

# Redox-flow batteries and their role in energy storage

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**Energy content in 1 liter: approx. 400 Wh**

# Intermittent electricity production by renewables

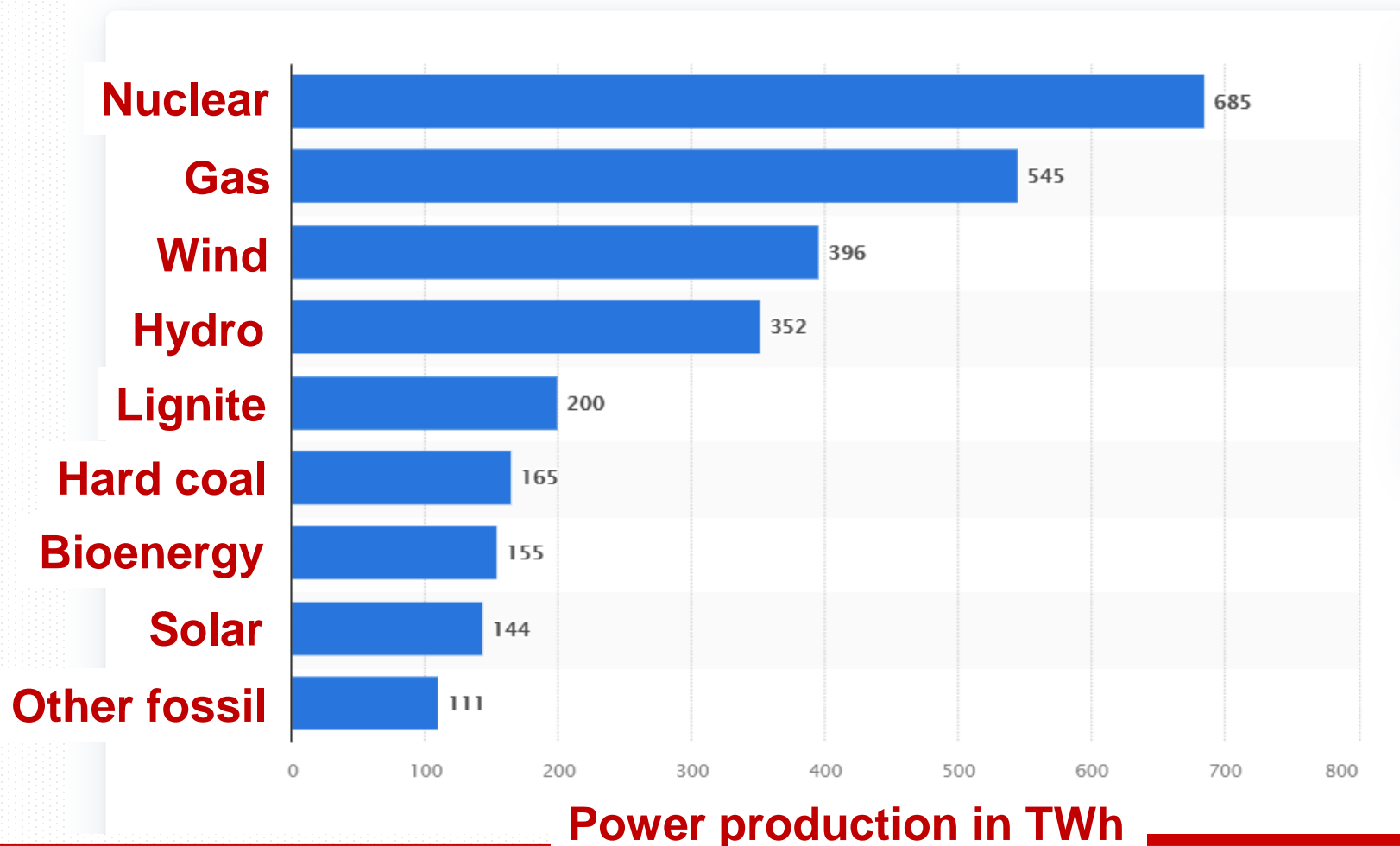
## Mitigation by:

- **Over-capacity** of renewables.
- **Natural gas** based peak power.
- **Weather forecasting.**
- **Grid expansion.**
- **Demand-side management.**
- **Energy storage** in pumped hydro, batteries or hydrogen.

