ENERGY STORAGE: BALANCING GRIDS AND POWERING MARKETS

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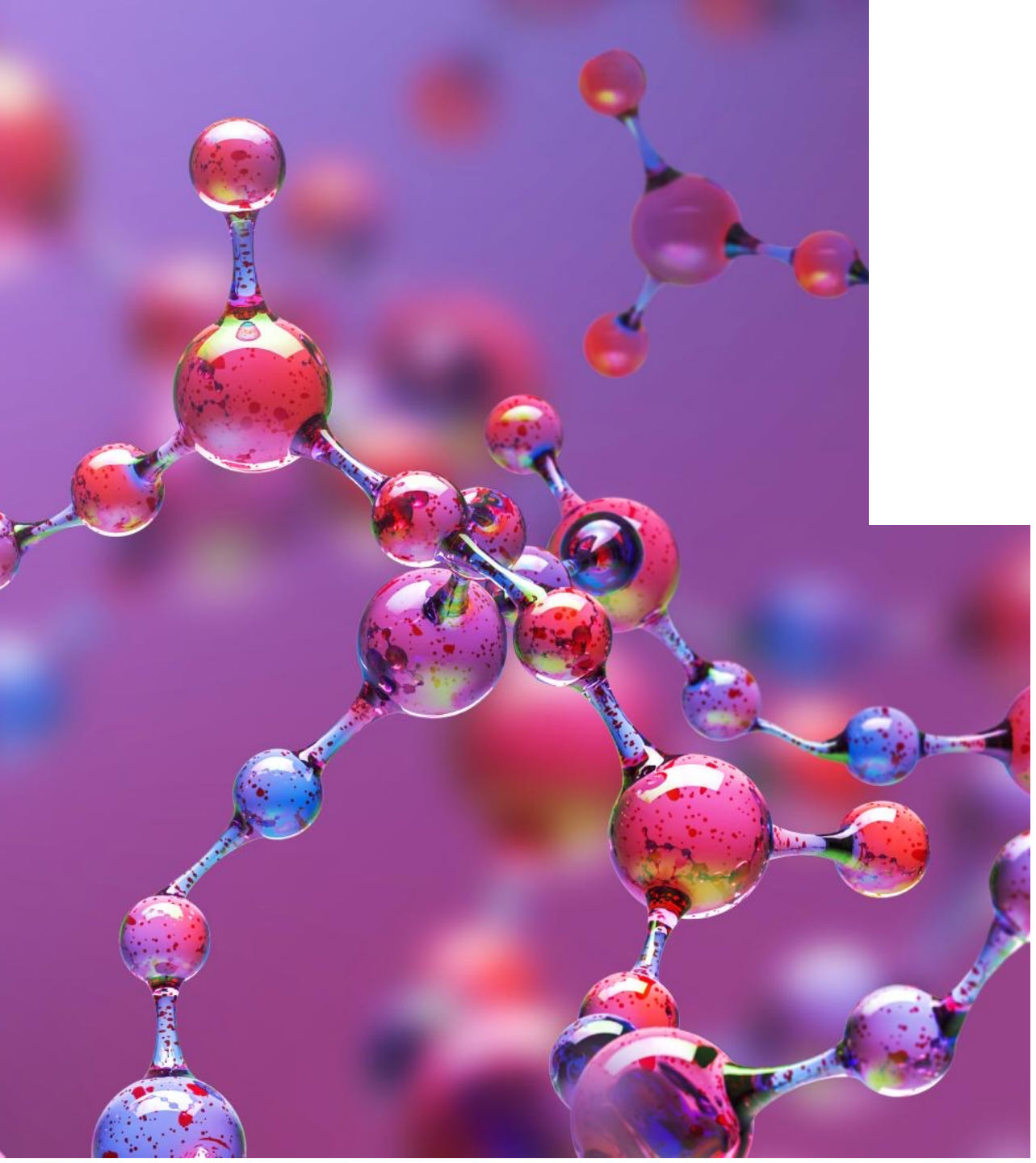
MY BACKGROUND

- **Energy Systems:** **Taltech**, **Five Wind Energy**
- **Energy Markets:** Fusebox
- **Financial Markets:** Bank of America / Merrill Lynch
- **Business Management:** Wallester, Vaba Maa
- **Financial Management:** Eesti Post, Nordica
- **Project Management:** **Baltic Workboats**, Infortar, SEB
- **Teaching Activities:** **Taltech,** Tartu Ülikool
- **Supervisory Roles:** **Printall, Baltic Workboats**

