Decarbonisation in SE Europe and the Role of Nuclear Power

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INSTITUTE OF ENERGY
FOR SOUTH EAST EUROPE

The SE European Region Defined

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

Why is SE Europe Important?

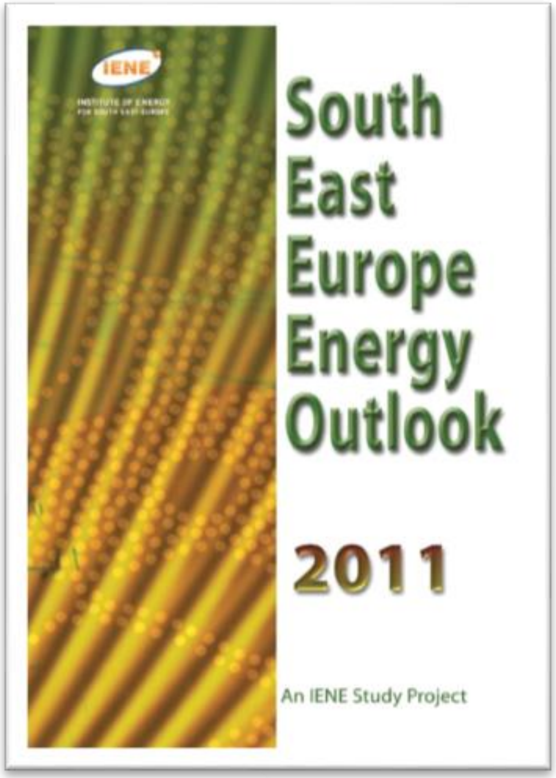
- SEE is a region of **great strategic interest** to the rest of Europe both in the context of political stability and as an energy viaduct.

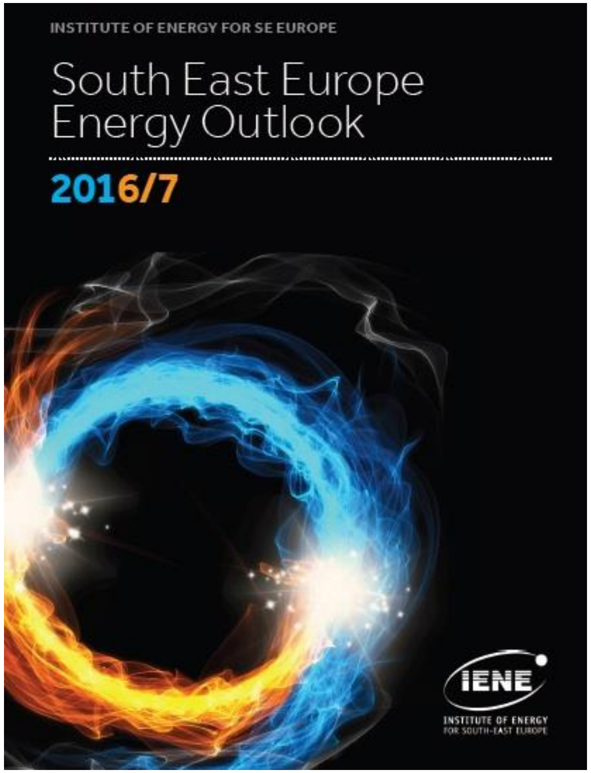
- From an economic perspective, SEE, part of Europe's main land mass, presents **serious investment and business development potential.**

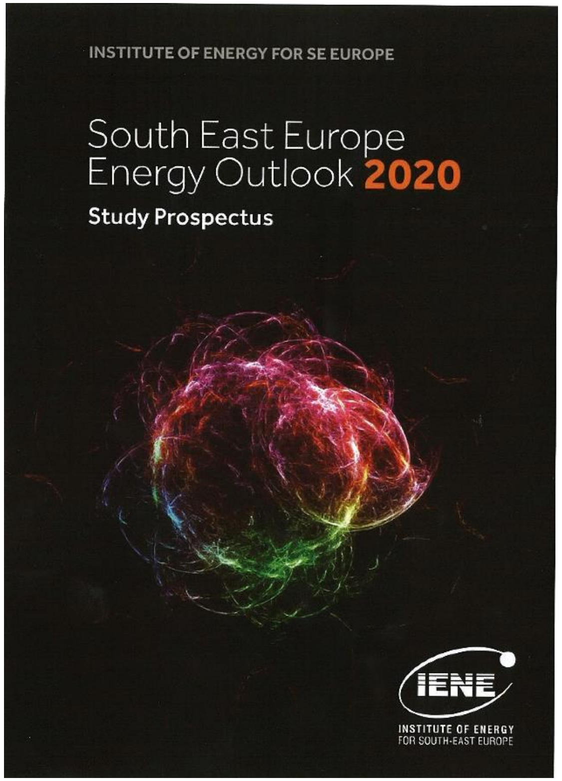
- **Turkey is a case by itself.** Whereas until recently it was widely assumed that it will eventually form part of Europe, such a prospect now looks remote as strong centrifugal forces are at play.

