National Strategies for Energy Transition in Greece: Impacts and Challenges to the Hellenic Electric Power System

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“National Strategies for Decarbonization of Energy Sector and impacts to Electric Power System”

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2024 CIGRE SEERC Colloquium – Ljubljana, February 29, 2024

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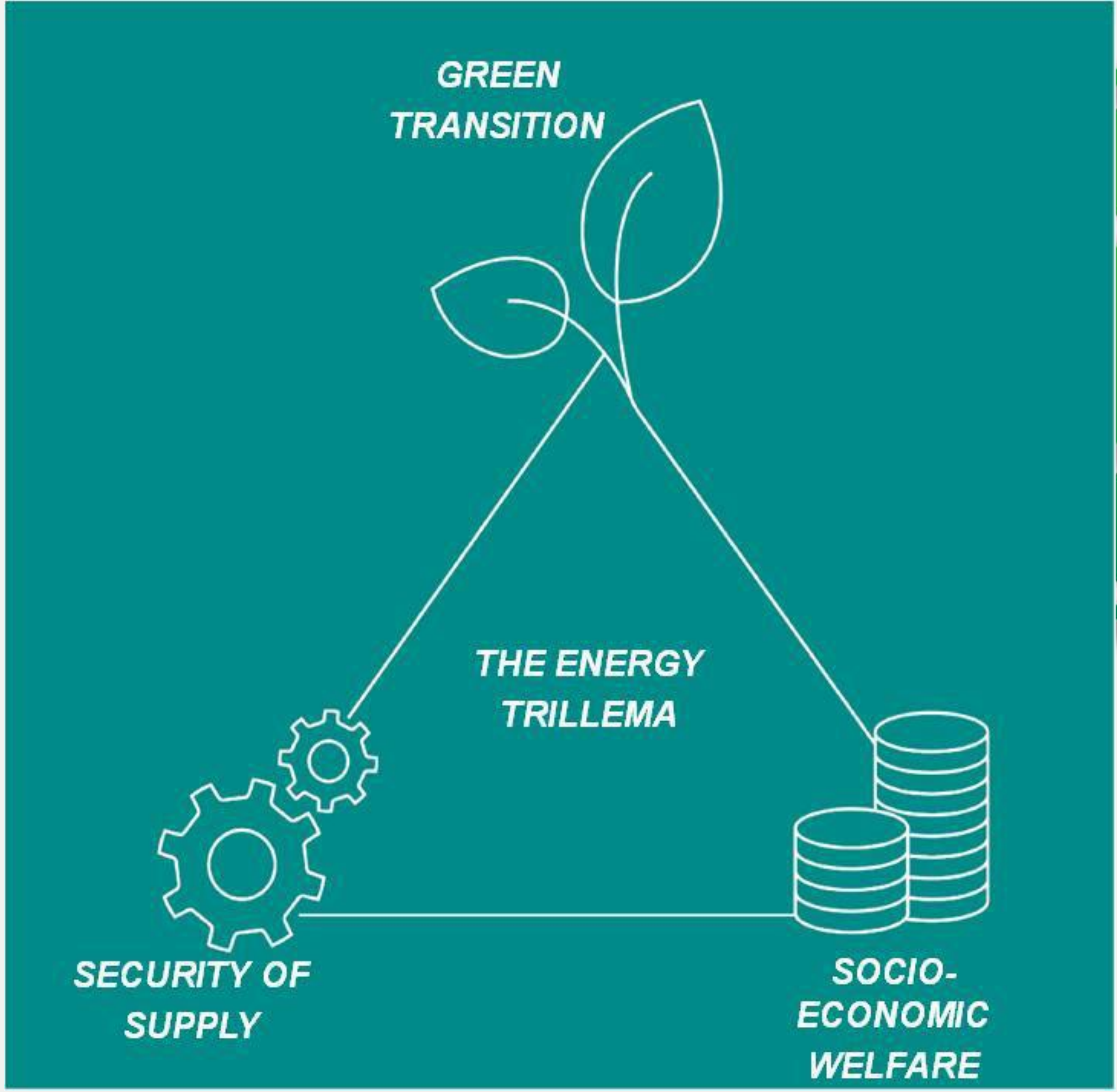


7 Core Technologies of the NECP (1/2)

I. **Rapid growth of RES**: PV and wind development (and the acceleration of offshore wind development) adding >12GW by 2030 and exploiting the country's remaining hydro potential.

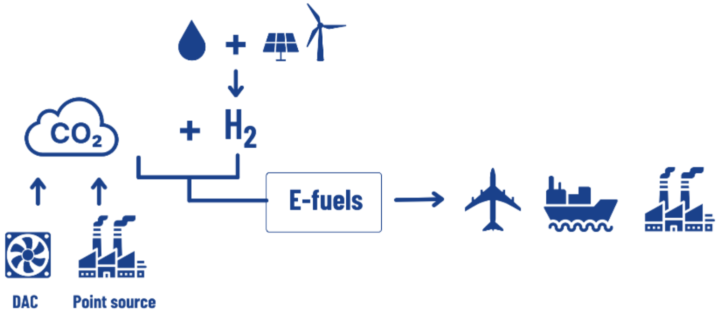
II. **Energy storage**: The high RES penetration should be accompanied by the development of the required storage to balance and stabilize the system (batteries, pumped storage, etc.)

III. **Energy efficiency**: Energy upgrading of buildings (thermal insulations, devices, heat pumps), smart energy consumption management and behavior change to reduce the required energy or the demand profile. These actions can have significant added value.

IV. **Electrification of light transport**: Electrification of light/medium vehicles with simultaneous development of charging infrastructure and interaction with the network. A large part of the required investments will be in vehicles and their batteries. A whole battery recycling economy should be created with a possible regional role in the Balkans

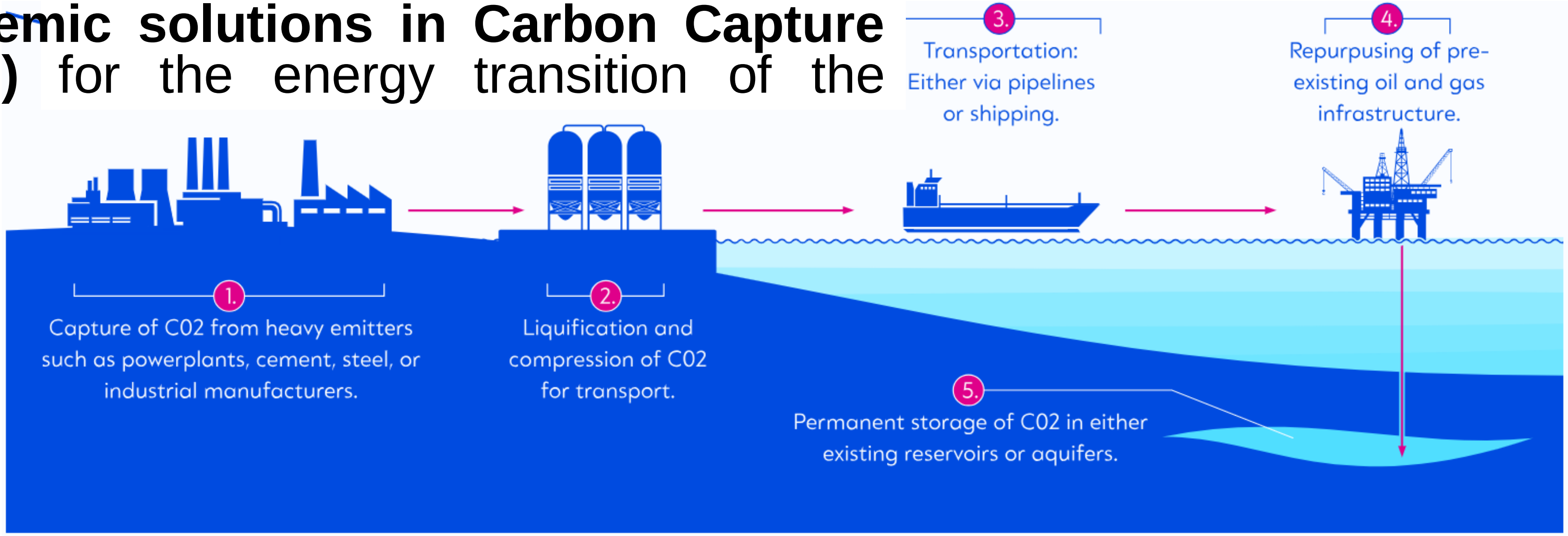
7 Core Technologies of the NECP (2/2)

V. **Creating a Green Hydrogen Economy**: Using it in transport (heavy vehicles, shipping, aviation), industry and under conditions in power generation.