**Battery energy storage goal: < 0.05 EUR / kWh / cycle**

# EU27: Role of natural gas in power generation

Electricity generation in the European Union (EU) in 2020  
*(in terawatt hours)*

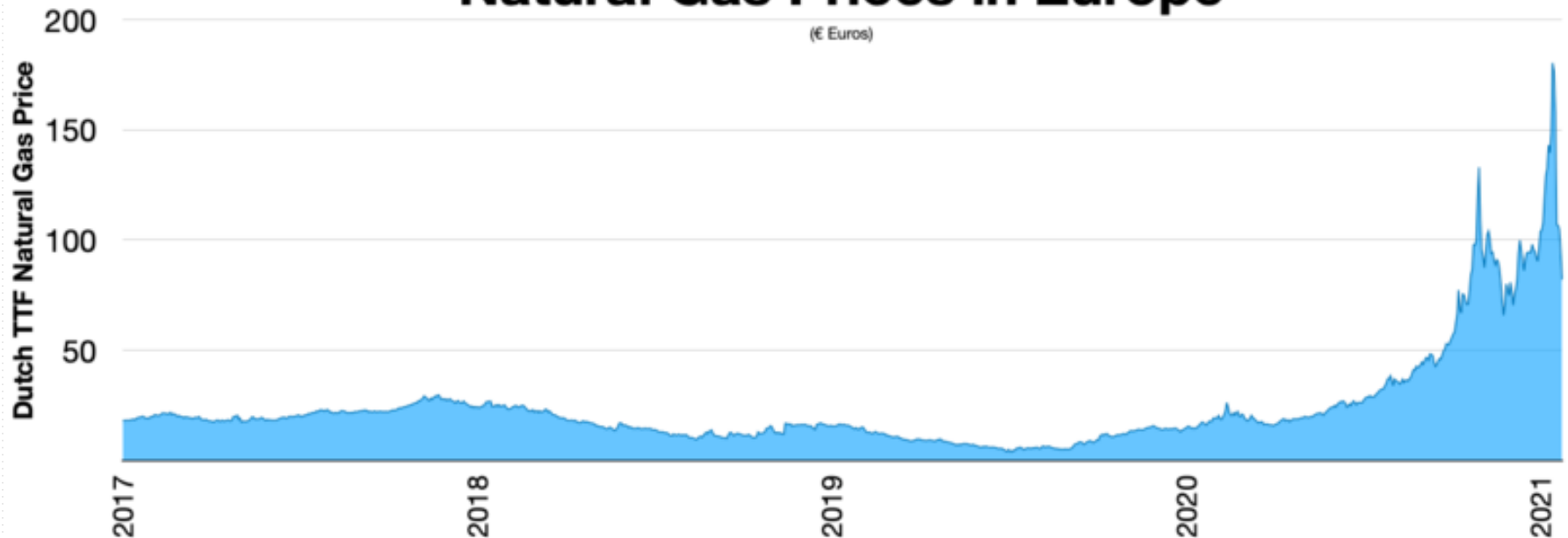


Source: EU Statista (2021)

