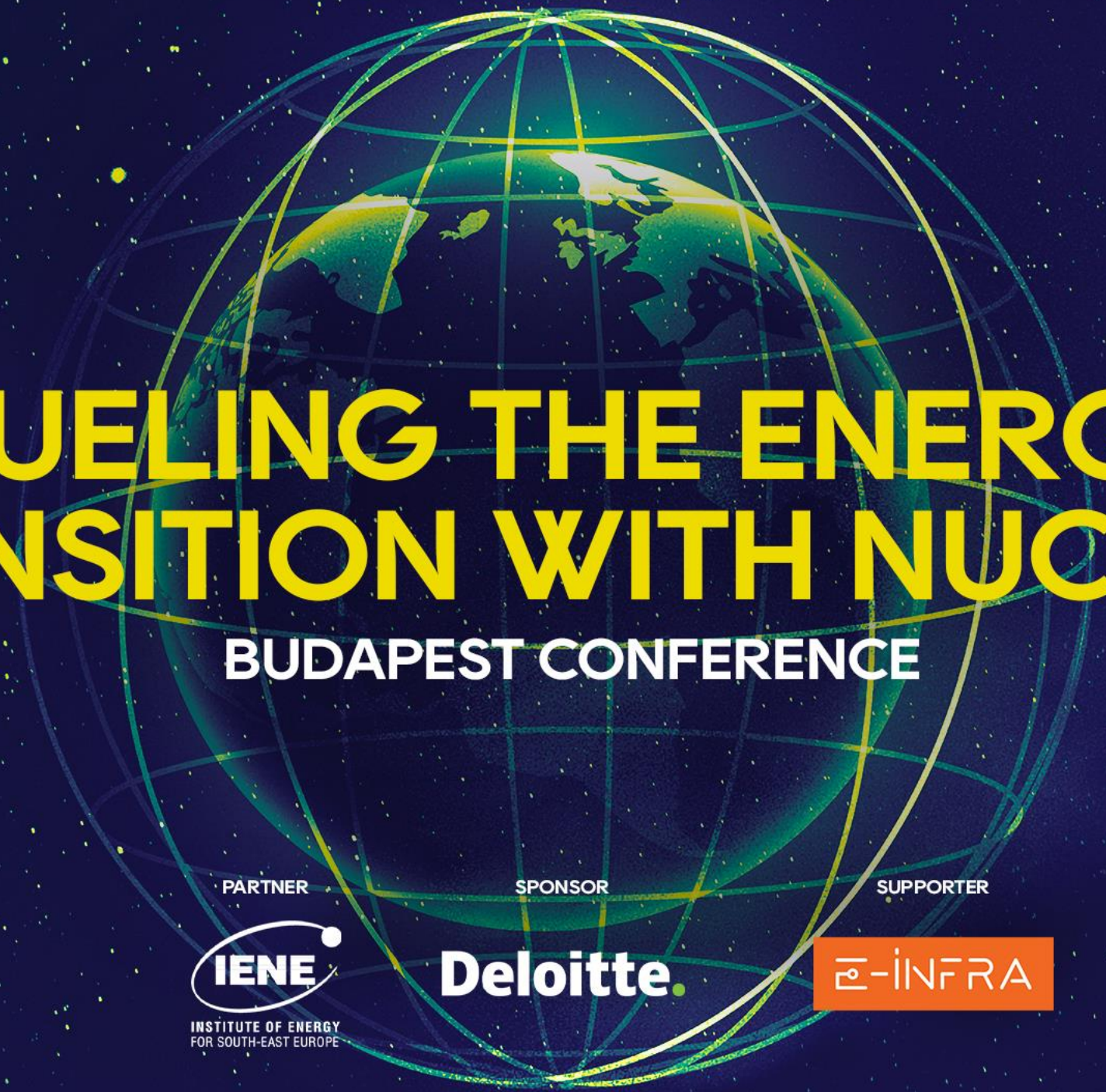
NNWI



FUELING THE ENERGY TRANSITION WITH NUCLEAR

BUDAPEST CONFERENCE

PARTNER

IENE
INSTITUTE OF ENERGY FOR SOUTH-EAST EUROPE

SPONSOR

Deloitte.

SUPPORTER

e-INFRA

Panel 2: The Future of Central Europe's Energy Mix

Chaired by Tim Yeo

- Tim Yeo, Chairman, New Nuclear Watch Institute
- Krisztian Szarvas, Technical Director, Paks II.
- Csaba Kiss, Deputy CEO, Chief Generation Officer and Chief Nuclear Officer, MVM Hungarian Electricity Ltd.
- Miroslav Lopour, Senior Energy Expert and Business Economist, Deloitte Central Europe

The Future of Central Europe's Energy Mix

Tim Yeo
Chairman
New Nuclear Watch Institute

chairman@newnuclearwatchinstitute.org

Maneuvering capabilities of the Paks II. new nuclear units

New Nuclear Watch Institute

Krisztián SZARVAS
technical director
Paks II. Ltd.

Budapest, 20.06.2023

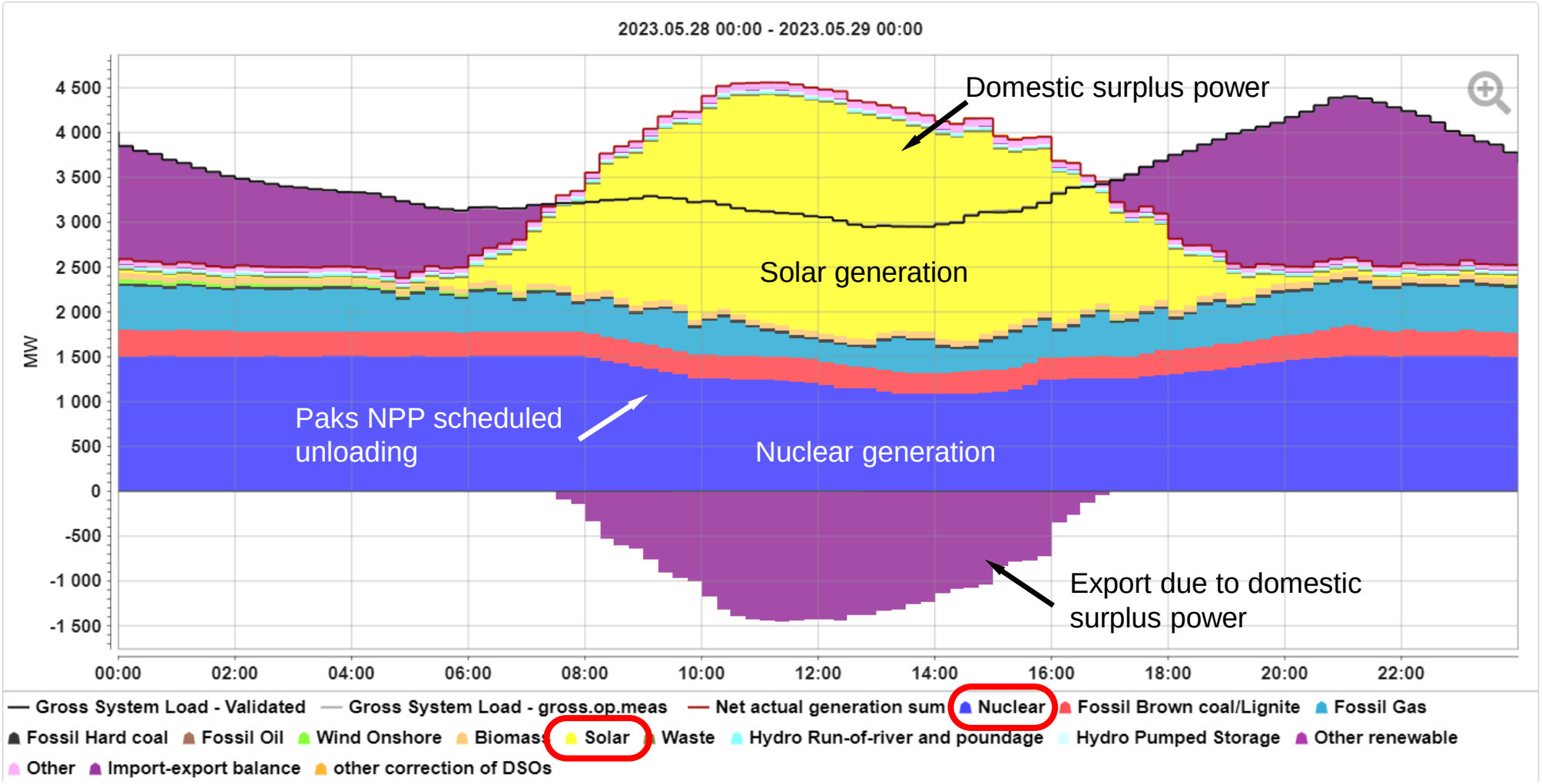
Main topics

- Legal framework
- Maneuvering related grid requirements
- Paks II specific technical requirements
- Main technical differences from the reference units
- Nuclear power plants unloading conditions





Nuclear power plants unloading conditions



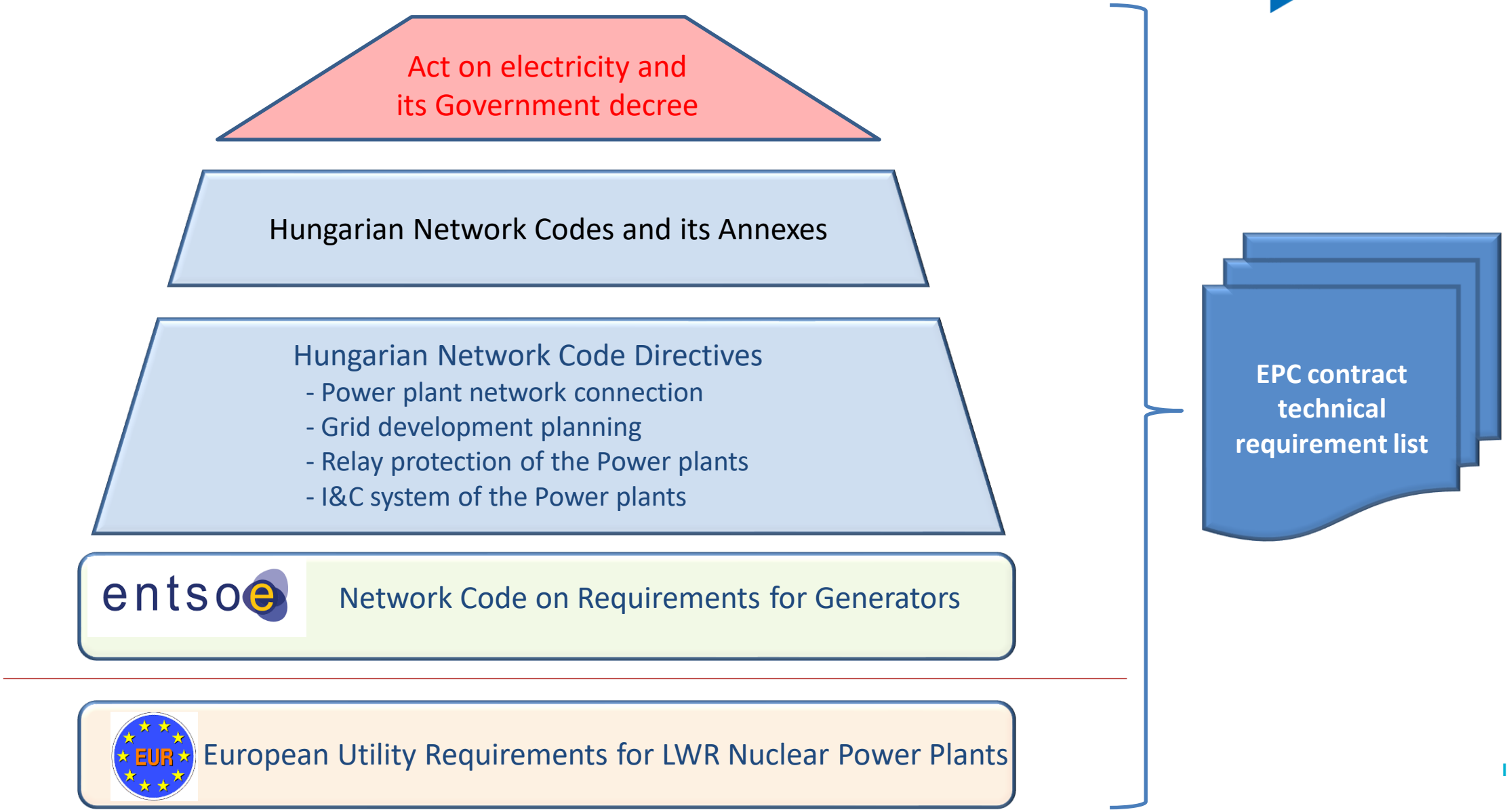
2023.05.28:

