THE DEVELOPMENT OF ELECTRICITY NETWORKS – EUROPEAN AND NATIONAL TRENDS AND PROBLEMS

A Roundtable Meeting
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Electricity Grids and Decarbonisation in SE Europe with Special Reference to Greece

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INSTITUTE OF ENERGY
FOR SOUTH EAST EUROPE

Presentation Outline

- The SEE area defined
- The challenge of decarbonisation in SE Europe and the key role of further electrification
- The importance of electricity grids
- The state of electricity grids in SE Europe
- Cross border electricity connections
- Expanding and upgrading electricity grids in SE Europe
  - The region
  - Greece
- The changing energy and electricity mix in the EU and in SEE
- The expanding role of RES in SE Europe
- RES in Greece
- RES competing against conventional base load power generation sources (daily and monthly 24h fluctuations)
- Regional electricity flows and prices
- Discussion

The SE European Region as Defined by IENE

Core countries

- Albania
- Bosnia and Herzegovina
- Bulgaria
- Croatia
- Cyprus
- Greece
- Hungary
- Israel
- Kosovo
- Montenegro
- North Macedonia
- Romania
- Serbia
- Slovenia
- Turkey

Peripheral countries

- Austria
- Egypt
- Italy
- Lebanon
- Moldova
- Slovakia
- Syria
- Ukraine

Source: IENE

IENE's Latest Major Study on SE Europe Covers all Aspects of Electricity Developments

Source: IENE

Key Regional Energy Issues – Decarbonisation in SE Europe

Challenges and Trends Towards SE Europe's Decarbonisation:

- The **coal predicament** of SE Europe – the region's great dependence on coal-fired power generation vs GHG emission reduction targets
  - According to IENE estimates, the **share of solid fuels to power generation** is anticipated to **increase steadily** in several countries of the region (most notably in Serbia, Kosovo, Croatia, Bosnia and Herzegovina, Montenegro and Turkey) over the next 10-15 years, as they will struggle to meet increased demand.
  - **North Macedonia and Serbia are the second most coal dependent countries after Kosovo at regional level**, while proposed lignite-based/coal-fired power plants in Bosnia and Herzegovina and Serbia would not be in line with EU climate targets, and would downgrade the solar PV, wind, hydropower, and biomass opportunities in the region.
  - **Effective climate change policies in SE Europe have not been implemented so far**, but there is still room for change in order to avoid becoming further "locked in" to the use of fossil fuels.
  - In SE Europe, **economic development**, largely based on the utilization of indigenous lignite/coal resources, **will have to be reconciled with COP 26 commitments**. Therefore, the planning of clean-cut and compatible long-term energy and economic strategies becomes a real challenge.
    - A lot more analytical and assessment work (e.g. examine CCS/CCU options) needs to be undertaken before introducing realistic policies for decarbonisation.

Decarbonisation and Related Technologies

The road to decarbonisation can be approached at two levels:

- through **policy**, which incorporates the energy mix issue and economic assessment through which the rate of decarbonization is determined.
  - The main question arising therefore is **how the rate of decarbonization can be related to economic development and what the investment implications are** and

- through **technology**, whose degree of deployment depends on the policies to be implemented and could contribute significantly towards decarbonisation through, for instance, the use of CCS/CCU or dual-fuel power plants.

What are the Benefits of Further Electrification?

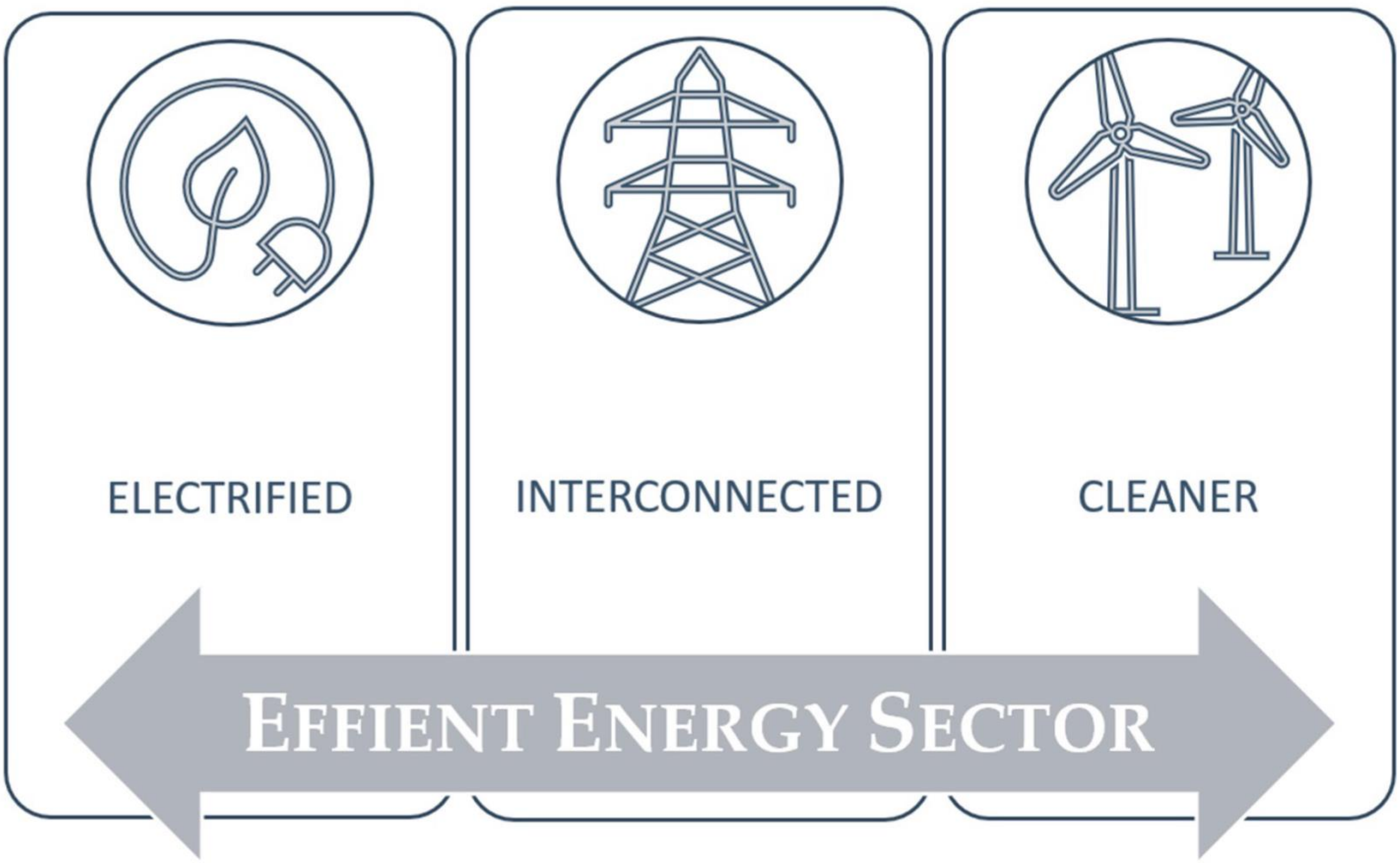
The main benefit of electrification is a reduction of greenhouse gas emissions in all sectors, which contributes to combating climate change. Greater use of electricity will also enable:

- Improvements in air quality, greater use of electric vehicles and a reduction in the use of heating systems that generate greenhouse gas emissions.
- An increase in the number of smart homes and offices. Electrical appliances to increasingly allow greater digitalisation using the latest technologies. Digitalisation not only provides greater flexibility and convenience, it also improves efficiency and reduces time and costs.
- Savings on our bills. Renewables are the most economical source of electricity available. With an increase in generation from renewable sources, the cost on the bill paid by consumers will decrease.
- Jobs to be generated.

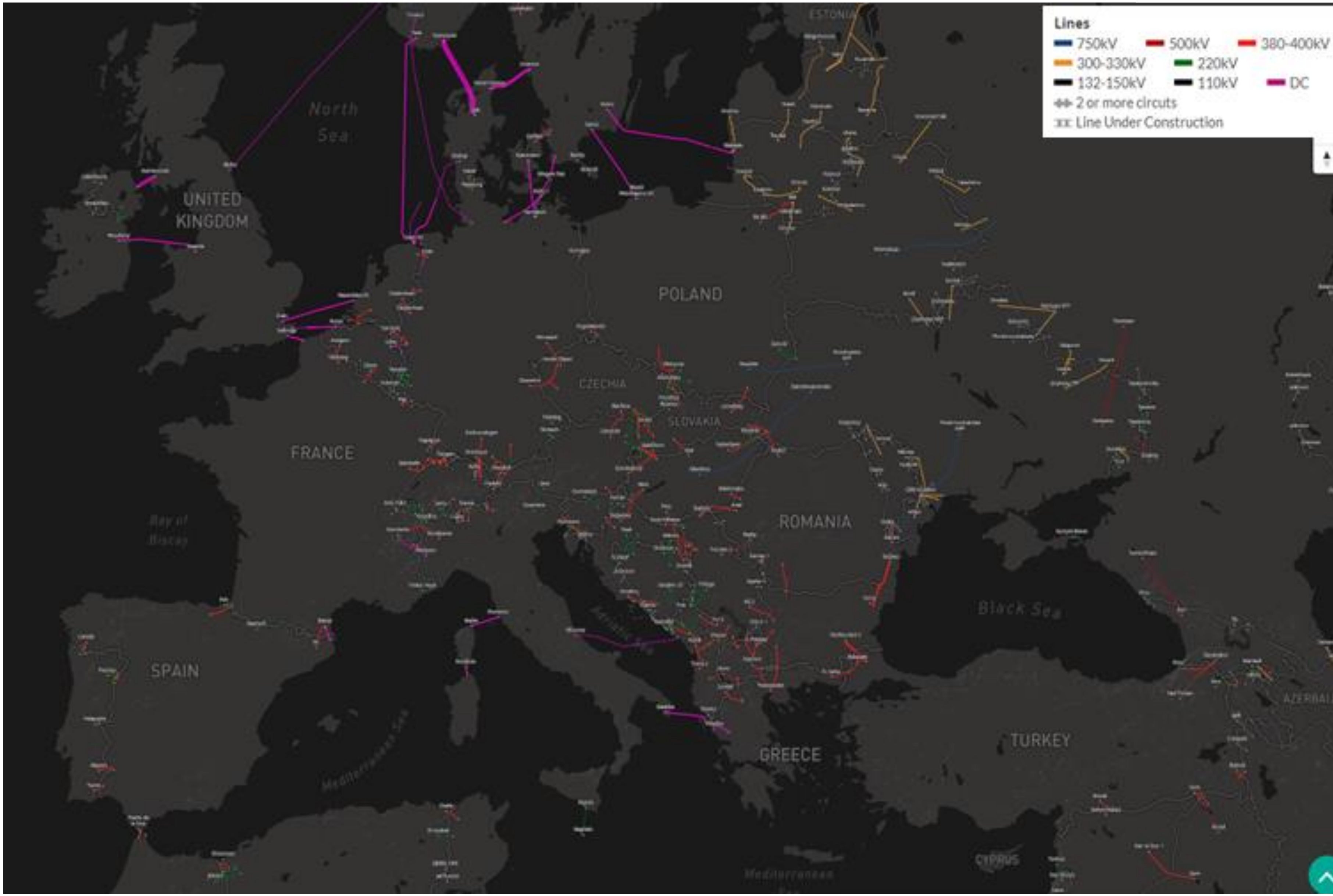
The Importance of Electricity Grids

- As we move towards greater RES penetration, we are also moving towards greater electrification
- Greater electrification means (which happens gradually) more expanded electricity grids.
- More expanded electricity grids means technological upgrading to allow more efficient management of electricity flows
- Technological upgrading means constant attention to grid requirements and consumer trends and the need for versatility in design, procurement and installation of infrastructure (i.e. power electronics, smart meters, software, interfaces, etc.)
- All these bring us to the realisation of a totally new operational environment for consumers, transmission operators and autoproducers alike.
- An environment which is already shaping right now as we talk and will soon come to dominate the energy scene.
- Hence, the need for consumer and producer adaptation is paramount.
- As far as our geographical area is concerned in SEE, there are great discrepancies between countries with some more advanced than others.
- Accelerated electrification, which is the objective in order to accommodate more inputs from a multitude of autoproducers, poses certain key challenges, which range from security of energy supply to management and funding issues.