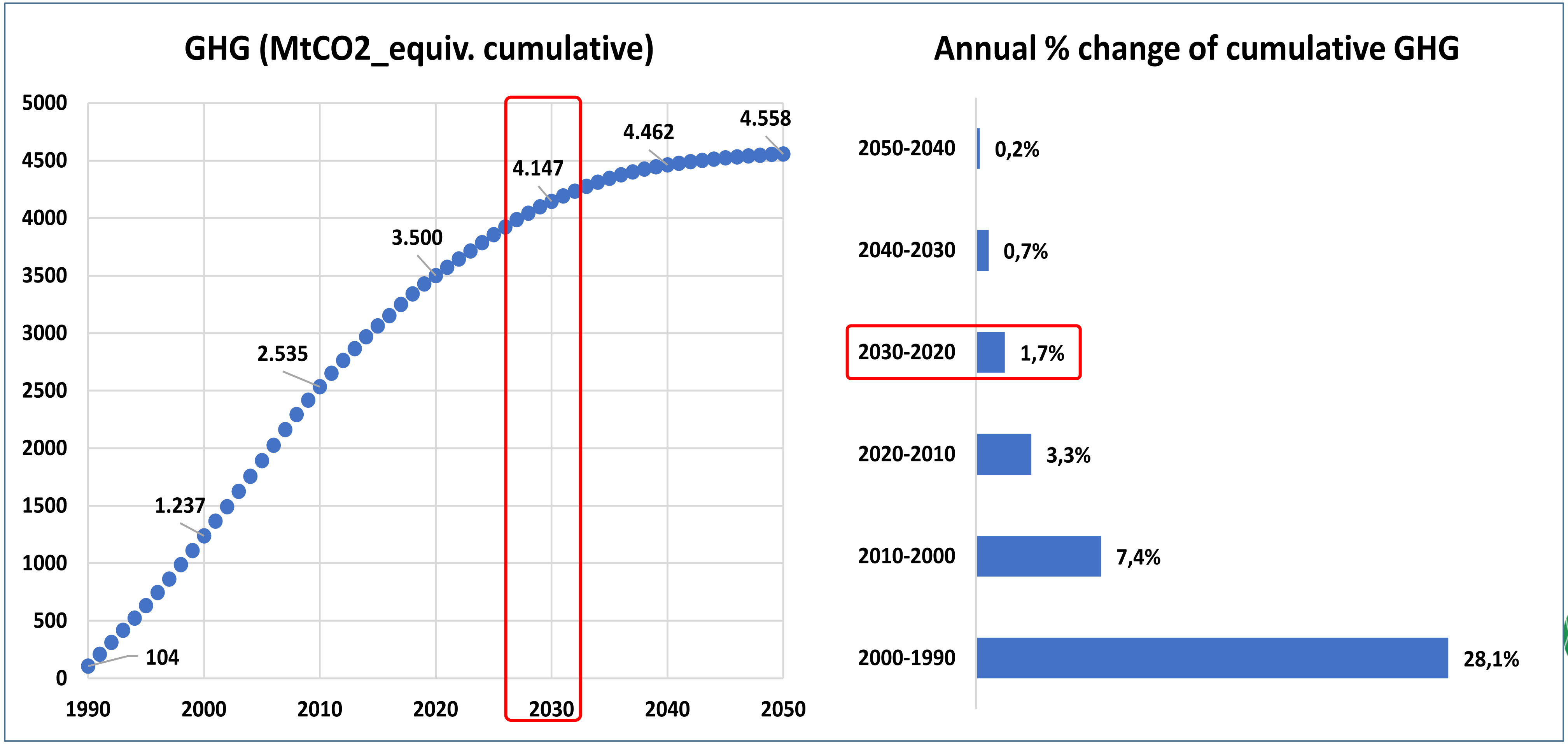


VI. **Development of Synthetic, Green Fuels** (RFNBO, Renewable fuels of non-biological origin): With use in transport (heavy vehicles, shipping, aviation) – a whole new industry that should immediately start to take shape.

VII. **Innovation and systemic solutions in Carbon Capture and storage (CCUS)** for the energy transition of the country's industry.



GHG (cumulative emissions)



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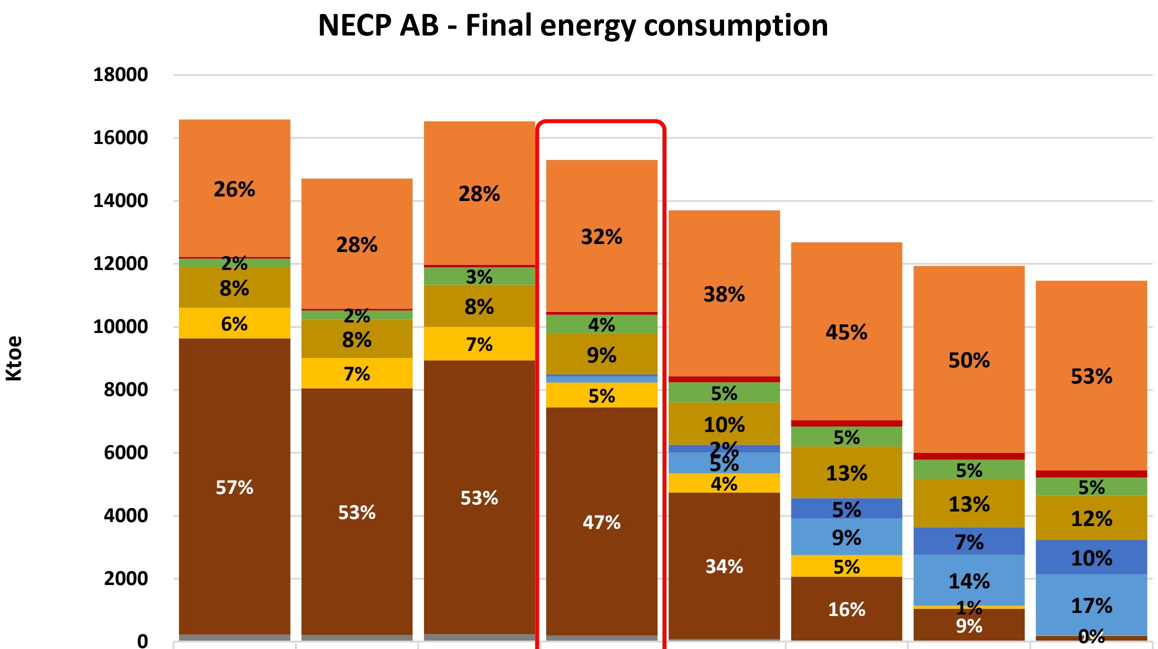
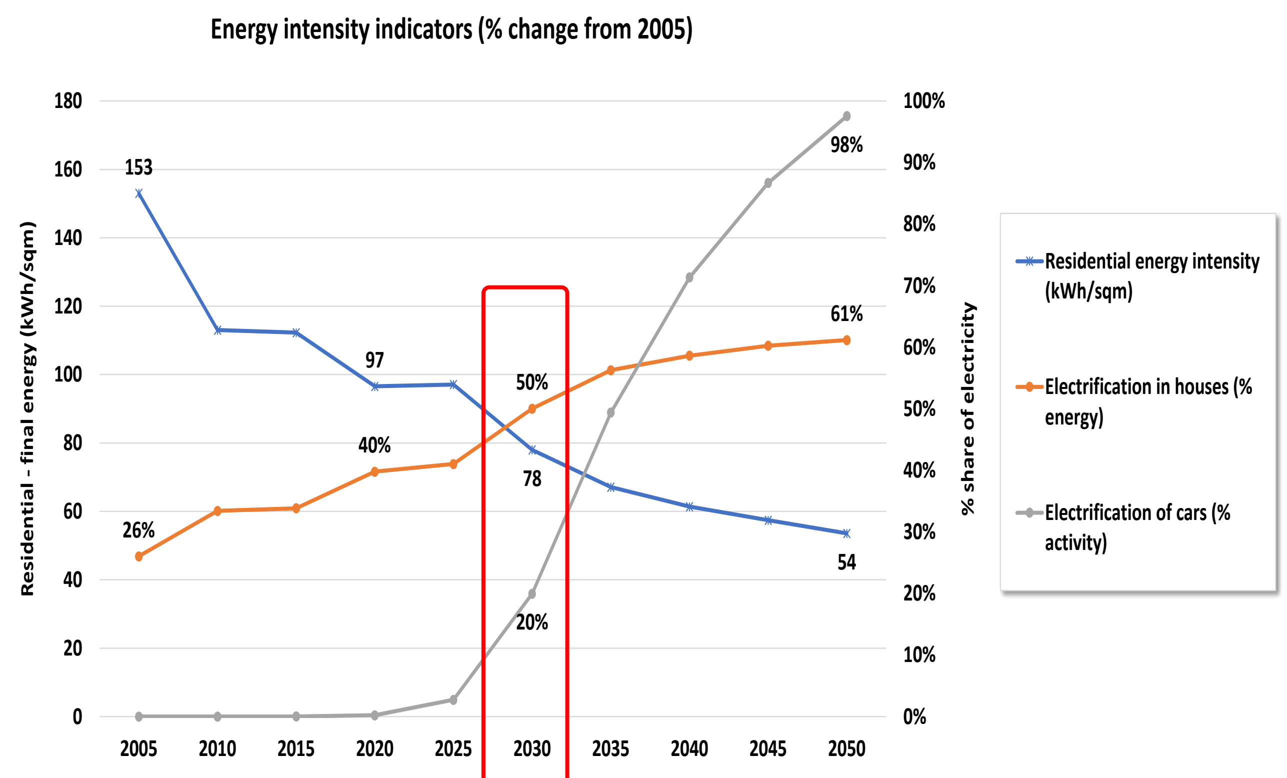
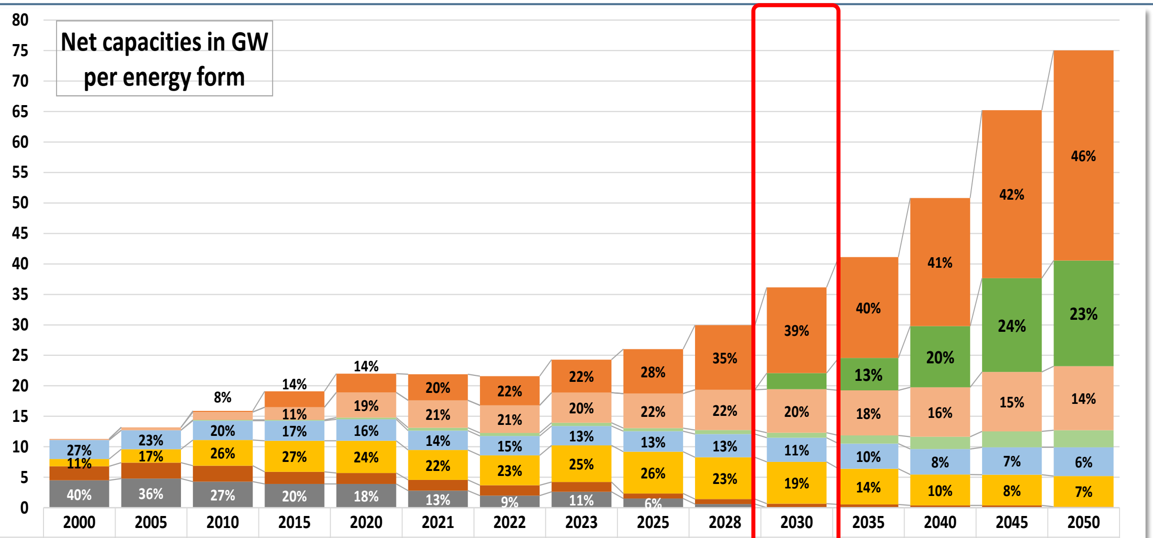
Final Energy Consumption and Energy Intensity Indicators



