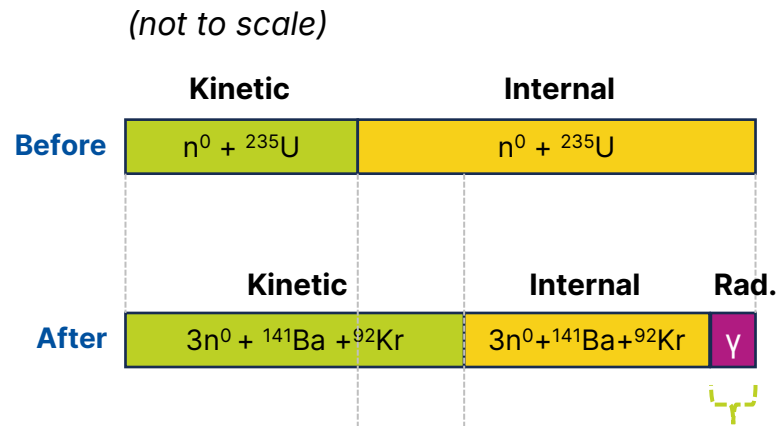
(Very advanced coal with CCS, achievable.)

(Very advanced gas with CCS, achievable.)

(Best cases, not many new options left)

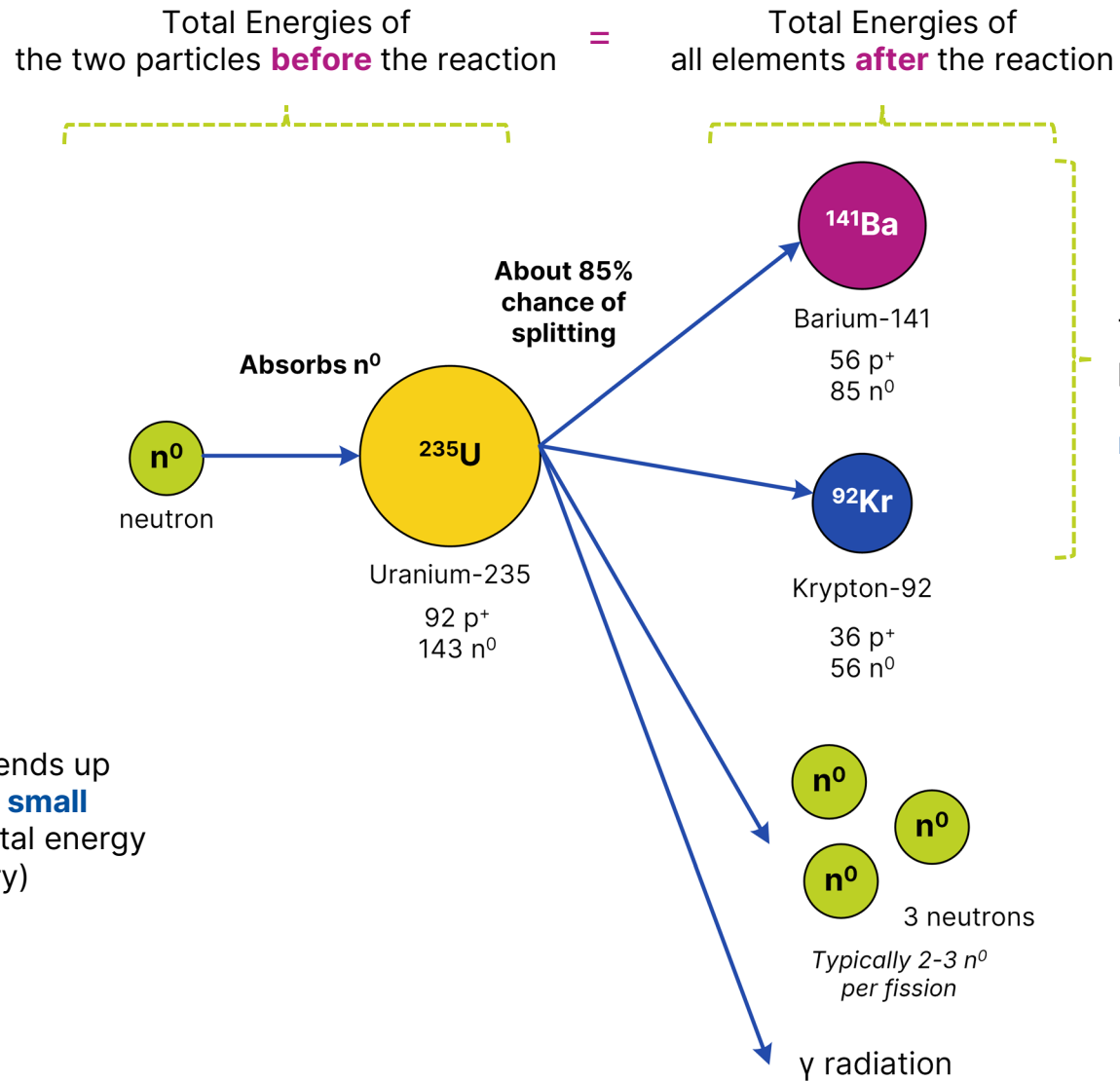
Sources: Ember - Yearly Electricity Data (2026); Energy Institute - Statistical Review of World Energy (2025). Adams et al. *Processes* 5:44 (2017). Gemecu and Kumar, *Renewable and Sustainable Energy Reviews* 167 (2022) 112684. Poponi and Hart, *Applied Energy*, Volume 290, 15 May 2021, 116743. Mehdi et al. *Applied Energy*, Volume 314, 15 May 2022, 118918. US EPA Rule E9-5711 with Aspen Plus utility defaults