Characteristics of the Energy System to Achieve the Decarbonization of the Energy Sector



Electricity Interconnections in Europe



Source: ENTSOe Grid Map

The State of Electricity Grids in SE Europe

- The SEE region is in need of more and better electricity interconnections, something which is especially visible in island regions, such as Greece and Cyprus.
- Advancing international electricity interconnections, especially between Italy and Western Balkans and between mainland Greece and the Israel-Cyprus-Crete axis, is becoming a priority in view of the fast advancing electricity market integration in the region.
- Of great significance are the developments regarding the electricity interconnections of the islands with the power grid in mainland Greece, and improved cross-border interconnections that will enable the national electricity transmission system to cover the requirements of the new targets for RES penetration and the incorporation of energy storage systems by 2030.
- Currently, planned projects for cross-border electricity infrastructure in SE Europe are critical both to prevent market congestion and to enable the integration of electricity from RES, but their impact is more clearly visible after 2030.
- The promotion of the use of hybrid stations with RES, i.e. RES and storage, is another solution in cases where the electricity interconnection of the islands is not economically viable, but such stations will have to be assessed as to technical and economic factors and compared to the existing situation, and their installation and operation can be promoted only if it is ensured that power generation costs are reduced in total in the autonomous system involved each time and as compared to other mature solutions.
- The so-called peripheral countries are playing an increasingly more influential role in the channeling of energy flows into the SEE region. Hence, there is a continuous need for the upgrading of international electricity interconnections.

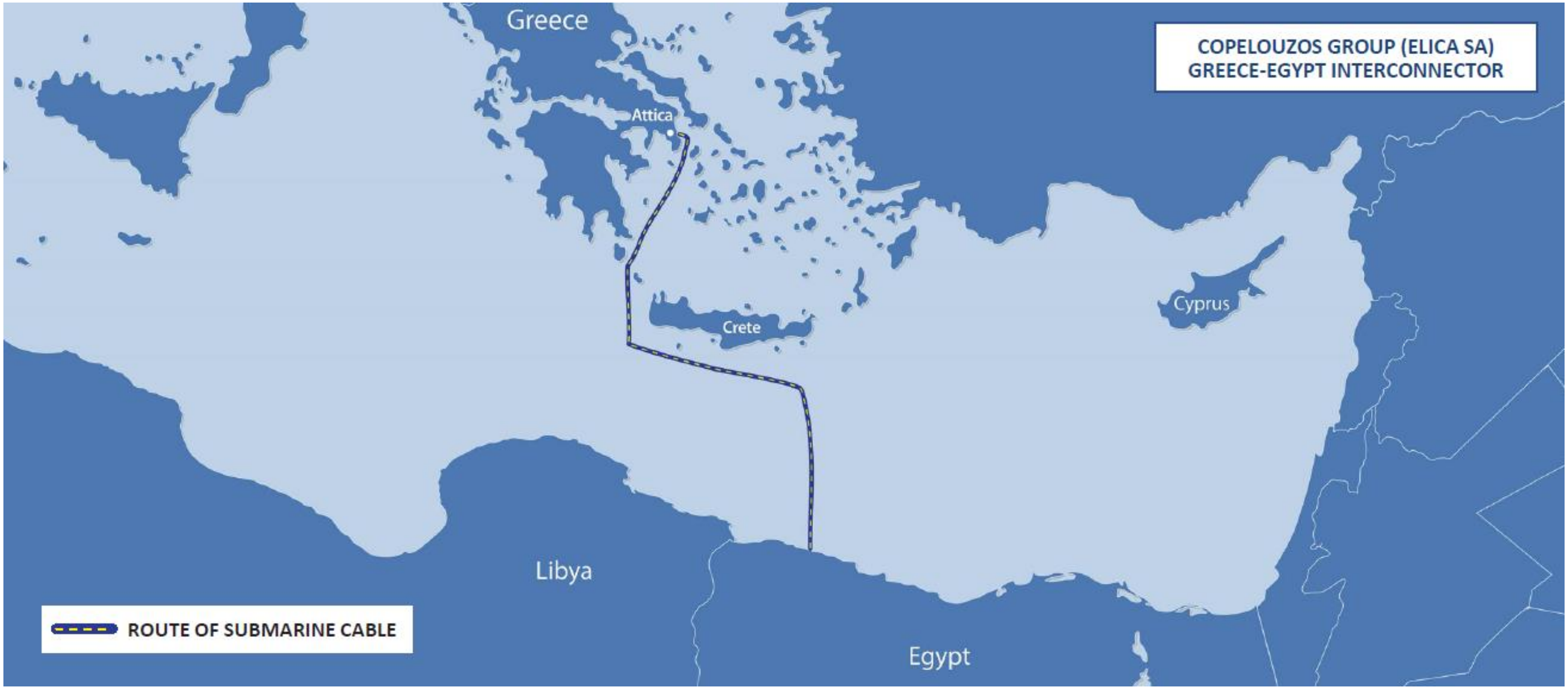
Electricity Interconnections in SE Europe

Source: IPTO's Ten Year Network Development Plan 2023-2032

EuroAsia Electricity Interconnector

Source: EuroAsia Interconnector

Greece-Egypt Electricity Interconnector



Source: ELICA Group

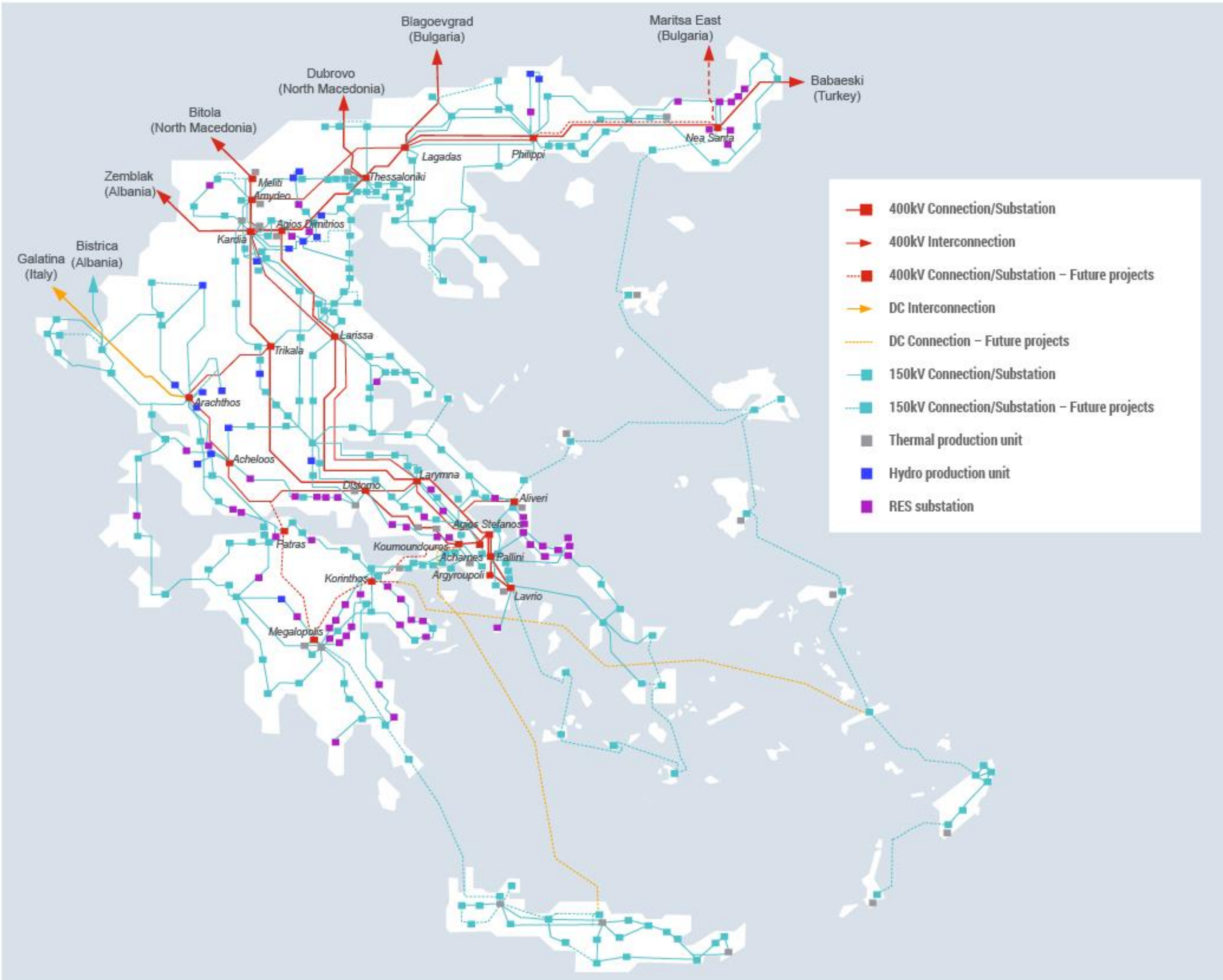
Electricity Interconnections and Energy Storage

- As electricity interconnections increase in Greece's mainland and islands, it is estimated that the penetration of renewable energy sources and hence the energy storage needs will rise.

- In Greece, important electricity interconnection projects are progressing, such as in the Cyclades, the NE Aegean and the Dodecanese, while the most important project is the interconnection of the mainland with Crete, which is being carried out in two phases: (a) the small interconnection of Crete-Peloponnese (completed) and (b) the large interconnection of Crete-Attica, which is expected to be completed in the first half of 2023.

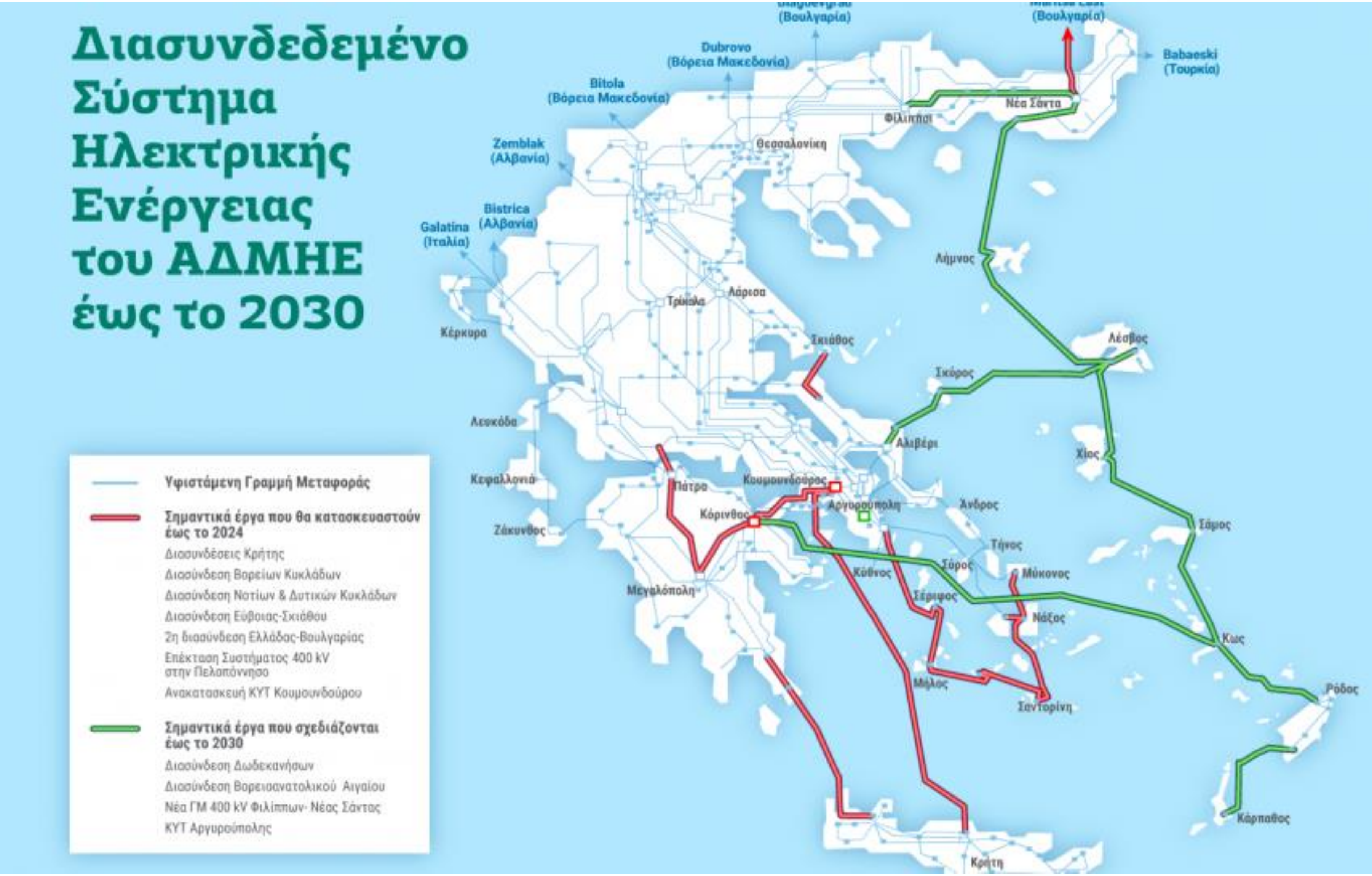
- Despite the extensive electricity interconnections in the islands, there will be 40 non-interconnected small islands for many years to come. These are suitable for the installation of integrated clean electricity systems, using batteries and RES, with the possibility of ensuring energy autonomy of 95%.