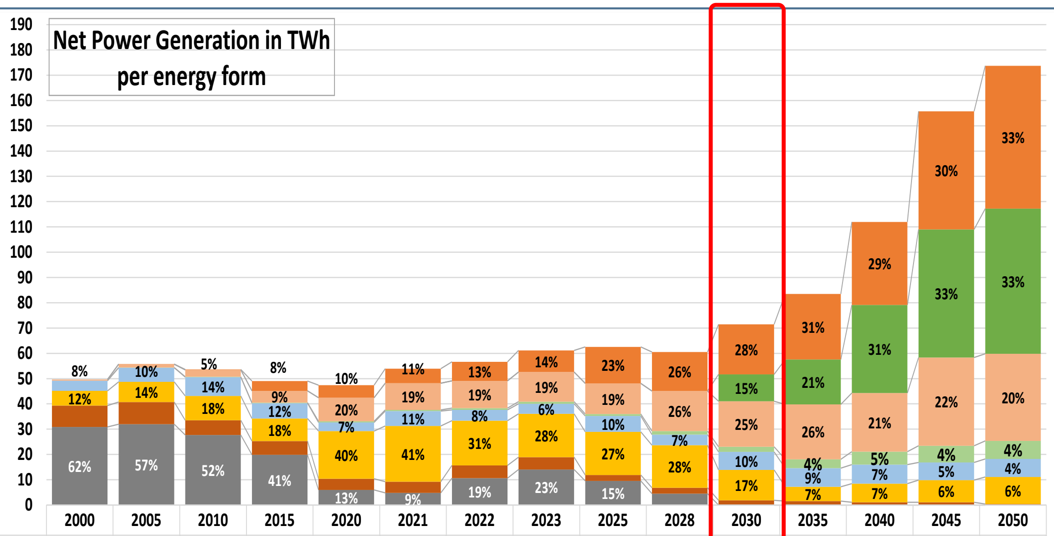
	2015	2020	2025	2030	2035	2040	2045	2050
Electricity	4367	4135	4553	4830	5275	5650	5937	6025
Heat	50	56	86	84	195	201	229	222
RES	270	296	556	598	635	640	607	583
Biomass	1297	1206	1329	1305	1345	1637	1536	1409
Hydrogen	0	0	0	74	249	652	877	1091
Synthetic fuels	0	0	0	181	658	1155	1618	1940
Gas	972	967	1077	788	616	682	89	8
Oil	9411	7841	8687	7243	4643	2042	1044	188
Solids	221	209	243	200	90	27	5	3
Total	16588	14710	16531	15303	13706	12688	11943	11469



Installed Capacity and Net Power Generation per Energy form



	2000	2005	2010	2015	2020	2021	2022	2023	2025	2028	2030	2035	2040	2045	2050
Solar	0.0	0.0	0.2	2.6	3.1	4.3	4.8	5.4	7.3	10.6	14.1	16.5	21.0	27.5	34.5
Wind offshore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	5.3	10.0	15.4	17.3
Wind onshore	0.2	0.5	1.3	2.1	4.1	4.5	4.6	4.9	5.6	6.6	7.1	7.4	8.1	9.8	10.5
Other RES	0.0	0.0	0.1	0.1	0.3	0.5	0.5	0.5	0.5	0.7	0.8	1.4	2.0	2.6	2.8
Hydro	3.1	3.1	3.2	3.3	3.5	3.2	3.2	3.2	3.4	3.8	4.0	4.1	4.2	4.5	4.7
Gas fired	1.2	2.2	4.2	5.1	5.3	4.9	4.9	6.0	6.9	6.9	6.9	5.8	5.1	5.1	5.1
Oil fired	2.3	2.6	2.6	2.0	1.8	1.8	1.7	1.6	0.8	0.8	0.7	0.6	0.4	0.4	0.2
Solids fired	4.5	4.8	4.3	3.9	3.9	2.8	2.0	2.6	1.5	0.6	0.0	0.0	0.0	0.0	0.0
Total Net-Capacity (GW)	11.3	13.2	15.9	19.1	22.0	21.9	21.6	24.3	26.0	30.0	36.1	41.1	50.8	65.2	75.0



	2000	2005	2010	2015	2020	2021	2022	2023	2025	2028	2030	2035	2040	2045	2050
Solar	0.0	0.0	0.2	3.9	4.9	5.8	7.5	8.6	14.4	15.5	19.8	25.9	32.8	46.7	56.5
Wind offshore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	17.8	34.8	50.7	57.4
Wind onshore	0.5	1.3	2.7	4.6	9.3	10.5	10.8	11.7	12.1	15.8	18.0	21.7	23.2	34.9	34.4
Other RES	0.0	0.1	0.2	0.2	0.5	0.5	0.7	0.9	0.7	1.4	2.0	3.5	5.1	6.6	7.1
Hydro	4.1	5.6	7.4	6.1	3.4	5.9	4.3	3.9	6.3	4.2	7.1	7.4	7.5	7.0	7.1
Gas	5.8	8.0	9.6	8.9	18.8	22.0	17.6	17.2	17.1	16.9	12.0	5.6	7.4	8.8	10.7
Oil	8.4	8.7	5.8	5.4	4.5	4.4	5.1	4.9	2.3	2.3	1.9	1.6	1.1	1.1	0.4
Solids	30.9	32.0	27.7	19.9	5.9	4.8	10.6	14.0	9.6	4.5	0.0	0.0	0.0	0.0	0.0
Total net generation (TWh)	49.6	55.7	53.6	49.0	47.4	53.9	56.6	61.1	62.5	60.5	71.5	83.5	112.0	155.7	173.7

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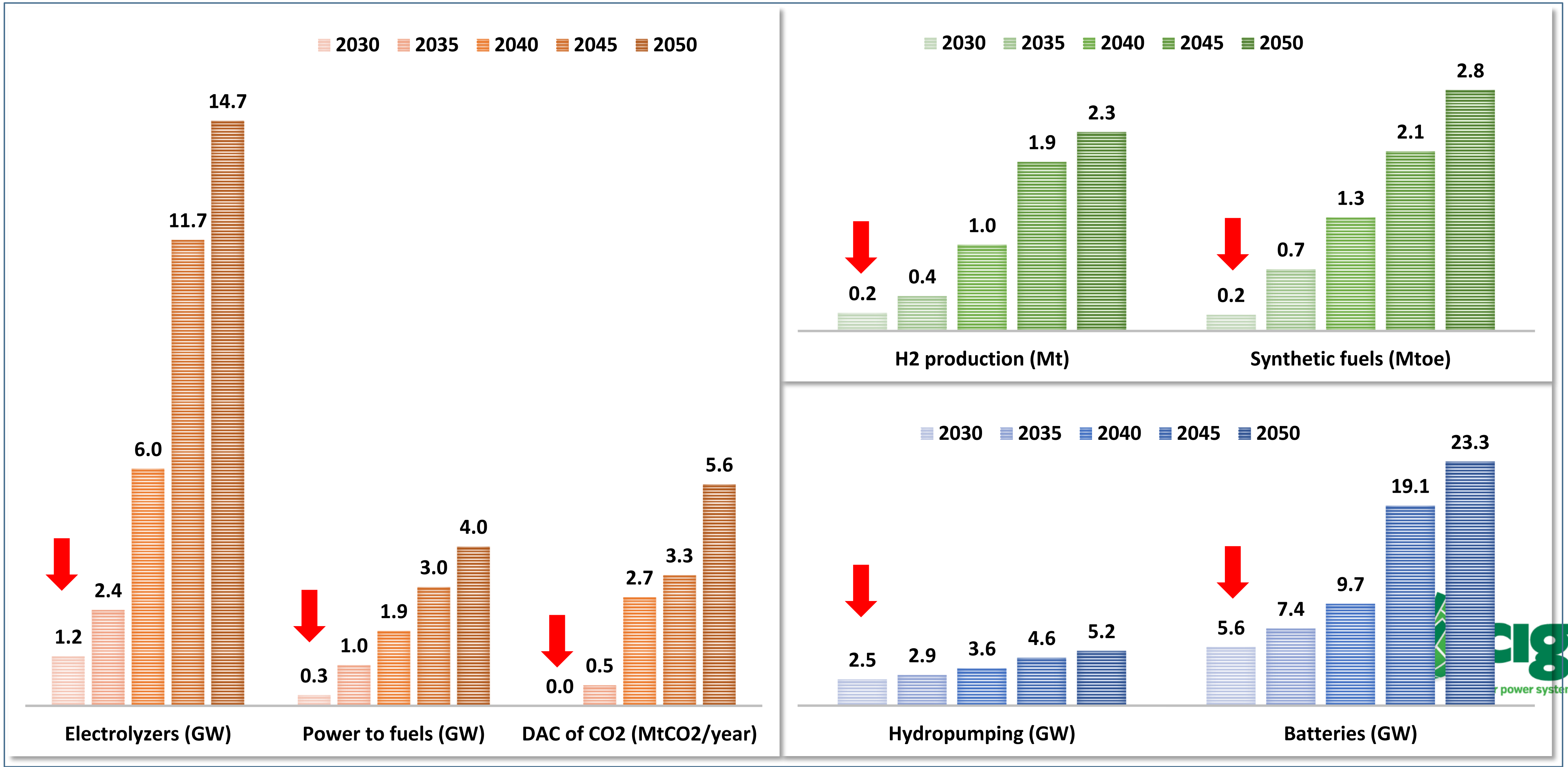
Energy Storage Capacity

H2 and Synthetic Fuels Production



Figures of the Transmission System

Transmission Lines and Substations

TRANSMISSION LINES (km)					
TYPE OF LINES	400 kV	DC 400 kV	150 kV	66 kV	TOTAL
OVERHEAD LINES	3.033,52	106,95	8.877,43	37,54	12.055,44
SUBMARINE CABLES	6,6		1.038,69	81,5	1.126,79
SUBMARINE CABLES (underground part)	13,4		32,15	2,68	48,23
UNDERGROUND LINES	31,45		378,13		409,58
TOTAL	**3.084,97**	**106,95**	**10.326,4**	**121,71**	**13.640,04**

SUBSTATIONS WITH IPTO ASSETS			
TYPE	TRANSFORMER	SWITCHING	TOTAL SUBSTATION
HVC - SWITCHING (400KV)	19	3	22
STEP-DOWN - SWITCHING SUBSTATION (150/20KV & 66/20KV)	219	4	223
SUBSTATION OF HV CUSTOMERS - MINES	40		40
STEP-UP (PRODUCTION STATIONS)	31	1	32
STEP-UP RES PRODUCERS	91		91
AC/DC TRANSFORMATION	1		1
TOTAL			**409**

IPTO Analytics App

Subject areas that are covered include:

- The System Load where you can be informed for the Actual Load and for the Forecasted Load
- The Total Energy Production Mix and the Interconnections Balance
- The Cross Border Physical Flows with neighboring countries, including imports and exports of electricity

Drivers for the Power System Planning in Greece

EU→GR

- **Clean Energy for all Europeans package**:
  - ✓ **Energy performance in buildings,**
  - ✓ **Renewable energy,**
  - ✓ **Energy efficiency,**
  - ✓ **Governance regulation (NECPs),**
  - ✓ **Electricity market design,**
  - ✓ **Non-legislative initiatives (coal regions in transition, clean energy for EU islands, measures to define and better monitor energy poverty)**
- European Green Deal → REPowerEU
  - ✓ **Diversifying our energy supply**
  - ✓ **Securing affordable energy supplies**
  - ✓ **Saving energy**
  - ✓ **Investing in renewables**
- **Fit for 55 package**

- **RES Integration**
- **System Security and Reliability**
- **Islands Interconnection**
- **New Int'l Interconnections**
- **Offshore Wind Integration**
- **Energy Storage Integration**
- **System Stability and Control**
- **Long-term System Development Strategy**

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HEDNO at a Glance

HEDNO Overview

Hellenic Electricity Distribution Network Operator "HEDNO" is the owner[1] and operator of the electricity distribution network in Greece, with 100% market share

HEDNO is responsible for the operation, maintenance and development of the power distribution network on the mainland and all Greek islands

- **Network length of approximately 245,000km, serving 7.8m customers**
- **Operates under a perpetual license**

HEDNO is regulated by the Regulatory Authority for Energy ("**RAE**") and has commenced a new four-year regulatory period in (2021–2024). A second four-year regulatory period will cover years 2025-2028

HEDNO is well positioned for **growth under a strong, performance-oriented management team**

HEDNO shareholders are Public Power Corporation ("**PPC**"), that possesses the 51% of the company and Macquarie Asset Management that possesses the rest 49% since February of 2022.