- Hence, the present analysis and energy demand scenarios, related to NPP potential, are confined to the EU countries of SEE and the Western Balkans.

SE Europe Energy Outlook Study

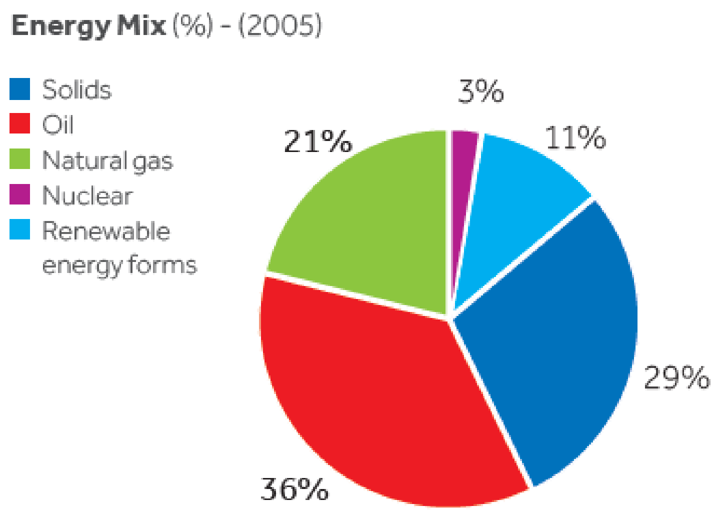


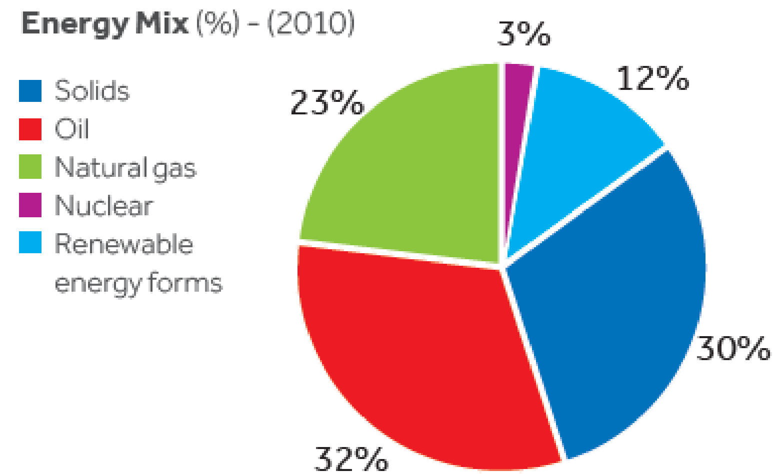


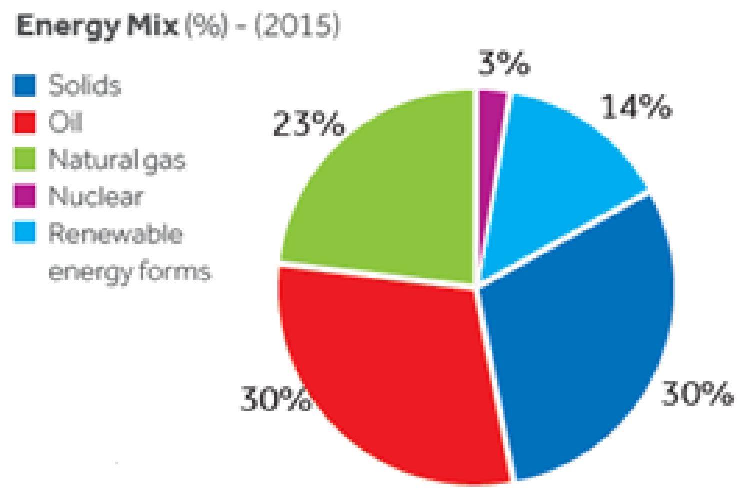


Source: IENE

SE Europe’s Energy Mix, **Including Turkey** (2005, 2010 and 2015)