Domestic and Cross Border Electricity Interconnections in Greece



Source: IPTO

IPTO’s Electricity Interconnected System By 2030



Source: IPTO

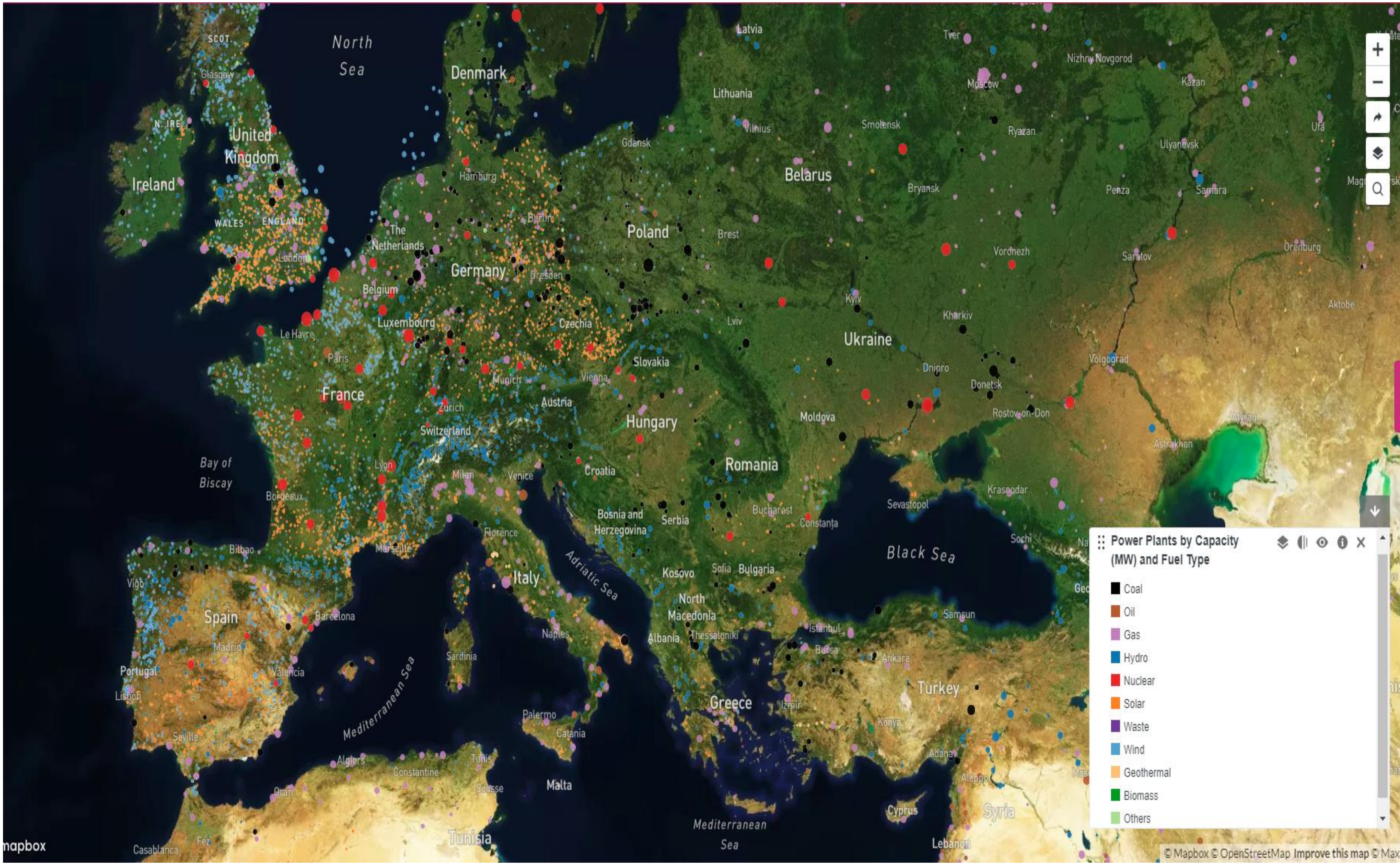
Electricity Interconnections in the Cyclades Islands

Source: IPTO

Electricity Interconnections of the Mainland with Crete

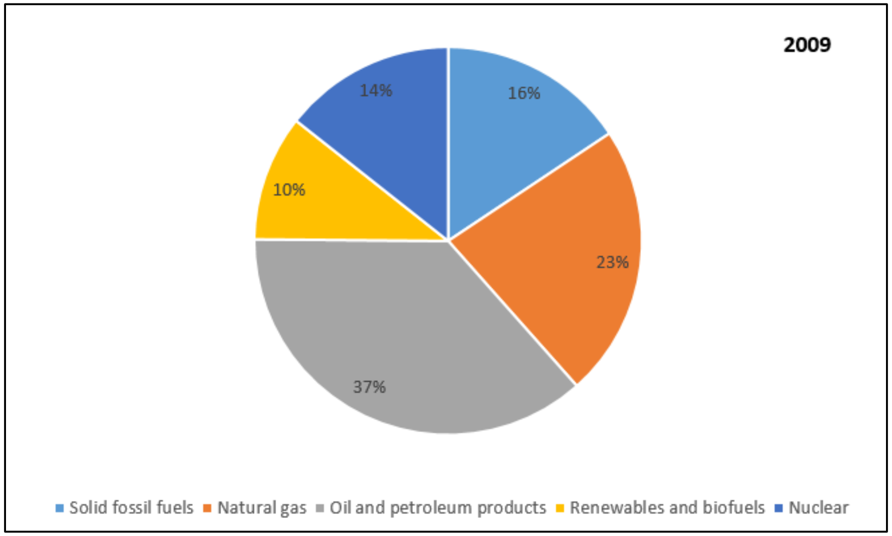
Source: Ariadne Interconnection

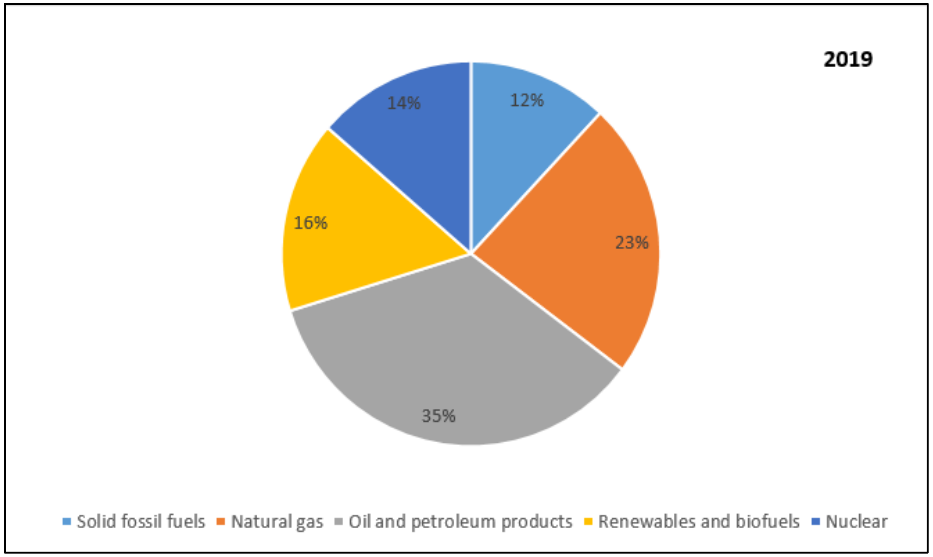
Power Generation Plants in Europe



Source: Resource Watch

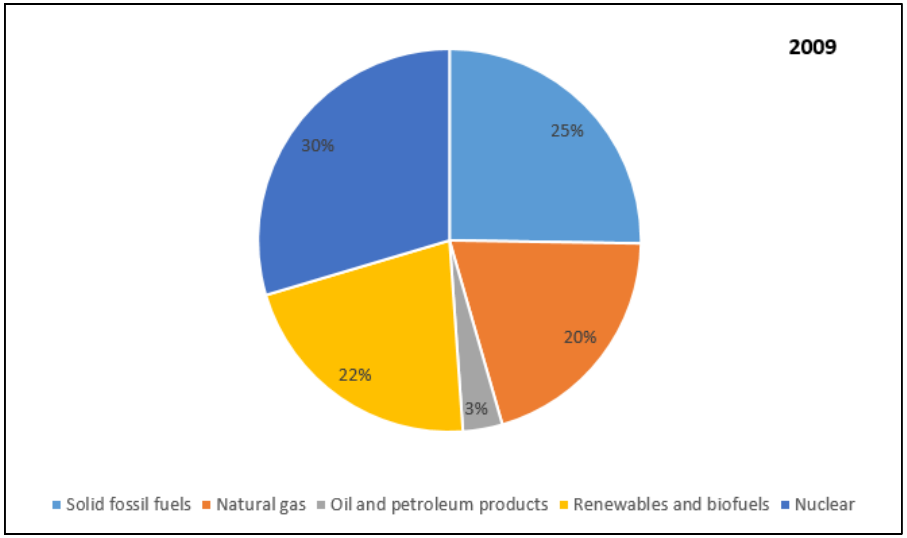
Energy Mix in EU-27 (2009 and 2019)

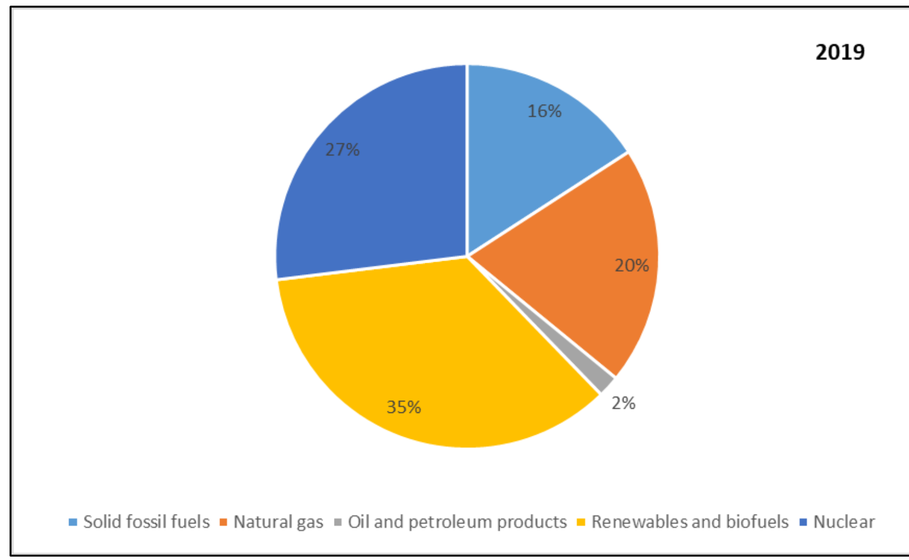




Source: IENE study "SE Europe Energy Outlook 2021/2022", Athens, 2022

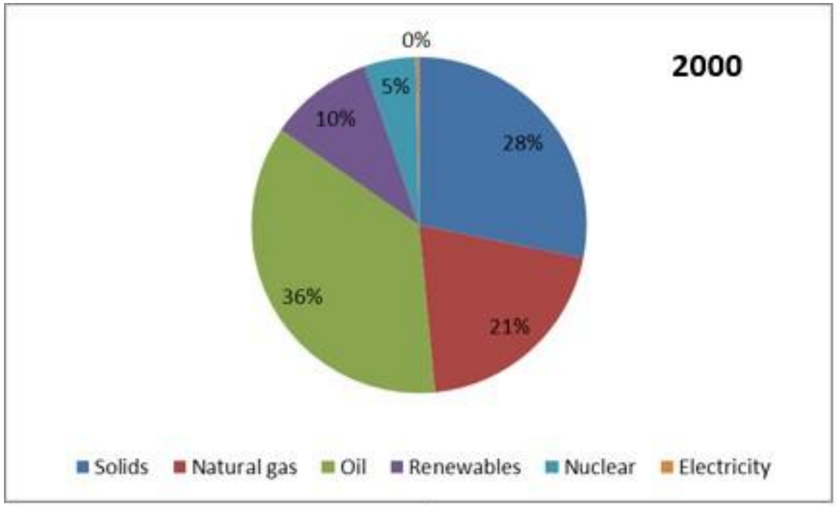
Electricity Mix in EU-27 (2009 and 2019)