Paks NPP scheduled unloading due to electrical energy market reasons (Renewable energy sources - feed-in tariff system)

Started from 1505 MW to 1081 MW and back.

Source: Energy MIX - Actual Generation per Production Type and Import Export Balanced - Based on Gross Operation Control measurement - MAVIR EN - Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zrt.

Legal framework



Maneuvering related grid requirements (*#REQ*)

Requirements for active power generation

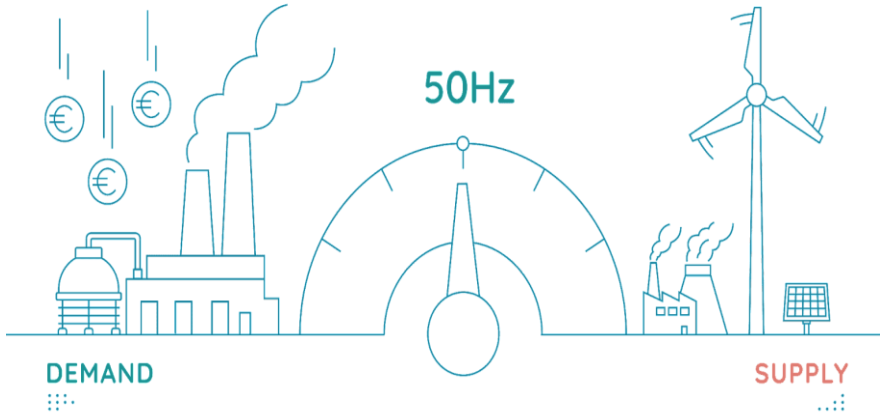
- Frequency Containment Reserves (FCR)
- Automatic Frequency Restoration Reserves (aFRR)
- Manual Frequency Restoration Reserves (mFRR)

} Electricity balancing product in the EU market

- Continuous operation between 50% and 100% of gross rated power Pr
- Active power frequency response capability (limited frequency sensitive mode)
- House load operation
- Starting capability from external black start source

Requirements for reactive power generation

- Voltage – reactive power control capabilities



Source: https://sympower.net/what-is-demand-response/

Paks II specific technical requirements - 1

- *#REQ 1* - Frequency Containment Reserves (FCR)
  - FCR capability range shall be at least ±2% of the gross rated power Pr.
  - FCR shall be active in a range between 50% and 100% of Pr
  - The units shall be capable of activating, within 30 s, the total FCR range of control (the 50% of it within 15 s) requested at a quasi-steady frequency deviation of ±200 mHz, and maintaining supply for at least 15 minutes

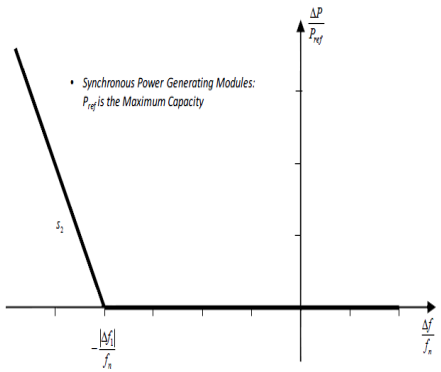
- *#REQ 2* - Automatic Frequency Restoration Reserves (aFRR)
  #REQ 3 - Manual Frequency Restoration Reserves (mFRR)
  - The control range for aFRR operation shall be up to ±10% of Pr above the minimum load taking into account the control range (50-100% of Pr) .
  - The variation rate of 1% of Pr/min shall be provided.
  - The operation shall be allowed during 90% of the whole fuel cycle.

Paks II specific technical requirements - 2

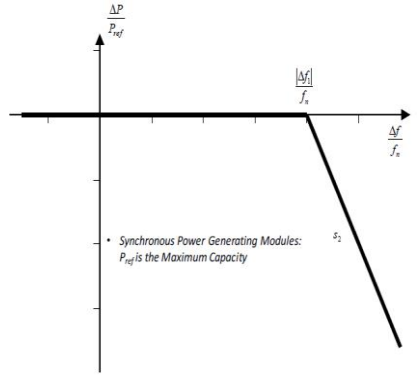
- *#REQ 4* - Continuous operation between 50 % and 100 % of gross rated power Pr
  - The unit shall be capable of load-following operation in the range of 100 % - 50 % of Pr considering the operation limits and conditions.
  - The variation rate of 1% of Pr/min shall be provided.
  - The operation shall be allowed during 90 % of the whole fuel cycle.
  - The unit shall be expected to go through the following number of scheduled load variations, from 100% -> 50 % -> 100% of Pr: 2 x a day, 5 x a week, cumulatively 200 x a year

- *#REQ 5* - Active power frequency response capability (limited frequency sensitive mode - LFSM)
  - The unit shall be capable to operate in:
    - Limited frequency sensitive mode Over-frequency and
    - Limited frequency sensitive mode Under-frequency

„LFSM-U" Under-frequency



„LFSM-O" Over-frequency

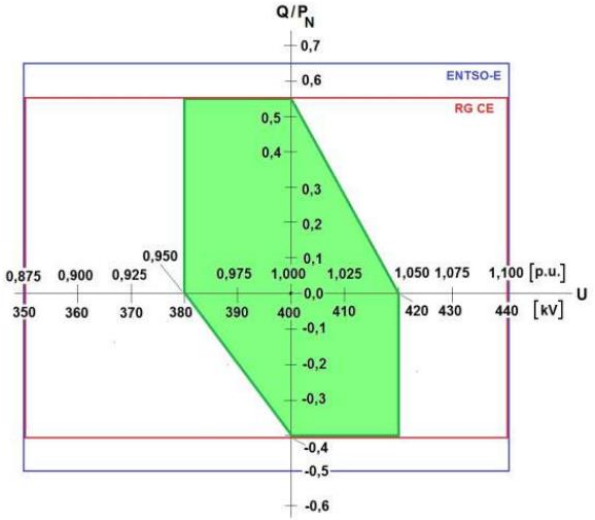


Paks II specific technical requirements - 3

- # *REQ 6* - House load operation
  - The plant shall be able to cope with loss of external grid by switching to house load operation without reactor and/or turbine trip
  - The turbine shall be capable of continued stable operation at house load.
    The expected house load operation is min. 12 hours

- # *REQ 7* - Starting capability from external black start source
  - The unit shall be able to contribute to grid restoration and shall be able to start with only external electric energy supply

- # *REQ 8* - Voltage – reactive power control capabilities
  - The unit is capable of taking part in the control of voltage and reactive power balance in the transmission system



Technical differences from the reference units

Considering the required maneuvering capabilities the Paks II. NPP will have technical differences from it's reference design (Leningrad II. NPP) as follows:

- different I&C design for power control,
- different TSO connection,
- different operational manuals,
- more intense online transient planning,
- more spare parts due to the increased number of operations,
- higher evaporator capacity,
- automatic boron regulation with increased pump capacities.

VISUAL

PAKS II. LTD.

PAKS II. LTD.

THANK YOU FOR YOUR ATTENTION!

MVM GROUP

The role of sustainable (nuclear) energy in Hungary

Csaba KISS, Ph.D.
Deputy CEO, Chief Generation Officer and Chief Nuclear Officer

Fueling the Energy Transition with Nuclear

19-20 June 2023

Providing energy

The flagship of the national energy and climate policy

Entrusted with ensuring the security of supply

‘National blue chip’

A catalyst for competitiveness

An entity augment-ing the value of the national wealth

A socially responsible group

MVM’s **mission is** to provide **affordable** and **clean energy** to its **customers in a sustainable manner**, which meets the requirements and customer expectations of the 21st century

NOWADAYS, THE "ENERGY TRILEMMA" AFFECTING THE ENTIRE ENERGY INDUSTRY HAS COME TO THE FORE

MVM GROUP IS THE NATIONAL ENERGY UTILITY IN HUNGARY AND A KEY ENERGY PLAYER IN CENTRAL EUROPE

MORE THAN 100 SUBSIDIARIES ACROSS 23 COUNTRIES

Generation
- Nuclear power plant
- Conventional and flexible power plants
- Renewables
- District Heating