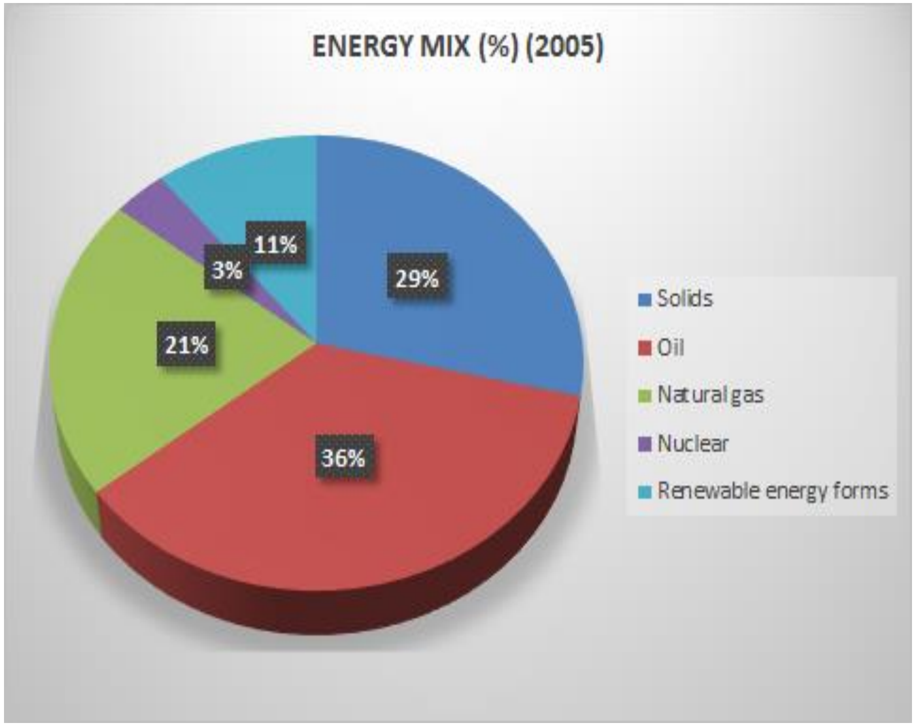


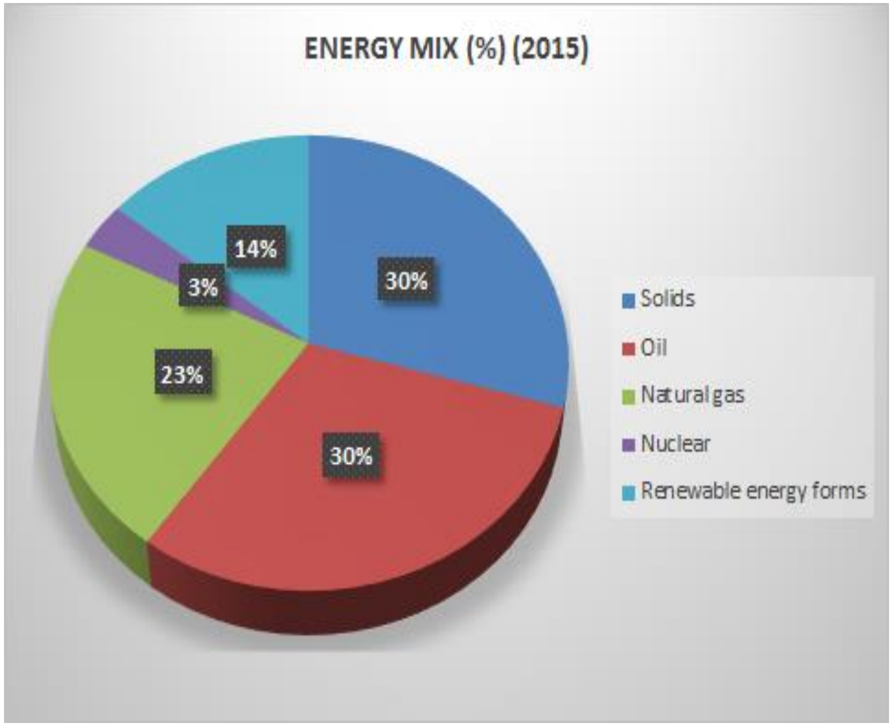




Source: IENE study “South East Europe Energy Outlook 2016/2017”, Athens, 2017