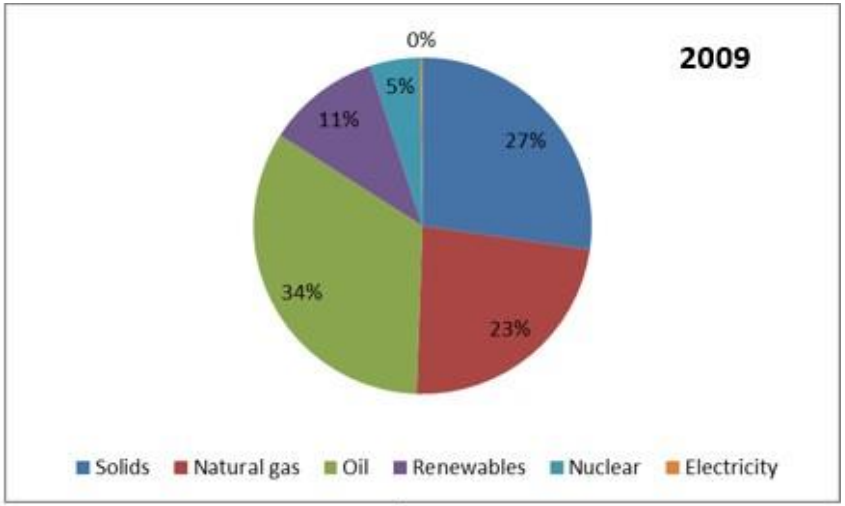


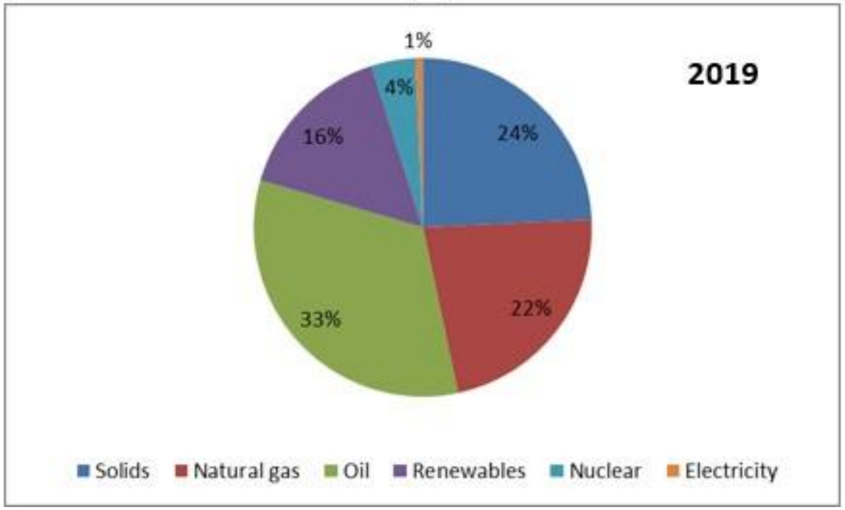


Source: IENE study “SE Europe Energy Outlook 2021/2022”, Athens, 2022

SE Europe's Energy Mix, **Including Turkey**, 2000, 2009 and 2019

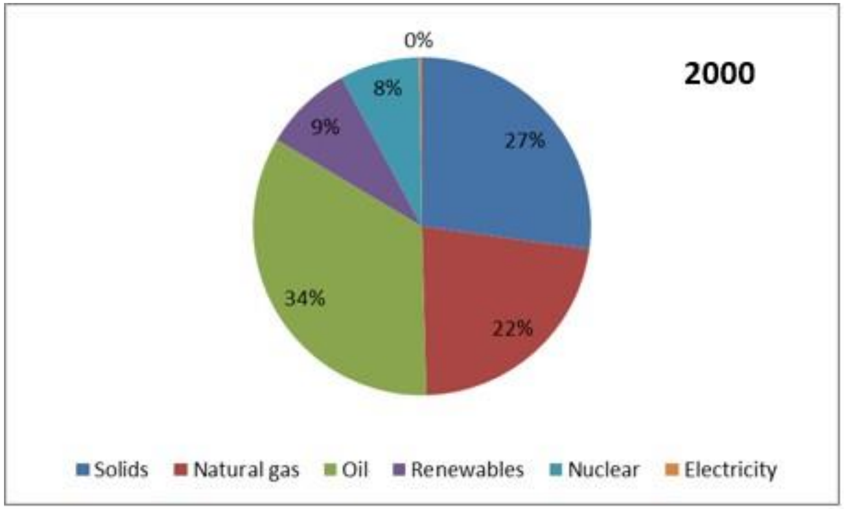


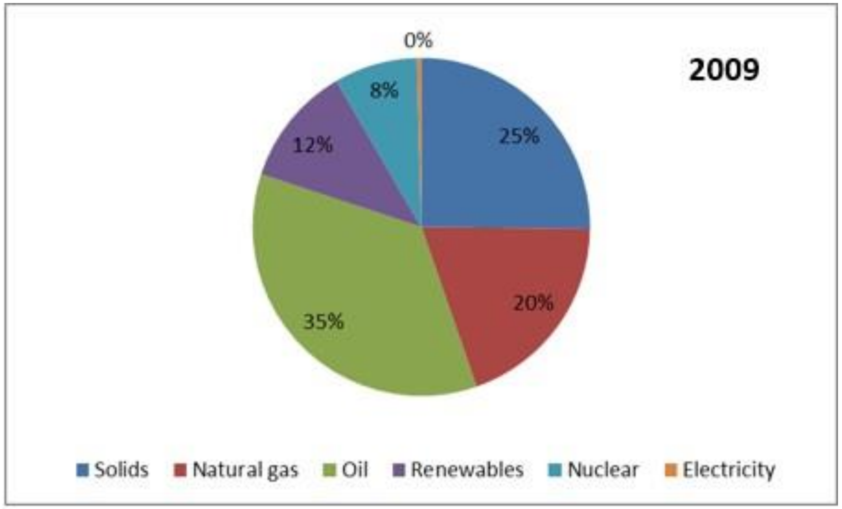


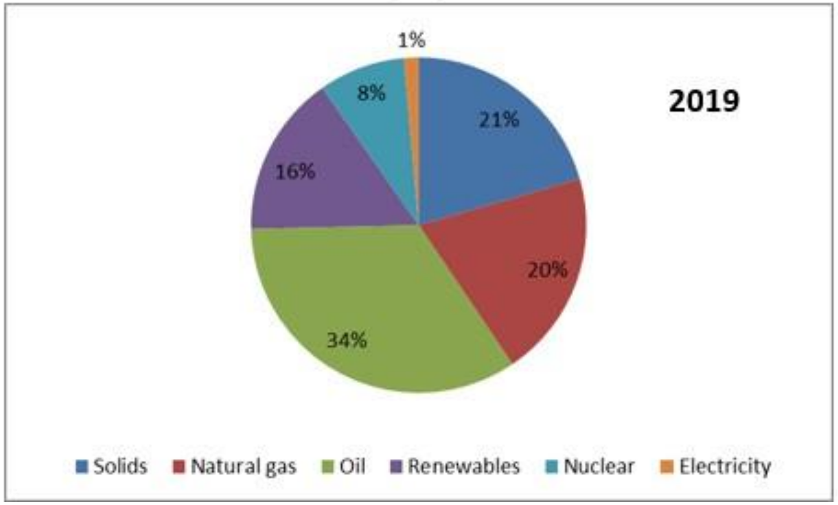


Source: Eurostat

SE Europe’s Energy Mix, **Without Turkey**, 2000, 2009 and 2019

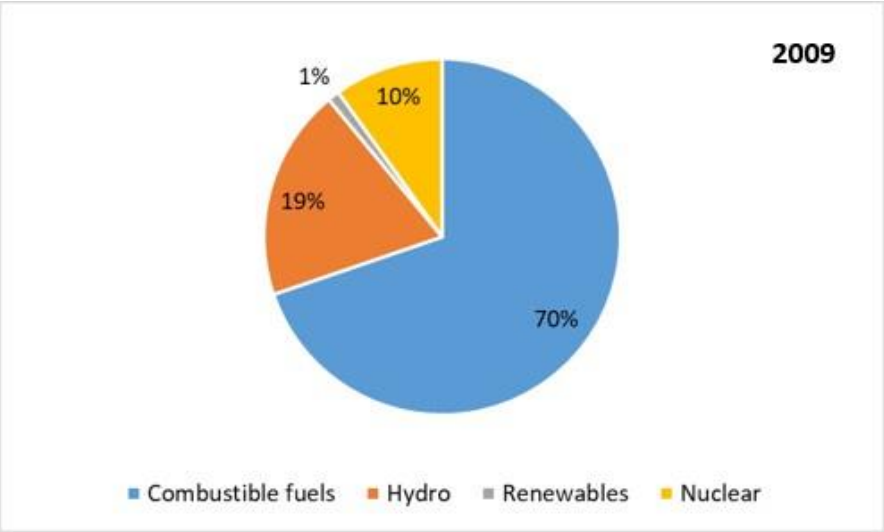


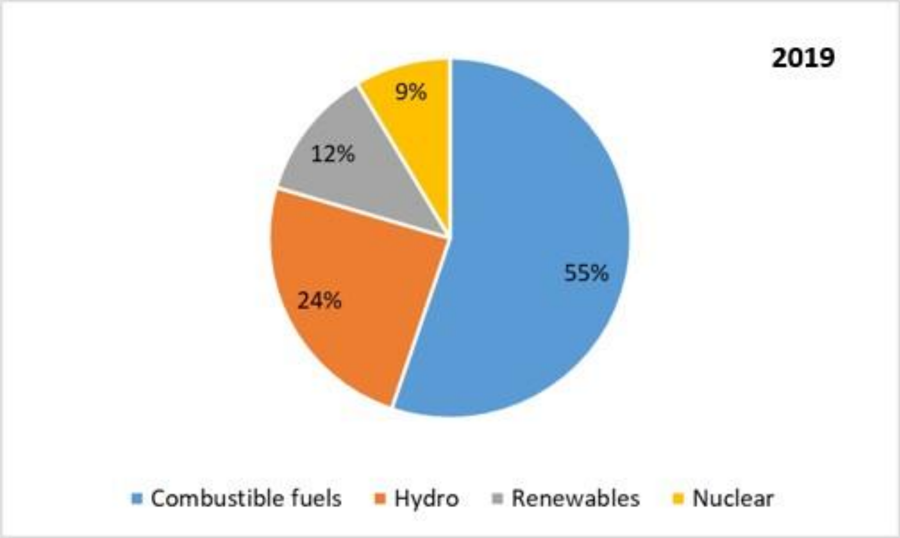




Source: Eurostat

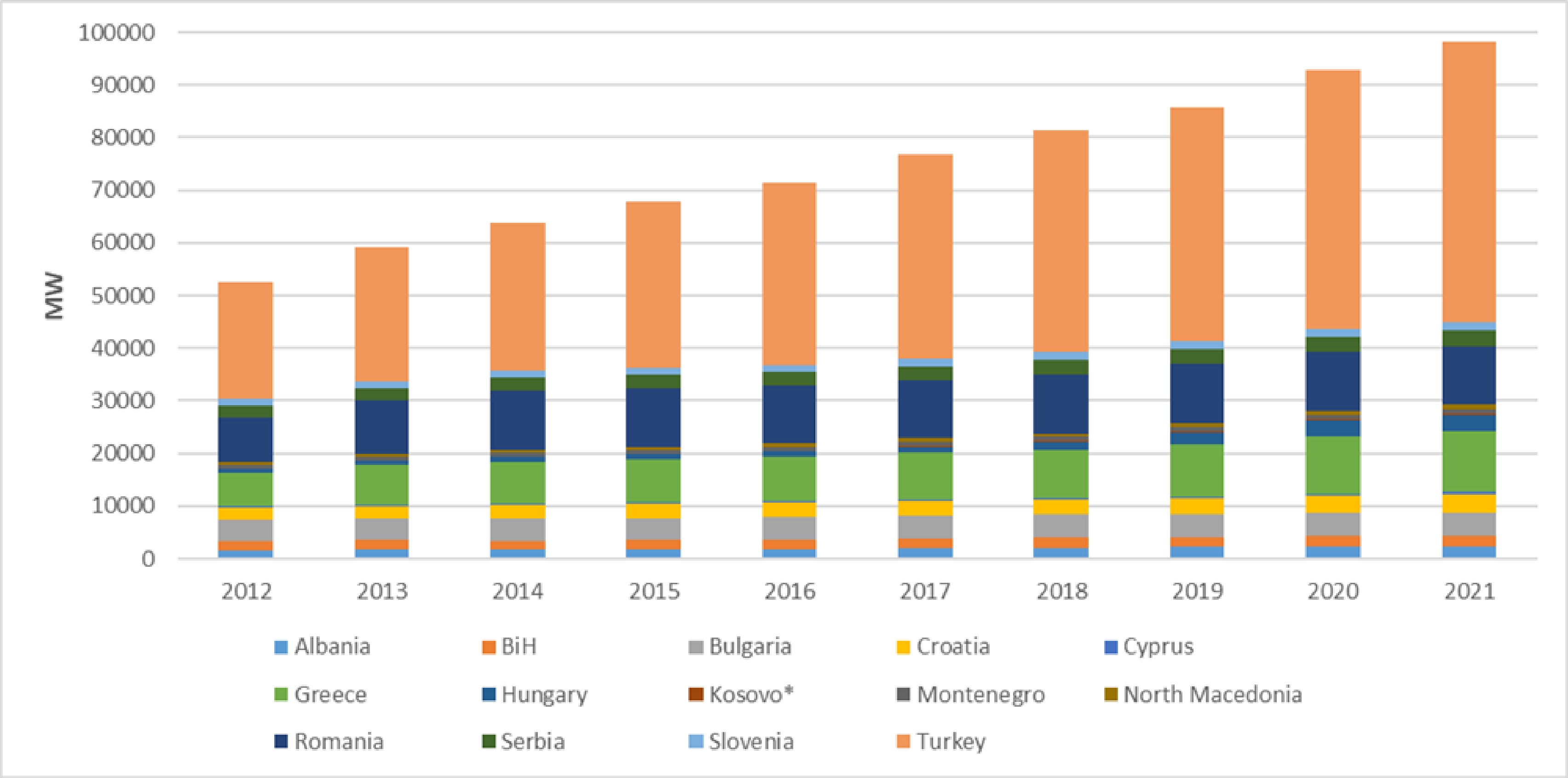
