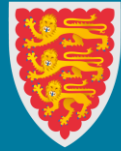


Environmental *Change* Institute



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Deep electrification & the primary energy fallacy

CIP Electrification Day

Dr Jan Rosenow

Leader of the Energy Group, ECI - Oxford University

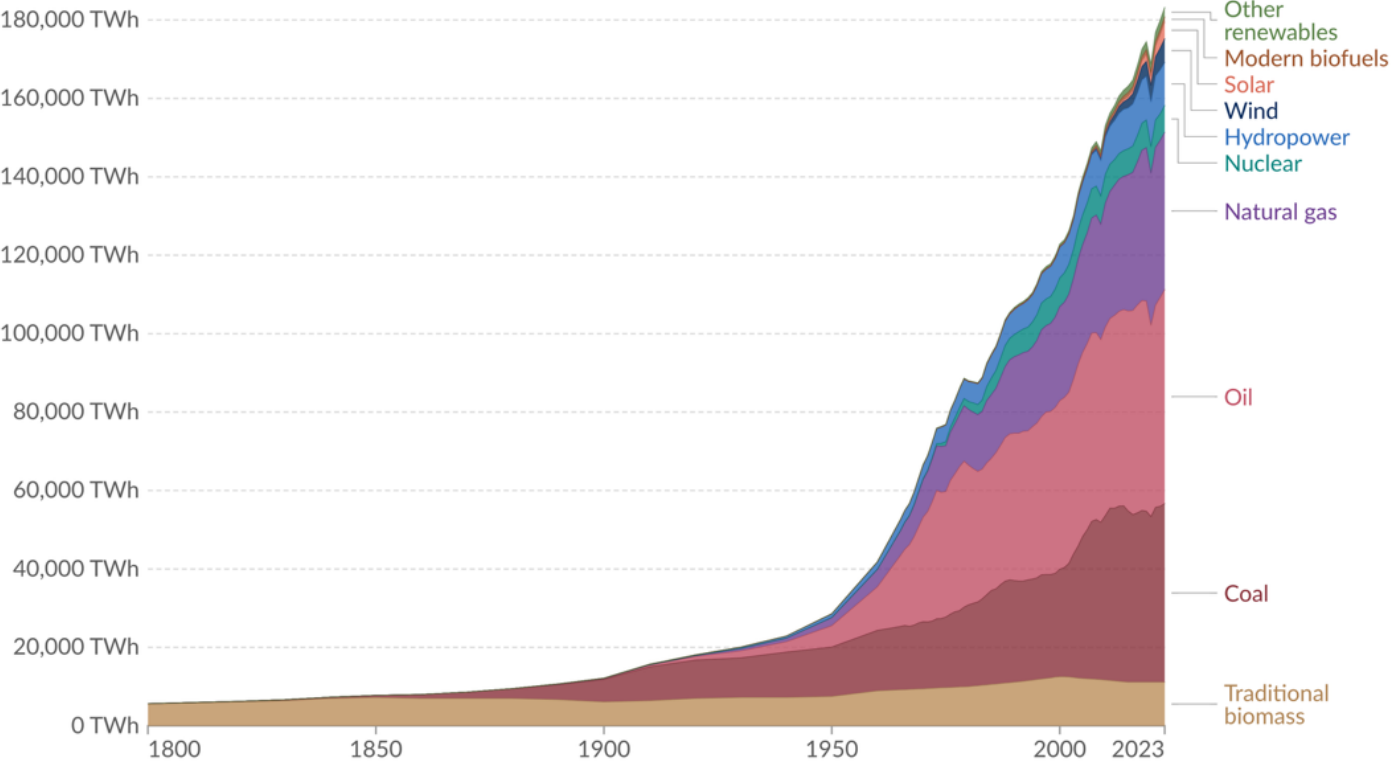
Senior Associate, CISL - Cambridge University

Copenhagen, 02 June 2025



Global primary energy consumption by source

Primary energy¹ is based on the substitution method² and measured in terawatt-hours³.



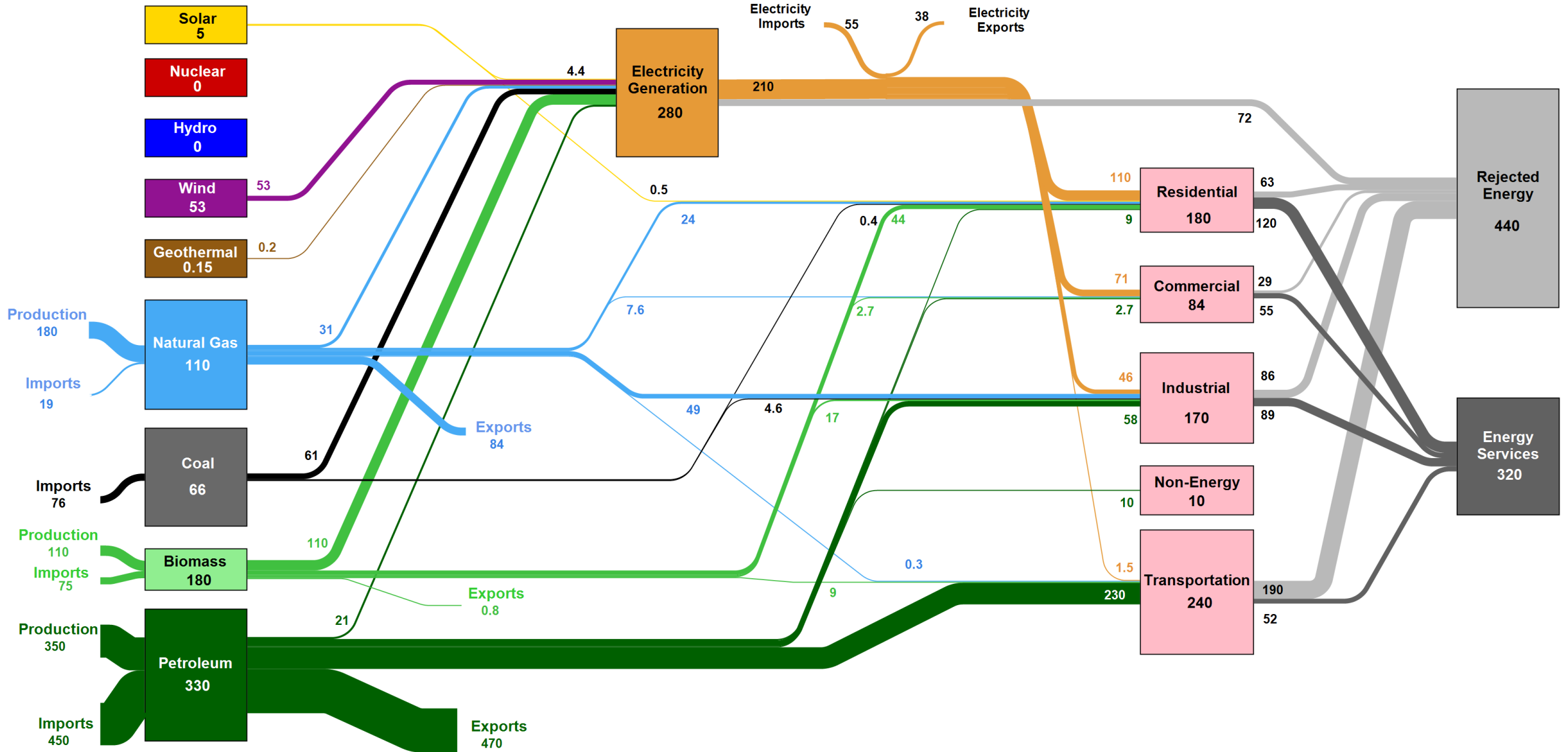
“The idea that we can replace fossil fuels with wind, solar, and batteries is pure fantasy” [because] “the scale of energy demand is too great, and renewables simply don’t have the reliability or density to power modern civilization.” (Bryce 2020)