How it works in 2 slides



This difference is the heat production. **And it is a lot!!!**

This portion ends up being **quite small** (about 6% of total energy recovery)



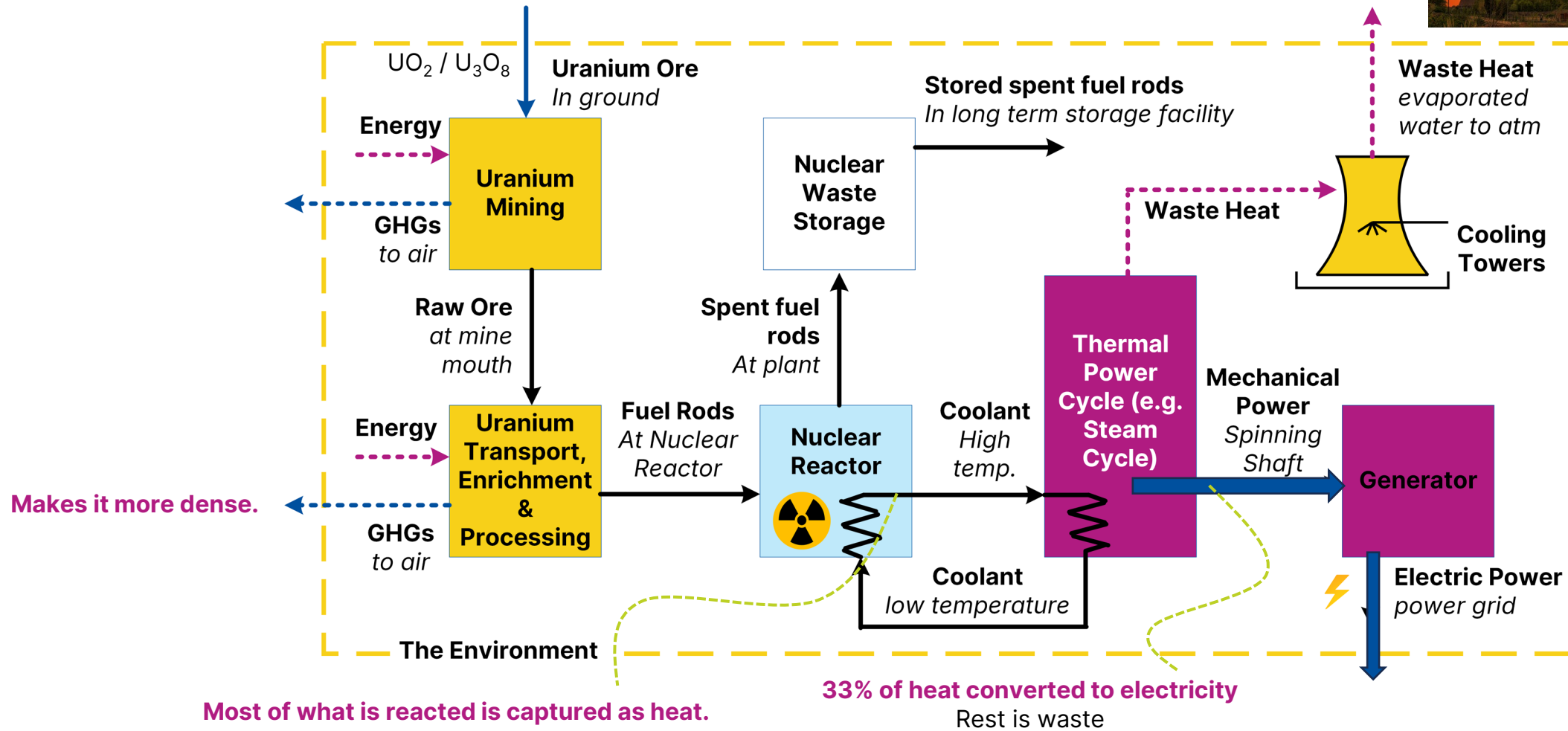
These also keep decaying, producing more heat later (even after you shut down the reactor!).