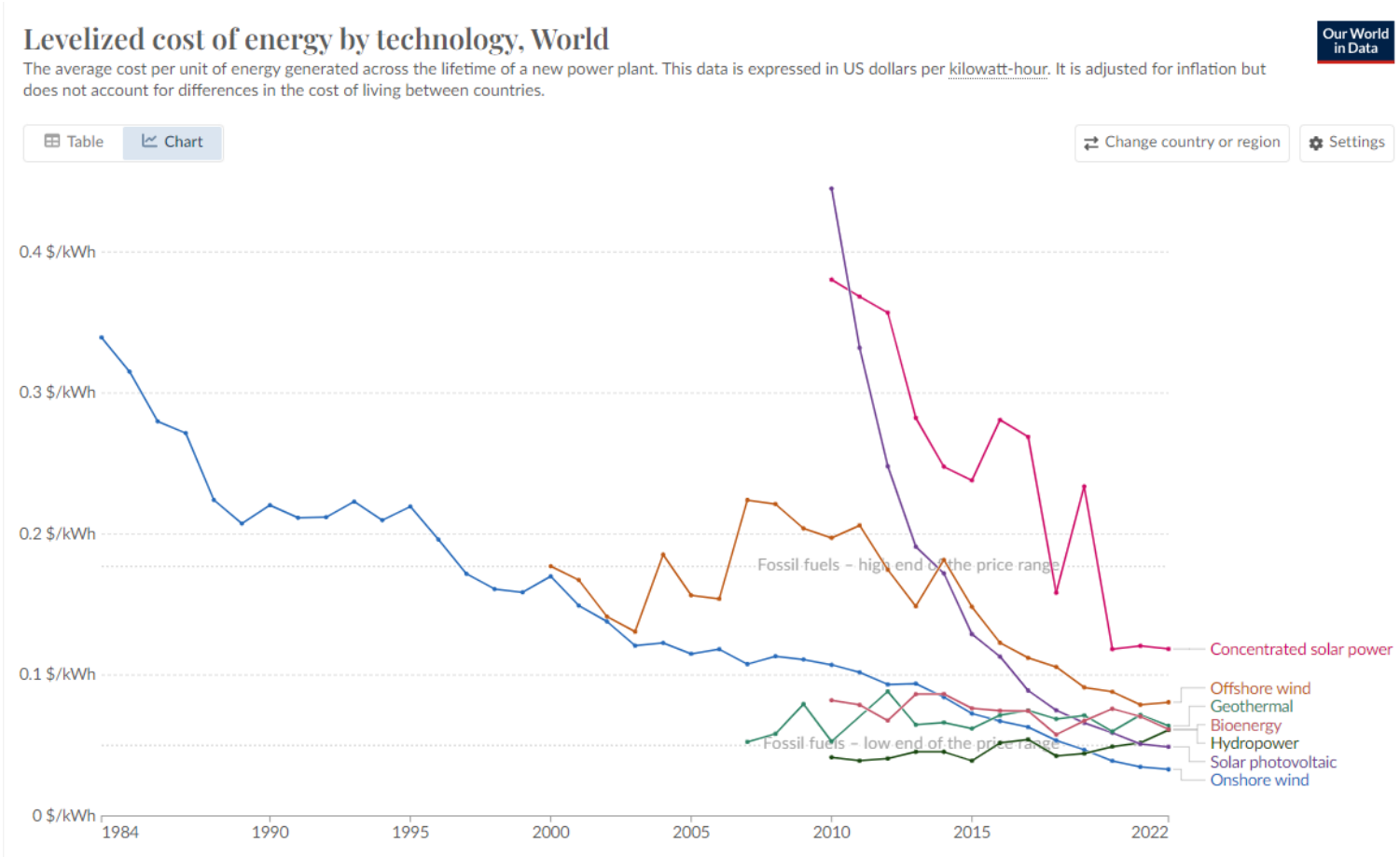
Praegused rollid



SUPPLY SIDE OF THE EQUATION: RENEWABLE ENERGY PRODUCTION

RENEWABLE REVOLUTION: AFFORDABLE, CLEAN ENERGY

- Renewable electricity generation has become the cheapest form of energy generation over the last 15 years
- Solar photovoltaic and onshore wind have outperformed all other asset classes and have reached the unsubsidized price level of fossil fuels



(1) IRENA – International Renewable Energy Agency. Our World in Data.

GREEN DEAL UNDERPINNING FURTHER RENEWABLE REVOLUTION

- The European Union's energy strategy is underpinned by the European Green Deal (climate neutrality by 2050), which main elements include
  - Saving energy
  - Diversification and security of energy sources
  - Increasing the share of renewable energy in production
- The European Commission forecasts that the **share of renewable energy in electricity generation should increase from 37% in 2021 to 69% in 2030**.
- Evolving perceptions will shape the future of nuclear power – in 2022 the share of nuclear was expected to fall from its 2020 level (24.6%) due to an ageing generation fleet and a lack of new projects

FIGURE 1 NET RENEWABLE POWER GENERATING CAPACITY INSTALLED IN 2022

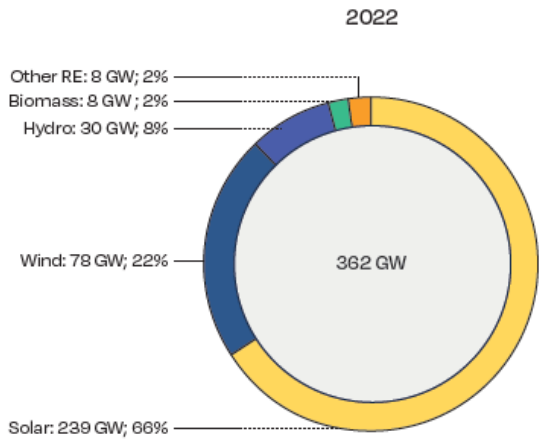
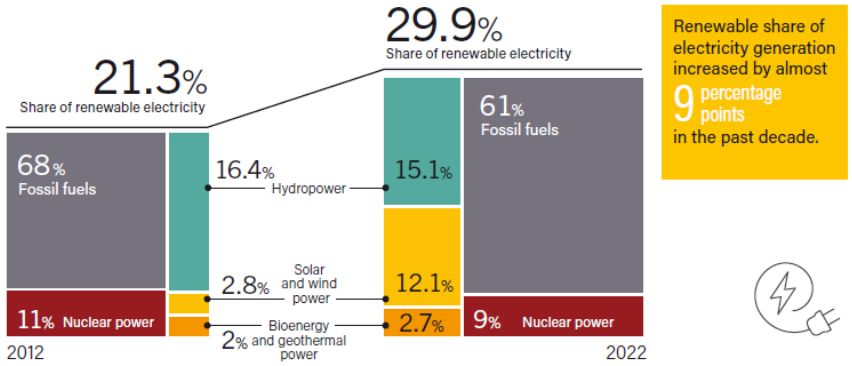


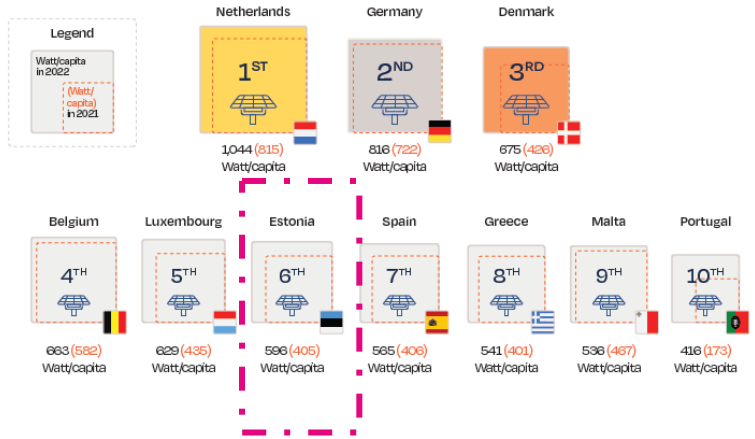
FIGURE 2.
Share of Renewable Electricity Generation, by Energy Source, 2012 and 2022

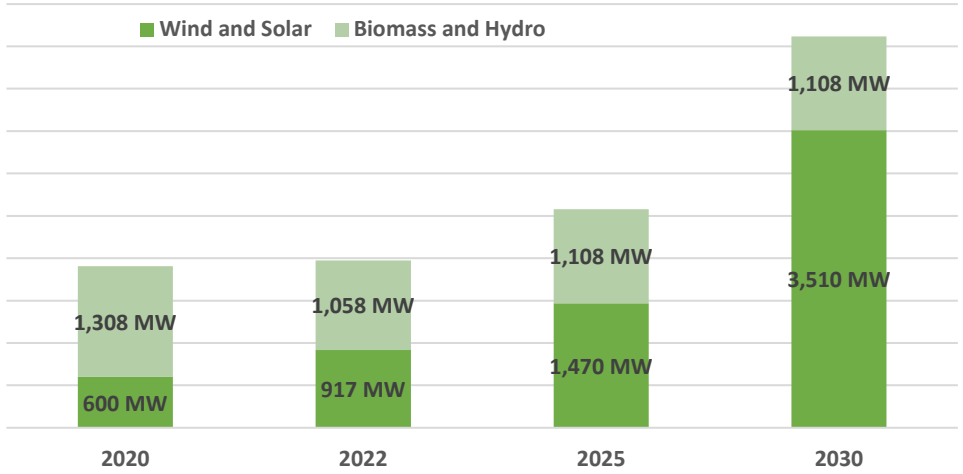


(1) *State of the Energy Union 2022. European Commission, 18.10.2022.*
(2) *Global Market Outlook for Solar Power 2023-2027, SolarPower Europe*
(3) *Renewables 2023, Global Status Report. Ren21*