Power Generation Mix per Fuel in SE Europe (2009 and 2019), **Including Turkey**





Source: IENE study "SE Europe Energy Outlook 2021/2022", Athens, 2022

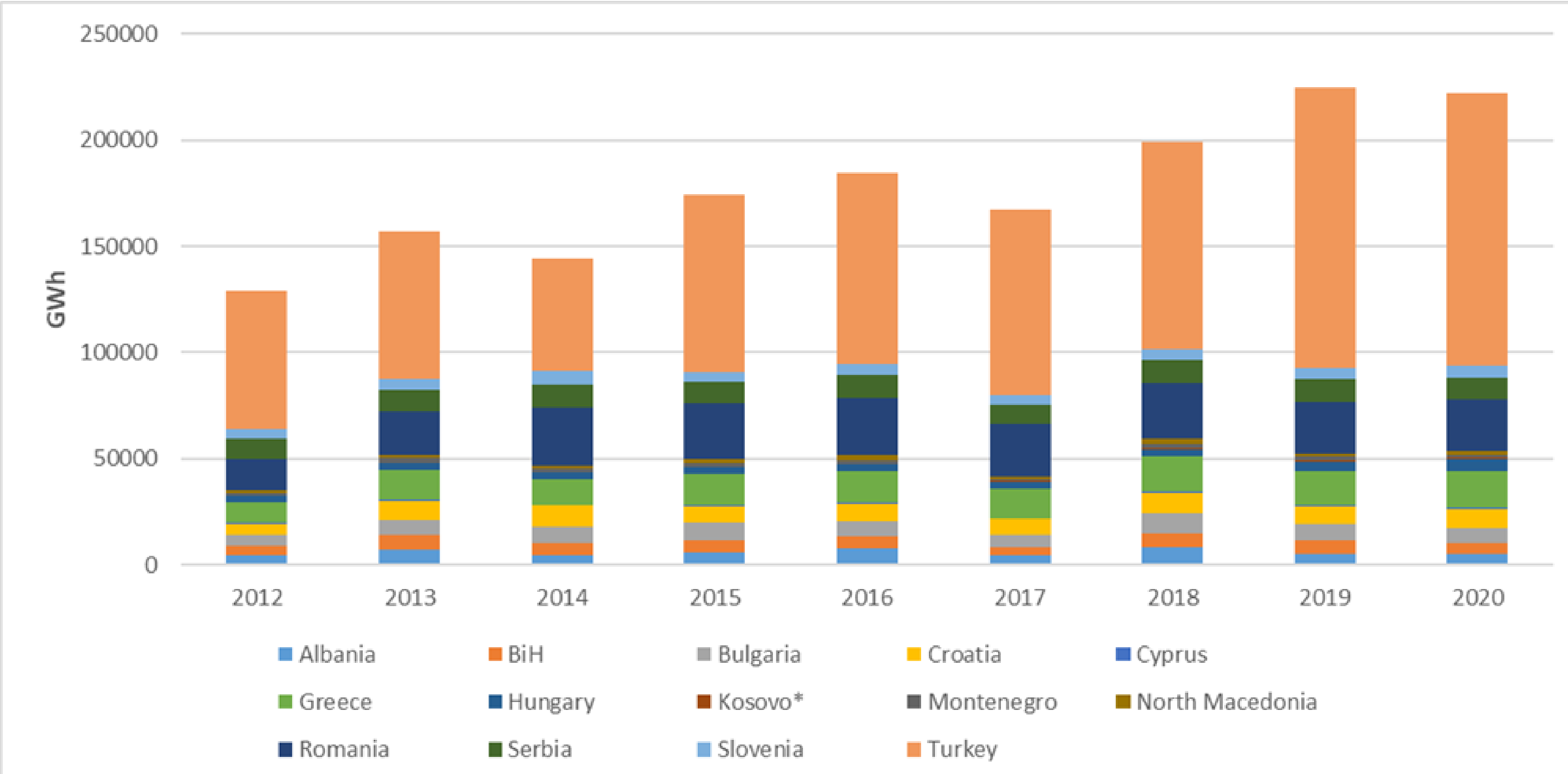
Total Installed Capacity of RES Systems by Country in SE Europe, 2012-2021



Note: *Kosovo is presented separately without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999)

Sources: IRENA, IENE

Power Generation From RES, Including Hydro, by Country in SE Europe, 2012-2020



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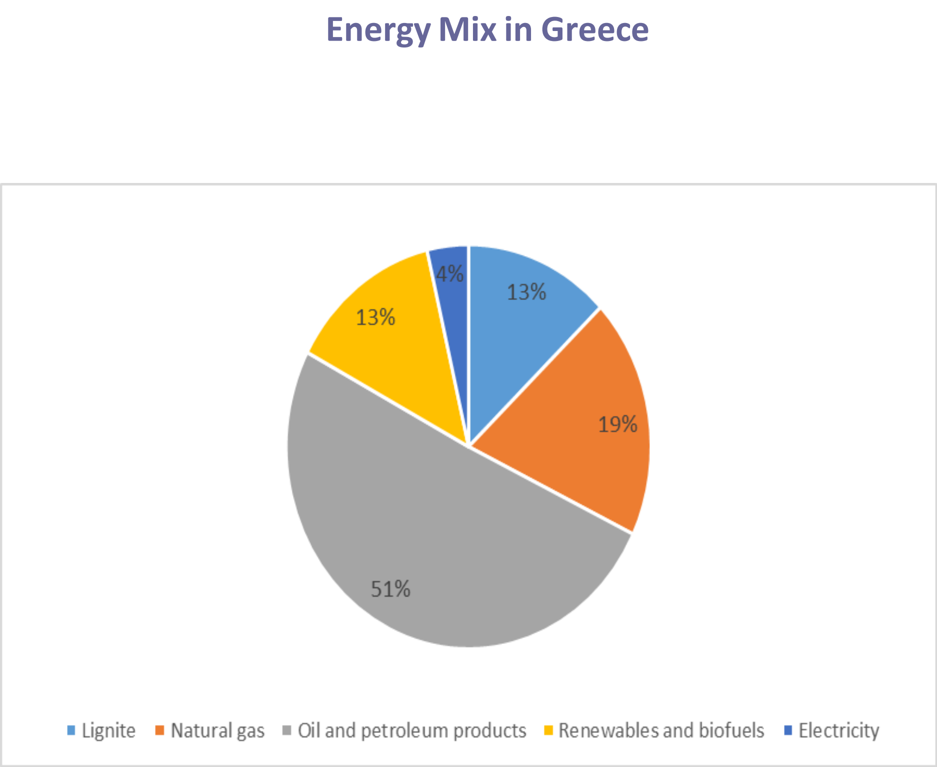
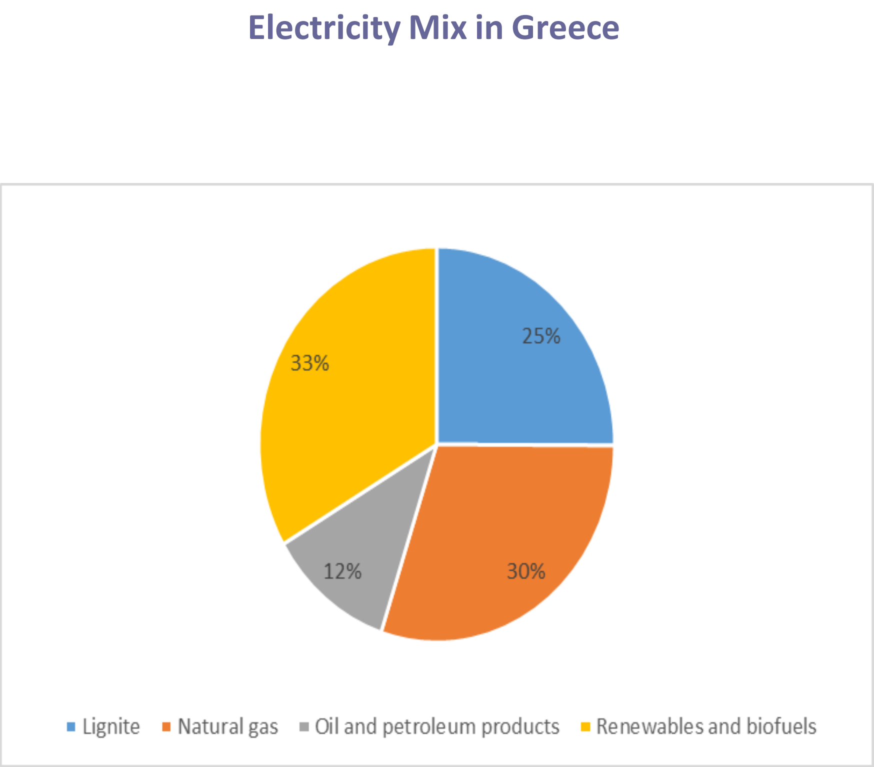
Sources: IRENA, IENE