Including the downstream decay, heat production is **about 200 MeV per ${}^{235}\text{U}$ fission.**

$(3.2 \times 10^{-11} \text{ J/fission})$

About 82 TJ/kg ${}_{\text{U}235}$
This is very large

Using it to make electricity



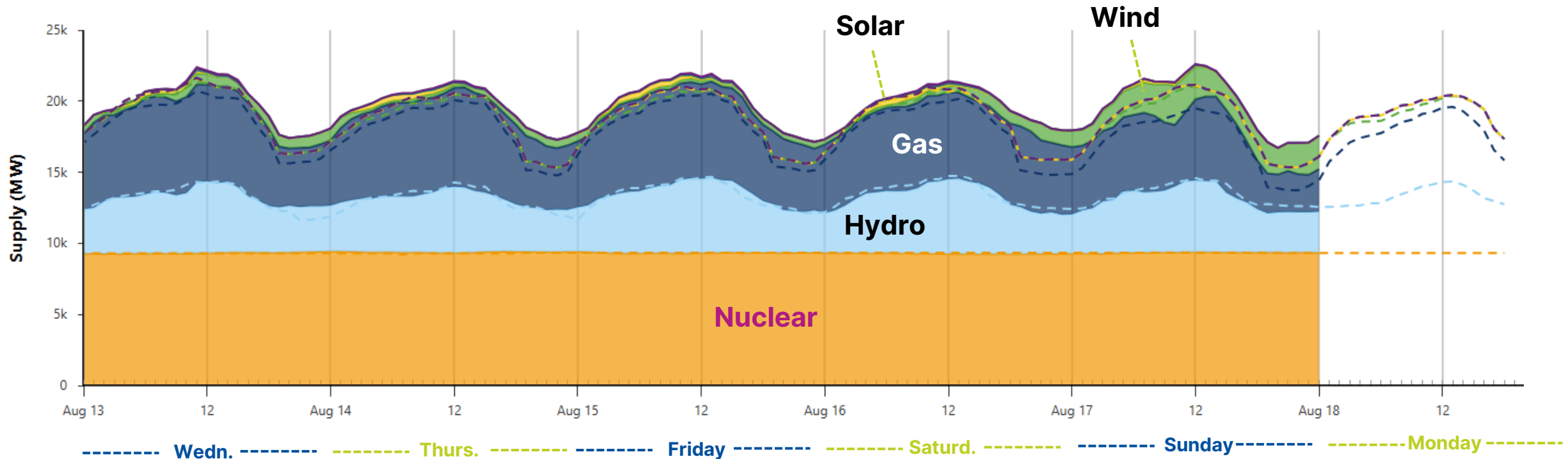
Example use in energy mix in Ontario, Canada