ESTONIA: RAPID ADOPTION OF SOLAR ENERGY

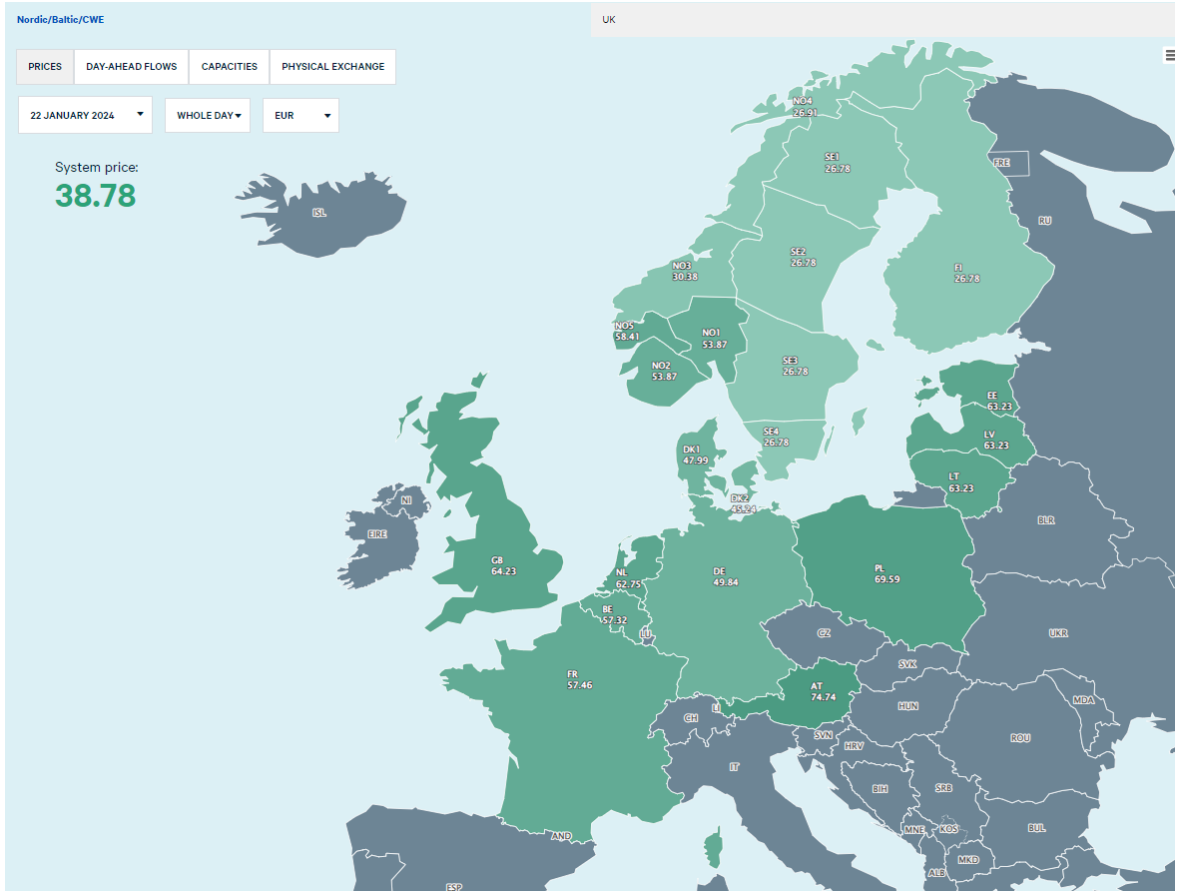
- Estonia has met its 2030 solar targets and there are no additional large-scale state expansion plans of solar energy
- On this basis, Estonia is ranked 5th within Europe in terms of installation per capita irrespective of our geographical location (629W/inhabitant in 2022)
- The country's main objective is to increase wind power generation, with solar power generation increasing minimally after 2025
- Wind installed capacity will increase 7x vs 2022
  - Solar installed capacity to increase 2x vs 2022
  - Essentially no added capacity to biomass and hydro

