Redox-flow batteries and their role in energy storage

Juraj Kosek









Energy content in 1 liter: approx. 400 Wh

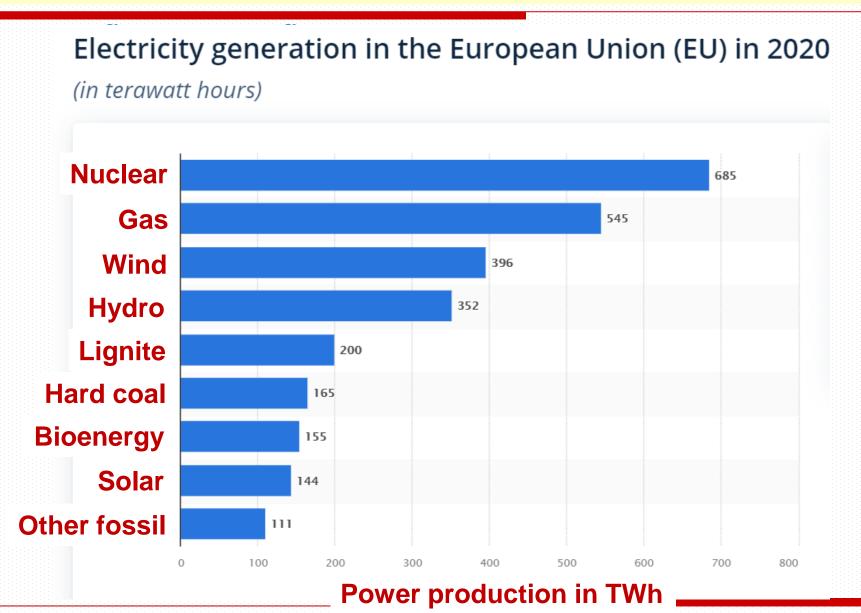
Intermittent electricity production by renewables

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.

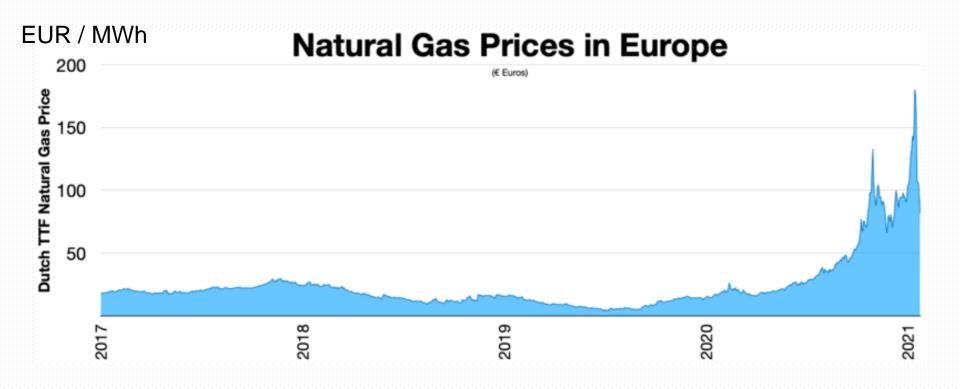
Battery energy storage goal: < 0.05 EUR / kWh / cycle

EU27: Role of natural gas in power generation



Source: EU Statista (2021)

EU: Price of natural gas



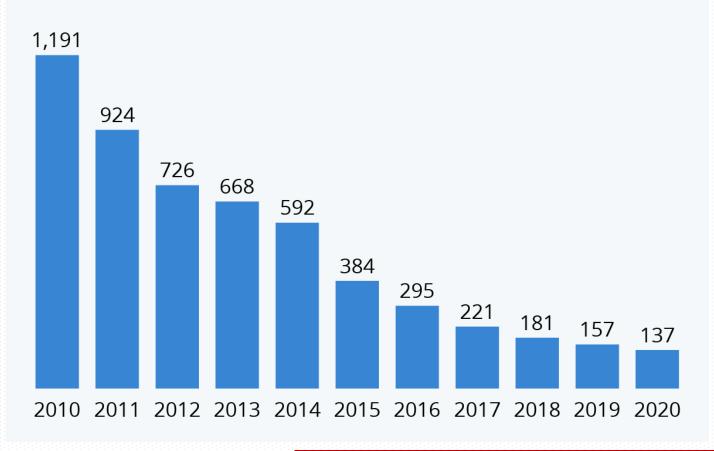
March 2, 2022: price at 196 EUR / MWh

Source: Dutch TTF Natural Gas (until Jan-2, 2022)

Li-Ion batteries (price per kWh)