Data source: Energy Institute - Statistical Review of World Energy (2024); Smil (2017)
Note: In the absence of more recent data, traditional biomass is assumed constant since 2015.
OurWorldInData.org/energy | CC BY



Primary energy fallacy

Denmark Energy Flow in 2017: 800 PJ

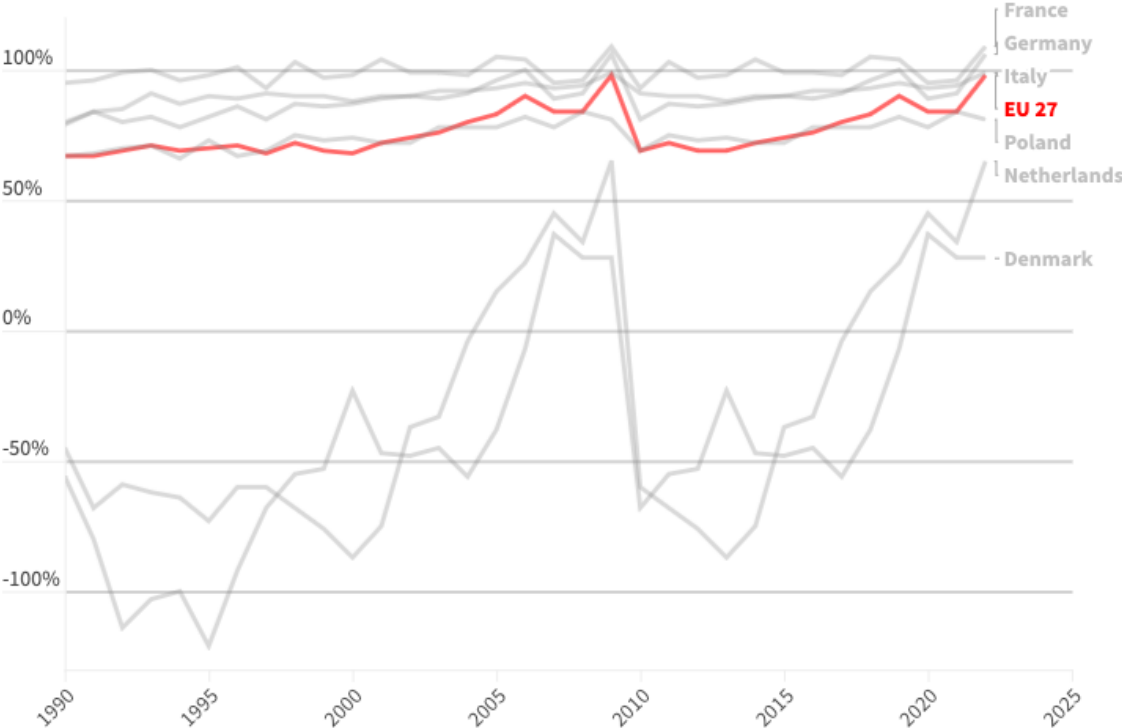


Source: LLNL 2021. Data is based on IEAs Detailed World Energy Balances (2019 Edition). If this information, or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the U.S. Department of Energy, under whose auspices this work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.10 PJ are not included. Total energy supply (top of chart) and energy resource statistics (left-side boxes) represent national energy use which is the sum of production and imports minus exports. Totals may not equal sum of flows due to independent rounding, stock changes, statistical difference and reporting inconsistencies. Further information can be accessed at <https://flowcharts.llnl.gov>. LLNL-MI-410527

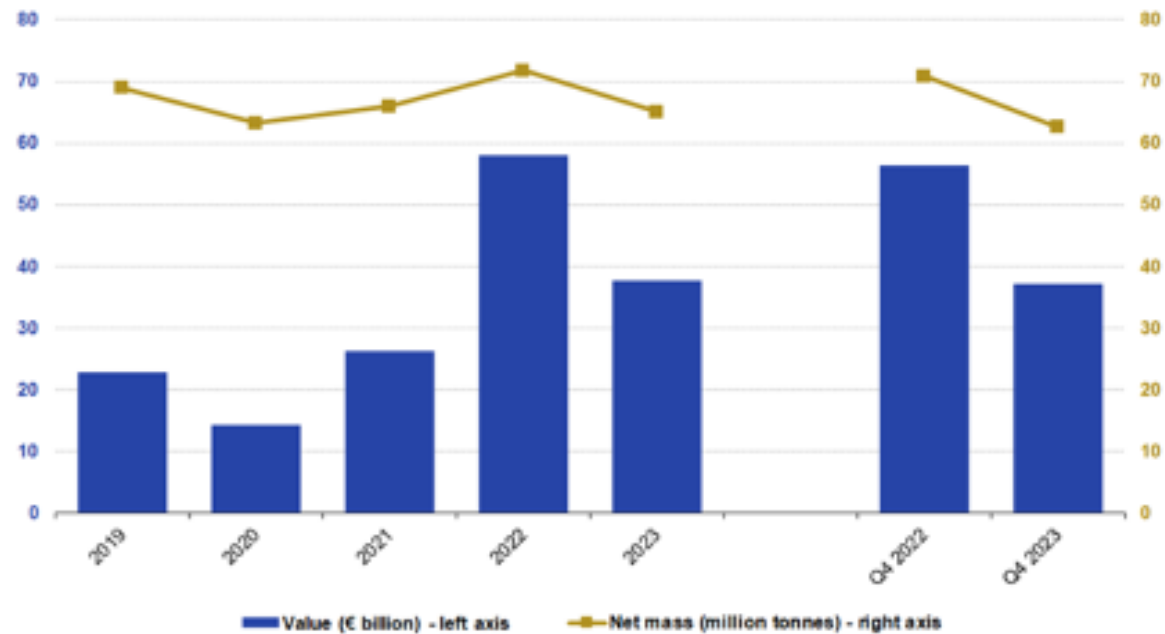
“Would you be happy to pay someone for one hour if after 20 minutes they stopped working?”

Fossil fuel import dependency (%), EU 27, 1990-2022

source: Eurostat



EU imports of energy products, 2019 - 2023
(monthly averages, € billion and million tonnes)



Source: Eurostat database (Comext) and Eurostat estimates





Electrification

An iceberg floating in the ocean, with a small tip above the water and a much larger, jagged mass submerged below. The sky is blue with scattered white clouds. The water is a deep blue, and the submerged part of the iceberg is illuminated from above, showing its complex, crystalline structure.

Electricity 23%

Heat 49%

Transport 28%

A large, jagged iceberg floats in deep blue water. The iceberg is the central focus, with its sharp peaks and textured surface clearly visible. The water is a vibrant blue, and the sky above is a lighter, clear blue. The iceberg's reflection is visible in the water below the surface line.