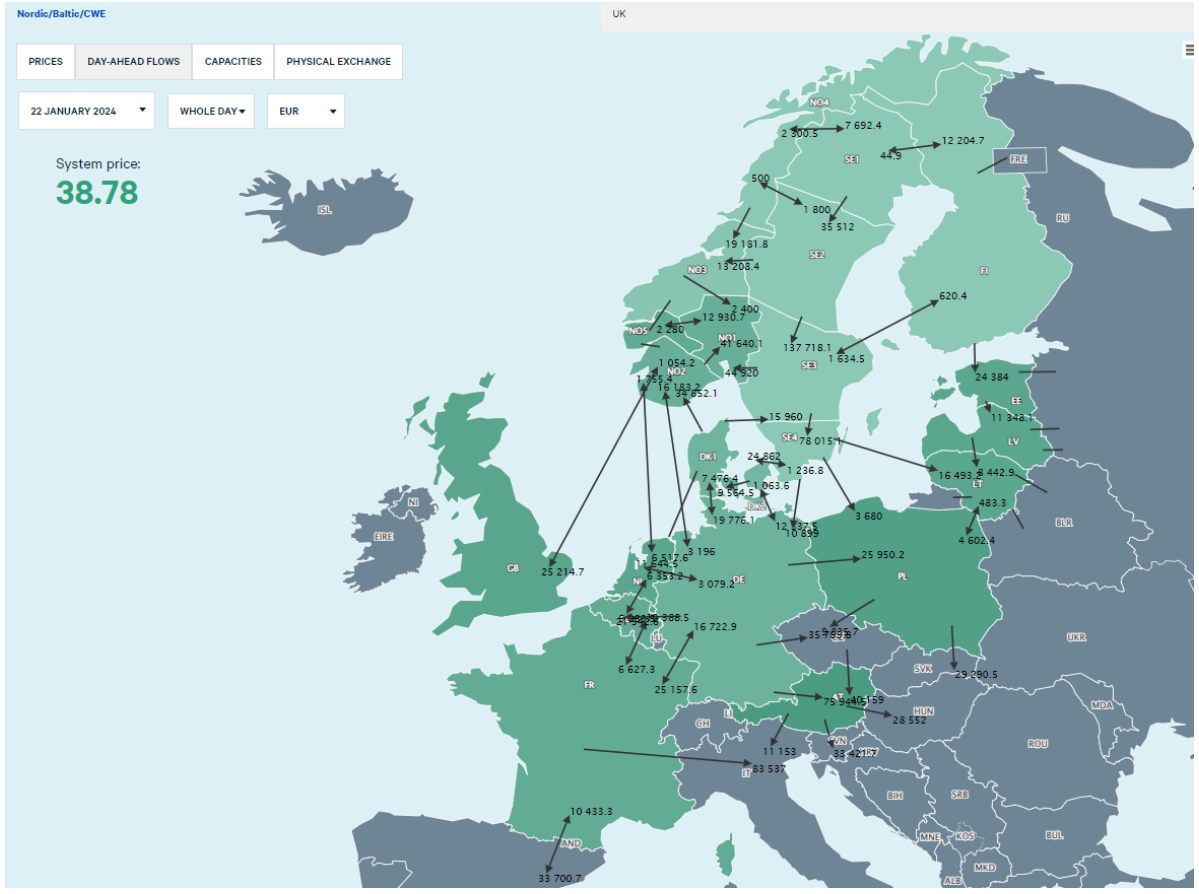




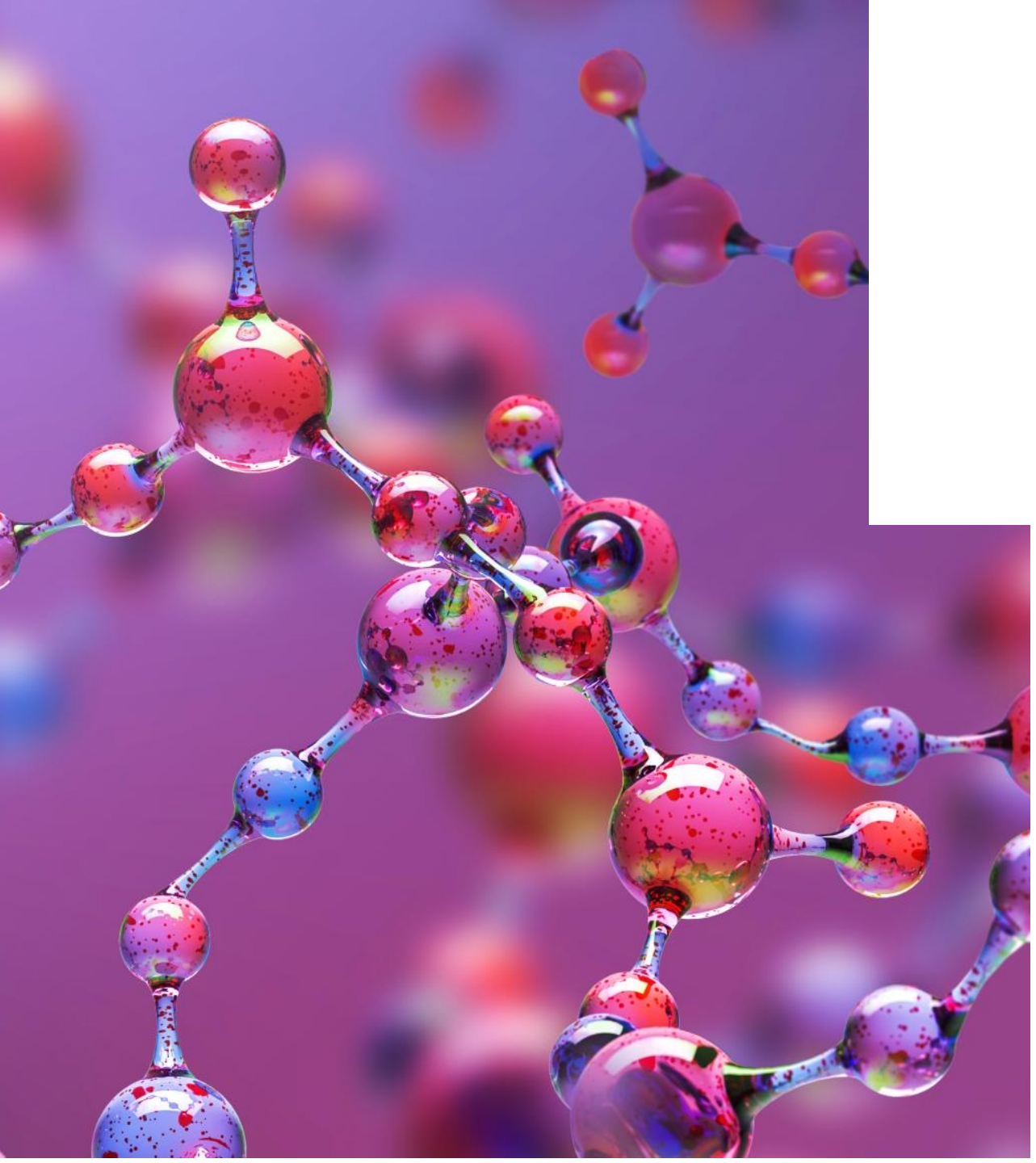
(1) *European Market Outlook for Solar Power 2023-2027, SolarPower Europe.*
(2) *Ministry of the Environment.*