Lithium Battery Prices Plunge

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



Source: Statista, Bloomberg (2020)

Li-Ion batteries (price per kWh)

real price development (blue line) and forecasted price trends (dottet lines) of battery grade Lithium carbonate [min 99,5 % Li,CO,] [statista 2018, DERA 2020, Ime.com 2022] 55.000 USD as of February 2022 50.000 USD $R^2 = 0,6845$ [CIF price Li₂CO₃ - 55.130 USD/mt] 45.000 USD 40.000 USD 35.000 USD between 13.000 USD/mt and 14.000 USD/mt in 2025 30.000 USD [SeekingAlpha 01/2020] 13.900 USD/mt in 2025 25.000 USD [Penisa et al. 2020] 20.000 USD 8.100 USD/mt in 2025 [UBS/Forbes 12/2020] 15.000 USD 10.000 USD 5.000 USD 9.000 USD/mt in 2030 7.200 USD/mt in 2022 between January 2021 and February 2022 [Citi/Citigroup 06/2020] [Citi/Citigroup 06/2020] price rise from 6.750 USD/mt to 55.130 USD/mt 0 USD 2002 2003 2004 2005 2006 2008 2009 2010 2011 2012 2013 2014 2015 2015 2016 2017 2018 2019 2020 2025 2026 2030 2022 2023 2024 2028 2007 2027 202 2029 GERMAN LITHIUM © 2022 | www.germanlithium.com

Source: www.germanlithium.com (2022)

PARTICIPATION

Li-Ion batteries

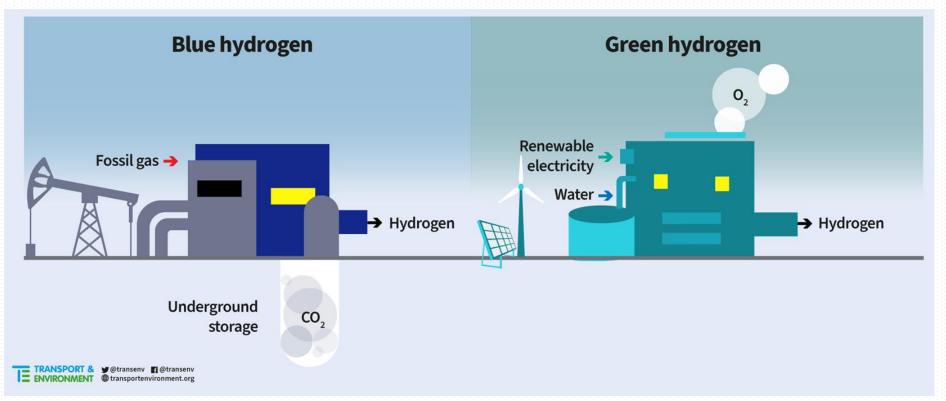
Giga-factories: In 2019 China was producing 72% of Li-Ion, USA 9%.
China: 150 giga-factories (one opens each week)
USA: 11 giga-factories
EU27: 6 giga-factories (summer 2021)
Global production in 2020: 755 GWh.
Global production in 2030: 3400 GWh (expected).

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

Li-lon energy density in cars:

2010 ... typical 120 – 130 Wh/kg 2020 ... best models 250 – 300 Wh/kg

Blue and green hydrogen



Blue hydrogen

Steam-methane reforming reaction

 $CH_4 + H_2O (+ heat) \rightarrow CO + 3H_2$ Water-gas shift reaction $CO + H_2O \rightarrow CO_2 + H_2 (+ small amount of heat)$

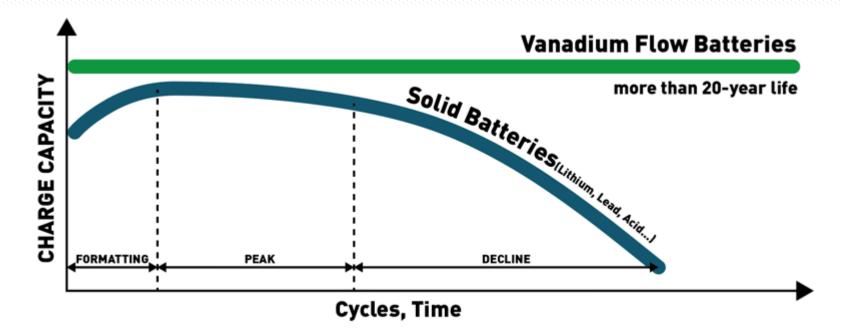
Green hydrogen

Water electrolysis. At present cca 1-3% hydrogen.

California: \$16.50 / kg H₂ (in 2020).

1 kg $H_2 = cca 40$ 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