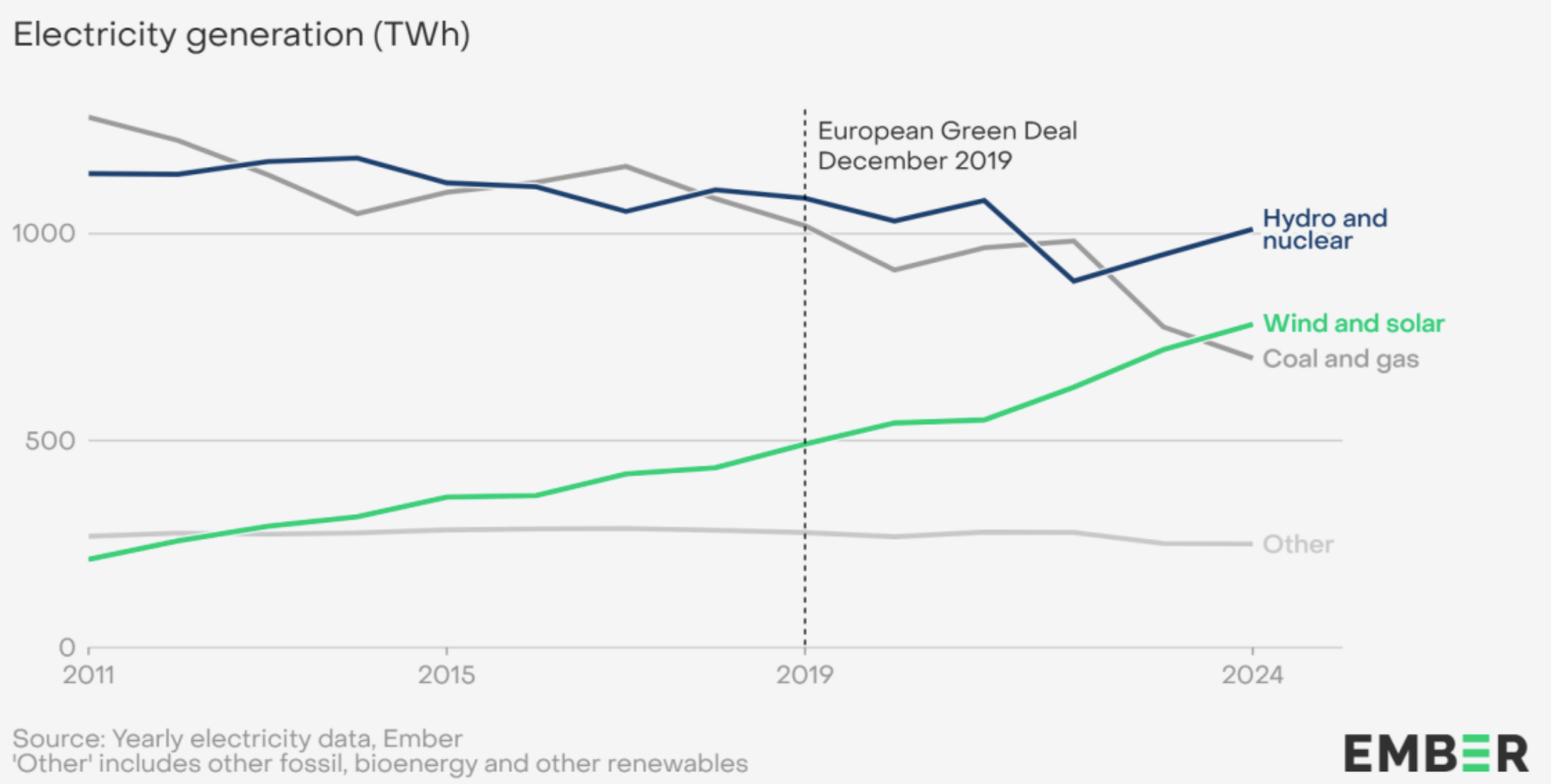
Electricity 53%

Heat 34%

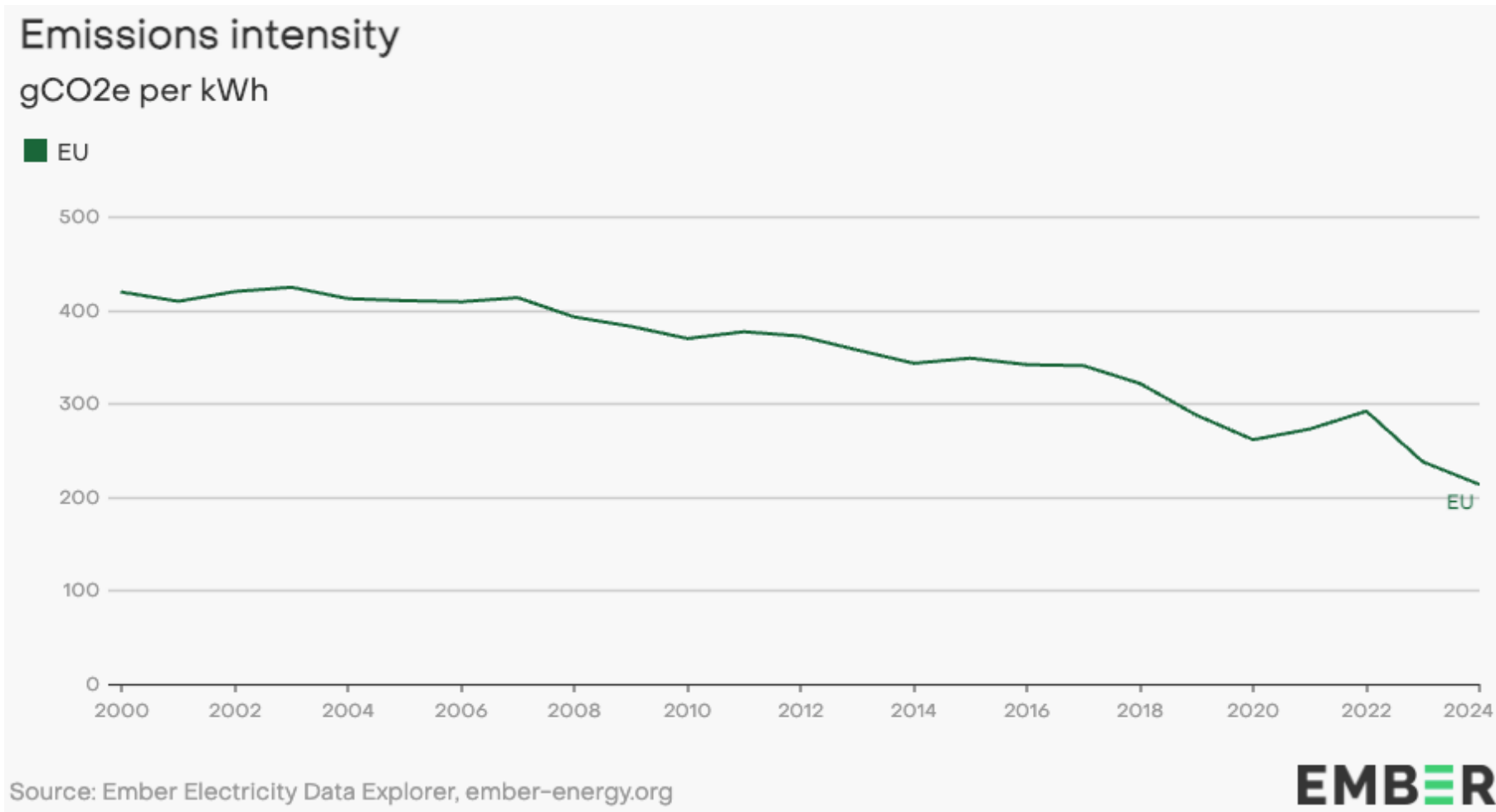
Transport 13%

Source: based on IEA 2023
% of global final energy use

>2/3 of EU electricity now from non-fossil sources...