ESTONIAN ELECTRICITY INCREASINGLY DEPENDENT ON NORDICS





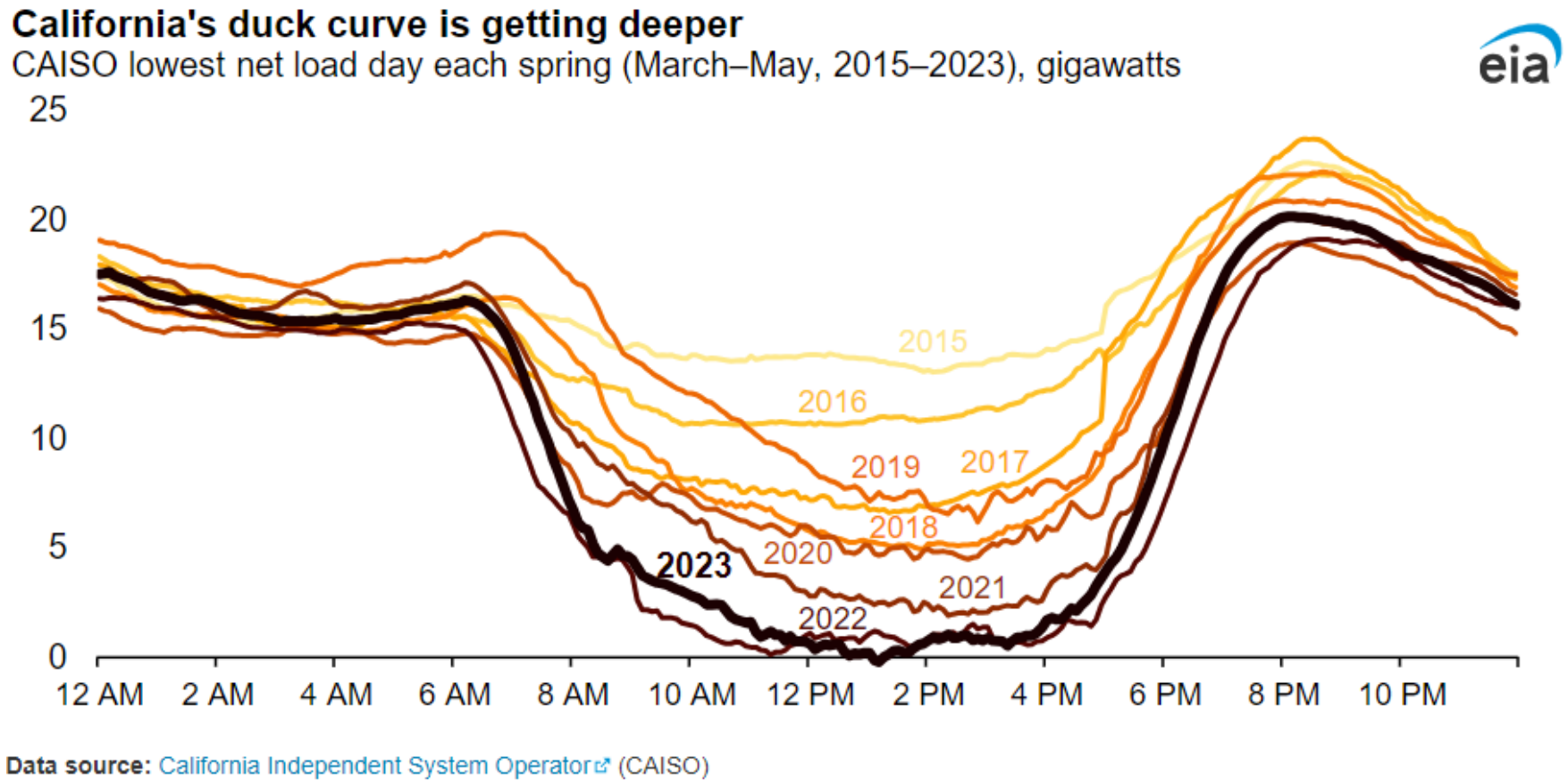
(1) *Nord Pool.*



ENERGY STORAGE AS AN ENABLER FOR RENEWABLE ENERGY

SO WHERE IS THE CATCH - WHY NOT MORE SOLAR?

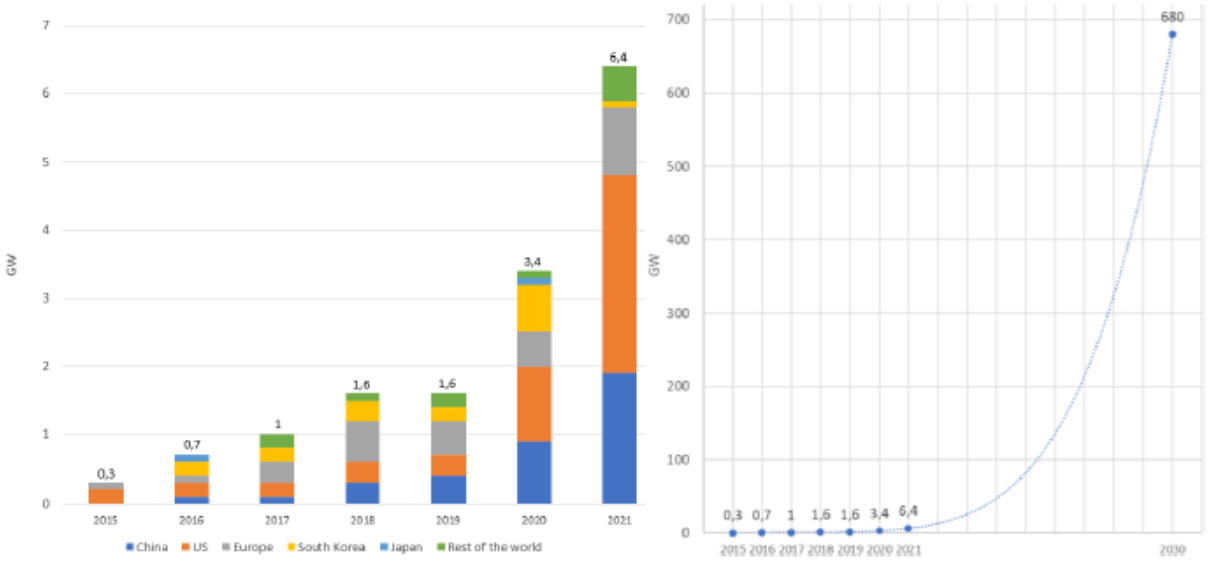
- Wind and solar power generation highly dependent on weather conditions - leading to intermittency and variability of production
- Lack of consistent power generation can create challenges in matching energy supply with demand



THE EUROPEAN COMMISSION'S VIEW - ENERGY STORAGE

- European Green Deal requires a transformation of the energy system, which in turn requires greater flexibility - the ability to adapt to the changing needs of the network and to manage demand and supply variability and uncertainty across all relevant time scales.
  - Direct, sometimes exponential, correlation between the need for flexibility (daily, weekly and monthly) and the uptake of renewable energy
  - The need for flexibility will therefore be particularly important in the coming years.
- Recommendations to Member States:
  - Remove market failures (e.g. tariffs) in view of the dual role of energy storage (producer, consumer)
  - Evaluate whether energy storage can be a more cost-effective alternative to grid investment
  - Identify potential financing gaps, consider the need for financing instruments
  - Investigate whether energy storage services, in particular the use of flexibility in distribution networks and the provision of non-frequency support services
  - Identify specific regulatory and other measures to remove barriers to the deployment of storage

Global "utility scale" battery system installations forecast (GW)



Europe needs 200+ GW of flexivilty by 2030 and 600GW by 2050, Estonia needs ~0.5-1.0 GW by 2030, up to 2 GW by 2050.

(1) *European Commission, https://eur-lex.europa.eu/legal-content/ET/TXT/HTML/?uri=CELEX:32023H0320(01).*

EVOLVING TECHNOLOGIES SUPPORTING DIFFERENT MARKET SERVICE OPPORTUNITIES

- Lithium based storage continues to see widest adoption rates
- Different technologies are suitable for different use cases
- Battery Technologies continue to evolve

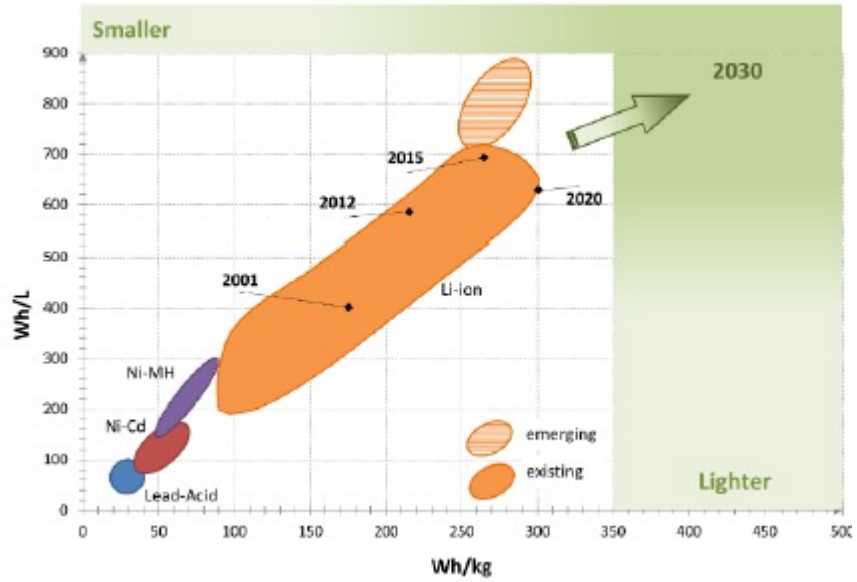


Figure 2 In-depth assessment of battery technologies for storage service applications