Service Territory and Operations[2]

HEDNO Key Financials

	2018	2019	2020	2021	2022[4]	2023
Revenues	€814m	€833m	€822m	€861m	€833m	€1,117m
Normalised EBITDA[3]	€412m	€426m	€405m	€396m	€374m	€530m
CAPEX	€148m	€149m	€174m	€221m	€312m	€449m
RAB	~€3.1bn	~€3.0bn	~€2.9bn	~€2.9bn	~€2.9bn	~€3.1bn

HEDNO Operational Stats (Q1 2023)

Connections points	7.8m
Market share	100%
Electricity consumption	41,983 GWh
Network length	244,795 km[4]
Sub-Stations	244 (HV/MV) & 164k (MV/LV)
Employees	5,806

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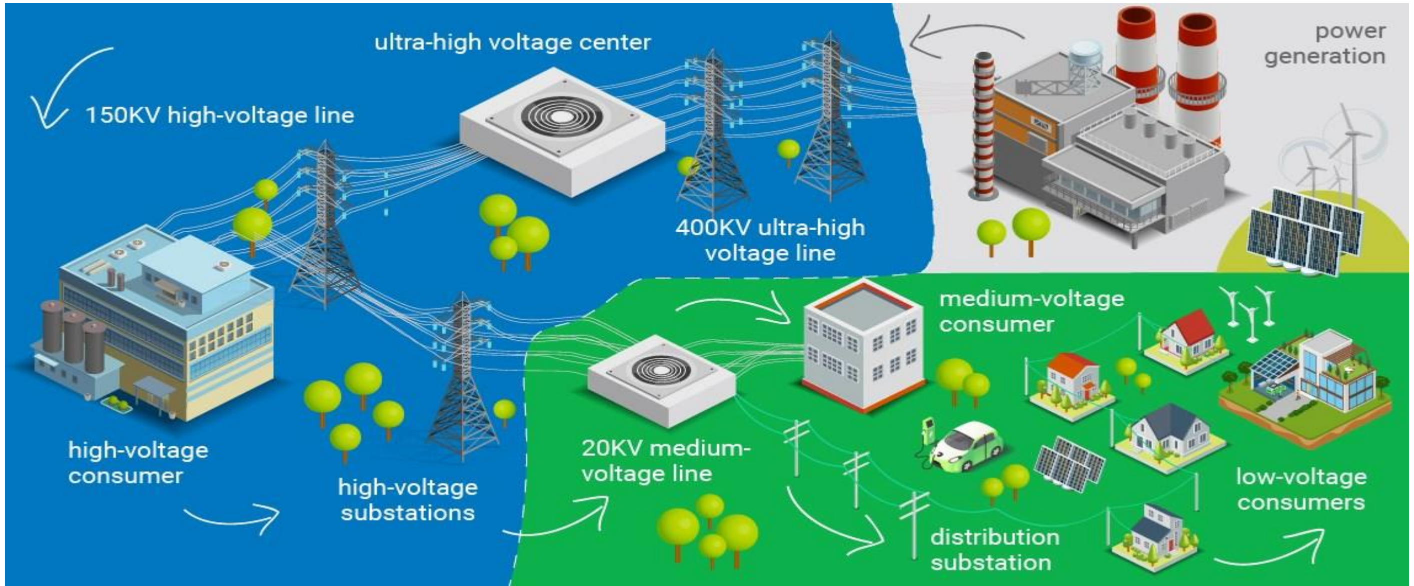
1. Post the envisaged asset carve-out from PPC that took place on 30 Nov 2021. 2. Of total connections. 3. Non-recurring items. 4. Due to the drop in consumption HEDNO had a very high under recovery which will be covered by a specific percentage in 2023 and 2024 according to RAEs decisions for 2023 & 2024 RR. 5. MV & LV Breakdown. consisting of 128 thousand kilometers of low voltage lines, 113 thousand kilometers of medium voltage lines in the Interconnected System and the Non-Interconnected Islands, as well as approximately one thousand kilometers of high voltage lines in Attica and in the Non-Interconnected Islands.

The 12 Strategic Projects in Distribution

1. Modernization of the Control Center of Attica Networks
2. Setting up a Control Center for Island Networks
3. Modernization of Network Control for the rest of the country
4. Upgrading of Remote Control equipment in Regional Networks
5. Installation of a Geographic Information System
6. New Information System for Customer Service
7. Installation of Remote Customer Service Systems
8. Upgrade of Network Development Planning
9. Development of Infrastructures for Non-Interconnected Islands (NII) to apply the NII Code
10. Development of "Smart Islands", Pilot and expansion
11. Reorganization of the supply chain
12. Development of a Unified Information Management System



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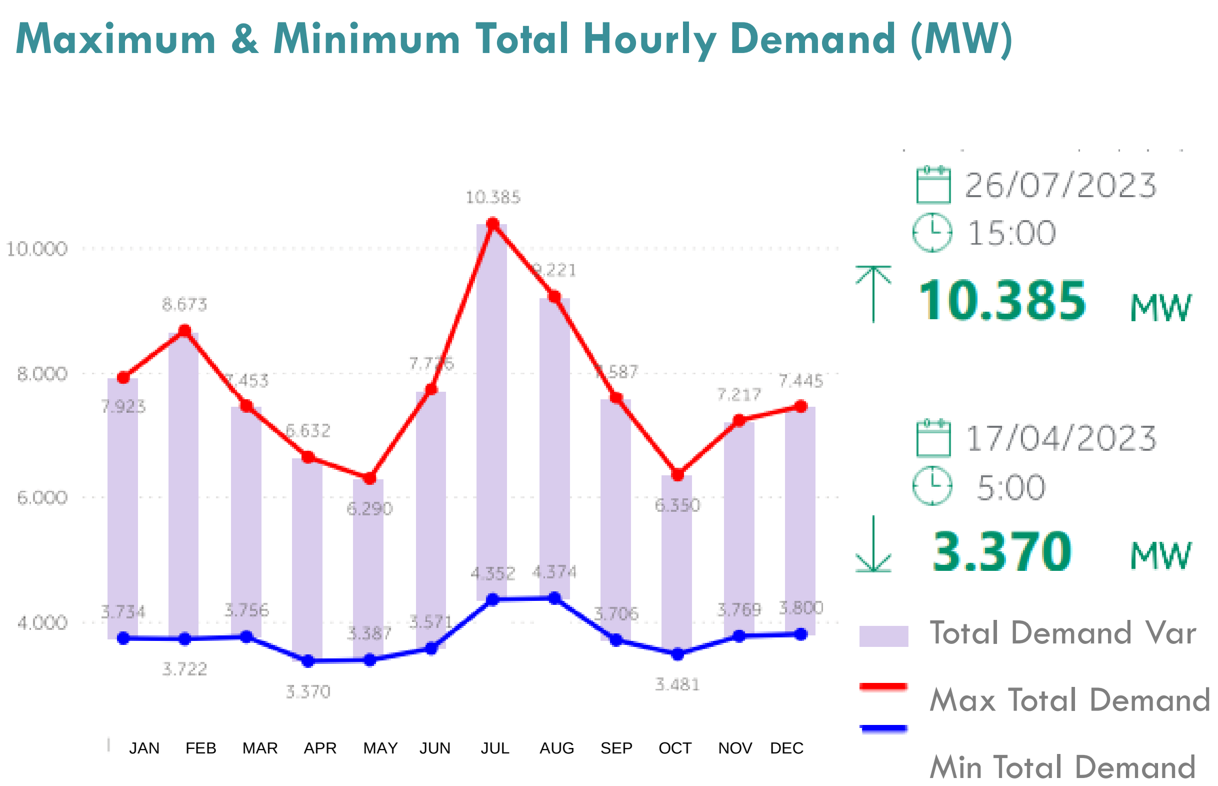
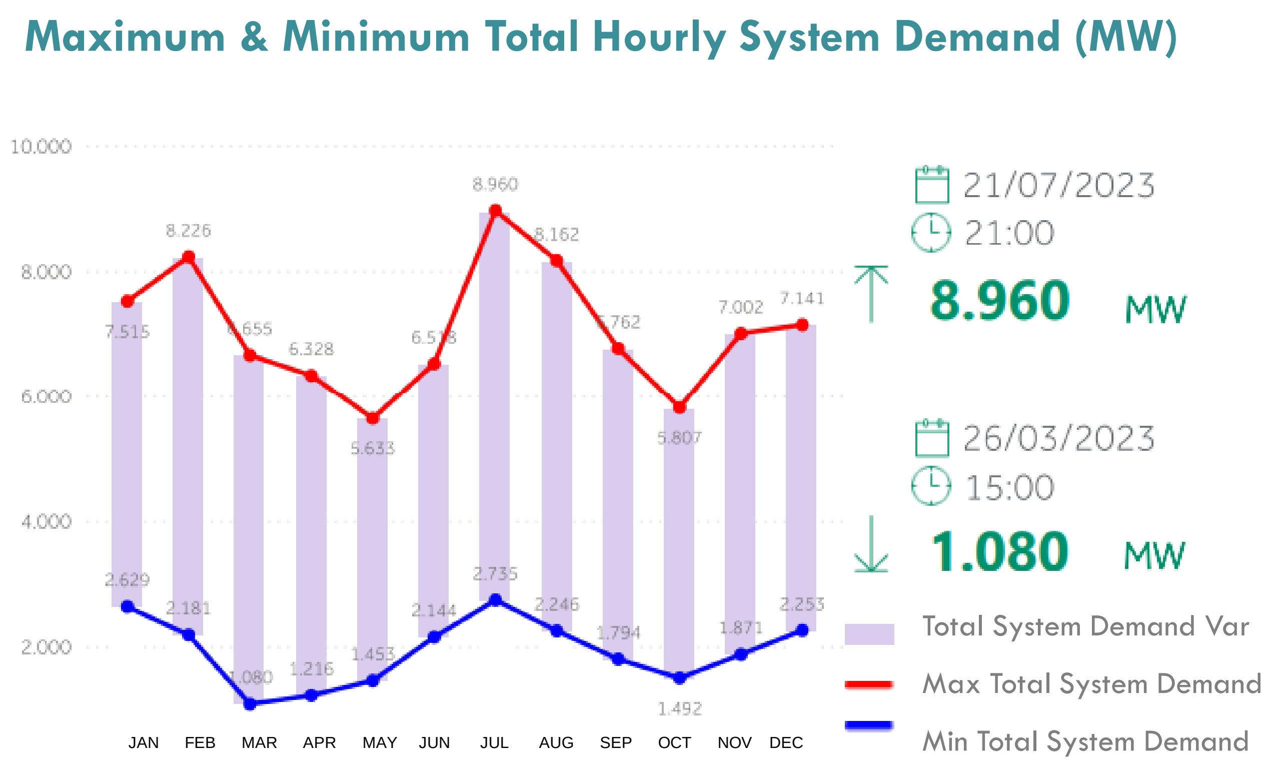
Maximum and Minimum Demand 2023