A high-demand week in August 2025, Ontario, Canada

Ontario is **a good example of how nuclear could best be used in Norway.**
(Integrated hydro and wind, with natural gas peaking power as backup)

Norway is ~85% Hydro, but growth is difficult.

Expanding the grid with nuclear at the bottom means you can **manage peaking with hydro without much natural gas** in most cases.



Source: Independent Electricity System Operator (Ontario, Canada). Energy Supply mix accessed August 19, 2025

A Generational Investment

Scale for reference:

Norway averages 18 GW of power production

Long Term View:

- Construction (8-10 years)
- Operation 60+ years
- Decommissioning (20+ years)

This is a generational investment.

Costs **highly sensitive** to:

- quality of project management
- regulations and politics
- financing

Plant			Startup	Capital Cost
<i>Recent Builds</i>				
Finland	<i>Olkiluoto 3</i>	1.6 GW	2023	€5.5 billion
France	<i>Flamanville</i>	1.6 GW	2024	€13 billion
South Korea	<i>Shin Hanul 3&4</i>	2.8 GW	2024	€8 billion
<i>Recent Approvals</i>				
Poland	<i>AP1000</i>	3.8 GW	2033	€43 billion (proj.)
Canada	<i>Western SMR</i>	1.2 GW	2030	€13 billion (proj.)

Sources: Magnus Korpås, NTNU Department of Electrical Engineering.
 energifaktanorge.no
<https://www.world-nuclear-news.org/articles/what-is-the-budget-for-canadas-first-smr-project>