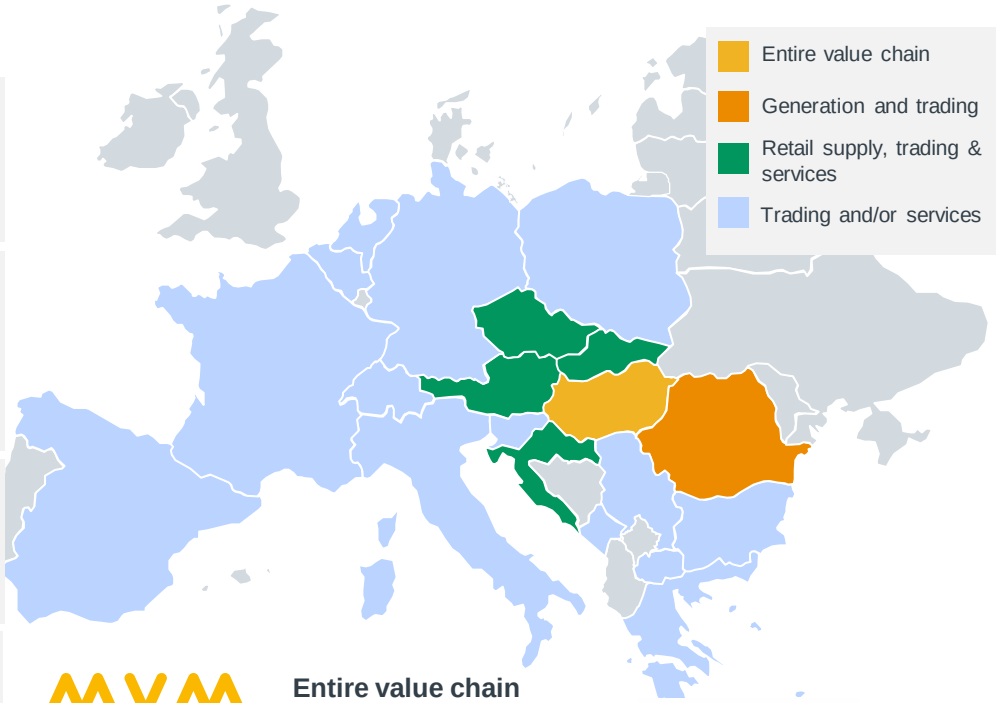
Infrastructure
- Electricity transmission and distribution
- Natural gas distribution
- Telecommunications
- Energy exchanges

Wholesale & Gas Storage
- Electricity wholesale
- Natural gas wholesale
- Natural gas storage

Retail & Customer Services
- Supply of electricity and natural gas in Hungary both in the regulated and in liberalized markets
- Customer services in digitalization, energy efficiency, residential energy generation and storage
- Mobility (e-mobility & CNG)
- Beyond-the-meter products & services

International
- Leading position in Czech natural gas market via Innogy CR, active in generation, electricity and gas wholesale and retail distribution in Czech Republic
- Romania – hydro generation and supply of gas & electricity

Other
- Engineering and construction services
- Holding company and group services



Entire value chain
Hungary

Generation
Romania, Czechia

Natural gas trading
Austria, Czechia, Croatia, Slovakia

Technical services
Czechia

Retail electricity and natural gas supply
Czechia, Austria, Romania, Slovakia, Croatia

Electricity trading
Austria, Belgium, Bulgaria, Czechia, Croatia, France, Germany, Greece, Italy, Montenegro, North Macedonia, Poland, Romania, Switzerland, Serbia, Slovakia, Slovenia, Spain, Netherlands

Industrial dry cooling technology supply
China

10th largest company in Central Europe by sales[1]

c. 11M direct customers[2]

4.4 bn m³ of natural gas storage capacity

18,000+ employees

7,648 bn HUF sales

453 bn HUF EBITDA

100% Owned by the Hungarian State

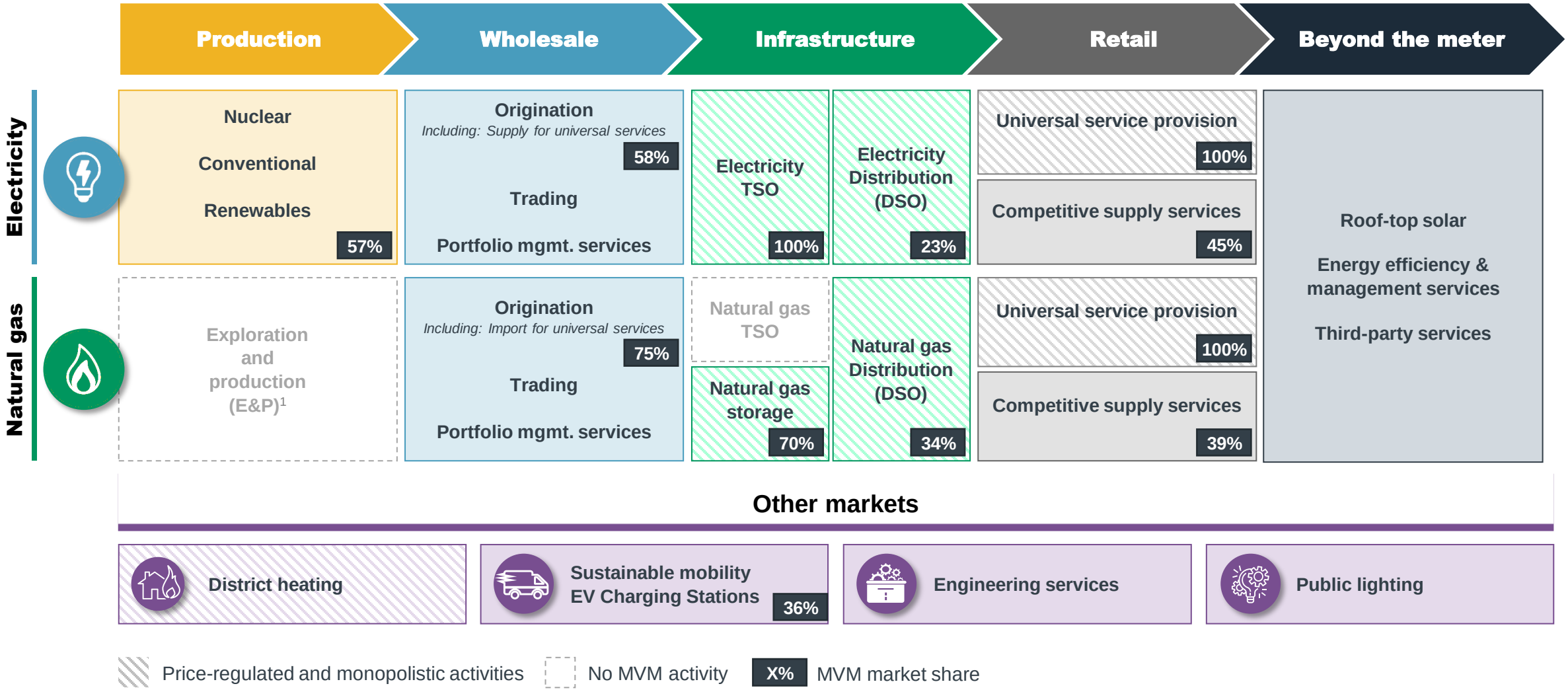
83% carbon neutral electricity generation[3]

42 TWh of electricity sold/year

143 TWh of natural gas sold/year

Note: (1) COFACE CEE TOP 500 Companies (2021); (2) Number of PODs; (3) Nuclear, wind, solar, hydro and biomass electricity generation

INTEGRATED UTILITY WITH LEADING POSITIONS ACROSS HUNGARY'S ENERGY VALUE CHAIN



Note: (1) Gas E&P Project launched in 50-50% joint venture with Aspect Holdings

MVM'S STRATEGY IS BUILT ON SIX PILLARS OF GROWTH AND DEVELOPMENT

Growth in new markets

Regional Expansion

- **Achieving 25% foreign EBITDA**
- **Diversified portfolio development** via DSO, retail customer, renewable portfolio acquisitions
- **Major target countries:** Hungary's neighboring countries are the primary targets

Attractive investment target

- **Outperform our regional competitors** on the investment markets
- Focusing and strengthening **ESG** initiatives
- Ensuring **stable financial performance** and maintaining **investment grading**

Investing in new business lines

- **Energy efficiency solutions:** Roof-top solar, energy management, ESCO investments, smart city and smart public lighting
- We play a key role in creating **alternative mobility services** (E-CNG-LNG)

Strengthen market positions in traditional value chain

Increasing clean energy generation

- **RES portfolio expansion:** (800MW+ by 2025)
- **Decarbonization**: Coal phase out & strategic transformation of Mátra PP into CCGT
- **Sustaining our nuclear capacities** (Paks)
- **Investment in flexibility assets:** Energy storage, CCGT & CHP projects
- **Hydrogen technology opportunities**

Digital Transformation

- **Secure energy supply and cost effective leadership** through optimization and simplification leveraging on synergies across the organisation
- **Implementation of digital developments along our entire value chain** to be competitive and secure

Future oriented infrastructure developments

- Integration of intermittent renewable energy sources to **increase the flexibility of the electricity grid** (energy storage, flexible capacities, DSR, etc.)
- Grid developments, **piloting R&D and technological advancements** in e-mobility, hydrogen technologies

Other Strategic Goals

- Security of electricity supply
- Sustaining nuclear capacity
- Management and development of transmission network
- Improving opportunities for capital investments in Hungarian energy sector
- Best management practices
- Investment in technology-based solutions to drive efficiency
- Advancing quality of human capital through training

MVM'S GENERATION PORTFOLIO

Largest and most strategically-important domestic portfolio

OVERVIEW

- **Large, diversified and mostly low-carbon, baseload generation portfolio of nearly 4 GW**, including the strategically-important ~2GW Paks nuclear power plant, which is the primary domestic source of baseload electricity (45% of national electricity production) and significantly contributes to the Group's low-carbon generation portfolio (**82.7% of MVM's electricity production is carbon-neutral**)
- **Leading market position** with MVM producing c. **57%** of **Hungary's overall electricity generation.**
- Increasing focus on renewable energy sources. **Key to the decarbonisation of Hungary** and the region, including development of new clean energy capacities
  - Significant renewable target capacity **(800+MW) by 2025**, primarily focused on solar PV. Renewable capacities grew by 52 MW to 312 MW in 2022. 145 MW additional capacities to be installed in 2023
  - Further opportunities in geothermal, hydro and biomass

4.0 GW	Total installed capacity of MVM Group's electricity generation units, incl. **60% of carbon-free generation fleet**	**57%**	MVM Group's market share in 2022 based on gross electricity output
20.1 TWh	Gross electricity output of MVM Group's power plants in Hungary in 2022	**800+MW**	MVM Group's target of **renewable units by 2025**