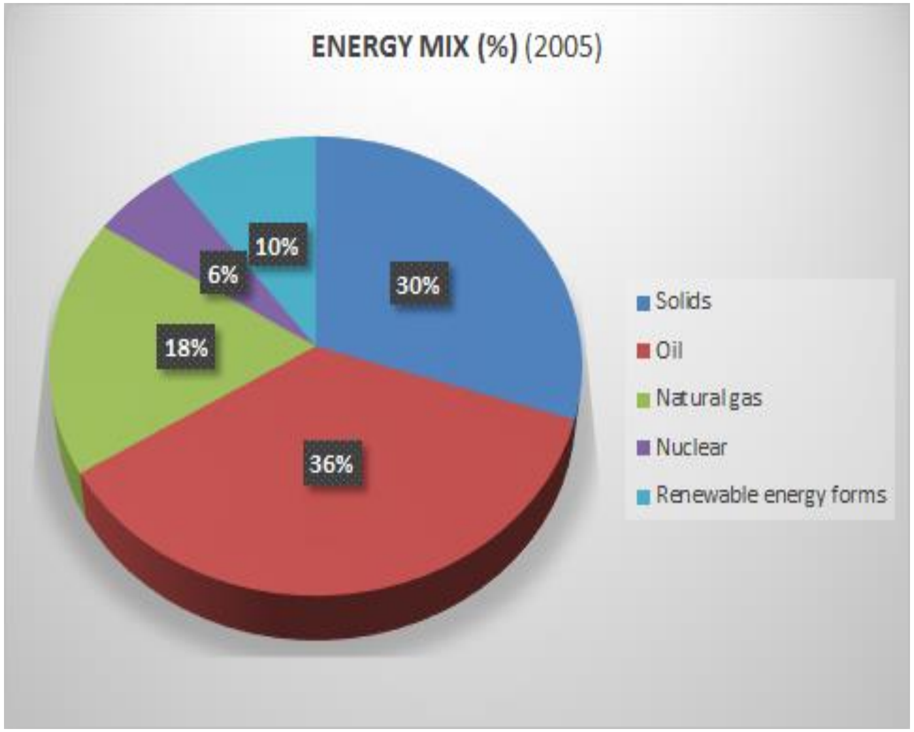
SE Europe: Gross Inland Consumption by Source, **Including Turkey** (2005 and 2015)