Storage Service Applications	Storage size range	Lead-acid batteries			Li-ion batteries			Sodium-based batteries [5]			Redox-Flow batteries [6]		
		st	*mt*	*lt*	*st*	*mt*	*lt*	*st*	*mt*	*lt*	*st*	*mt*	*lt*
Generation Support Services and Bulk Storage Services [1]	< 100 kWh												
	100 kWh - 1 MWh												
	1 MWh - 1 GWh												
Services to Support Transmission Infrastructure [2]	< 100 kWh												
	100 kWh - 1 MWh												
	1 MWh - 1 GWh												
Services to Support Distribution Infrastructure [3]	< 100 kWh												
	100 kWh - 1 MWh												
	1 MWh - 1 GWh												
Ancillary Services	< 100 kWh												
	100 kWh - 1 MWh												
	1 MWh - 1 GWh												
Services to Support Behind the Meter Customer Energy Management	< 100 kWh												
	100 kWh - 1 MWh												
	1 MWh - 1 GWh												
Vehicle-to-Grid (V2G) [4]	< 10 kWh												
	< 100 kWh												

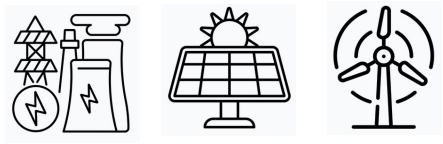
(st = short-term storage, mt = mid-term storage, lt = long-term storage)

Legend

suitable:	The technology represents a common solution for the service or or is a promising option for the near future.
possible:	The technology is (still) limited for the service or is mainly not used for this purpose, even if it is technologically possible. Nevertheless, the technology is used in some cases.
unsuitable:	The technology is rather less to not suitable for the service. Through further research & development, however, it could be an option in the distant future.
not existing:	The technology doesn´t exist.

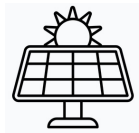
(1) *European Commission.*
(2) *Frauhofer ISE.*

LOCATION OF THE STORAGE PROJECT - THE MOST SUITABLE SOLUTION KEY TO ENERGY STORAGE REQUIREMENTS



Large scale production

Central, 1MW+, container solution



Small scale production

Distributed, 50kW-1MW, cabinet solution

Main grid

Mostly centralised, 10MW+, container+ solution

Distribution grid

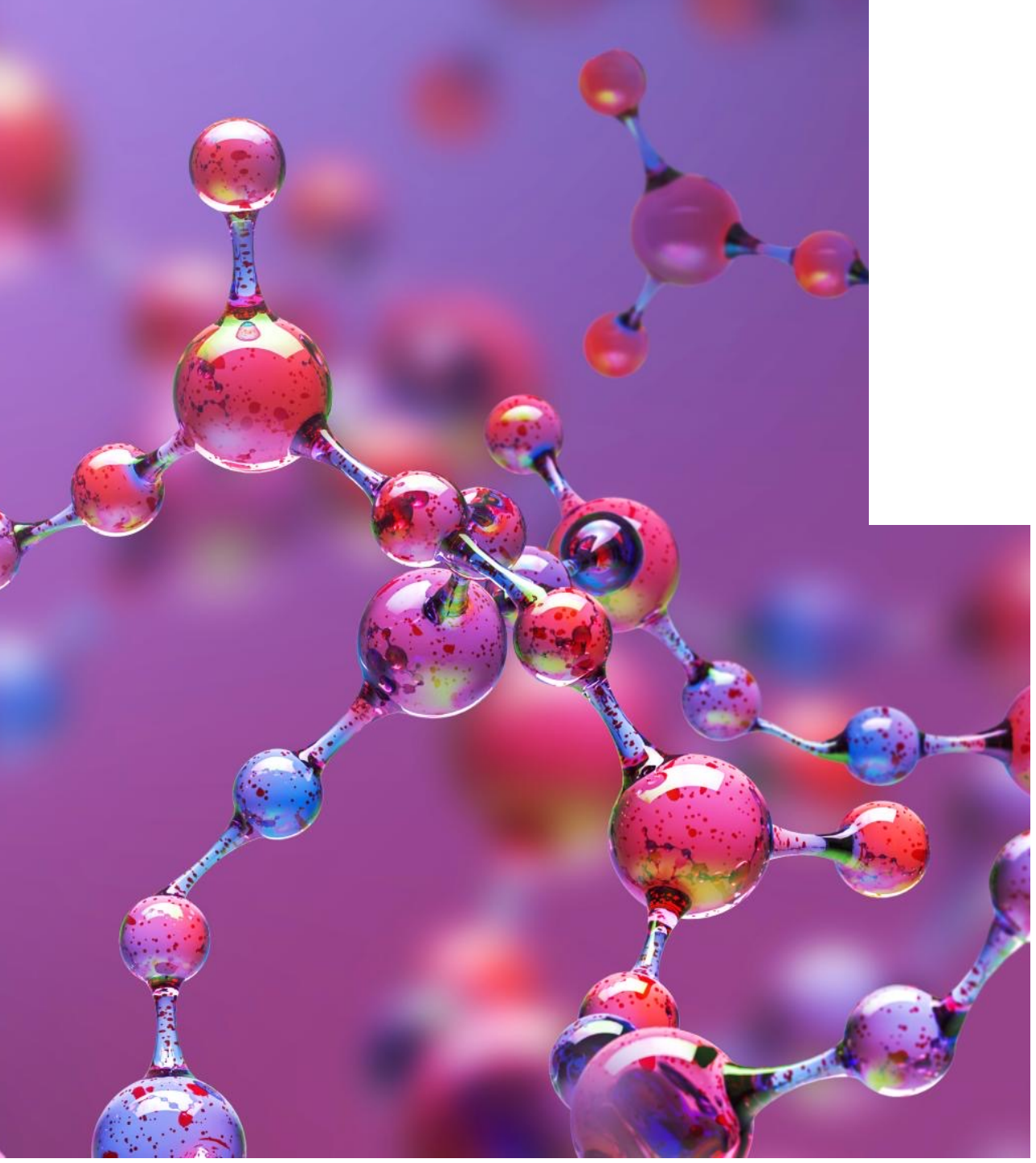
Mostly distributed, 1MW+, container+ solution