Energy Mix and Electricity Mix in Greece, 2019

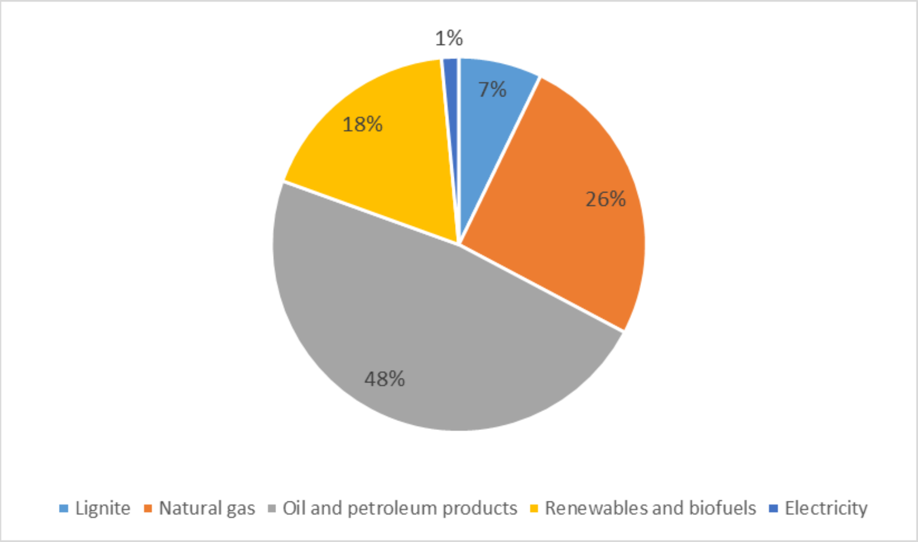




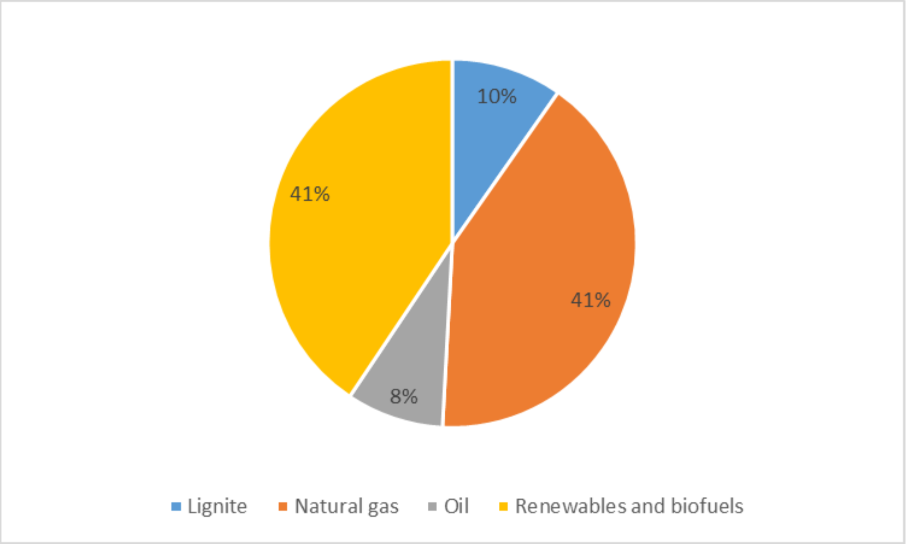
Source: Eurostat

Energy Mix and Electricity Mix in Greece, 2021

Energy Mix in Greece



Electricity Mix in Greece



Source: Eurostat

Huge RES Momentum in Greece

70% RES prior to 2030

1.5 GW storage by 2025

2.5 GW Off-shore Wind

Auctions: RES, Storage, Hybrid

Green Pool

Net-metering

Hydrogen Initiation

Doubling

XB interconnections

LNG > 20 bcm

Revamping Networks

Green Funding

22 bn € :

RRF / RePowerEU +

ESPA+ Islands Fund+

Modernization Fund

Licensing Simplified

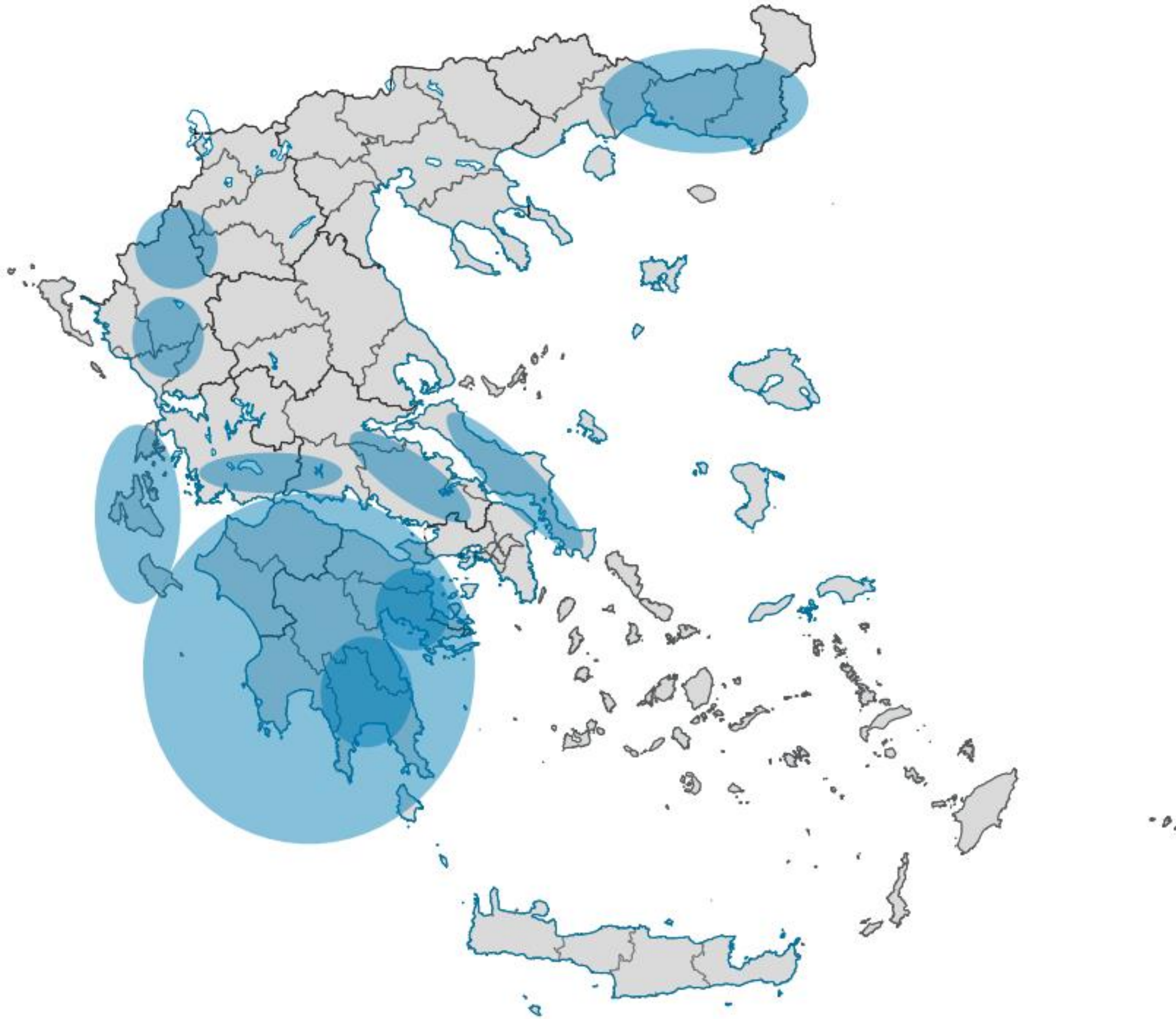
Guarantees

Fair incentives

Energy companies:

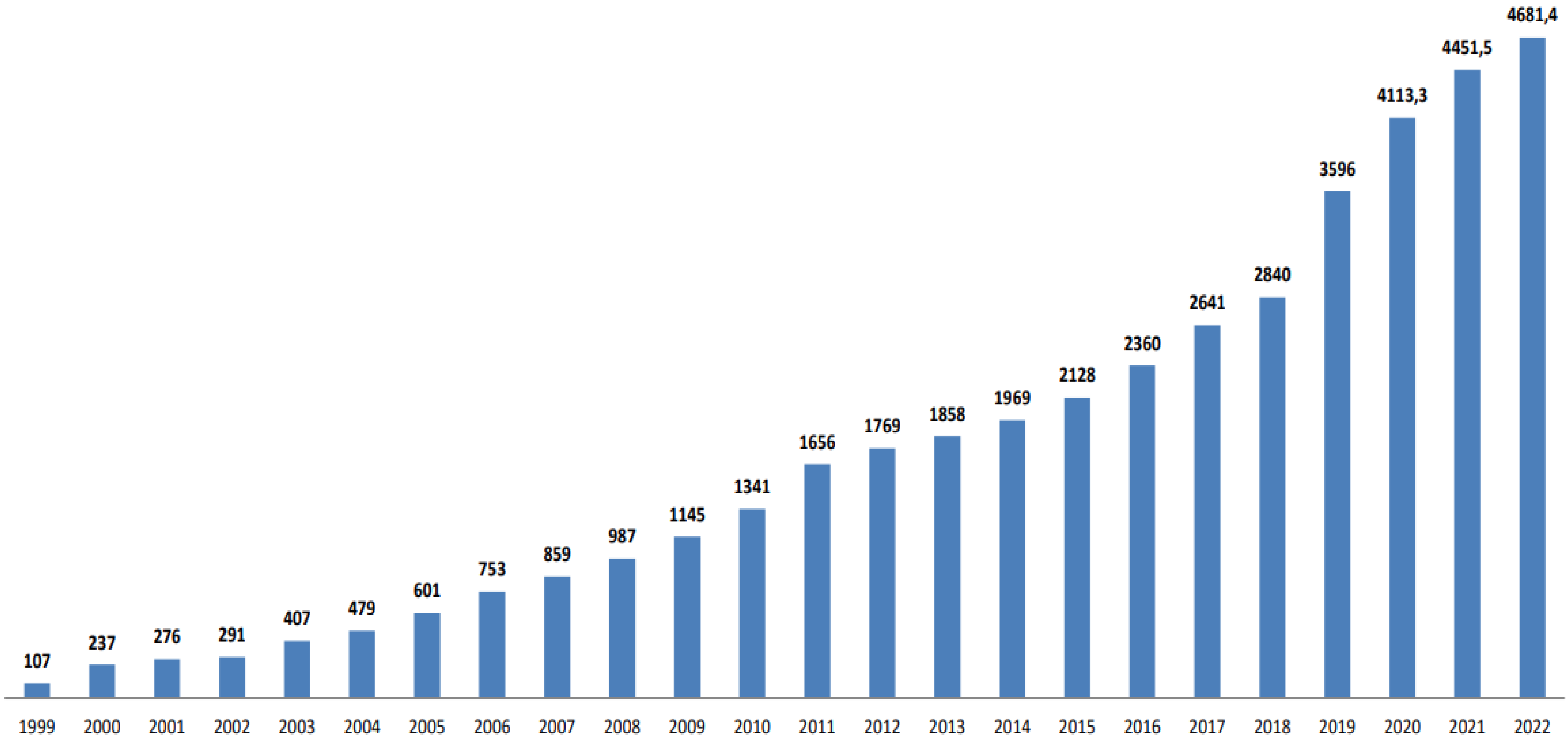
Profound and fast green transformation

Areas with High RES Penetration in Greece's Interconnected System



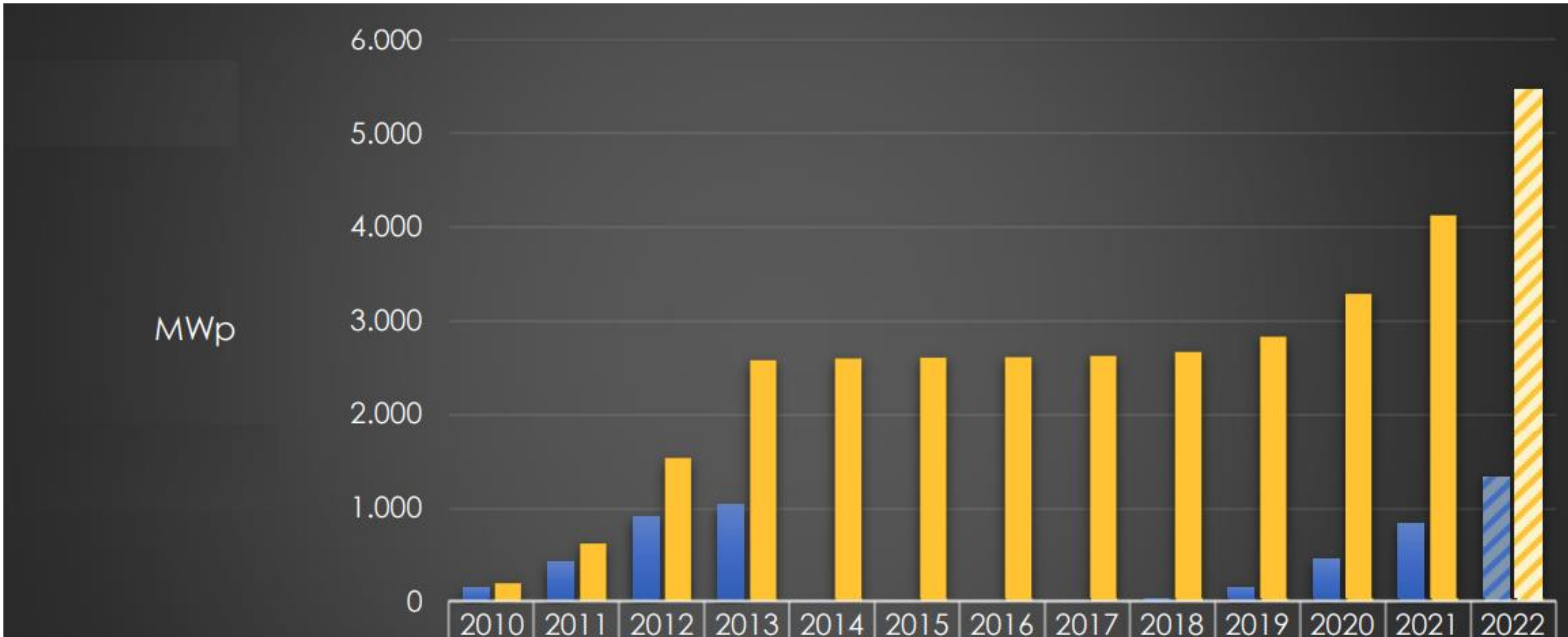
Source: IPTO

Total Installed Wind Capacity (MW) to Greece's Grid, 1999-2022



Source: HWEA

Total Installed Solar PV Capacity (MW) to Greece's Grid, 2010-2022

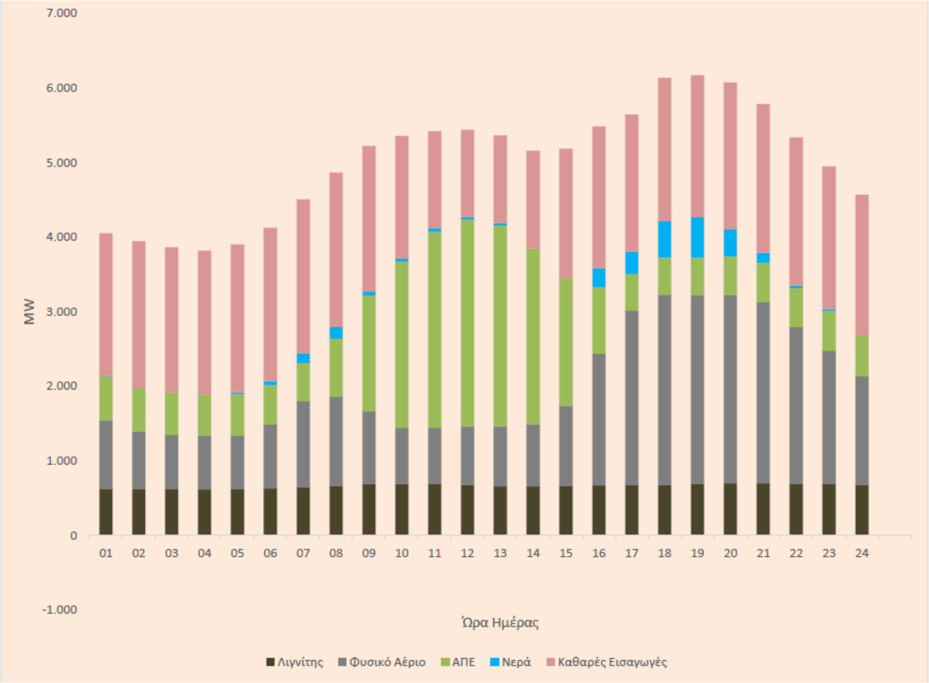


	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Annual installed capacity	152	426	912	1.043	17	10	6	13	43	161	459	838	1.340
Total installed capacity	199	625	1.537	2.579	2.596	2.607	2.612	2.625	2.668	2.829	3.288	4.126	5.466

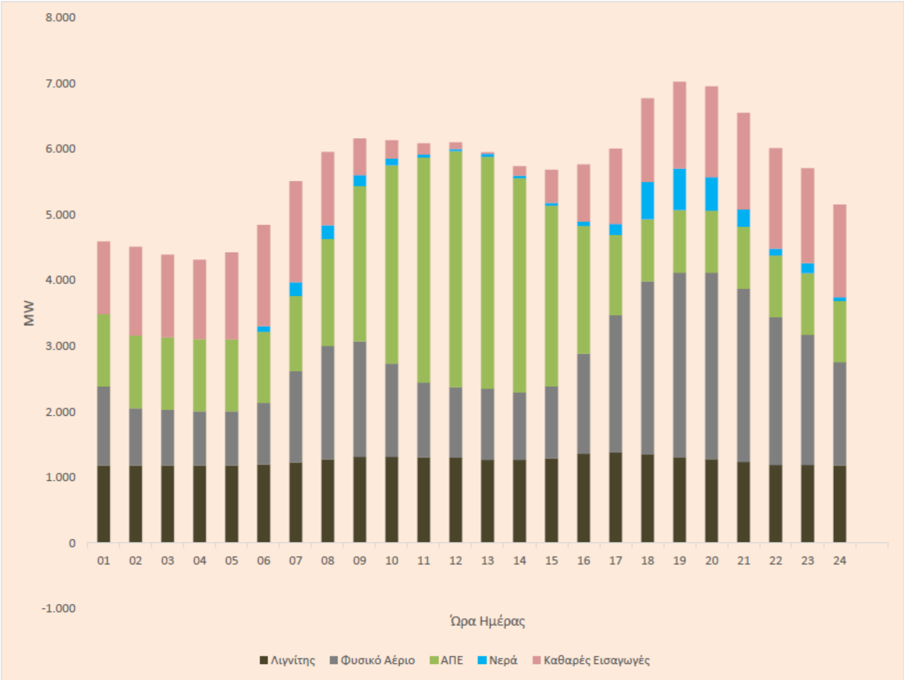
Source: HELAPCO

RES Competing Against Conventional Base Load Power Generation Sources (I)

Fuel Mix per Hour (Week 1: 2023)



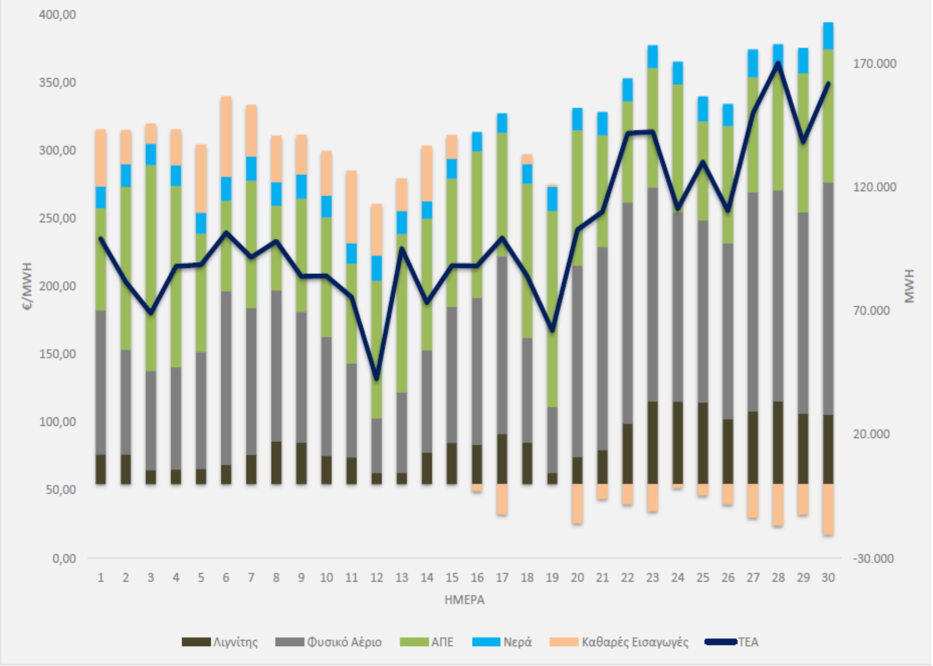
Fuel Mix per Hour (Week 7: 2023)



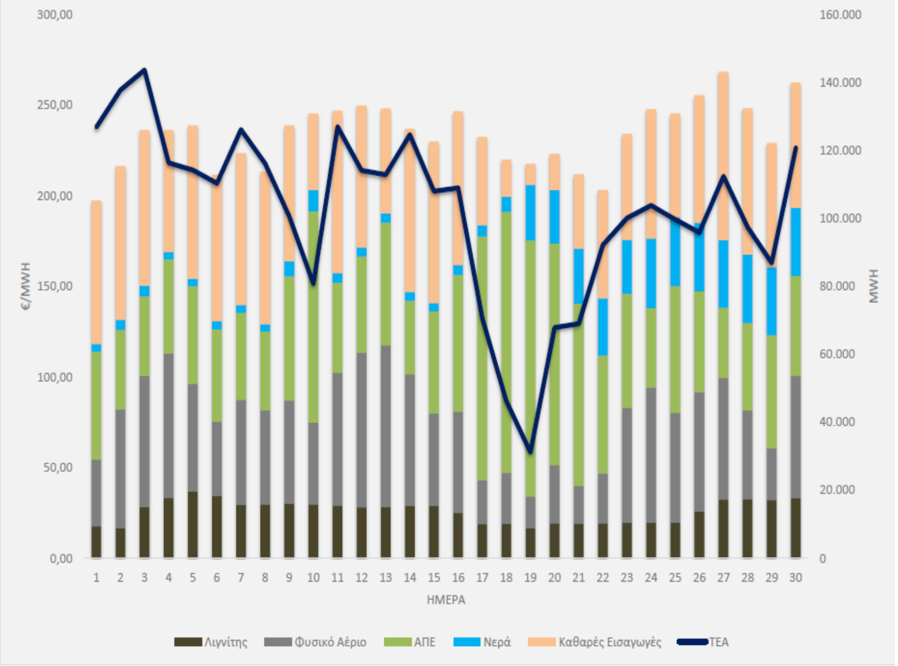
Sources: HENEX, IENE

RES Competing Against Conventional Base Load Power Generation Sources (II)

Fuel Mix per Day (June 2022)

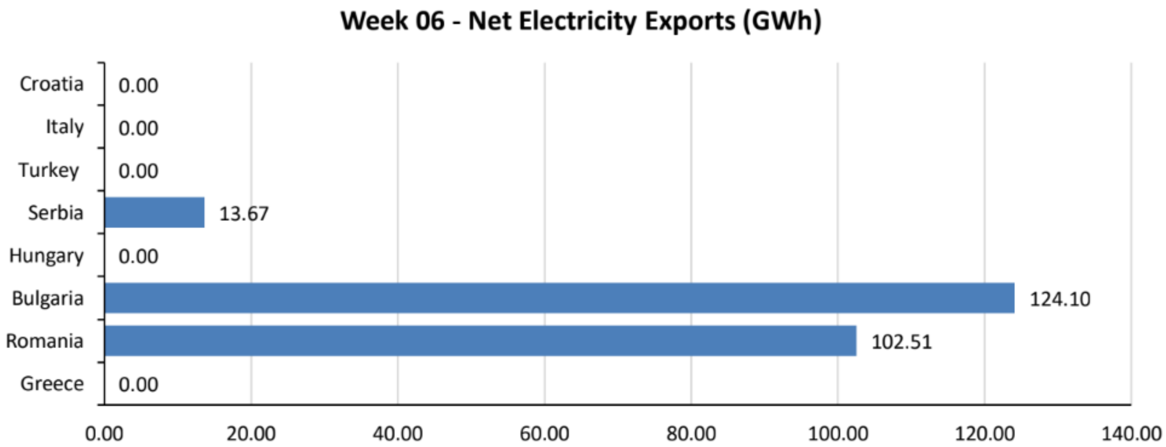


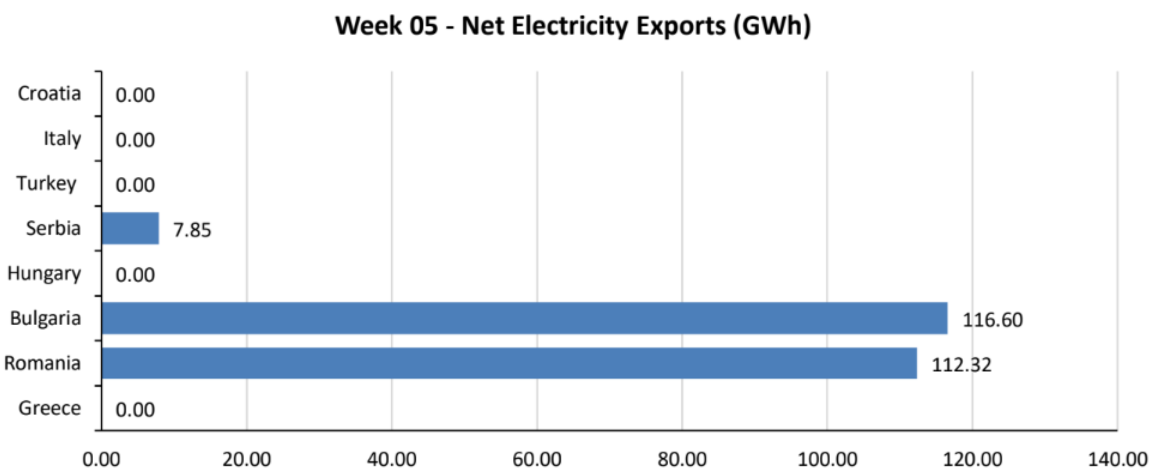
Fuel Mix per Day (January 2023)