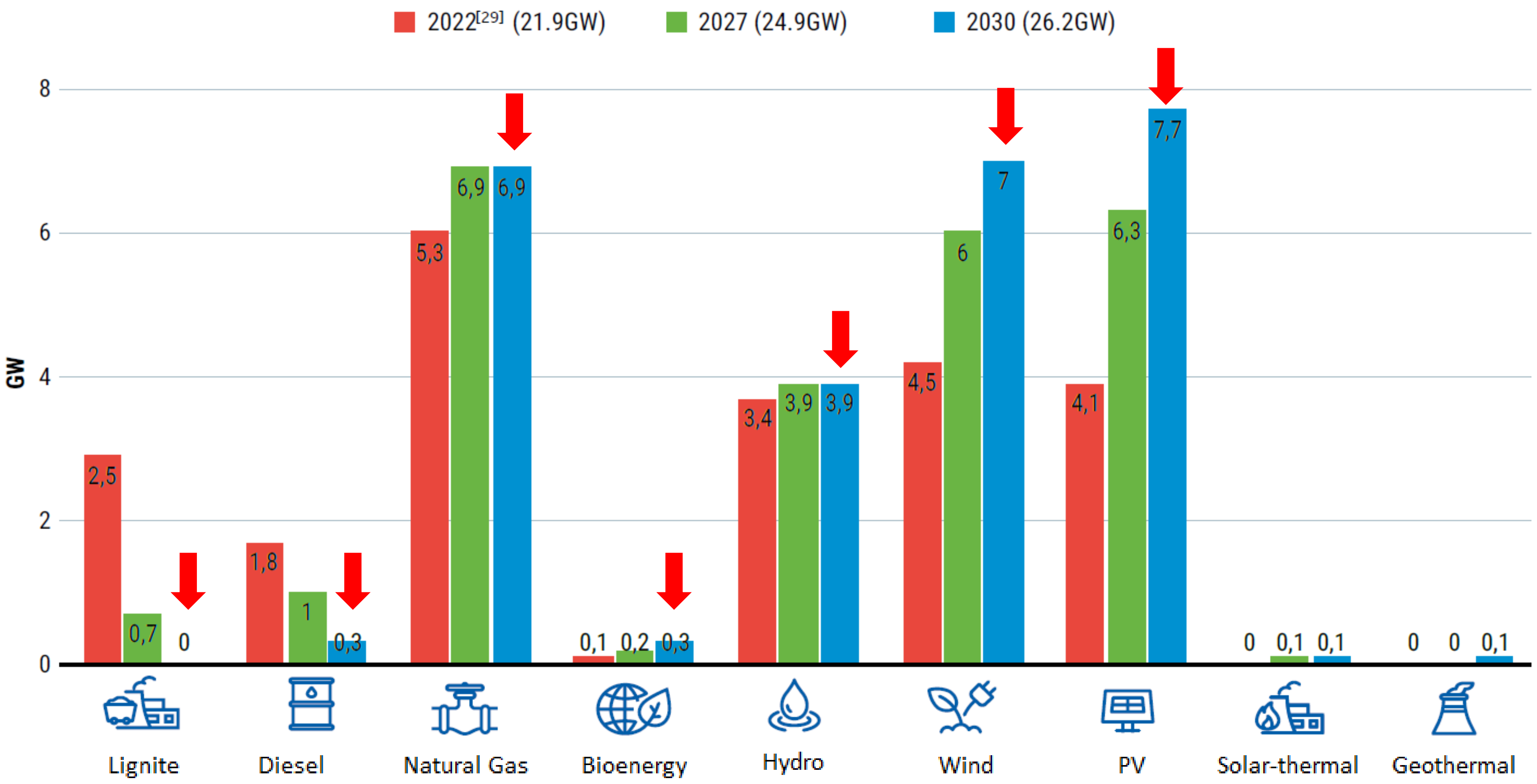
Total Demand and System Demand





National Plan for Energy and Climate

Electricity generation mix today and by 2030



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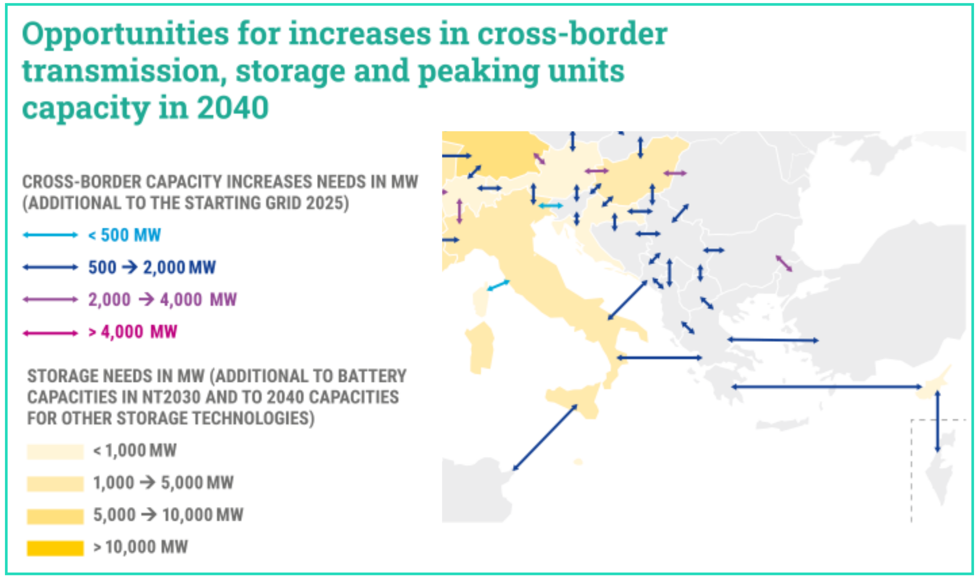
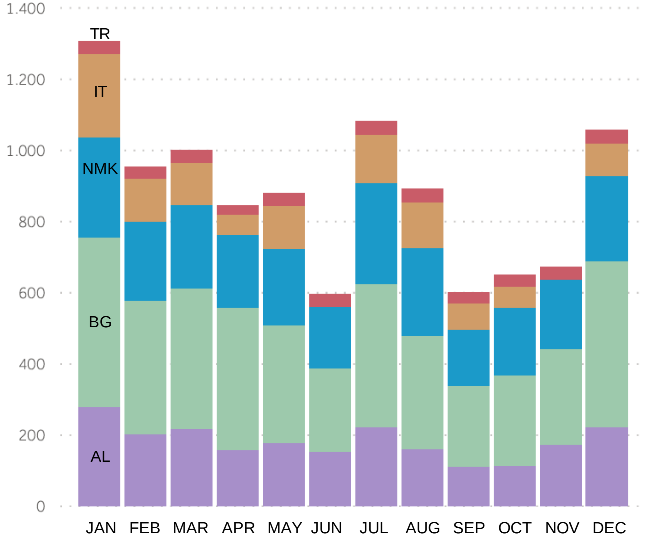
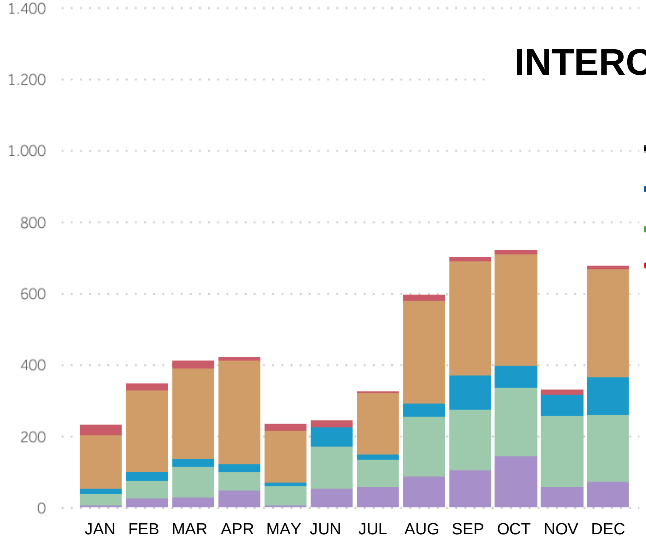
Cross-Border Interconnections