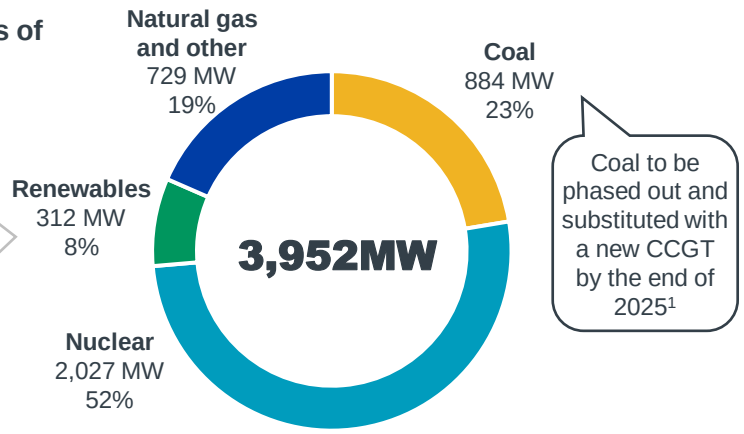
339 MW **RES in operation**

83% **of carbon-neutral electricity generation in 2022**

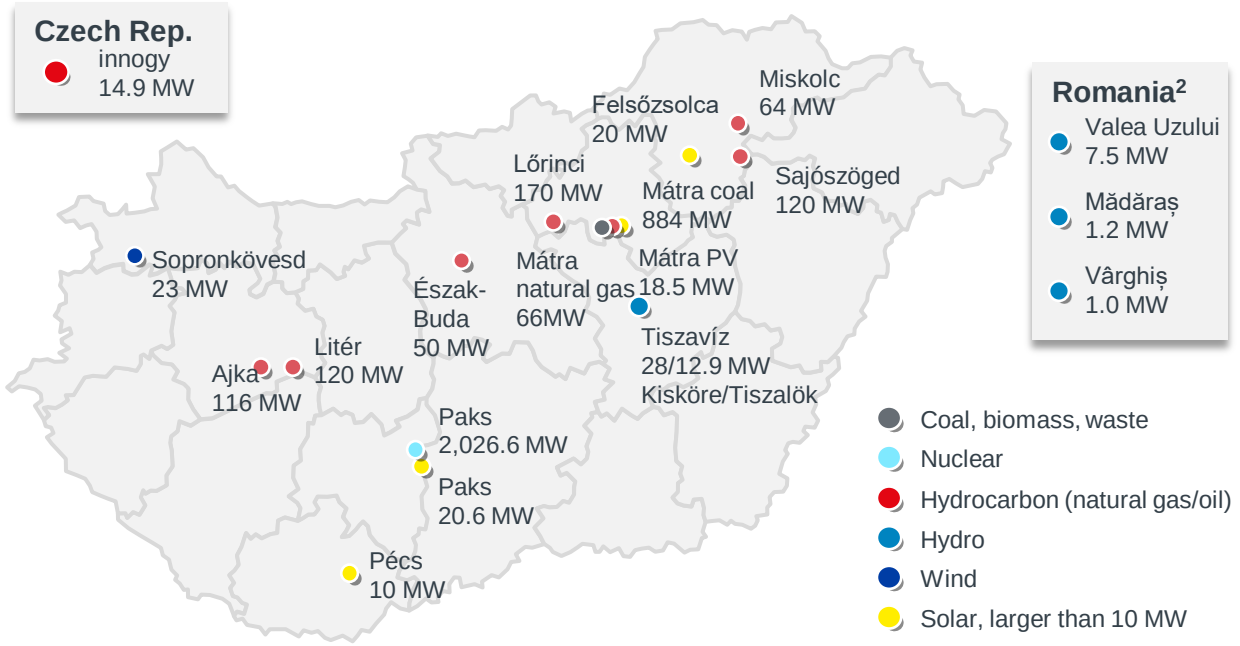
SPLIT OF CAPACITY BY TECHNOLOGY (MW)

338.9 MW of renewable units of the MVM Group (2023)

Solar	275 MW
Hydro	40.9 MW
Wind	23 MW



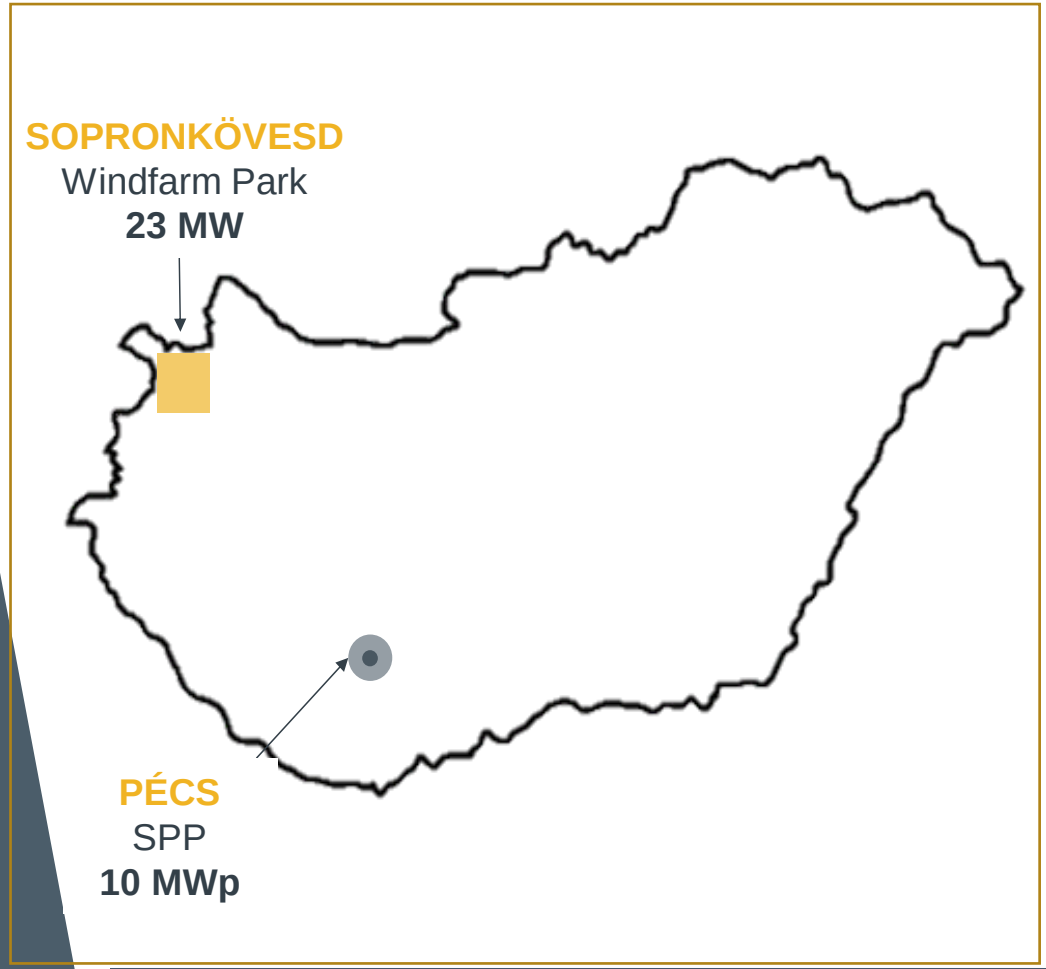
Coal to be phased out and substituted with a new CCGT by the end of 2025[1]



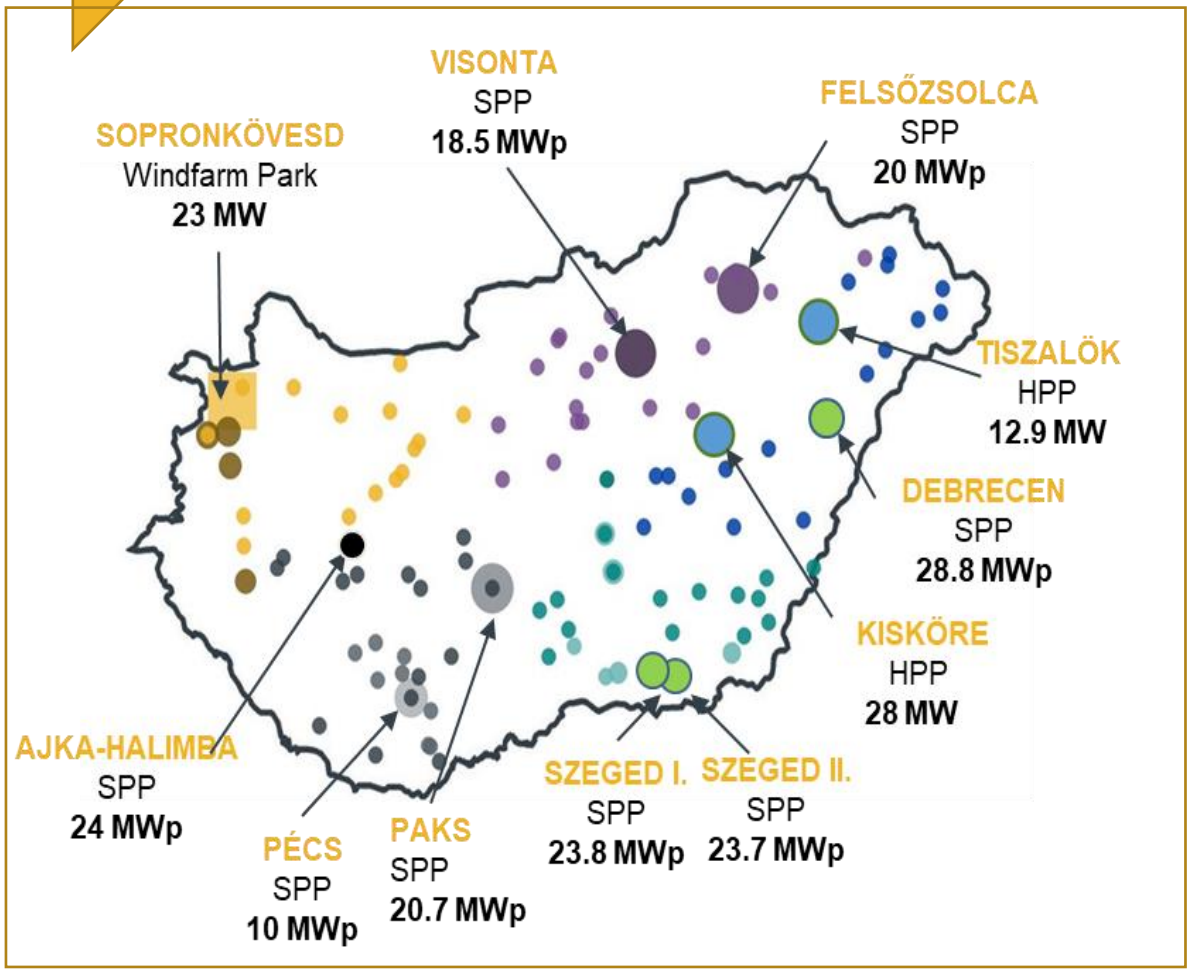
Note: (1) The phase out of coal planned in 2025, however, an extension of the operation might only be justified in case of security of supply needs until the new CCGT plant at the site of Mátra becomes operational, which we expected to take place in 2026. Even in the case of a possible extension of the production, the phase-out of coal and lignite-based electricity production will NOT be beyond 2030, which is the date set in the current National Climate Plan. (2) Reported within 'International' Segment

THE DYNAMIC GROWTH OF OUR RENEWABLE PORTFOLIO IN FIVE YEARS

2017



2023



**The total installed RES capacity of MVM Group's 167 in generating sites;
338.9 MW (23 MW wind power plant; 40.9 MW hydropower plant; 275 MWp SPP).**

THE PAKS NUCLEAR POWER PLANT (NPP) IS THE LARGEST POWER PLANT IN HUNGARY (2021)