Sources: HENEX, IENE

Net Electricity Importers/Exporters in SE Europe

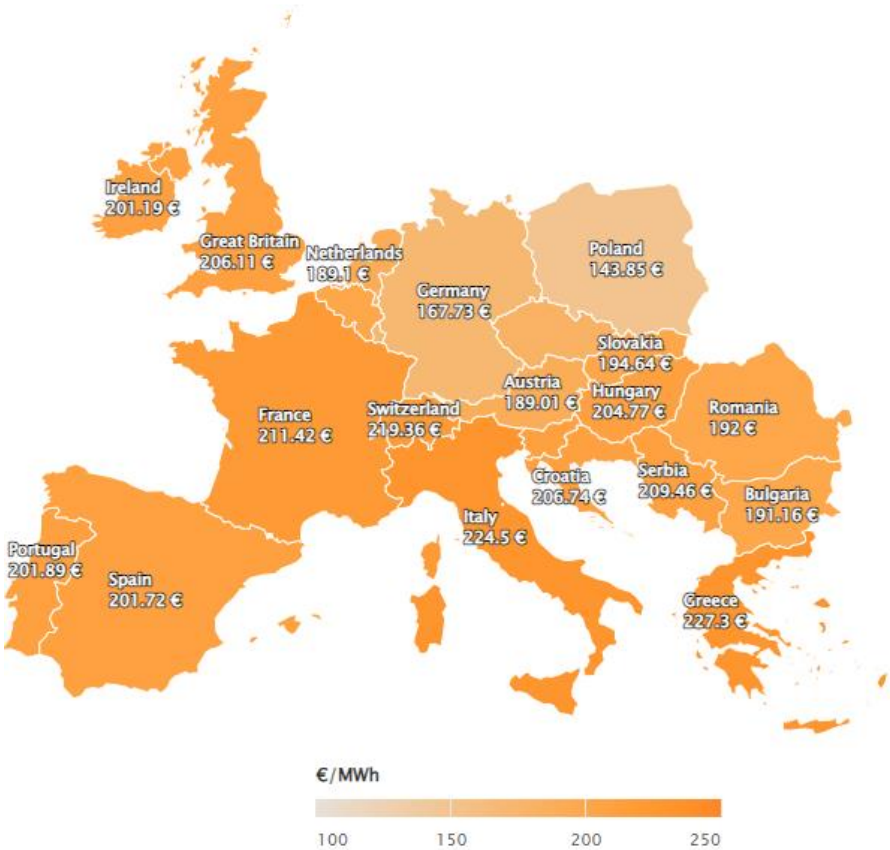




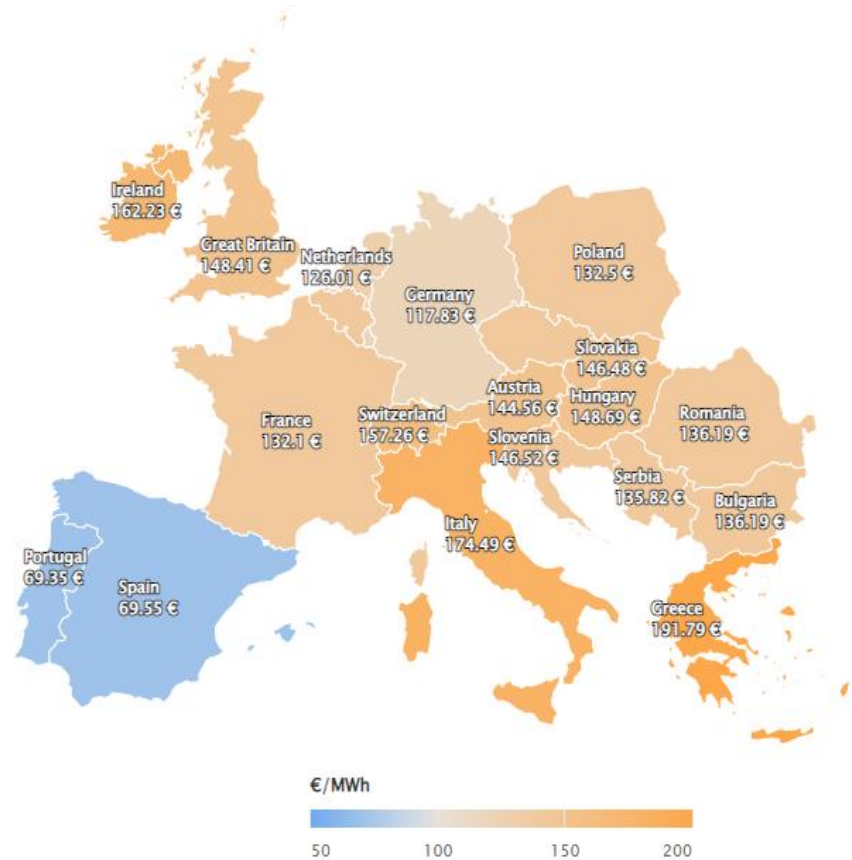
Weeks 5-6, 2023	Net Electricity Importers/Exporters
Croatia	Net importer
Italy	Net importer
Turkey	Net importer
Serbia	**Net exporter**
Hungary	Net importer
Bulgaria	**Net exporter**
Romania	**Net exporter**
Greece	Net importer

European Wholesale Electricity Prices (January 2022 and January 2023)

January 2022

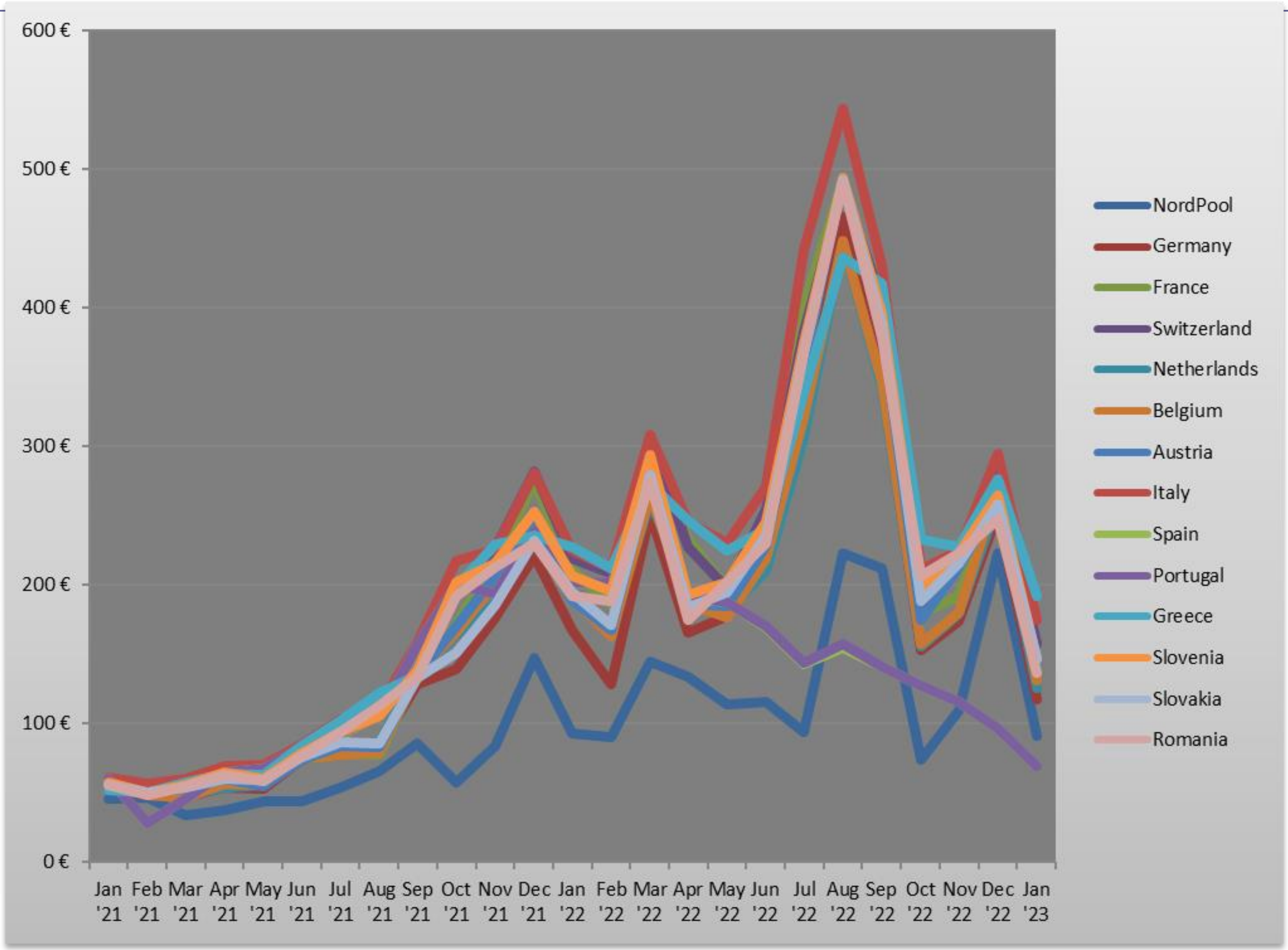


January 2023



Source: Energylive

Variation of European Wholesale Electricity Prices (January 2021 – January 2023)



Source: Data from power exchanges websites

Discussion (I)

- The electricity sector and its infrastructure are the veins and arteries that power modern society. Electricity grids are important in overall electrification effort.

- EU will need to install, approximately 45 GW per year in order to achieve the EU 2030 renewable targets. To meet these targets will involve changes to power system planning and operations.

- **Major challenges:**

  1. Power quality issues: Major power quality issues are voltage, frequency fluctuations, and harmonics. When integrating renewable energy production make the frequency and voltage produced unreliable. Especially weather conditions and time of the day affect continuously the production and the operation of the grids. Voltage and frequency fluctuations are caused by the unpredictable nature of the renewable resourcing thus grid disturbances.

  2. Overloading of existing transmission lines: The variable nature of wind and solar adds problems for balancing supply and demand. During peak hours, the existing transmission face a challenge matching the inflow and outflow of power. The distributed nature of these energy resources adds complexity to the existing grid infrastructure. A surge might occur when producers generate too much power without warning, and the entire system would shut down. A transmission line has a specific capacity, and if this limit gets passed, thermal loads will lead to damage.

  3. Electromobility: Charging vehicles takes a significant amount of time especially when we need to use a supercharger which consumes an extremely large amount of energy. To compare, one full charge using a supercharger equals the launch of 70 air-conditioning units at once. Such an instant change in power demand is a huge problem to the grid. The increasing demand of electrical vehicles adds additional challenges and the grid need to face.

Discussion (II)

- **Proposed solutions:**
  1. **Energy storage:** It plays an important role in balancing grid supply and demand when integrated with RES. Backup sources, such as large lithium-ion batteries storage, offer protection in case of power outages and ensures continuous operation of renewable equipment. Energy storage manages peak loads, improves power quality, manages distributed power generation, and reduces energy import during peak demand periods.
  2. **Microgrids:** The microgrid is a group of energy users that may include solar panels, wind turbines, CHPs that can provide clean RES to reduce GHG emissions. These decentralized solutions, including mini grids and stand-alone systems, are based to a great extent on RES.
  3. **Clean hydrogen:** Many countries are working in developing clean hydrogen produced from wind and solar energy. Clean hydrogen is to play an important role in grid integration. It can manage the oversupply, can capture spare energy and ensures that it doesn't go to waste, through storage such as electrolysers that produce hydrogen. Hydrogen can be stored and used as a fuel or as an energy carrier to balance variable energy flows. Many countries have rolled out policies and targets for boosting the development of hydrogen storage technologies.
  4. **Virtual power plants:** They act as a central entity that combines, manages, and controls distributed energy resources, moving power plants, e.g. EVs, and RES. Electricity is generated by these energy sources and transmitted to the grid. These virtual power plants enable small energy producers to participate in energy markets, net metering, and enhance the grid performance.
  5. **Grid codes:** They ensure that the frequency and voltage variations are not out of balance when a power plant supplies energy to the grid. They need to comply with grid code regulations to be connected to the grid and need to be able to monitor, control and regulate their power output. It is the power plant owners' responsibility to meet the local grid code requirements and control the power output.
  6. **Changing mindsets:** Making the necessary changes to policy, regulation and markets in helping everyone in society shift to a low carbon future.

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