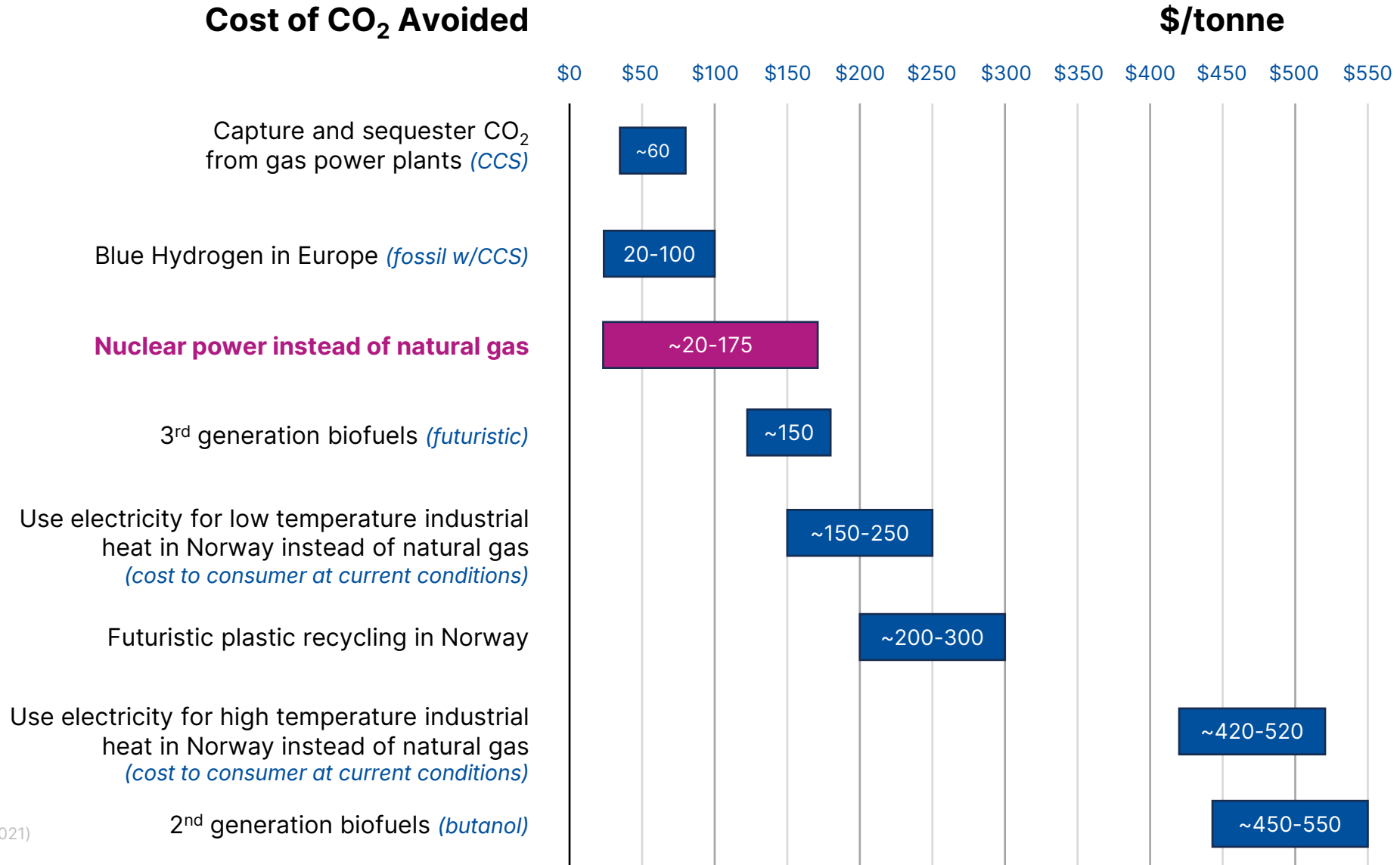
Cost of CO₂ Avoided

- The extra money you pay **for the purposes of** avoiding CO₂
 - business as usual is usually cheaper with more CO₂ emissions

$$CCA = \frac{\text{Extra costs to be green}}{CO_2 \text{ avoided by doing it}}$$

Sources: Adams et al. *Processes* 5:44 (2017).
 Dalle Ave, Adams, *Energy Convers Manage* 156 (2018) 288–300
 Okeke, Ghantous, and Adams. *Chem Prod Process Model* aop (2021)
 Okoli and Adams, *Ind Eng Chem Res* 2017, 56, 1543–1558
 Deng and Adams, *Energy Convers Manage* 204 (2020) 112315
 Subramanian, Gundersen, and Adams. *Energy* 205 (2020) 117830
 Maier, Schulze-Netzer, Adams. *Ind Eng Chem Res* 64, 575–589 (2025)
 Roth, Jaramillo. *Energy* 131:67-77 (2017)
 Schwab, Adams. *Comput Chem Eng* 200:109154 (2025)