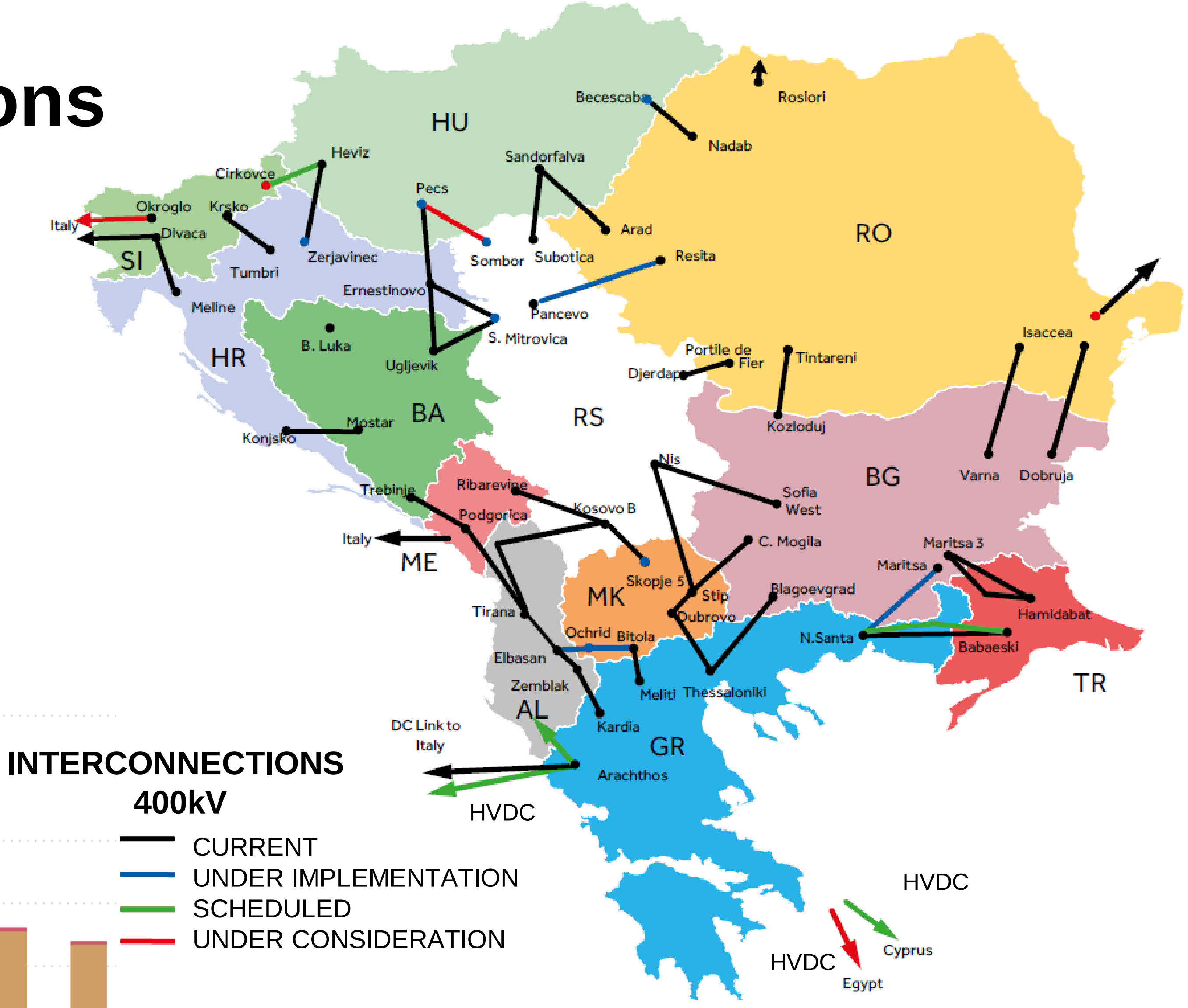


IMPORTS 2023



EXPORTS 2023

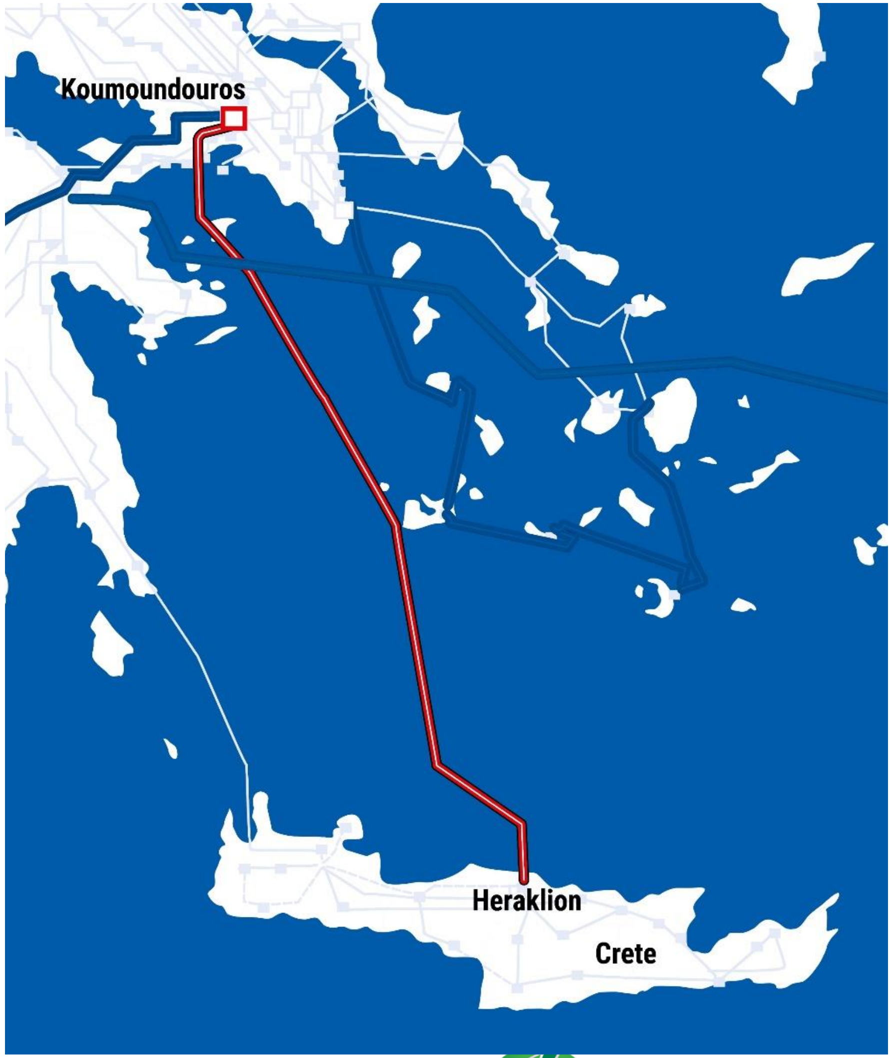




Greek islands interconnections

Interconnection Crete-Attica (expected 2025)

- The 2nd phase of the interconnection of Crete with the HETS (2x500MW HVDC ± 500kV)
- Ariadne Interconnection SPSA
- Interoperability with CY-IL Interconnector
- The 1st of its kind in Mediterranean (500kV DC cables and VSC)
- Among the top 3 deepest interconnections worldwide (1,250m)
- Largest energy infrastructure ever in Greece
- Budget 1B€



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Greek islands interconnections

Interconnection of Southwestern Cyclades

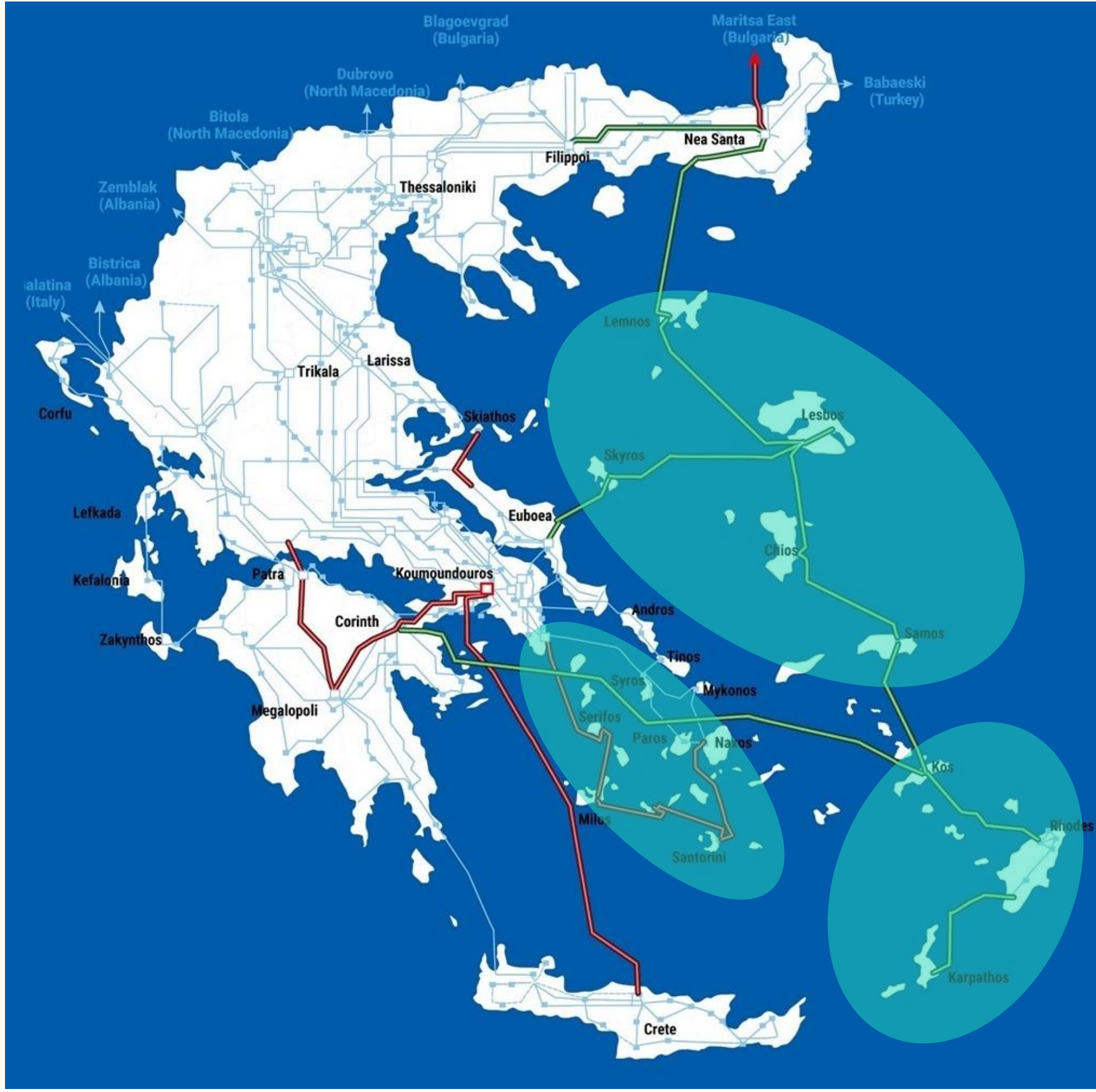
- Santorini, Folegandros, Melos, Serifos

Interconnection of Dodecanese islands

- Kos, Rhodes, Karpathos

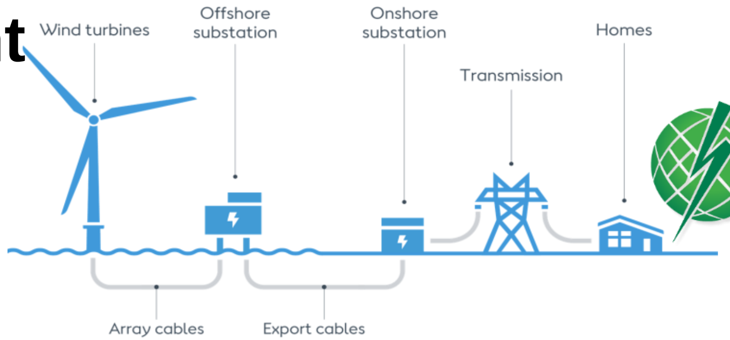
Interconnection of Northeastern Aegean islands

- Skyros, Lesvos, Limnos, Chios, Samos



Offshore transmission network development

- Responsible for all stages of offshore transmission network assets for OWFs connection