GENERATION

2,027 MW

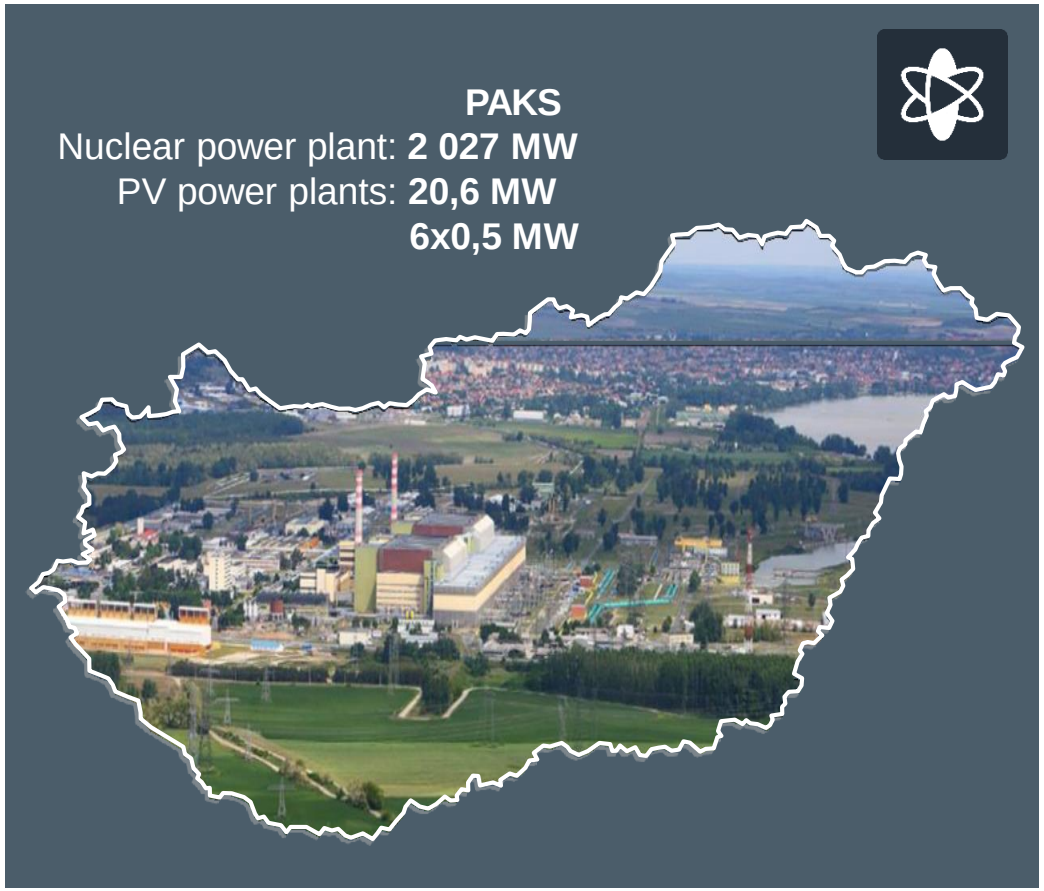
The total installed capacity of the Paks NPP is 2,027 MW

The gross electricity output of the Paks NPP was 16 TWh in 2021.

16 TWh

46.8* %

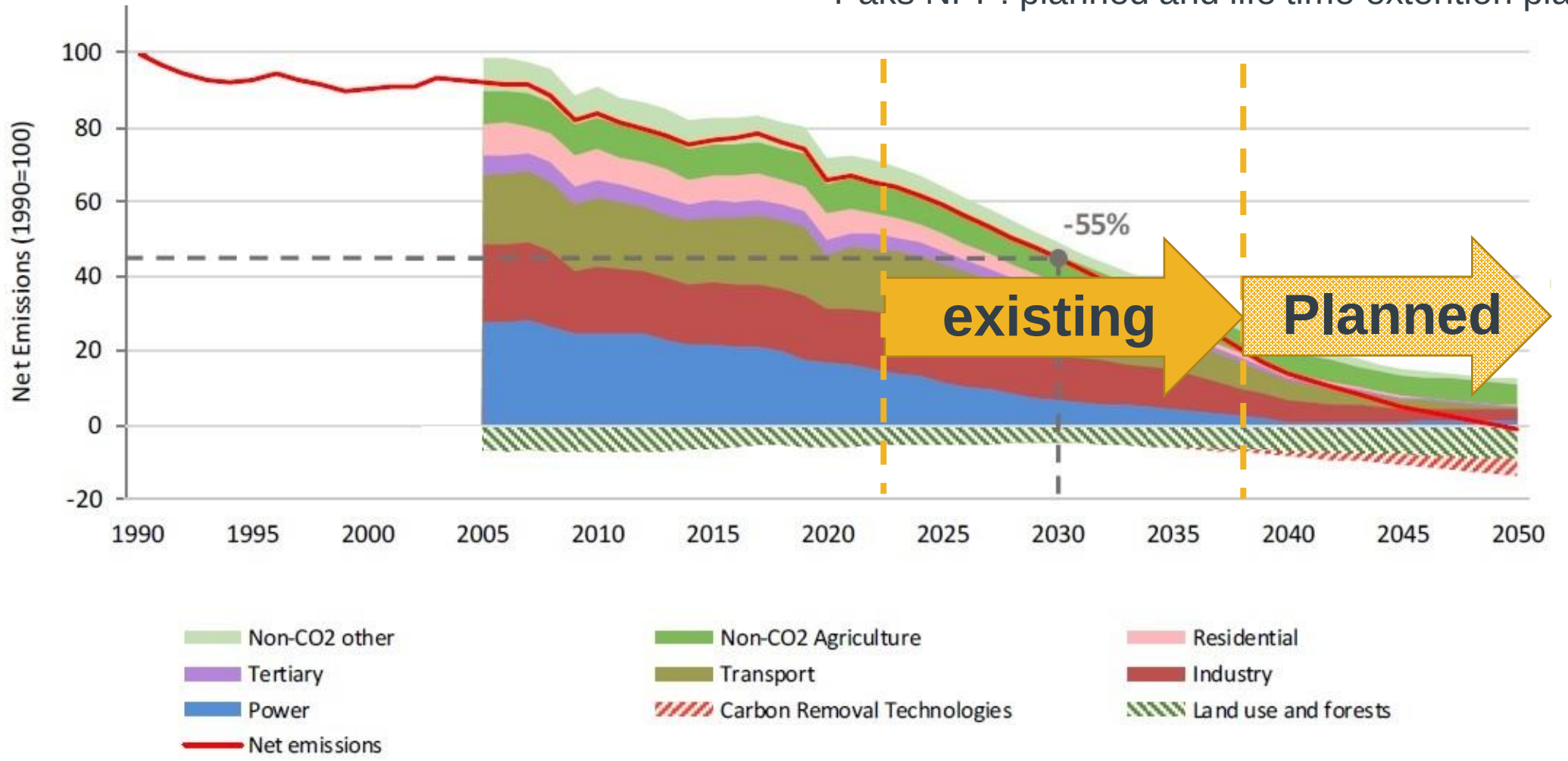
Based on gross electricity output, the market share of the Paks NPP was 46.8% in 2021.



** Based on national gross electricity production (34,2 TWh), Source: MAVIR*

DECARBONISATION OF THE EU ECONOMY

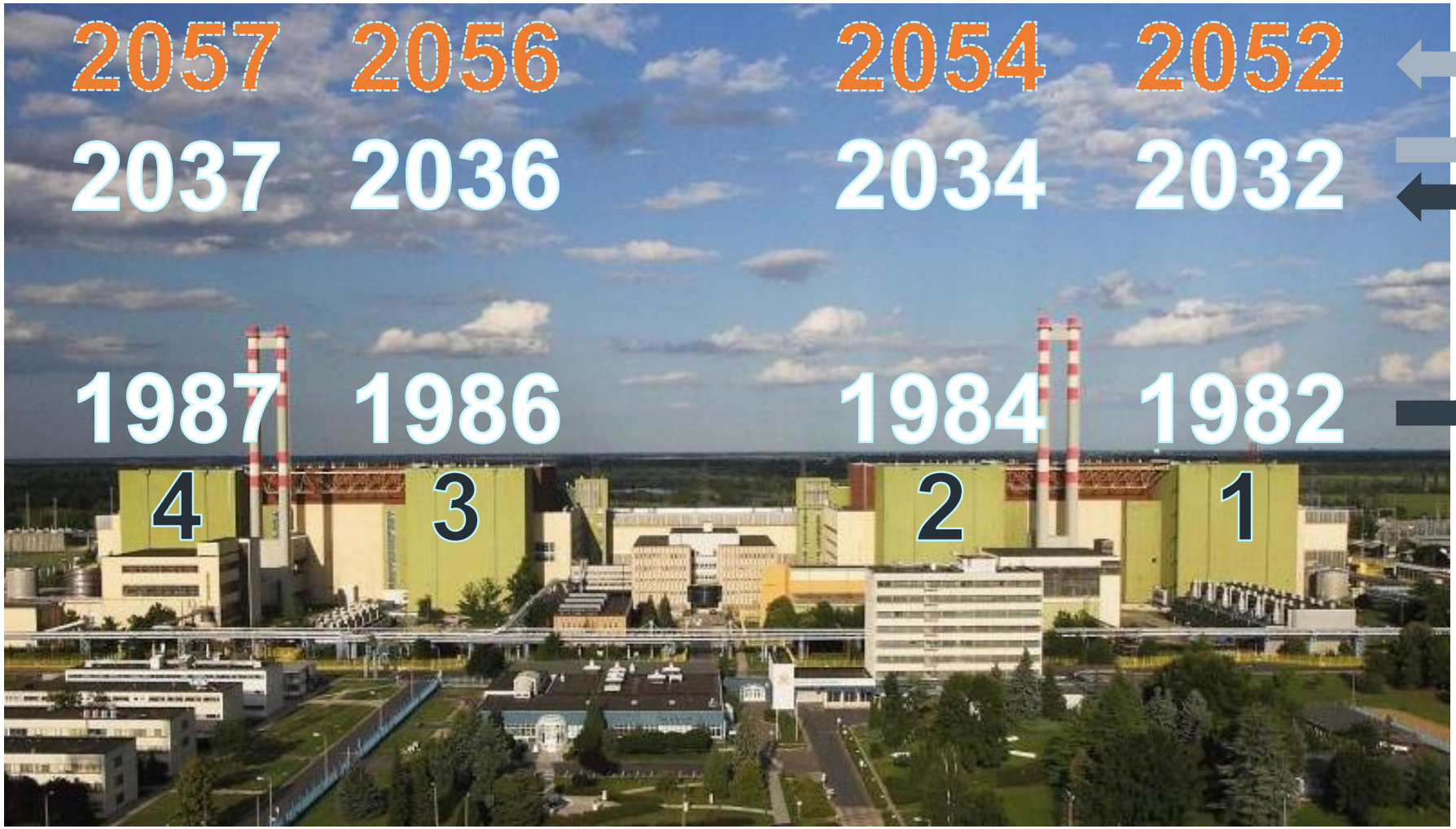
Paks NPP: planned and life time extention plan



Forrás: Stepping up Europe's 2030 climate ambition - COM(2020) 562 final

NUCLEAR ENERGY PRODUCTION IN HUNGARY

	4	3	2	1
~20 years life extension of	2057	2056	2054	2052
Existing operation licence	2037	2036	2034	2032
Unit	1987	1986	1984	1982