Cost of CO₂ Avoided



*All numbers approximate and depend on study assumptions

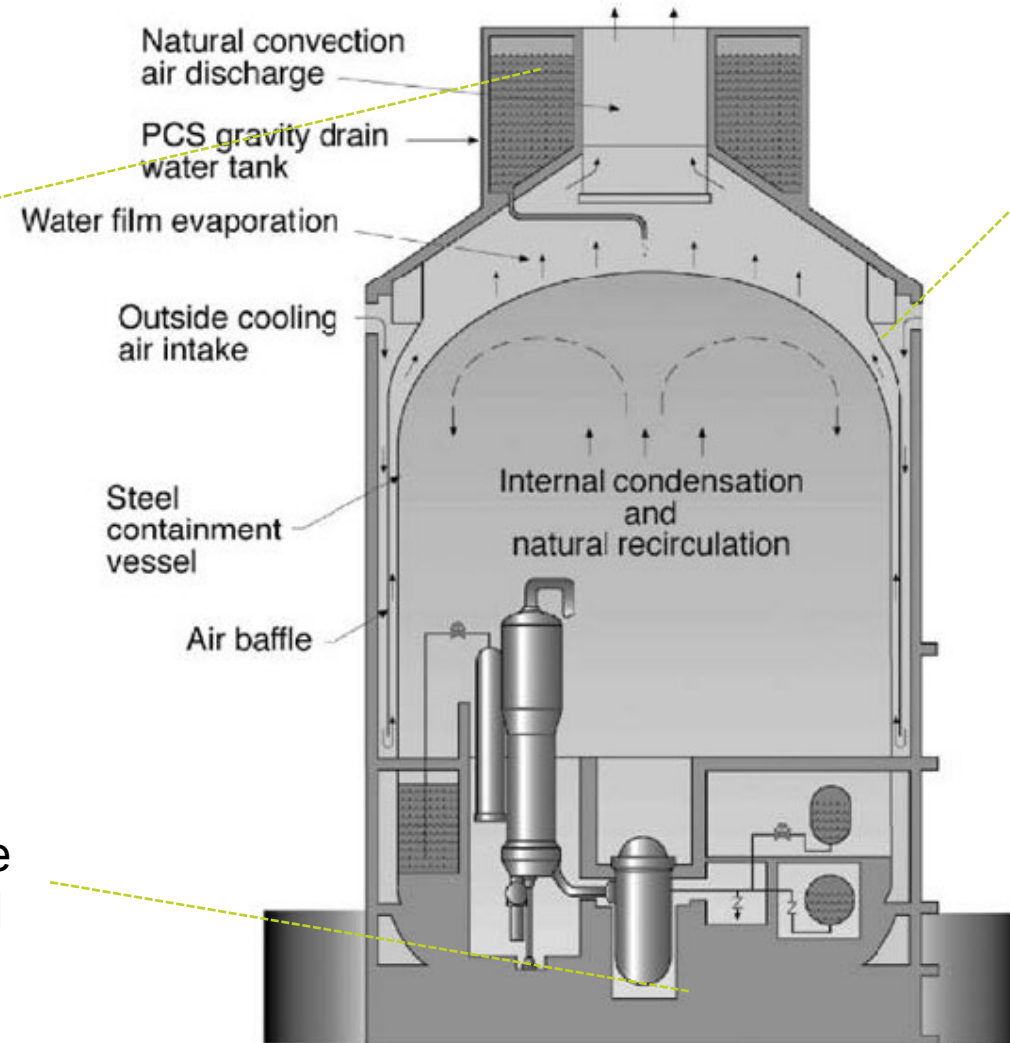
Gen III: AP1000 – Passive Cooling

(Example of what is new and different now)

Tanks of stored water are released to fall onto the containment vessel.

Other systems: control rods are held above the fuel by electromagnets

As soon as power is lost, the control rods immediately fall into place by gravity.



When all else fails, heat exchange occurs through wall of outer containment vessel by natural convection of air.

Sources: Wood, J. Nuclear Power. (2009) Ch 8.

Suggested Research Priorities

Technical

- SMR mass production
- Thorium-based systems
 - Norwegian company Thorkraft is trying to develop Thorium systems sourced from Europe only
- Waste decay acceleration
- Continue GenIV research to improve efficiency and expand uses (up to $\sim 800^{\circ}\text{C}$)
 - Helium coolants, molten salts, etc.
- Fusion

Political

- The political aspects are hugely important
- Requires a real assessment and re-assessment of fundamental priorities and values of what is important to society, followed by a commitment at the society and cultural level
- Norway might seriously consider if you should just be making electricity from natural gas (w/CCS) again and letting mainland Europe use nuclear for its own needs.