# EU: Price of natural gas

EUR / MWh

## Natural Gas Prices in Europe

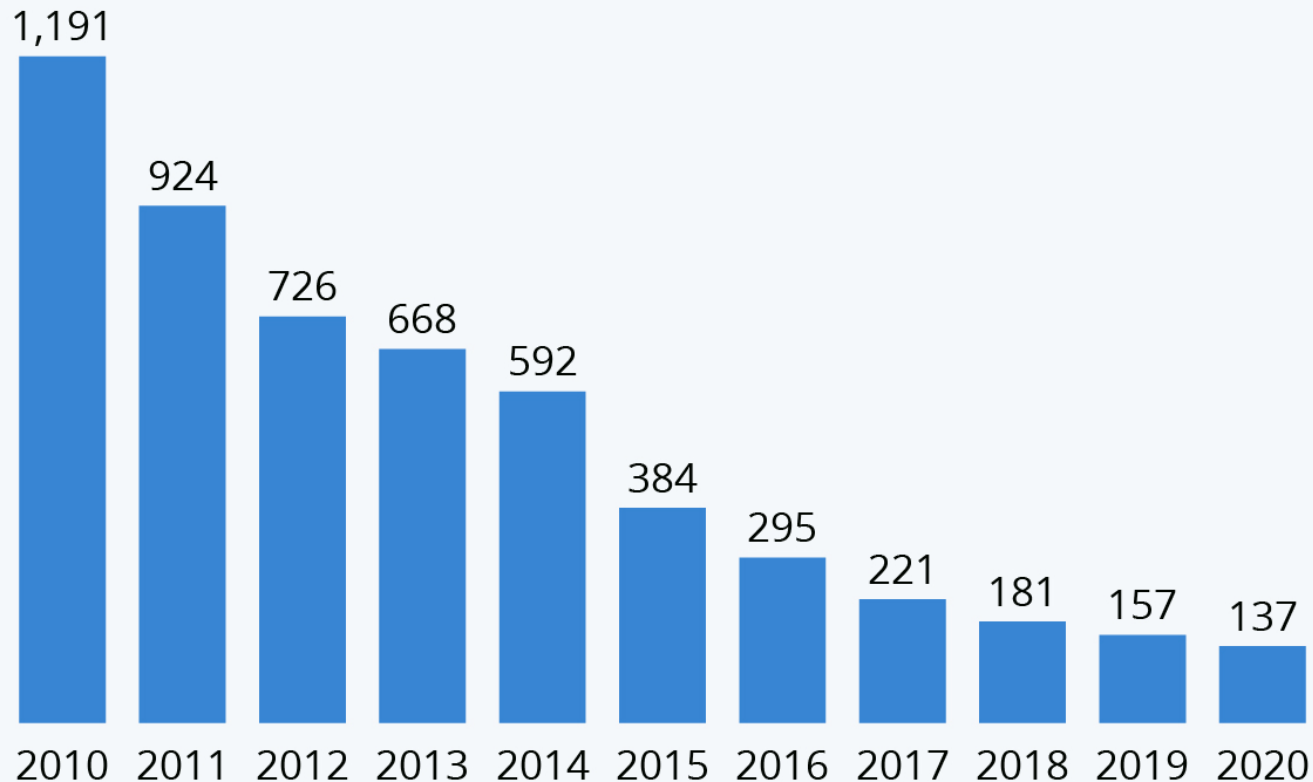


**March 2, 2022: price at 196 EUR / MWh**

# Li-Ion batteries (price per kWh)

## Lithium Battery Prices Plunge

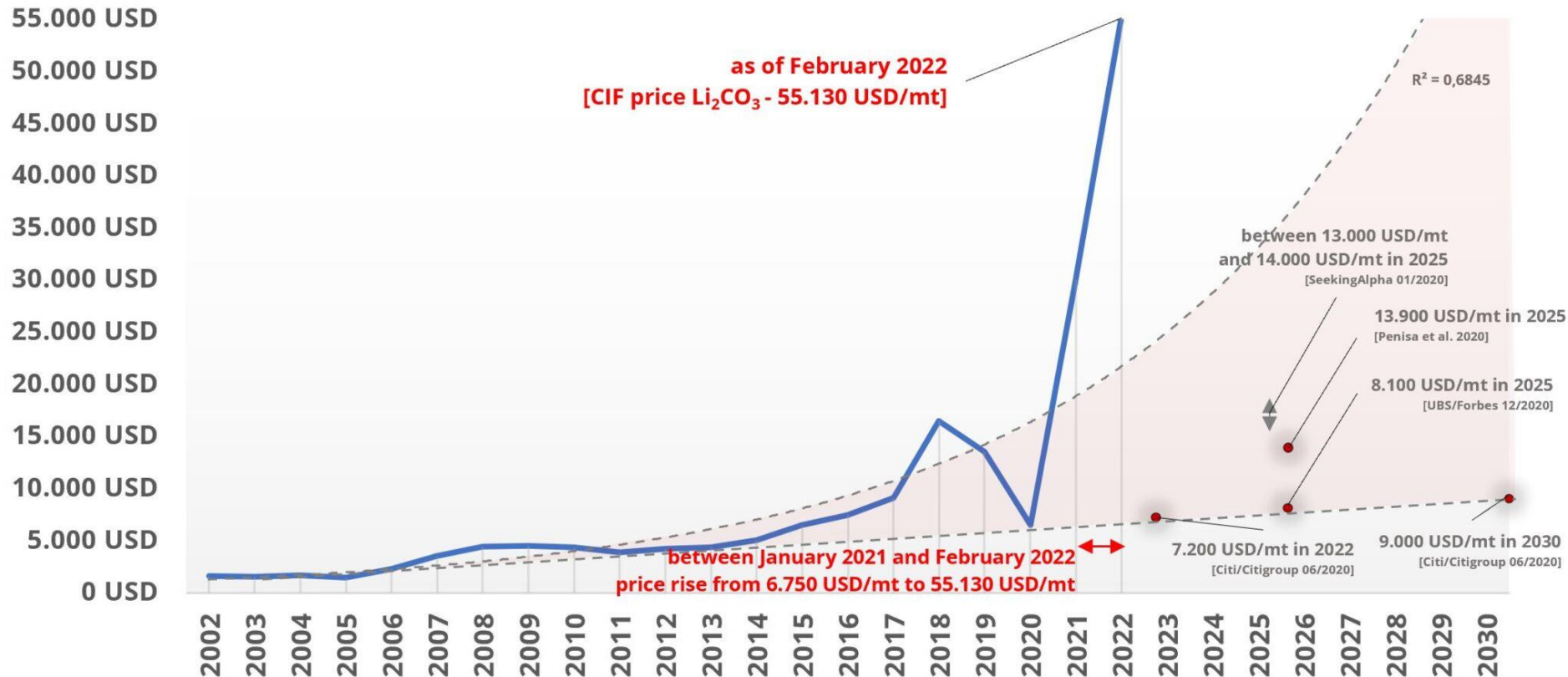
Volume-weighted average of lithium-ion battery price from all sectors (in USD)