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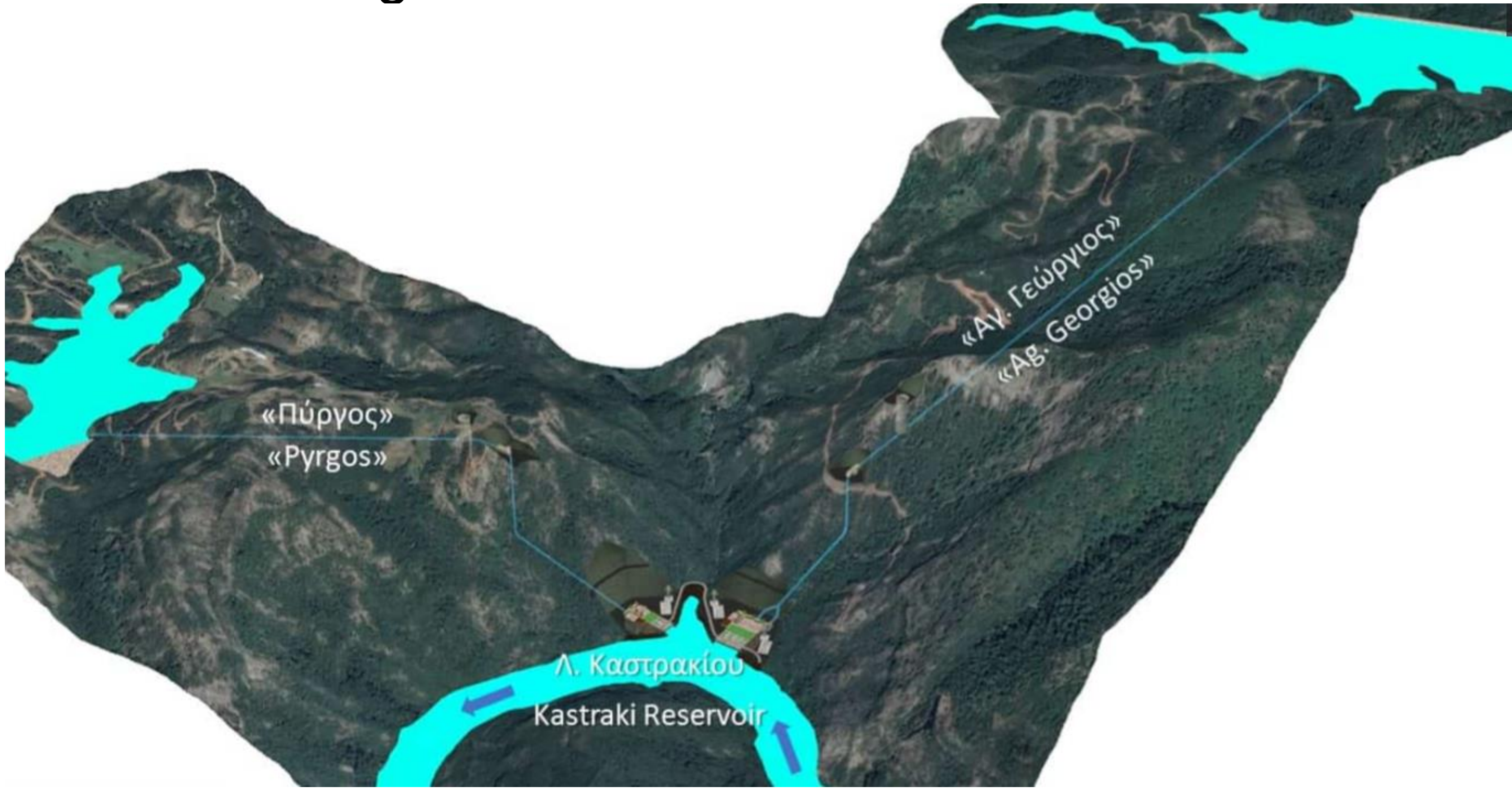
Hydro Pumped Storage Complex in Amfilochia

The Mega Energy Storage Project in Western Greece

- The project includes two autonomous reservoirs, Pyrgos and Ag. Georgios, and will use the existing lake of Kastraki of PPC, as a lower reservoir.
- The total installed capacity of the unit will reach 680 MW in production and 730 MW in pumping, with energy production reaching 816 GWh on an annual basis.

The water used to generate electricity, directed from the upper reservoir to the lower one, can be pumped back to the upper reservoir with the help of turbines. The pumping is done using RES power generation, which is thus stored as a hydroelectric “reserve” in the upper reservoir and can be used whenever the need arises.

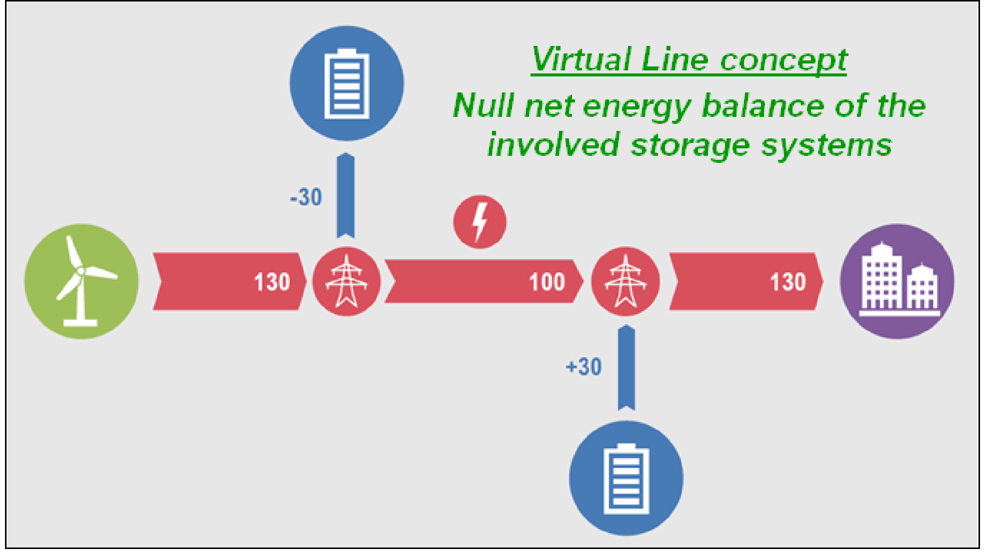


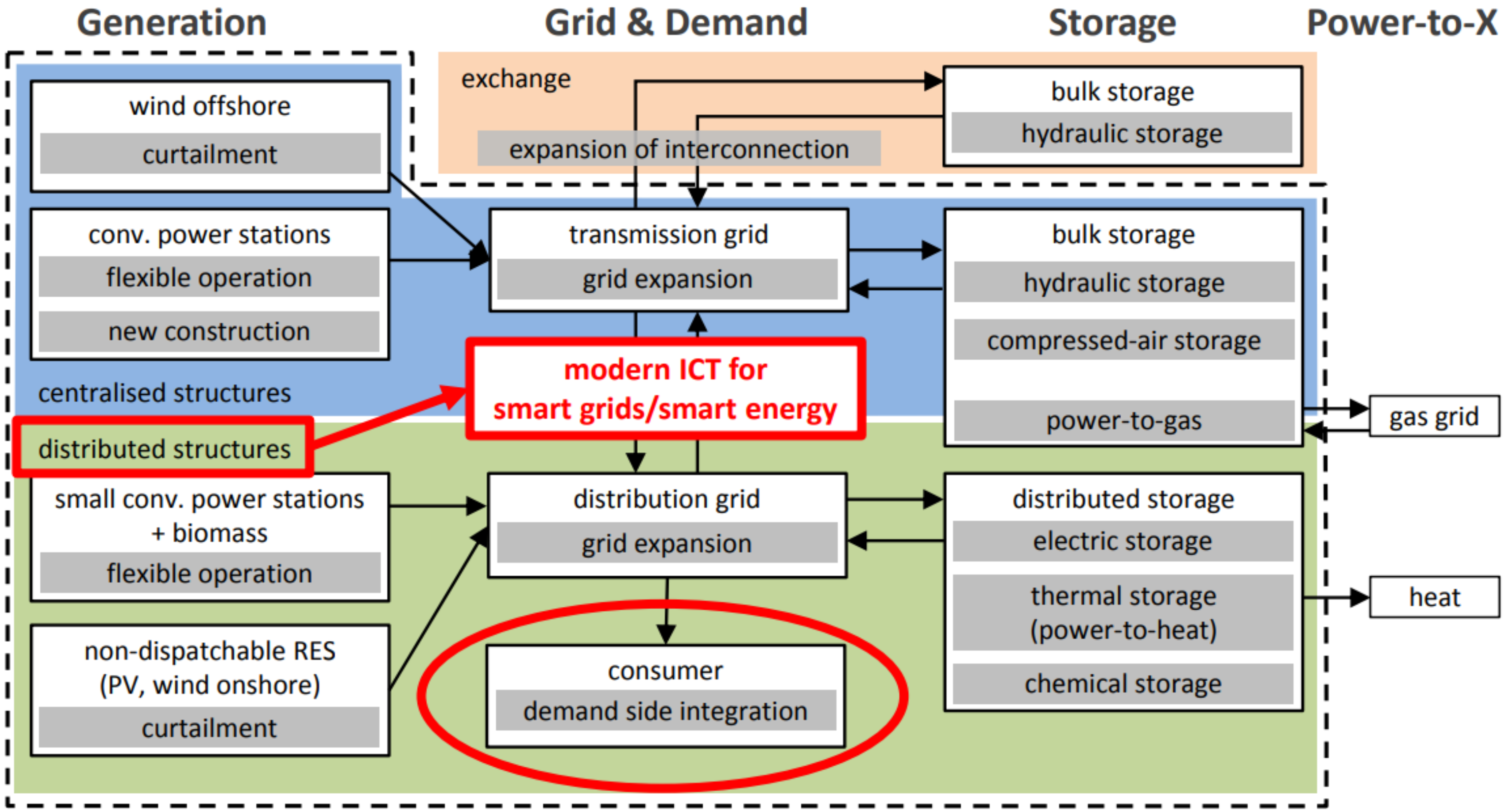
Challenges

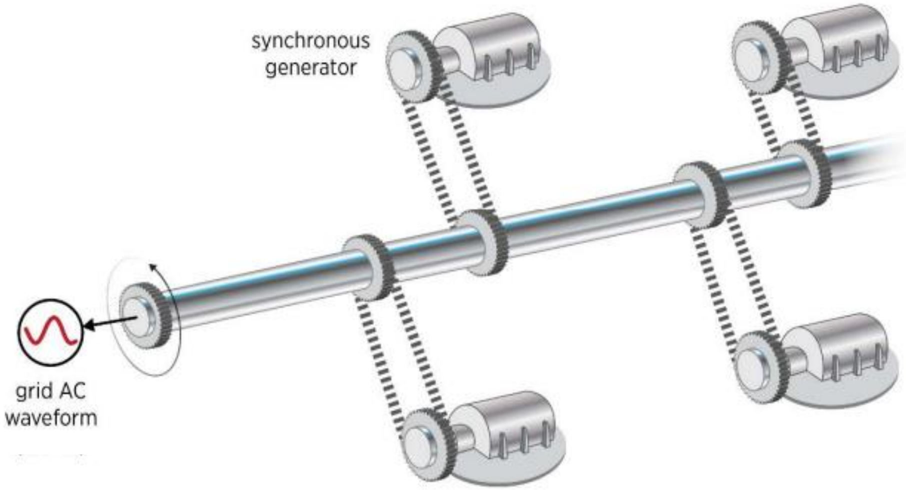
Overcome Challenges to achieve Energy Transition