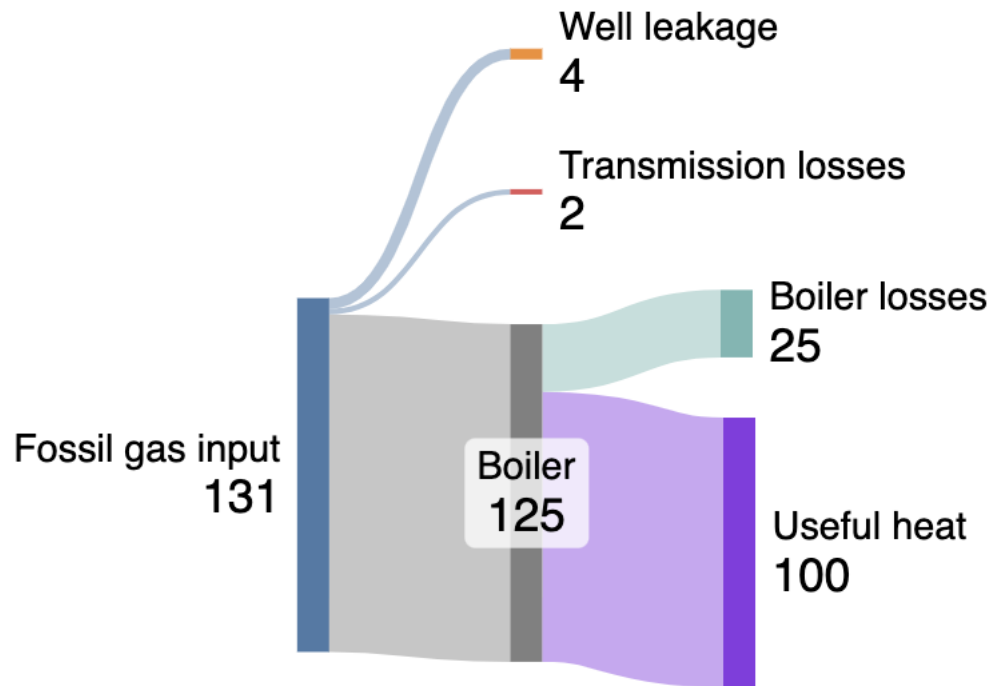


...which halved carbon intensity of EU electricity

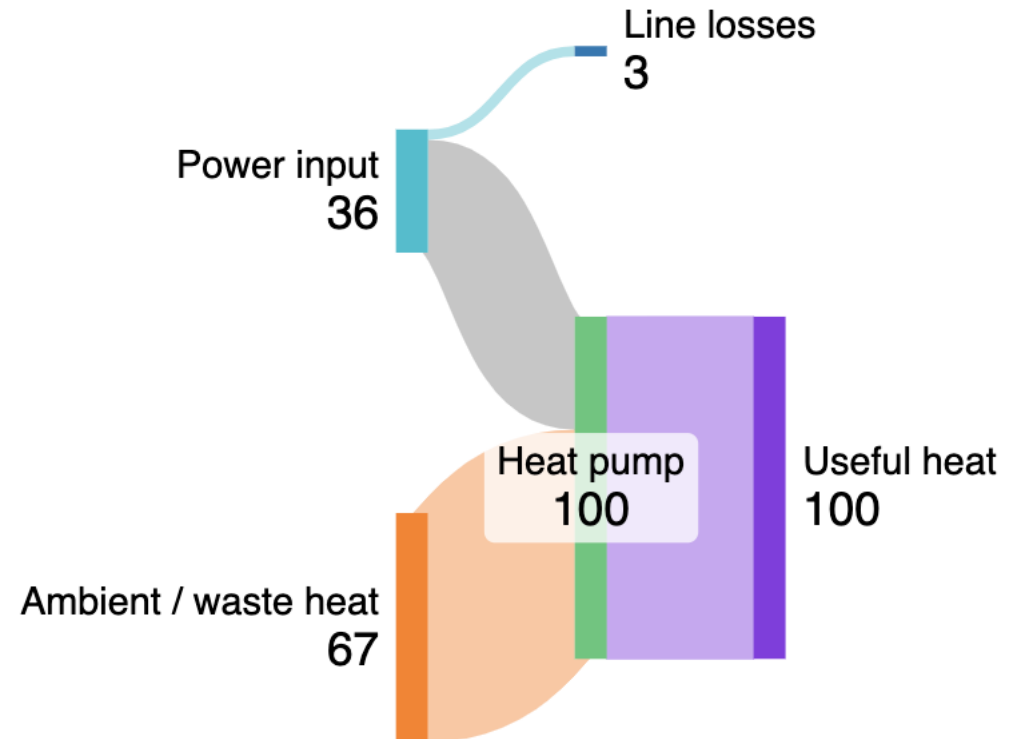


Heat pumps are >3x more efficient than gas boilers

Gas boiler