# Li-Ion batteries (price per kWh)

real price development (blue line) and forecasted price trends (dotted lines) of battery grade Lithium carbonate [min 99,5 %  $\text{Li}_2\text{CO}_3$ ]

[statista 2018, DERA 2020, lme.com 2022]



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# Li-Ion batteries

**Giga-factories:** In 2019 China was producing 72% of Li-Ion, USA 9%.

China: **150** giga-factories (one opens each week)

USA: **11** giga-factories

EU27: **6** giga-factories (summer 2021)

Global production in 2020: 755 GWh.

Global production in 2030: 3400 GWh (expected).

**Charging speed of electric cars:** improved many times over last 10 years.

**Li-Ion energy density** in cars:

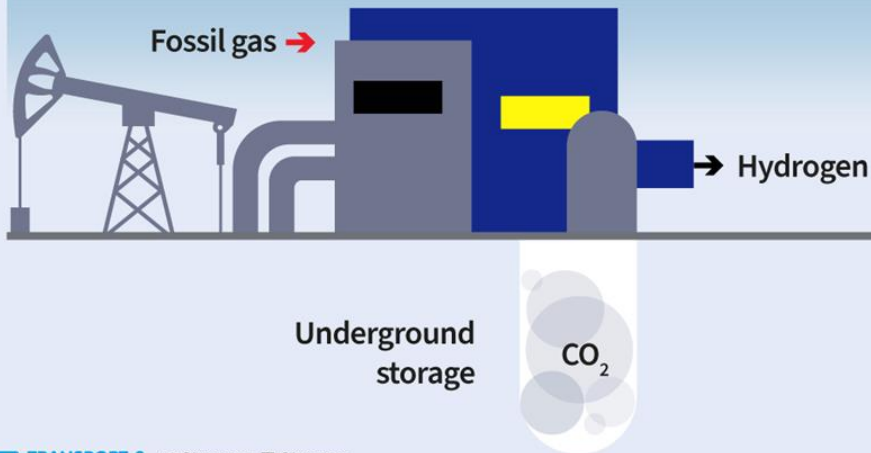