- **Increasing the flexibility** of available generation resources to effectively restore the generation-load balance due to the randomness and variability of RES generation that strongly depends on weather conditions.
- **Planning of the future networks as well as preparation and organization of Operation Planning**; the electric networks in the future will have to acquire different characteristics and capabilities from today's.
- **Development of new energy infrastructures** by accelerating the development of electrical networks and securing the financing of the required investments.
- **Designing the electricity market with new mechanisms and products** to ensure the long-term undisturbed development of RES generation stations and to include new auxiliary services for effective regulation of voltage and frequency, ensuring flexibility, inertia, etc.
- **TSO – DSO cooperation**, since a large part of the new RES generation is dispersed in the distribution networks which acquire new properties and capabilities as they cease to be passive (servicing only loads).
- **Digitization of the operation** of Transmission and Distribution networks.
- **Regional Security Coordination (RSC) and inter-RSC cooperation**: multiple challenges for the balancing of the power systems, due to the increased penetration of the RES, the increase of the volume but also the variability of cross-border flows and the gradual integration of demand response and storage.

Overcome Challenges to achieve Energy Transition







The INERTIA Challenge

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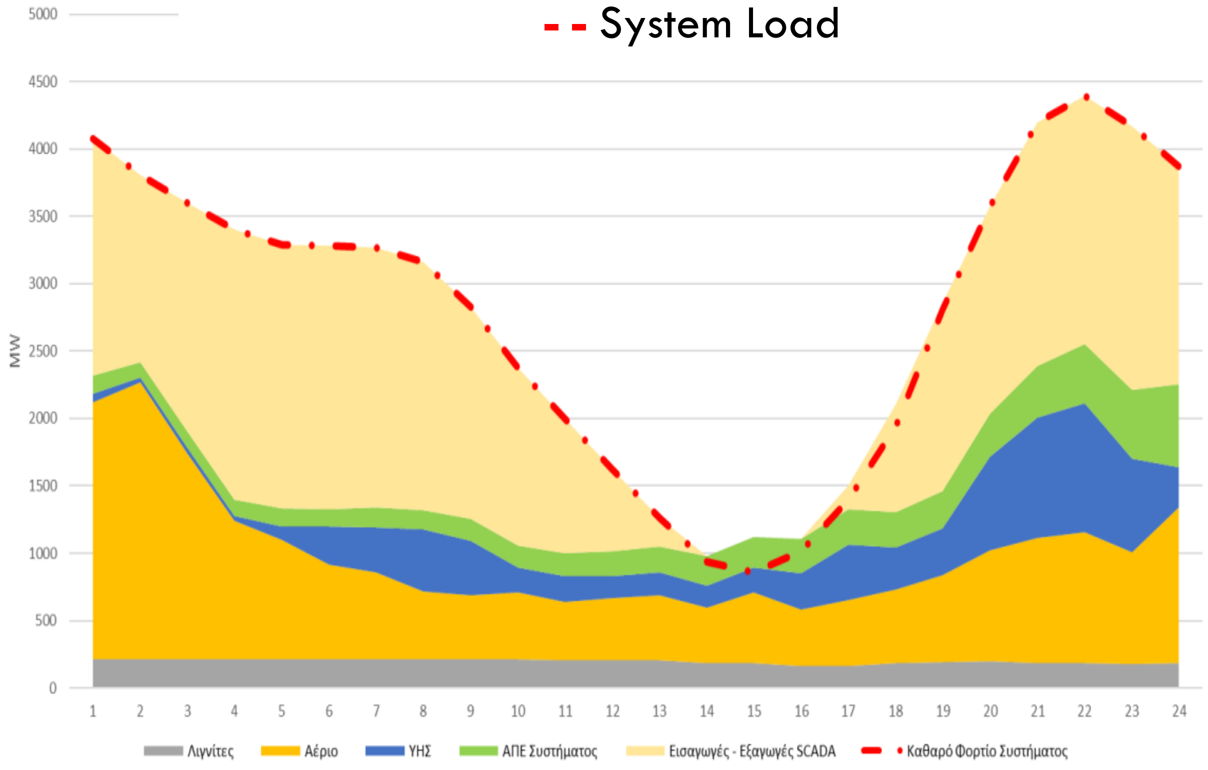
Kai Hufendiek, Martin Steurer, Sebastian Bothor A Cost Effective Mix of Flexibility Options for Integrating a High Share of Variable Renewables, Paris, 2015.

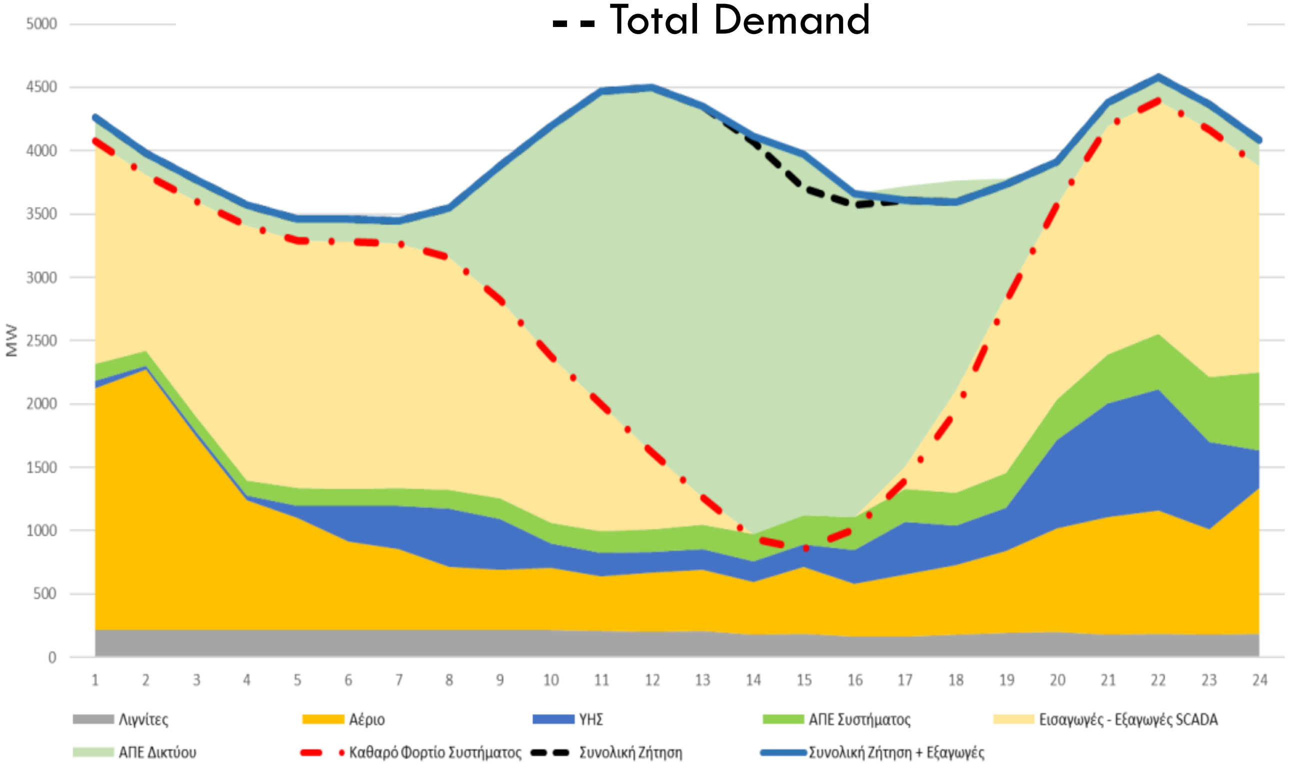
Overcome Challenges to achieve Energy Transition

Operating under High-RES Penetration: from the TSO point of view

Energy MIX 24/4/2022 – From TSO side of view
- - System Load



Energy MIX 24/4/2022 – Real Picture (RES @DSO)
- - Total Demand



PYLONS

e-magazine

- The magazine is published by CIGRE Greece NC biannually hosting articles both in Greek and English language
- Editorial Board: Emeritus Prof. Costas Vournas, *Editor in Chief*
  Dr. A. Koronides and Dr. G. Georgantzis
  f. Chairmen of CIGRE GREECE

Issues:

- ✓ ***Issue 1, Jul. 2021: Regional Cooperation in Europe***
- ✓ ***Issue 2, Apr. 2022: Uncertainty – Security – Resilience***
- ✓ ***Issue 3, Mar. 2023: Green Energy Transition***
- ✓ ***Issue 4, Sep. 2023: Electromobility***

- *Recurring Themes*
  - ✓ ***Flashback***
  - ✓ ***CIGRE Greece NC News***
  - ✓ ***Exhibition and Book Reviews***
- *Available for free on CIGRE Greece web-site www.cigre.gr*

Further reading.. articles in Greek

…from the Editorial of PYLONS The Magazine of CIGRE GREECE NC

In this issue the special topic is ***Green Energy Transition****. A transition that is not an option, but a necessity so that the present* ***climate crisis*** *is kept in control by limiting greenhouse gas emissions.*

- *In the 1st article D. Lalas highlights this fact* ***Climate Change, the Road to Decarbonization, and the Role of Electric Energy****.*
- *The latter becomes even more prominent in the 2nd paper on* ***Electrical Systems on the Way towards the Energy Transition****, where M. Karystianos and Y. Kambouris present the challenges faced by electricity networks are described. One of the first facts we are taught about electrical energy is that it should be consumed at the same time as it is generated, since it is difficult to store. Energy Transition is changing this condition.*
- *The consequences of this new reality in our country are treated by Prof. S. Papathanasiou in the article* ***Electricity Storage in Greece: Present State and Future Prospects****.*
- *The high penetration of time-varying renewables brought about by the Green Energy Transition has already changed dramatically the balance between generation and consumption, having a significant impact on the everyday operation of the power systems. Indicative of this is the article* ***Operating under High-RES Penetration: from the point of view of the Transmission Operator*** *by Y. Kambouris, V. Ziogas*
- *RES penetration has not only a bright future but has already a very interesting and significant past in Greece. This is highlighted in the article of J. Chadjivassiliadis entitled* ***RES in the Hellenic Power System: Past, Present, and Future****.*

Thank you!

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