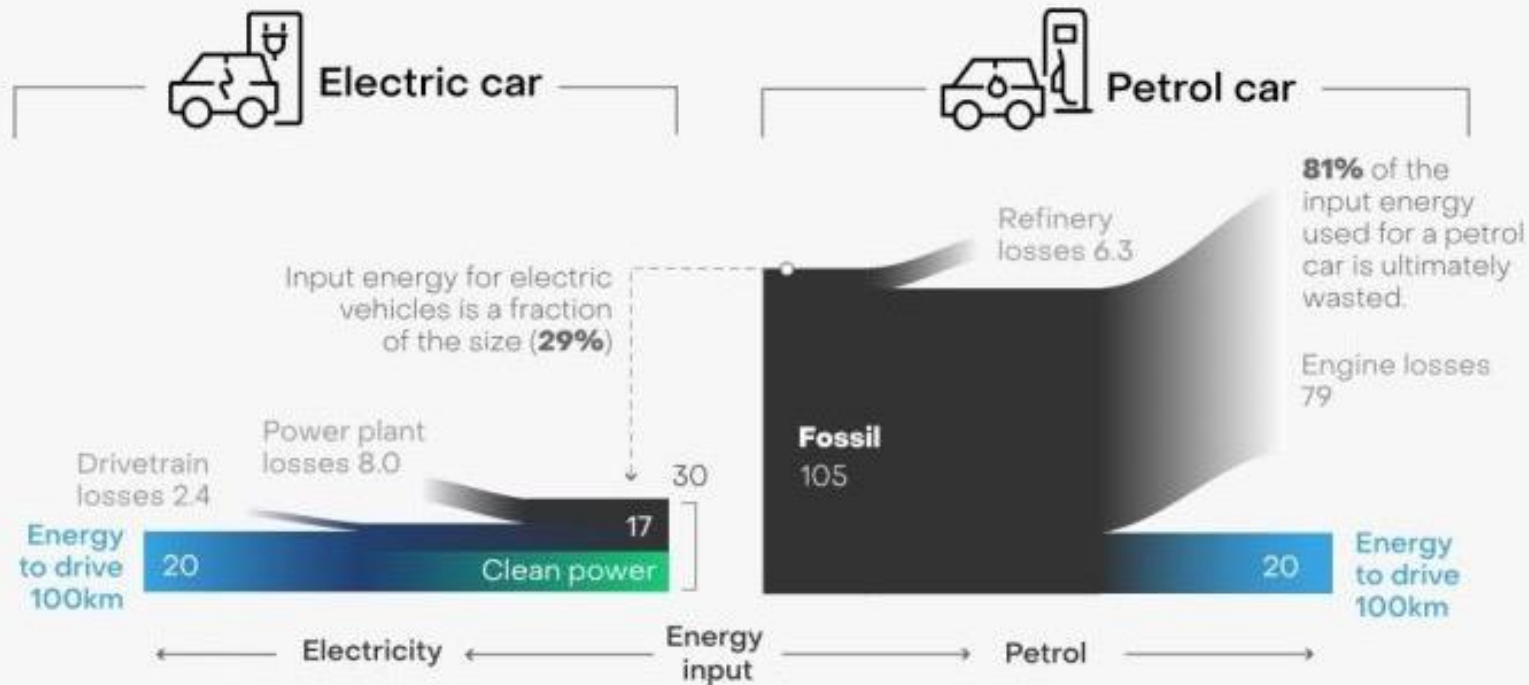
Heat pump





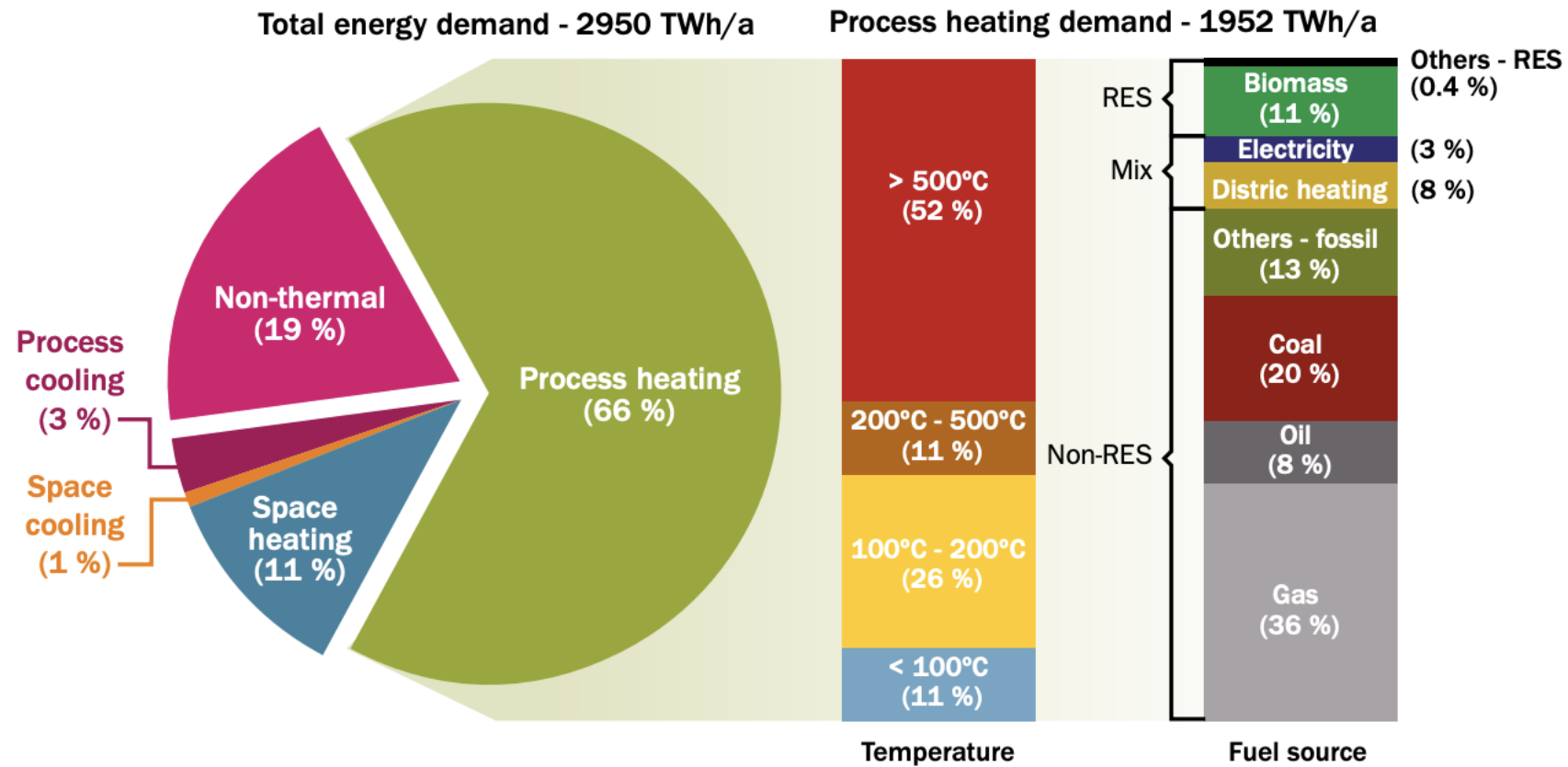
EVs are 3x more efficiency than ICE cars

Energy needed for 100km of travel, based on 2023 data (kWh)