Commercial user

Distributed, <1MW, cabinet solution

Residential user

Distributed, <100kW, cabinet/residential solution

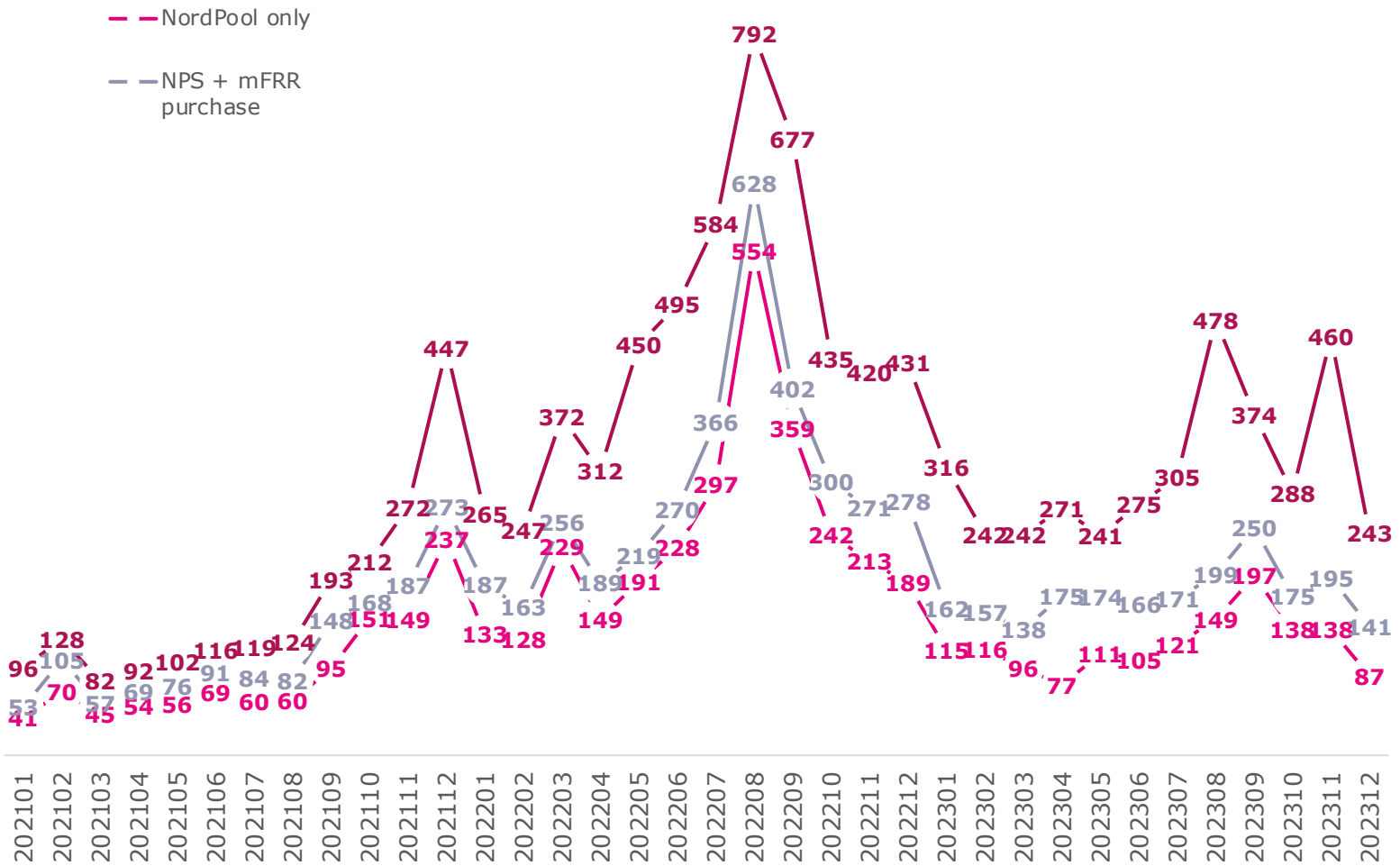


ENERGY STORAGE: BUT WHERE IS THE MONEY?

PRICE VOLATILITY AND ADDITIONAL MARKETS SHAPE PROFITABILITY IN ENERGY STORAGE

- **It's not the price level that matters, but its volatility**
- In Estonia, **price volatility has increased**, allowing Nord Pool to also profit from price differences
- In addition, buying and selling on the mFRR market - an additional revenue generating opportunity

AVERAGE DAILY VOLATILITY (EUR/MWH)