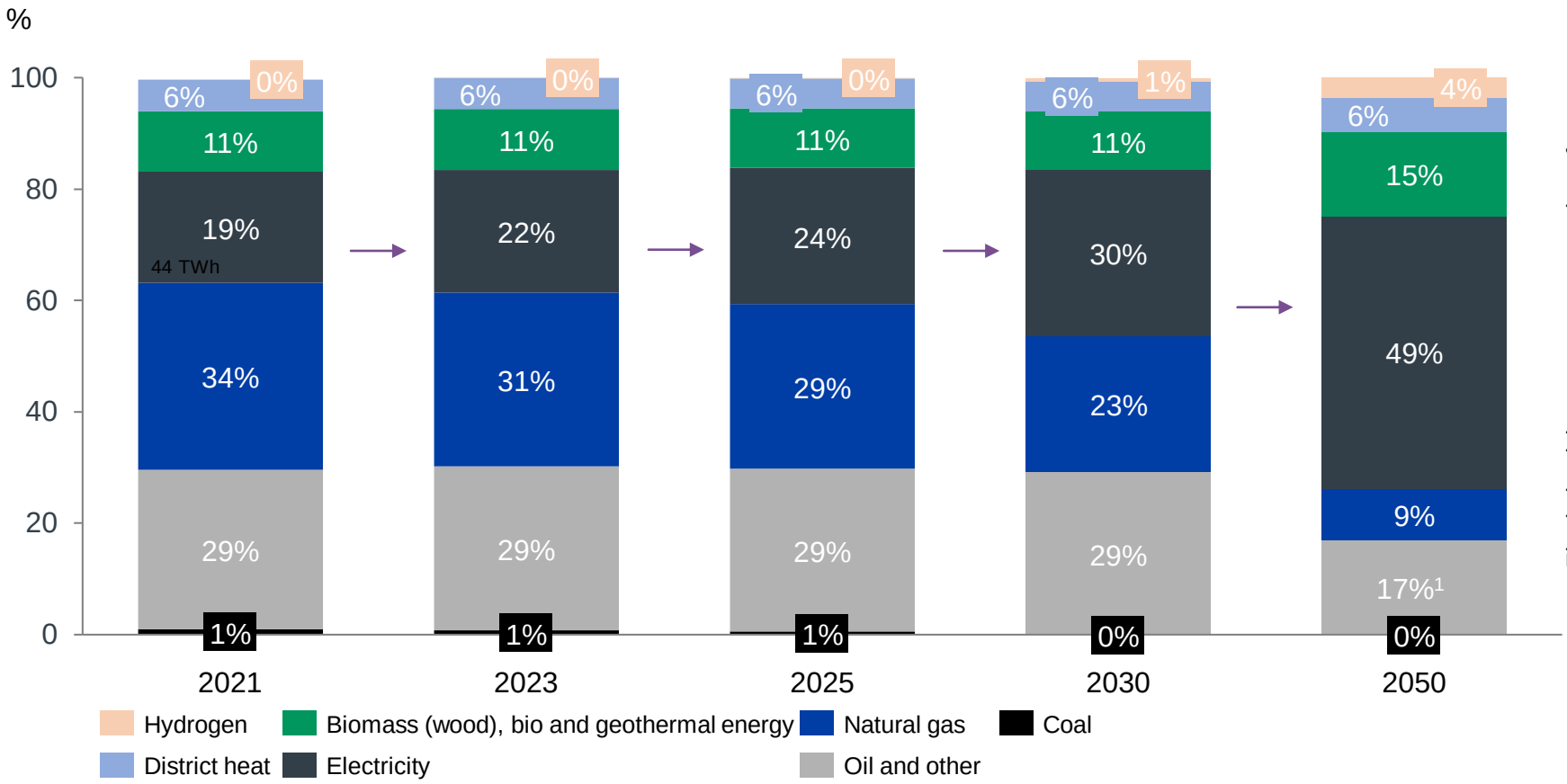
Between 1982 and 1987 four reactors of VVER-440 type entered commercial operation.

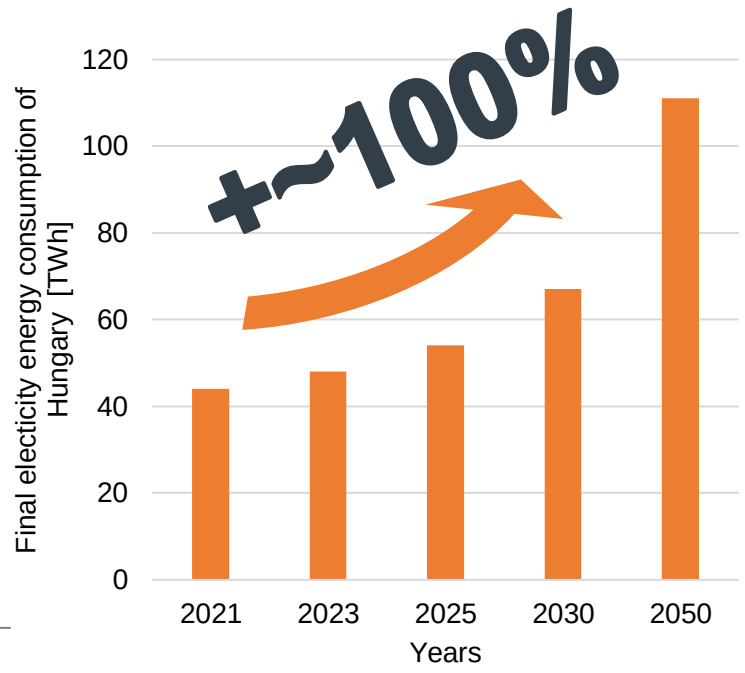
FROM ENERGY DEPENDENCE TO ENERGY SOVEREIGNTY PAKS I. AND PAKS II. INDISPENSABLE ROLE IN ENERGY SUPPLY

- The additional possibilities inherent in the plant must be used
- Nuclear capacities must be maintained and expanded
- Paks I. reactors produced more than 50% of Hungary's electricity production
- In order to achieve energy sovereignty and meet increased energy demands, the operating time of Paks I. must be extended
- Fossil energy imports can be replaced, providing a long-term clean solution
- Paks II. project

There is no sustainable climate policy without nuclear energy

FORECAST OF FINAL ENERGY CONSUMPTION OF HUNGARY BY ENERGY SOURCE (2021-2050) *





Reducing natural gas consumption by increasing electrification. Due to electrification, our electricity consumption will double.

*figures just for illustration

KEY STRATEGIC GOALS FORMULATED FROM THE PERSPECTIVE OF SECURITY OF SUPPLY IN HUNGARY

Reduce natural gas share in the energy mix

- Reduce natural gas demand and dependence of Russian gas imports in Hungary through demand reduction, energy efficiency and electrification measures

Ensure supply of increasing electricity and flexibility

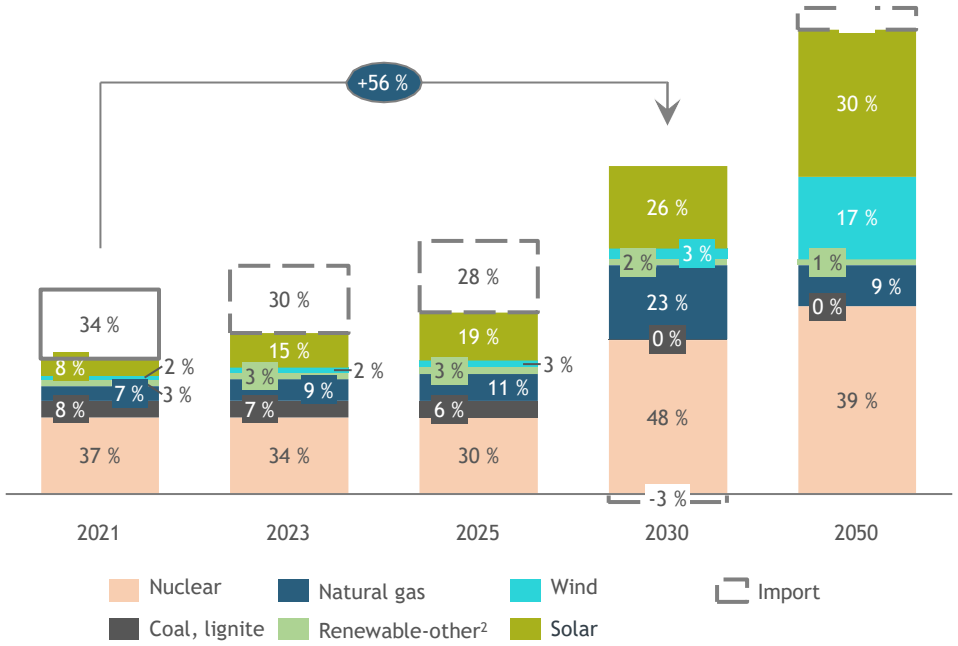
- Secure supply for the constantly increasing demand for electricity and flexibility (due to RES) by adapting new market design and regulation, developing additional generation, storage capacities and investing to the infrastructure

Increase share of alternative energy sources

- Exploit alternative natural gas supplies, domestic production, LNG, other diversified sourcing routes, and utilization of biogas, biomass, waste and hydrogen in the energy mix

SERVING GROWING DEMAND FOR ELECTRICITY AND FLEXIBILITY
A review of the market organization, producer capacity expansion and network development are justified

Expected electricity-mix[1] (TWh)



Major finding

Imports: Quasi disappear from the current 30%

Solar: By 2050, it will cover more than a quarter of the electricity produced

Wind: Can be increaseing its role in the production mix

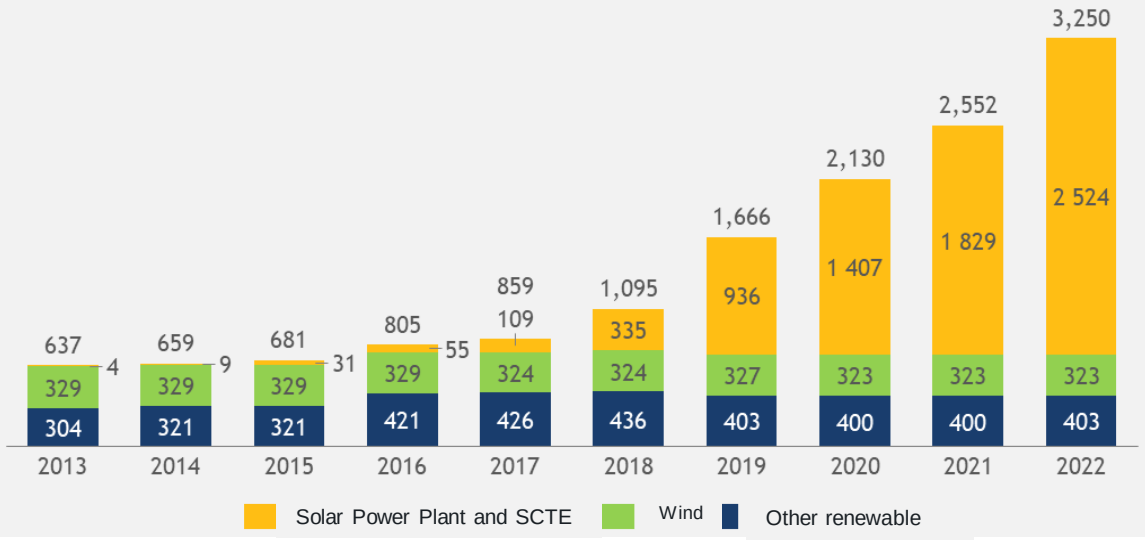
Gas: Construction of gas power plants to reduce import dependency and provide peak and regulation capacity