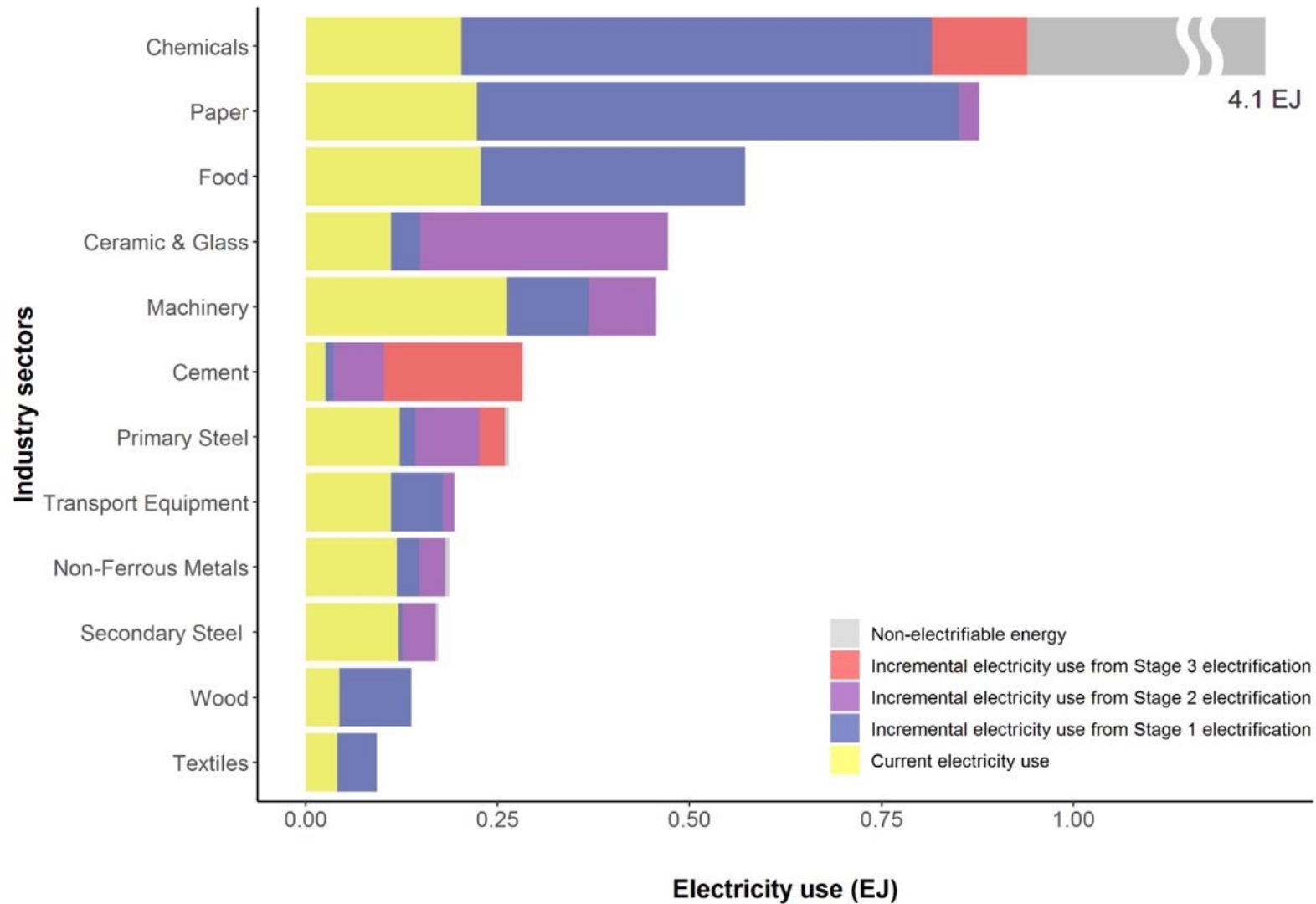
Source: Ember 2024

78% of Europe's industrial process heat is fossil with only 3% from electricity



Source: de Boer et al. 2020

Industry: 78% electrifiable with existing technologies

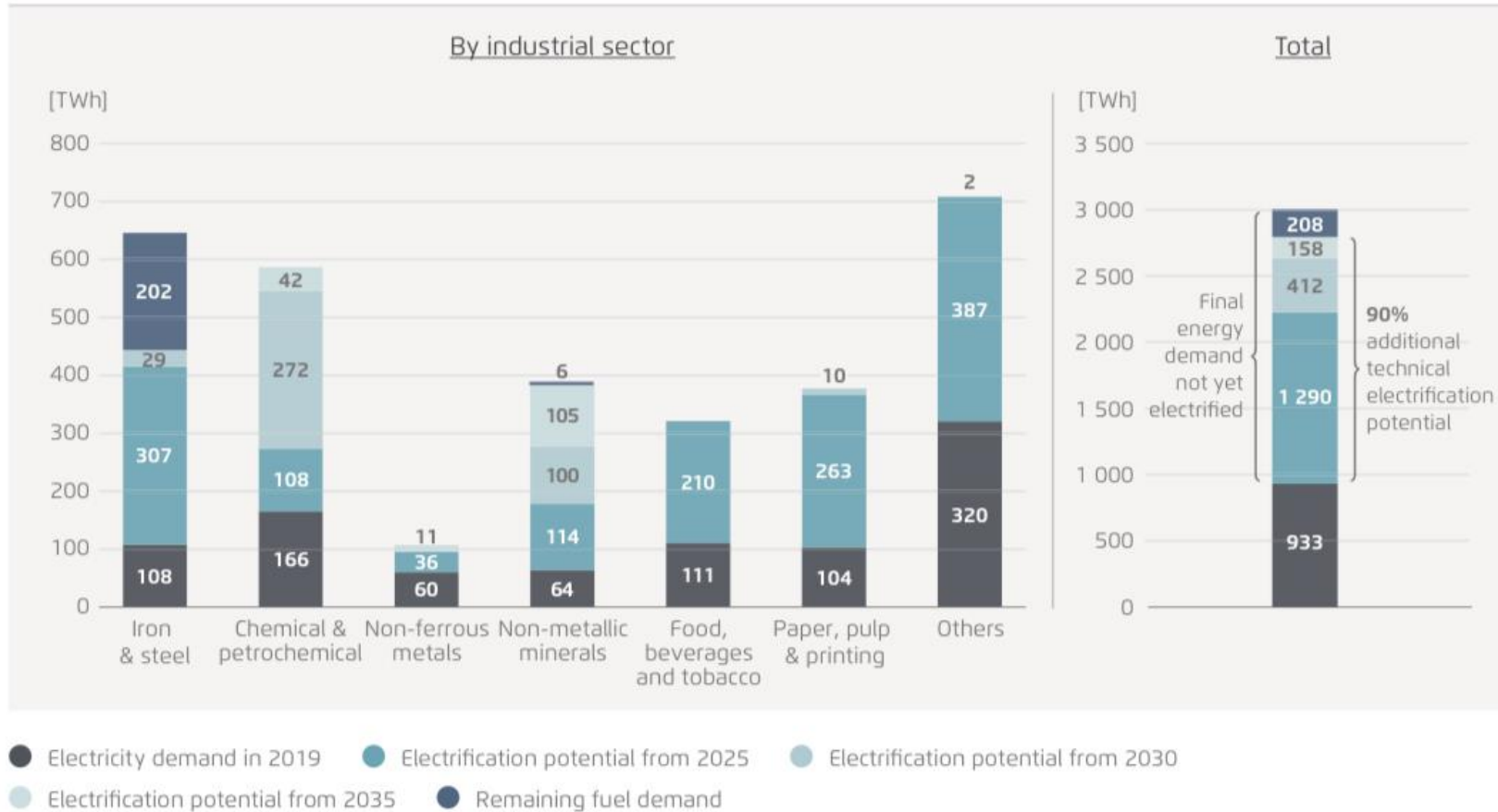


Source: Madeddu et al. 2020

Industry: 90% electrifiable by 2035

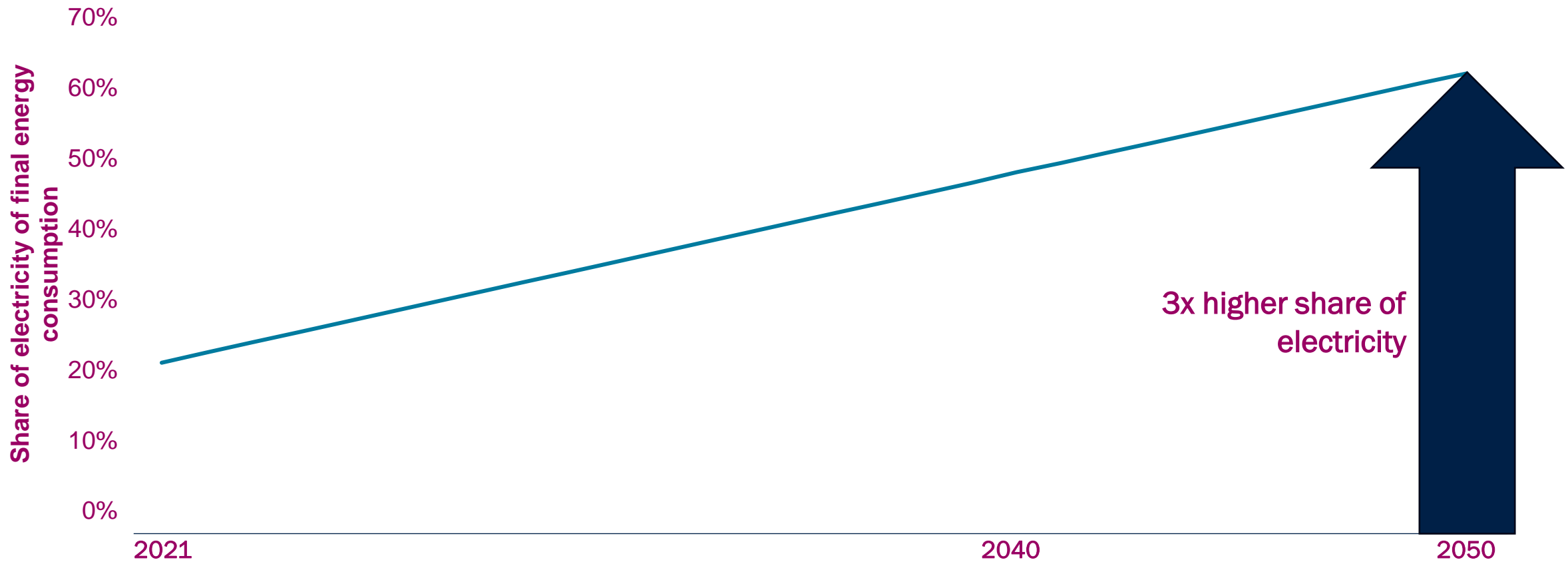
Technical potentials for direct electrification in the EU-27 based on 2019 energy demands

→ Fig. 1



Source: Agora Industry 2024

EU industry electrification under 90% GHG reduction target by 2040 and climate neutrality by 2050