2010 ... typical 120 – 130 Wh/kg

2020 ... best models 250 – 300 Wh/kg

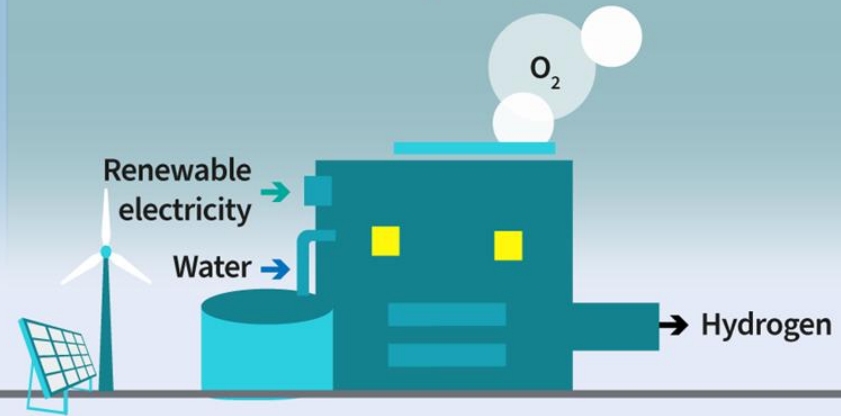


# Blue and green hydrogen

## Blue hydrogen



## Green hydrogen

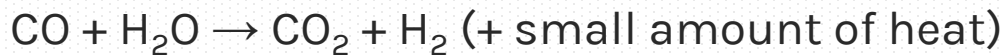


## Blue hydrogen

Steam-methane reforming reaction



Water-gas shift reaction



## Green hydrogen

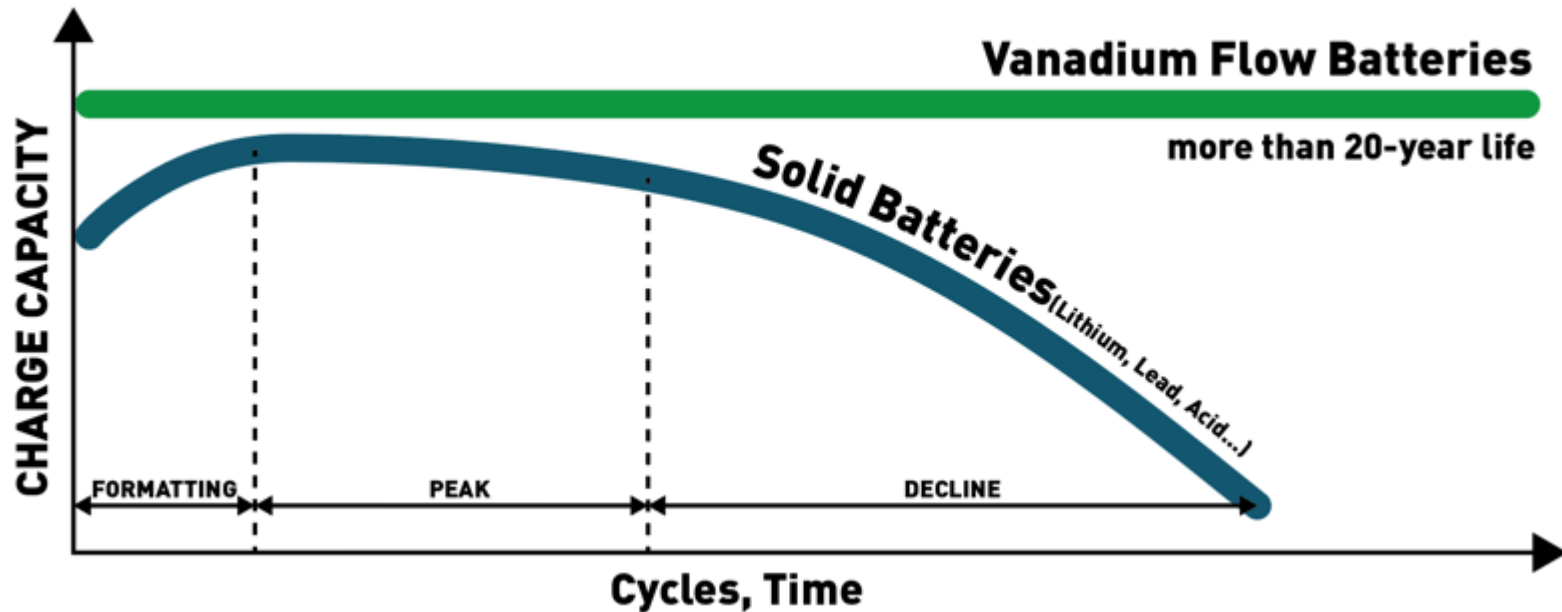
Water electrolysis.

At present cca 1-3% hydrogen.

California: \$16.50 / kg H<sub>2</sub> (in 2020).

1 kg H<sub>2</sub> = cca 40 kWh.

# Lifetime: Redox-flow vs solid-state batteries



- Recycling costs for LiB over \$100 / kWh.
- Flow-batteries: ecological recycling or disposal of electrolytes.
- Vanadium redox-flow batteries: electrolyte is „immortal “ → excellent recyclability