Nuclear: Paks I production with Paks II (parallel operation);

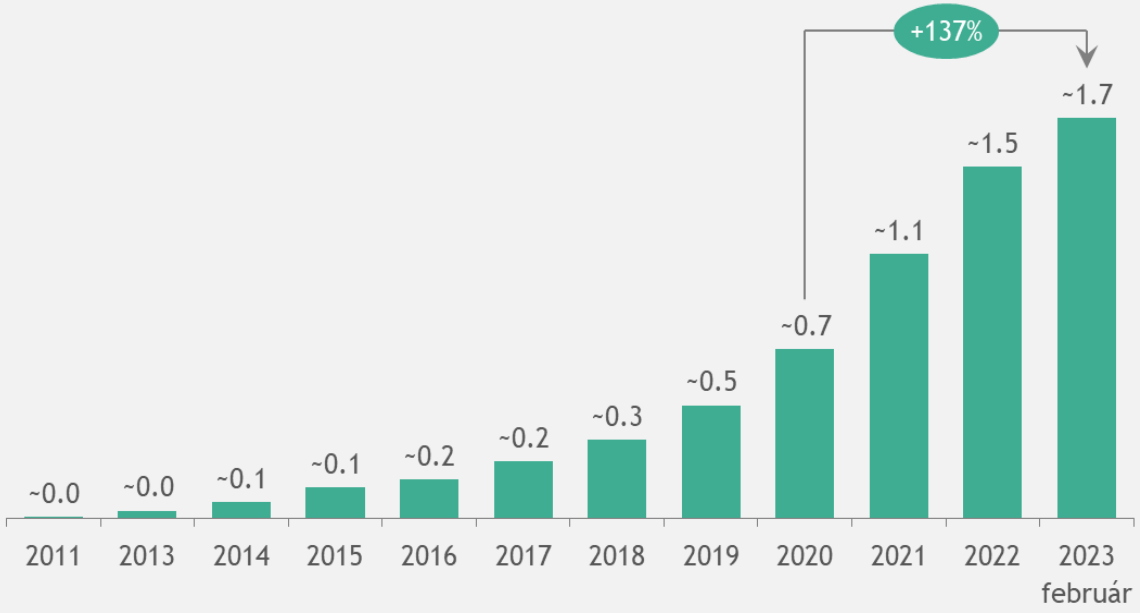
*figures just for illustration

INCREASE IN PV CAPACITIES

Development of installed large-scale renewable capacity in Hungary [MW] 2013-2022



Development of the solar panel installed on the roof of the house in Hungary [GW] 2013-2023. February



Record growth in the Hungarian PV market

From energy dependence to energy sovereignty

Closed-cycle gas turbine, CCGT

In the next 4 years, some gas fired CCGT power plant with a capacity of about 1,600 MW can be built in Hungary

- Natural gas fired
- High efficiency
- Low CO2 intensity
- Can be flexibly regulated
- Electricity generating gas turbine unit
- 5-30% Hydrogen usage

Intended location:

- Mátra Power Plant
- Tisza Power Plant

Renewal of reserve power plants:
Extending the lifetime of power plants in Liter, Bakony, Lőrinci and Sajószöged

Source: youtube.com, power.mhi.com

CONCLUSION

Development and introduction of new energy technologies is essential

Electrification is the most effective means of replacing natural gas

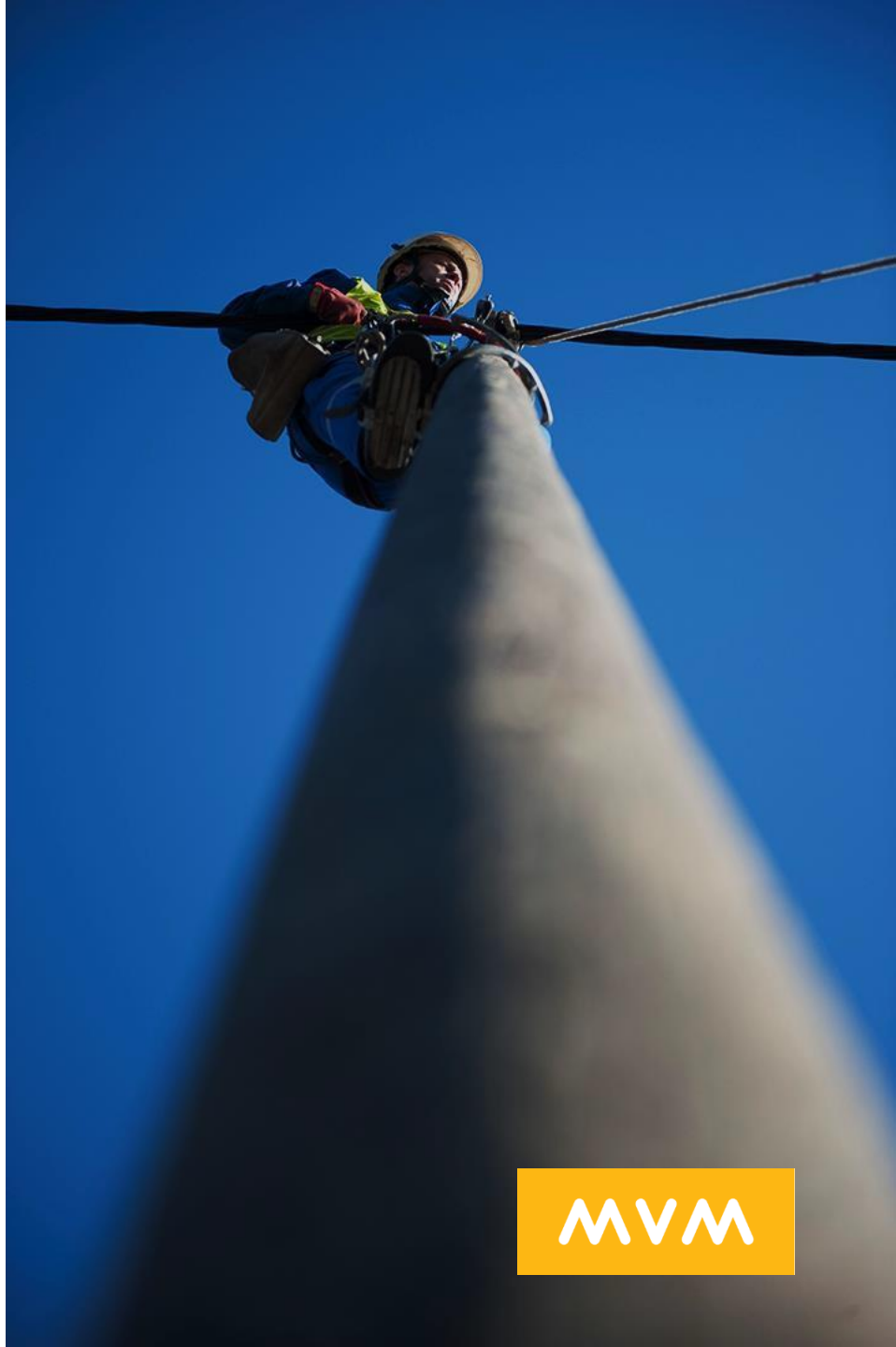
All scenarios assume an increase in electricity consumption

Fossil energy sources must be minimized

Our only option to replace fossil energies is the implementation of energy production based on nuclear energy in Hungary, which can be done in two steps:

- New nuclear capacities must be built
- The capacity of the Paks Nuclear Power Plant must be maintained (+ (10)-20 years (life extension))

There is a clear need to revitalise the European nuclear industry



THANK YOU FOR YOUR ATTENTION!

Csaba KISS, Ph.D.
Deputy CEO, Chief Generation Officer and Chief Nuclear Officer

E-mail: mvm@mvm.hu

Providing energy

Deloitte.

Future energy mix in the CEE

Fueling energy transition in nuclear

Miroslav Lopour

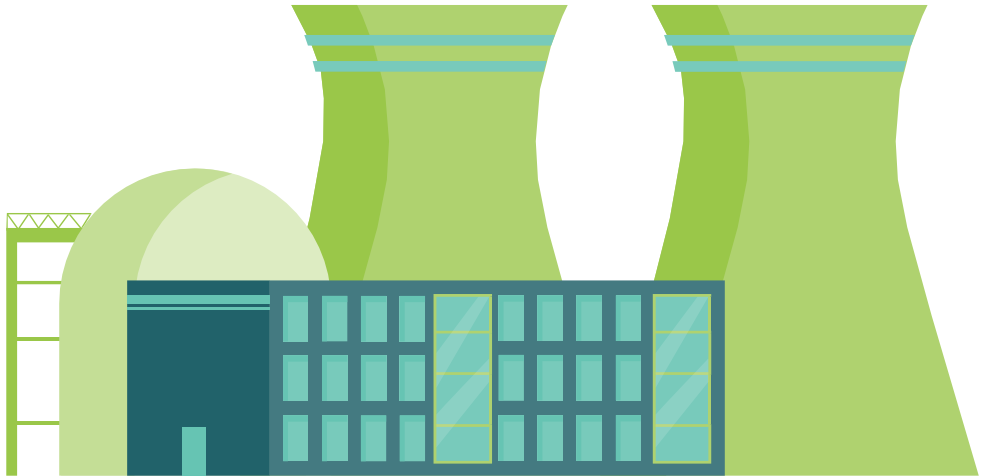
2023

Fact: Nuclear plays an important role in decarbonization

IEA proves in their modelling scenarios (WEO 2022) that nuclear will have meaningful place in the energy mix, Its role will be deeply challenged by renewables boosting capacity additions to new unprecedented levels.