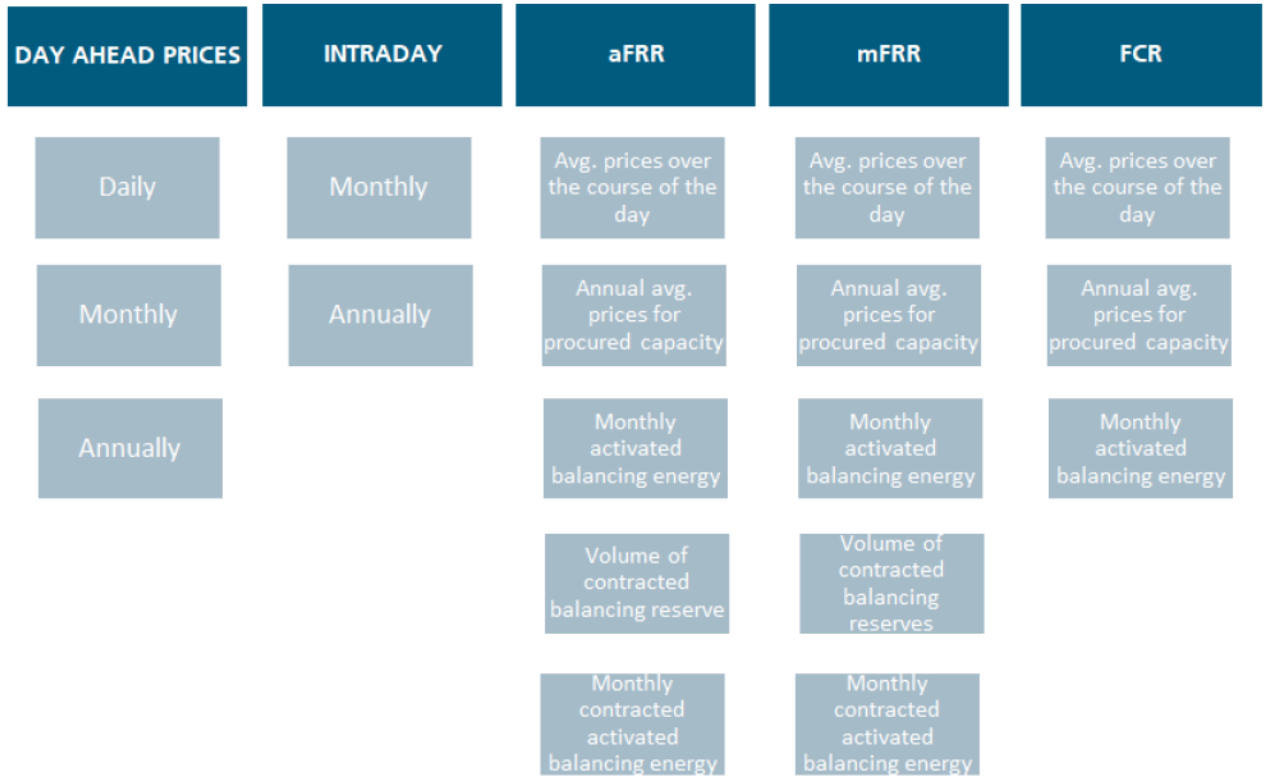
TURUD – SOOME NÄIDE

	FFR	FCR-D	FCR-N	aFRR	mFRR
	Fast Frequency reserve, Finland 18 %, Nordics total 0-300 MW (estimate)	**Frequency Containment Reserve for Disturbances,** Finland ~300 MW, Nordics total 1450 MW upwards and 1400 MW downwards	**Frequency Containment Reserve for Normal Operation,** Finland ~120 MW, Nordics total 600 MW	**Automatic Frequency Restoration Reserve,** Finland 60-80 MW, Nordics total 300-400 MW	**Manual Frequency Restoration Reserve** Reference incident + imbalances of balance responsible parties
Activated	In large frequency deviations In low inertia situations	In large frequency deviations Up-regulation and down-regulation separately	Used all the time	Used in certain hours	Activated if necessary
Activation speed	In a second	In seconds	In three minutes	In five minutes	In fifteen minutes

FINGRID

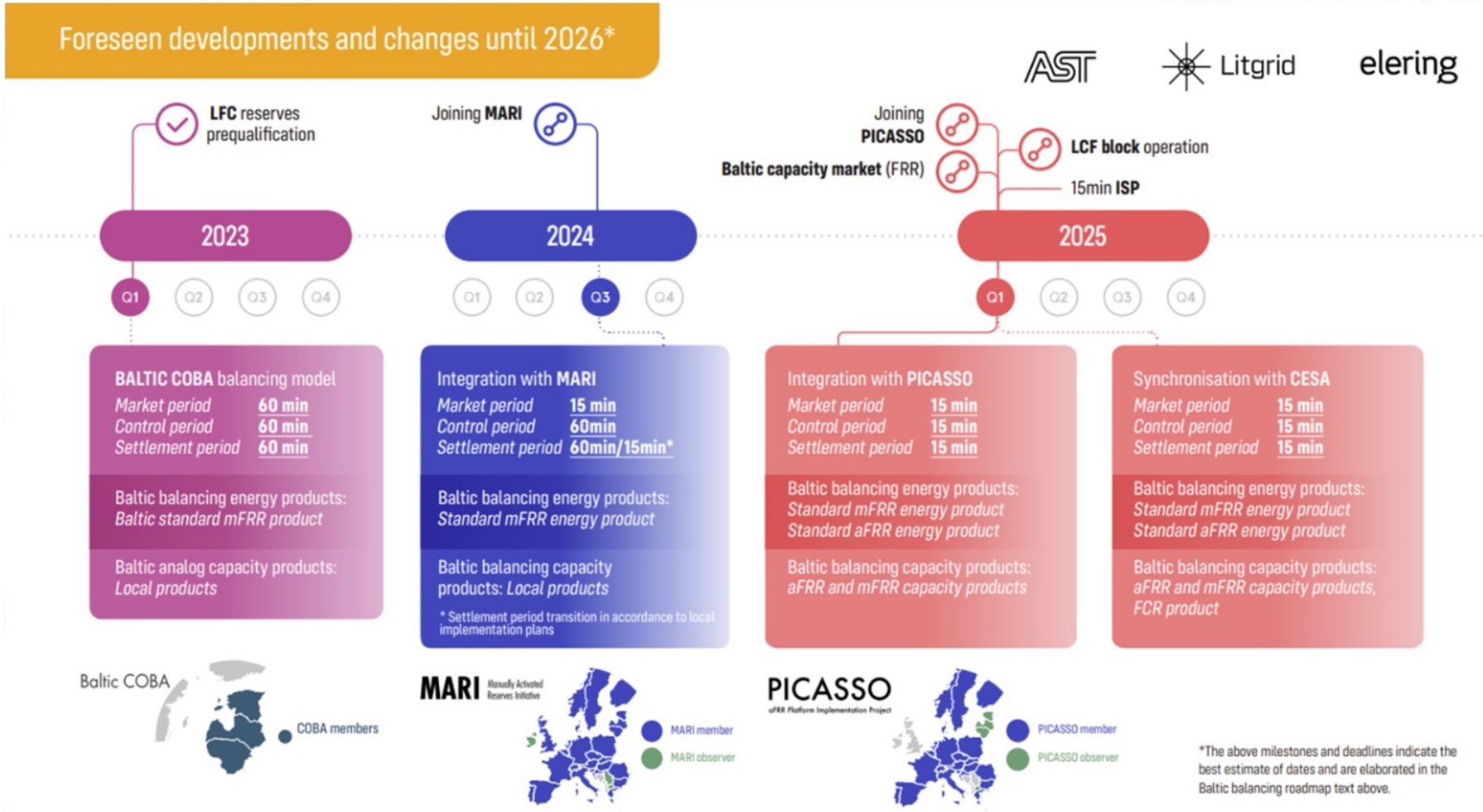
„REVENUE STACKING“ POSSIBILITIES ACROSS DIFFERENT MARKETS

- In developed markets, there are constantly additional revenue stacking opportunities, including
  - Nord Pool Ancillary aFFR, mFRR, FCR
- Most markets have a time dimension:
  - Year-ahead, Month-ahead, Day-ahead
- Market players are developing increasingly better solutions to optimise revenues (Machine Learning and Artificial Intelligence)
- It is important to have a long view and technological capability when investing, **need to take asset owner view into account!**



(1) *Euroopa Komisjon.*

BALTIC MARKET UPDATE

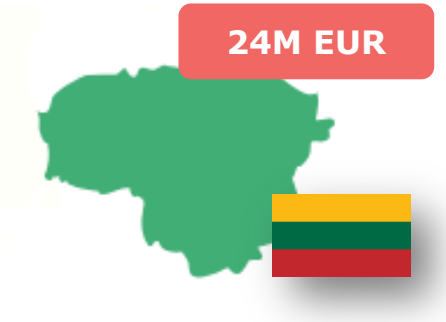


(1) *Elering.*

TÄNASED TURUMAHUD – ANCILLARY SERVICES

6M EUR

- FFR: opens in ‘25
- FCR: Fingrid pilot early ’24?
- aFRR: opens in ‘25
- mFRR: ~6M EUR



24M EUR

- FFR: opens in ‘25
- FCR: opens in ‘25
- aFRR: opens in ‘25
- mFRR: ~24M EUR

131M EUR

- FFR: ~1M EUR
- FCR: ~54M EUR
- aFRR: ~9M EUR
- mFRR: ~67M EUR

5M EUR

- FFR: opens in ‘25
- FCR: opens in ‘25
- aFRR: opens in ‘25
- mFRR: ~5M EUR

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