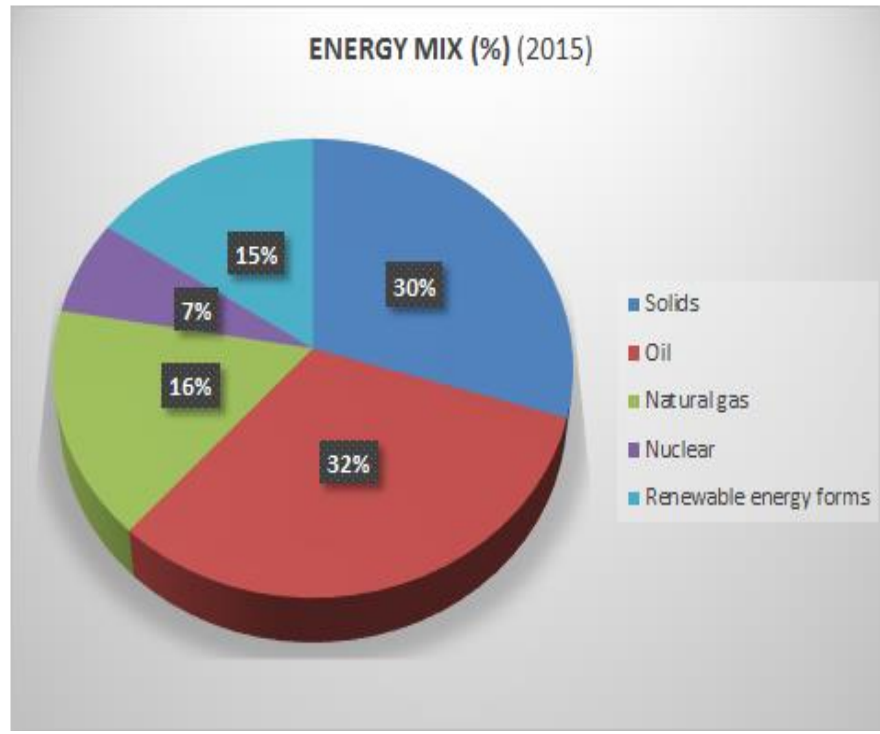




Source: IENE study "South East Europe Energy Outlook 2016/2017", Athens, 2017

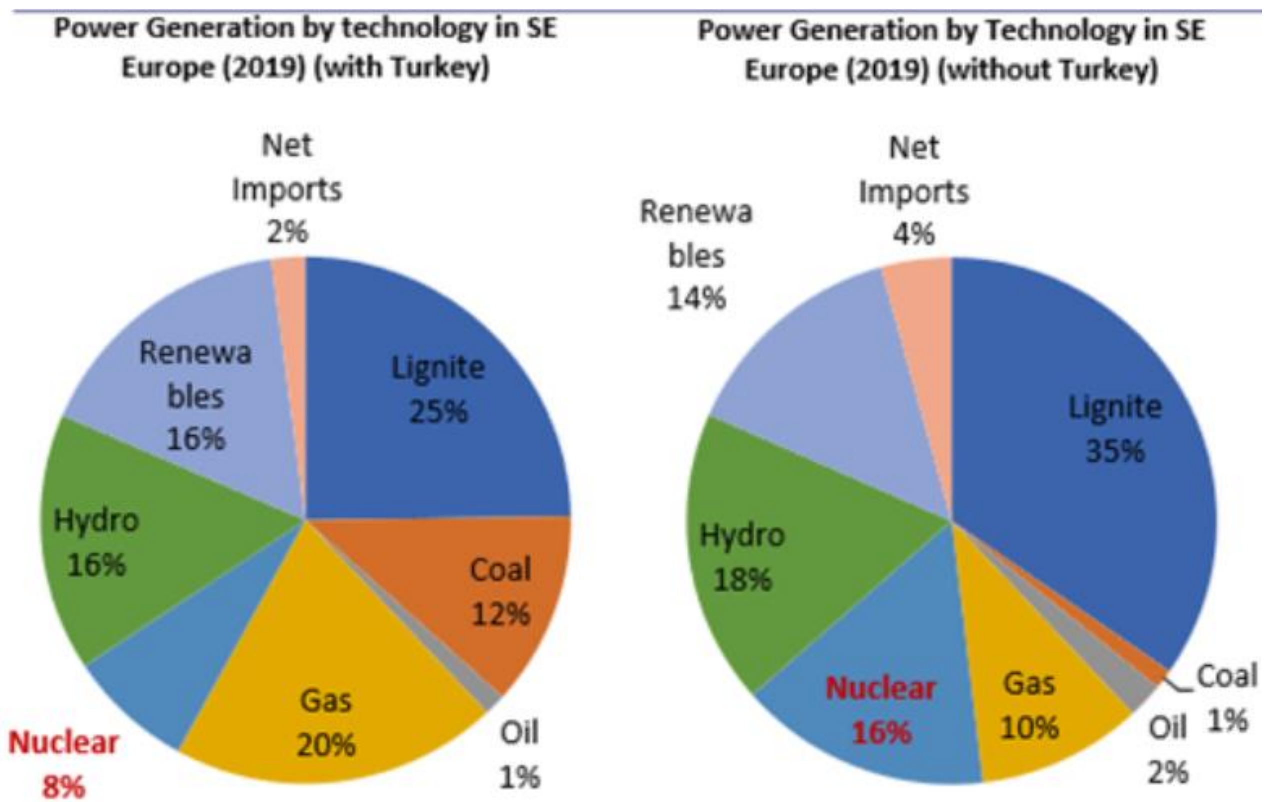
SE Europe: Gross Inland Consumption by Source, **Without Turkey** (2005 and 2015)