- According to the net-zero emission scenario (NZE) by the IEA, the global electricity generation will more than double between 2021 and 2050
- The share of electricity in the consumption is projected to increase from 20% in 2021 to almost 30% in 2030 and reach more than 50% in 2050
- The share of renewables in electricity generation is expected to increase to more than 60% in 2030 and reaching nearly 90% in 2050
- The total installed capacity of renewables triples by 2030 and rises sevenfold to 2050

- The remaining share of 10% in the electricity generation will be covered by nuclear energy in the NZE scenario,
- Annual nuclear capacity additions to the 2050 scenario are nearly four-times their recent historical average



Nuclear will play and important role in CEE

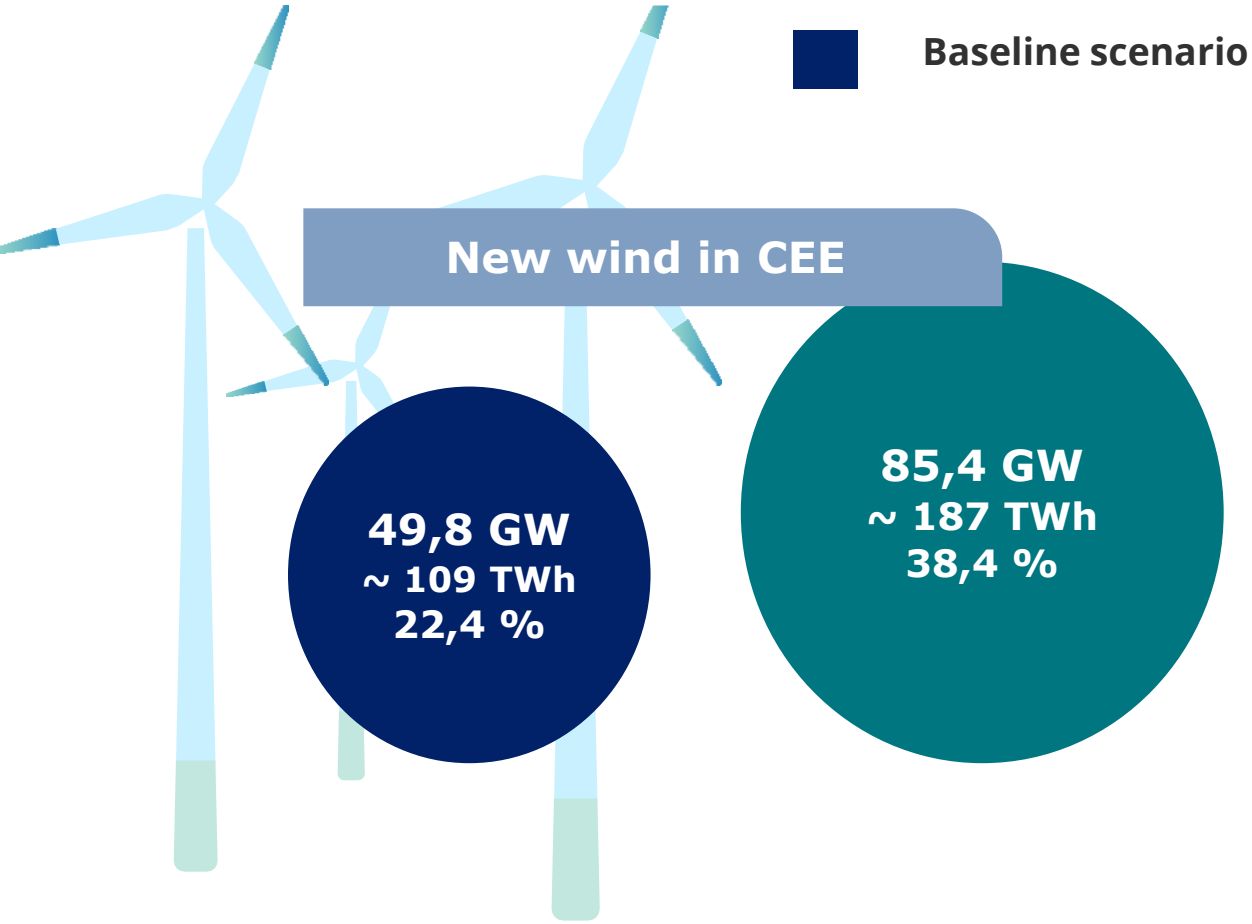
CEE is a region with increased production for the past two decades - from 81 TWh in 2000 to 95 TWh in 2021. Currently, there is around 24 GW of planned new reactors replacing aging fleet and some additions between 2030-2050.

	Bulgaria	Croatia	Czechia	Estonia	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia	Total
Nuclear gross production in 2000 (GWh)	18 178	0	13 590	0	14 180	0	8 419	0	5 456	16 494	4 761	**81 078**
Nuclear gross production in 2021 (GWh)	16 487	0	30 731	0	15 990	0	0	0	11 284	15 730	5 706	**95 937**
Total gross production in 2021	47 568	15 210	85 082	7 204	36 120	5 846	5 079	179 631	59 470	30 016	15 877	**487 104**
Share of nuclear in 2021	35%	0 %	36%	0 %	44%	0 %	0%	0 %	19%	52%	36%	**19,7 %**
Planned new reactors – additions + replacements (GW)	2	0	6,8	0,3	2,4	0	0	7,3	1,9	2,3	1,2	**24**

Source: Eurostat, Deloitte research

Renewables in CEE by 2030

CEE region will benefit significantly from new RES additions. EMBER study forecasts 184-317 TWh of green electricity accounting for 38-65 % of current gross production. Our scenarios are similar to Baseline prediction.



Baseline scenario

Ambitious scenario

New wind in CEE

49,8 GW
~ 109 TWh
22,4 %

85,4 GW
~ 187 TWh
38,4 %

New solar in CEE

75,1 GW
~ 75 TWh
15,4 %

130,3 GW
~ 130 TWh
26,7 %

Notes:
Calculation assumes capacity factor of – 25% for onshore wind, 33 % for offshore wind and 11 % for solar
Share is calculated for countries from previous slide - 2021 gross electricity production – 487 TWh.

Source: Ember, calculations by Deloitte

Three CEE energy markets hindering factors for nuclear

Nuclear additions will have to face three factors, which will decide its future in CEE.

1

Not the best fit

Nuclear is unfortunately not the right solution for providing energy security for the 30s decade, as the region will be slowly moving into an energy deficit with a diminishing coal fleet, Nuclear will be able to contribute at the end of the decade and may face fierce competition from other sources – mostly gas.

2

Large proliferation of renewables

Integration with renewables will be important for a clear business case as nuclear will be facing enormous solar capacity in the summer months. Solar boom will finally overtake CEE as it did in Western Europe, Wind capacity will also make the maneuvering room smaller,

3

Standardization vs. perception

Nuclear is striving to implement new concepts of parallel builds and unit standardization to drive down final CAPEX costs, this is ultimately challenged by more demanding licensing processes, safety guarantees and NIMBY effects,

Key takeaways

- CEE region has still positive approach towards nuclear and it can use this technology for decarbonization.
- Large proliferation of new renewables will be shaping market conditions for new nuclear. Increased demand from electrification may contribute to the addressable market.
- If nuclear decisions and policies will be quick and tailored to future market conditions, CEE may enjoy nuclear renaissance.
- If conditions won't be met, it may become that nuclear will be slowly pushed out the energy mix.

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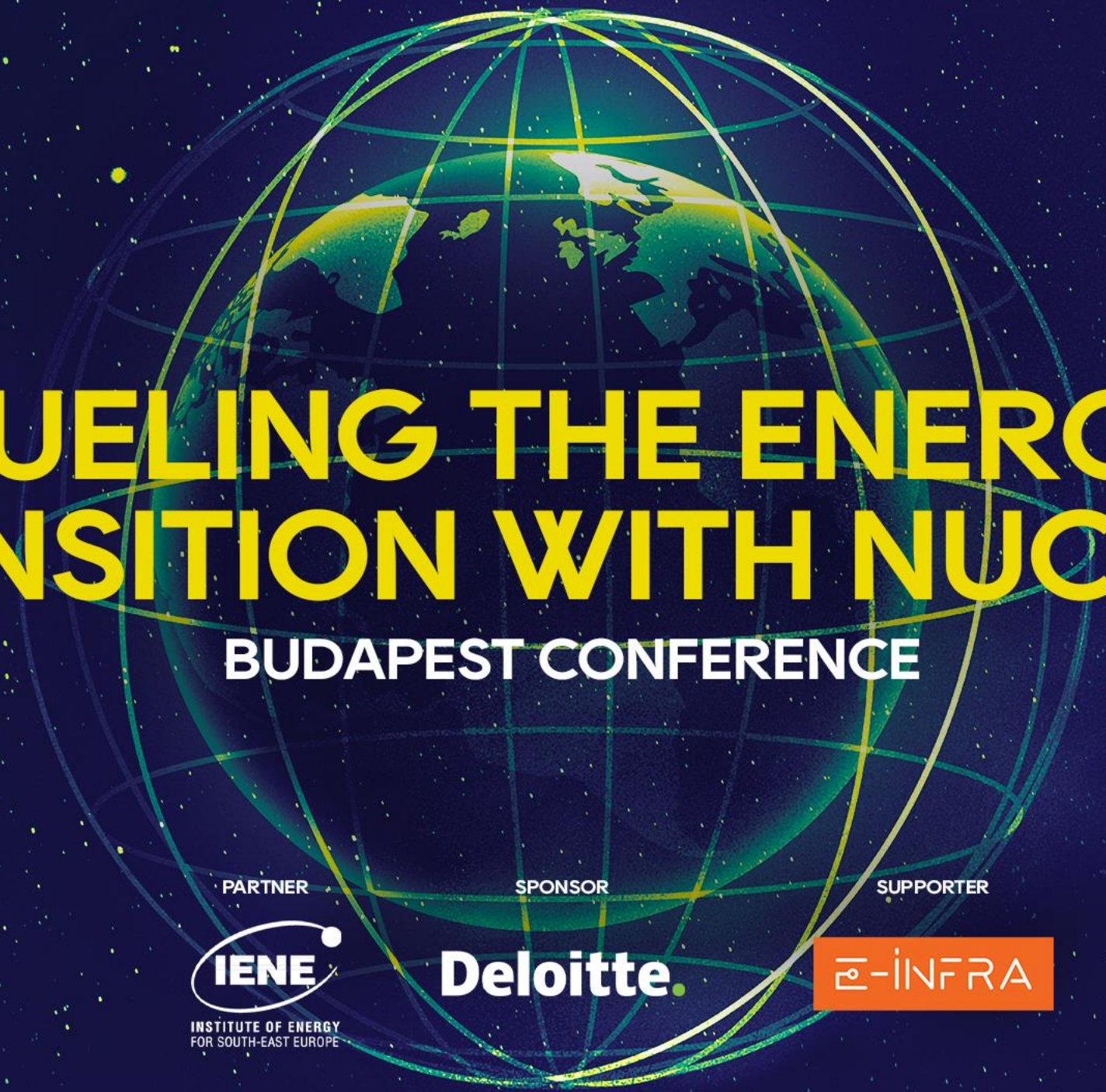
Panel 2: The Future of Central Europe's Energy Mix

Chaired by Tim Yeo

- Tim Yeo, Chairman, New Nuclear Watch Institute
- Krisztian Szarvas, Technical Director, Paks II.
- Csaba Kiss, Deputy CEO, Chief Generation Officer and Chief Nuclear Officer, MVM Hungarian Electricity Ltd.
- Miroslav Lopour, Senior Energy Expert and Business Economist, Deloitte Central Europe

NNWI



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