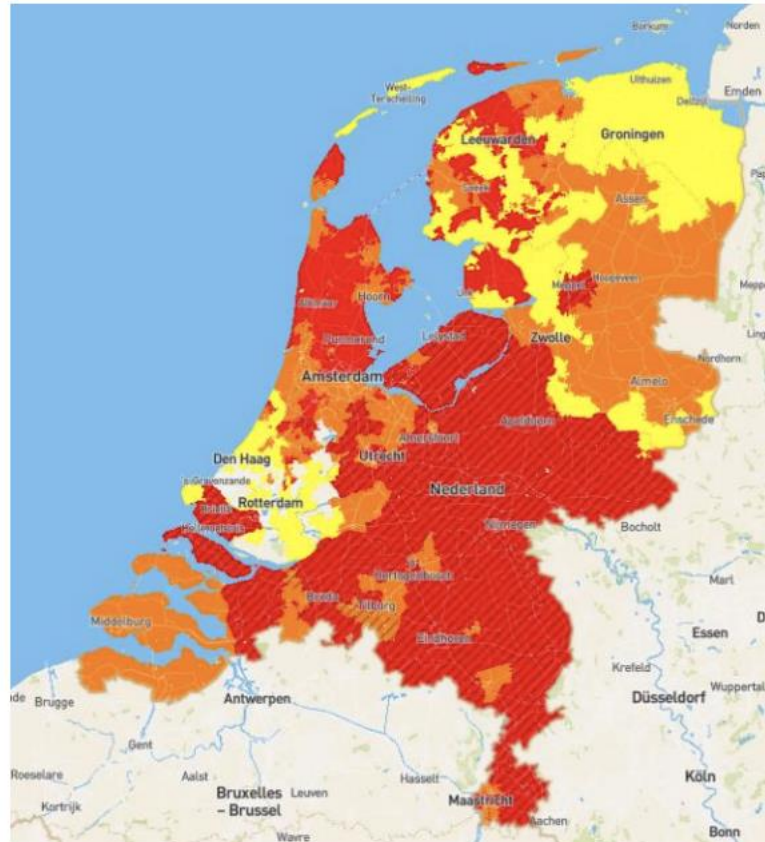
Source: European Commission 2024



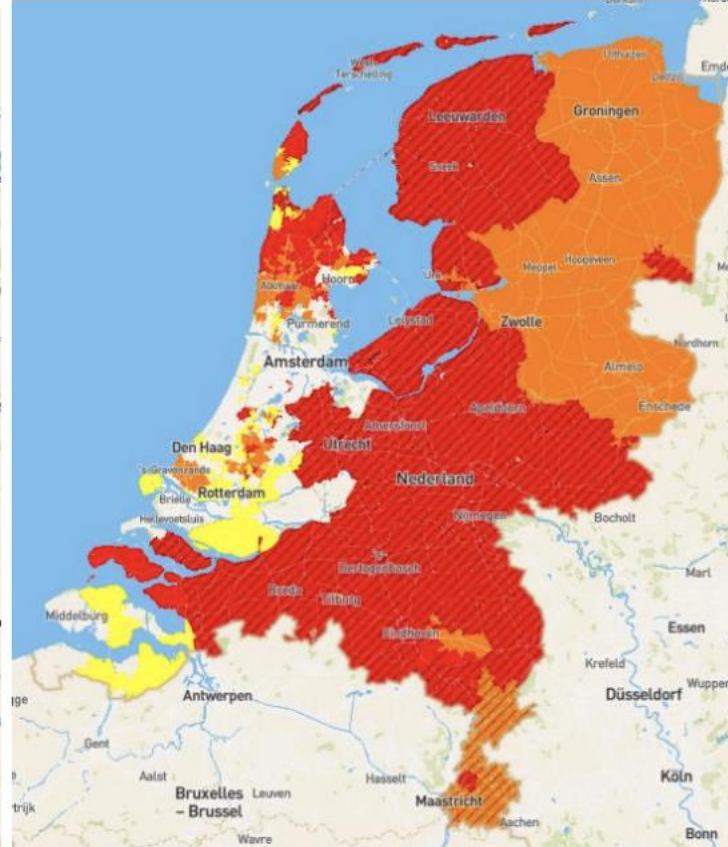
System integration

Grids: the new frontier of the energy transition

New load



Feed in



Meaning of the color codes

- Transparent: Transport capacity available
- Yellow: Limited transport capacity available
- Orange: No transport capacity available for the time being pending the outcome of the congestion management study
- Red: No transport capacity available: congestion management cannot be applied

With congestion management:

- ▨ Transparent hatched: Transport capacity available based on application of congestion management
- ▨ Shaded yellow: Limited transport capacity available based on application of congestion management
- ▨ Shaded orange: No transport capacity available for the time being pending distribution of the released capacity over the queue based on congestion management. (it is still unclear whether and how much power will become available for new requests that are not yet in the queue)
- Shaded in red: No transport capacity available: the limits for the application of congestion management have been reached.

Source: RAP 2024

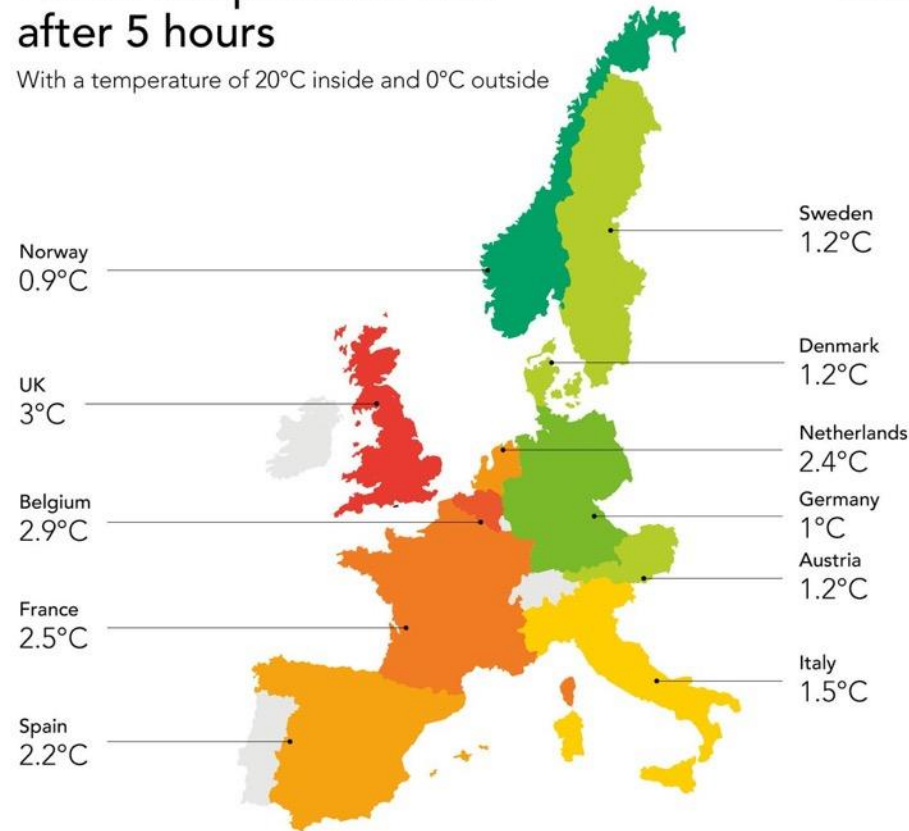


Thermal storage potential across Europe

Home temperature loss after 5 hours

With a temperature of 20°C inside and 0°C outside

tado°

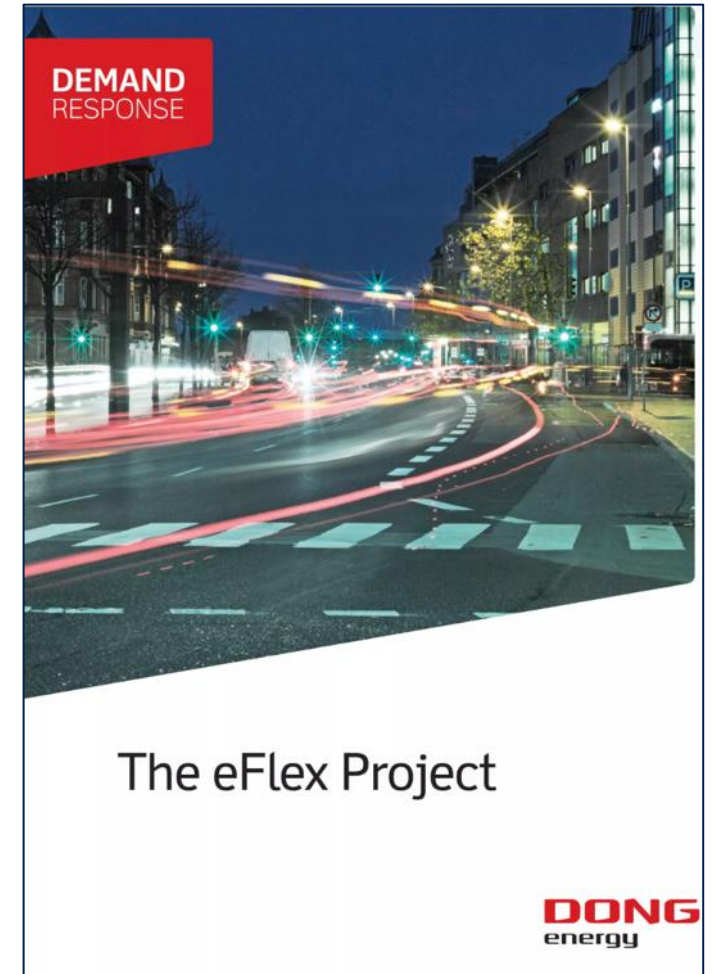


Based on a sample of over 80,000 European homes

Early pilot project in Denmark

“Heat pump portfolio optimisation can reduce the peak by 30% of the heat pumps’ own contribution in the peak.”

“In 2/3 of the planned two hour optimisations the heat pumps did not consume energy in the full two hour period.”



Time-of-use tariffs make heat pumps flexible

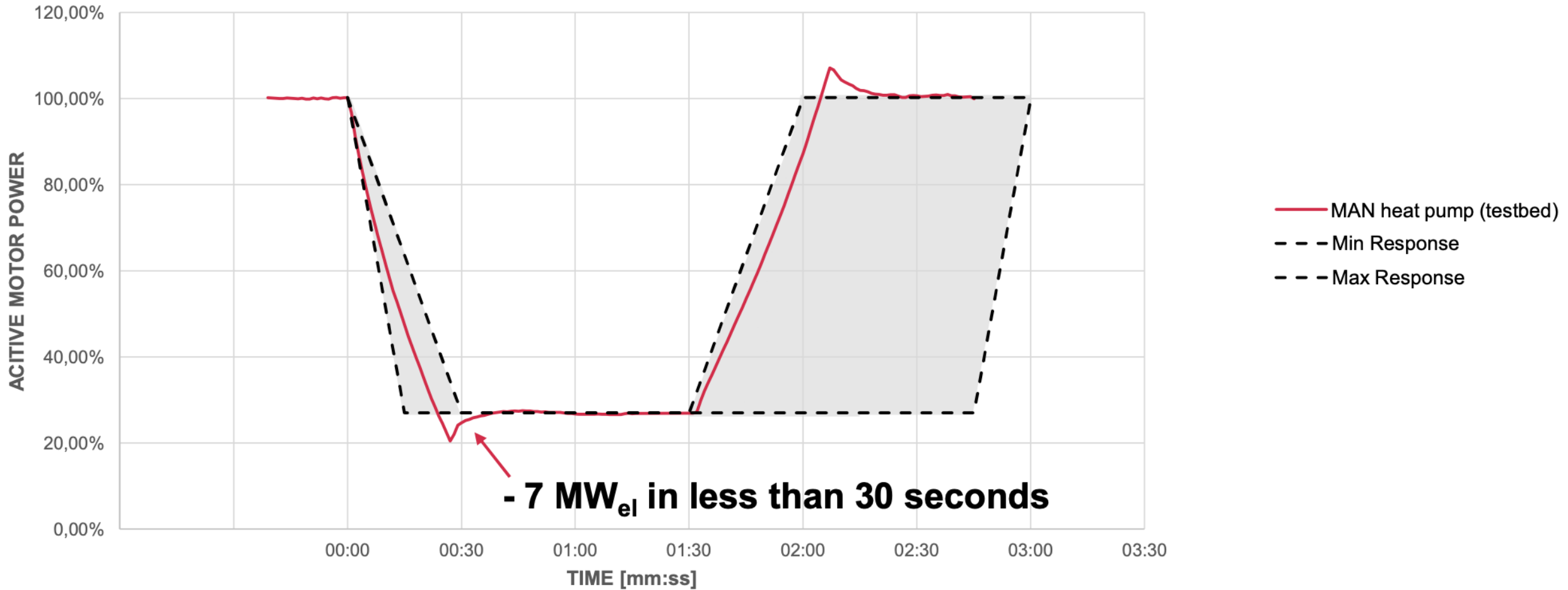
Impact of heat pump adoption and heat pump time-of-use tariff on consumption throughout the day



“Based on Octopus Energy’s Cosy Octopus tariff designed for heat pump owners, we see an approximate doubling of consumption during off-peak periods and a halving of consumption during the evening peak.”

Source: Bernard et al. 2024

Large heat pumps can offer demand response



Source: Wolscht 2023

Thermal storage combined with district heating



Industrial electro-thermal energy storage



Solutions Industries Projects Company

Start project

Volt with Eneco and PepsiCo. Food industry, Netherlands

Kraftblock replaces a 25 MW gas boiler with Net-Zero Heat System.

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June 26, 2024

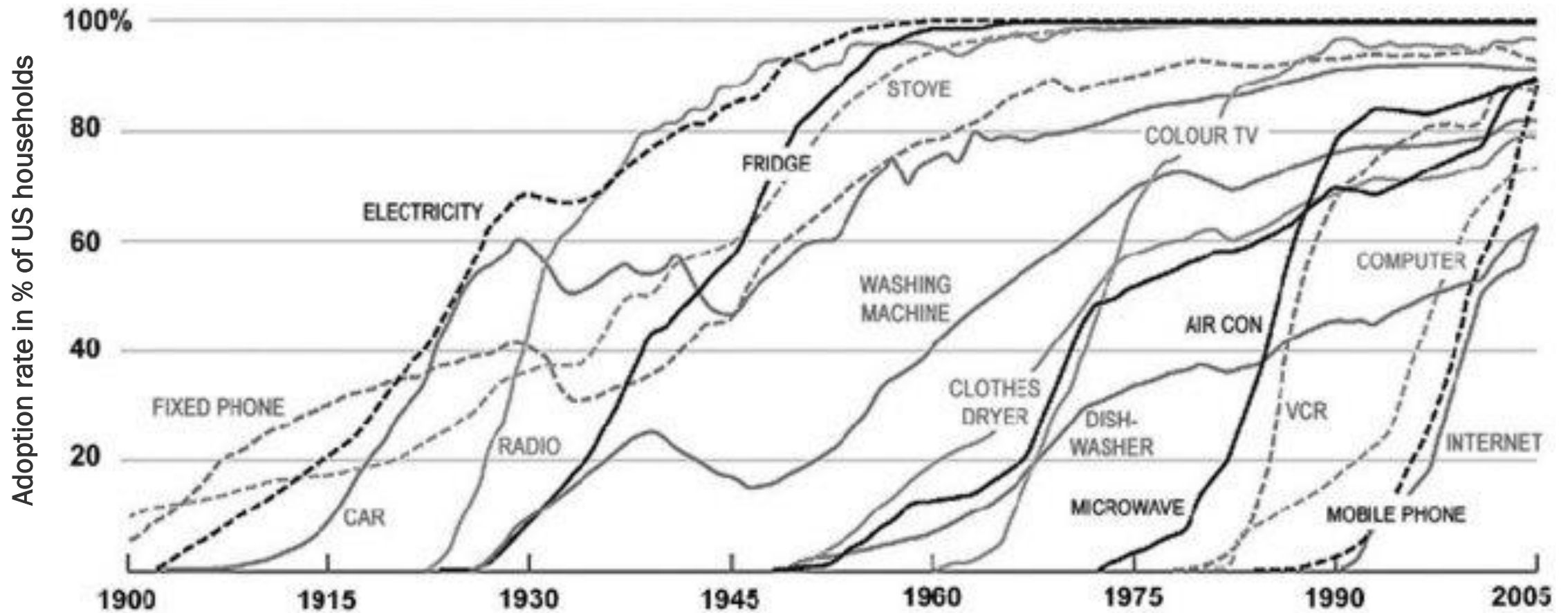
Rondo Energy announces €75M project funding with Breakthrough Energy Catalyst and the European Investment Bank

Three Rondo Heat Battery installations will decarbonize food, clean fuel, and chemical production across Europe.



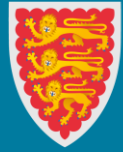
Wrap up

Recent innovations are spreading faster due to a highly connected and globalised world



Source: NYT 2008

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Thank you

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