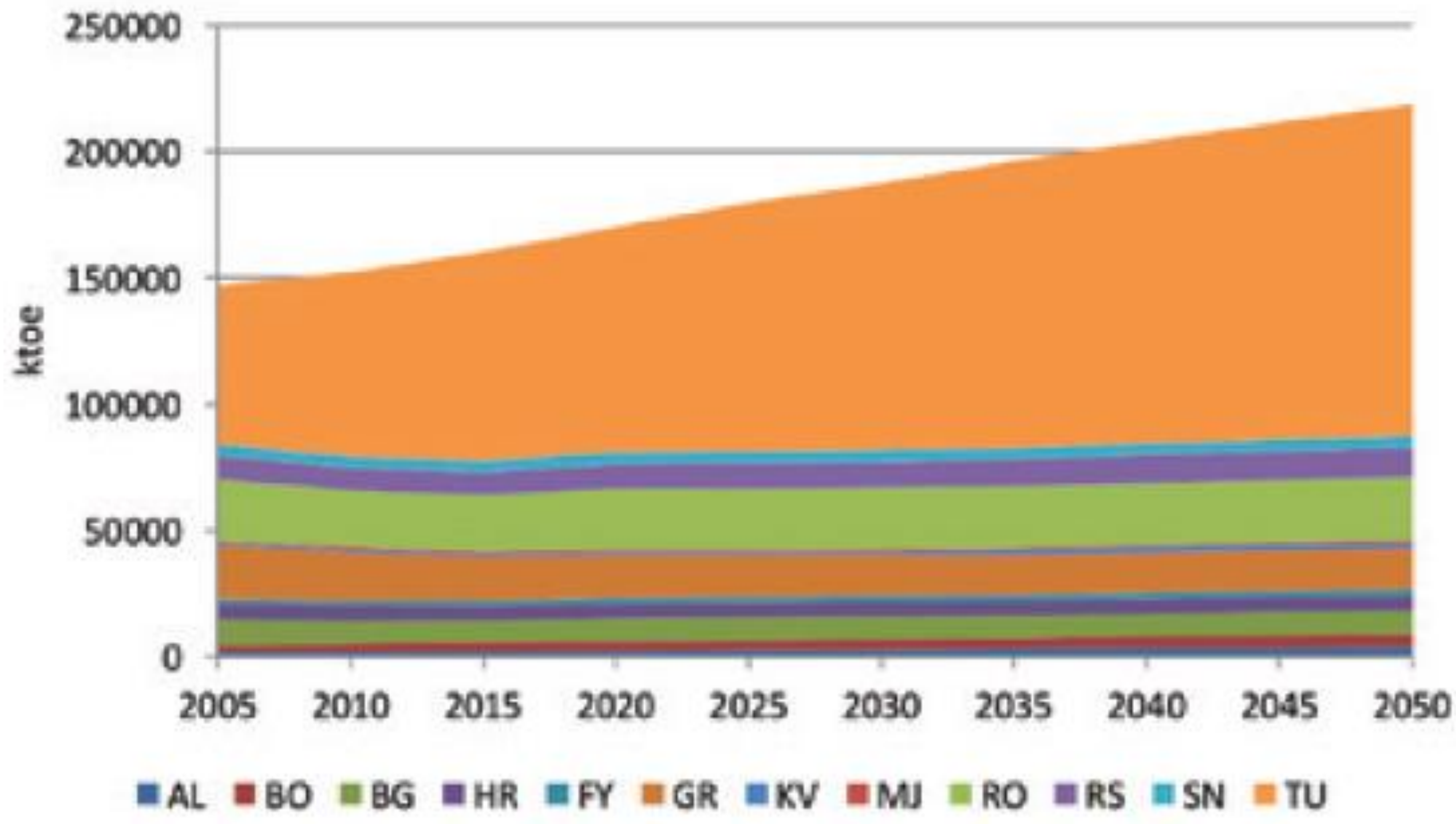
Source: IENE study "South East Europe Energy Outlook 2016/2017", Athens, 2017

SE Europe's Power Generation Mix, **With and Without Turkey** (2019)



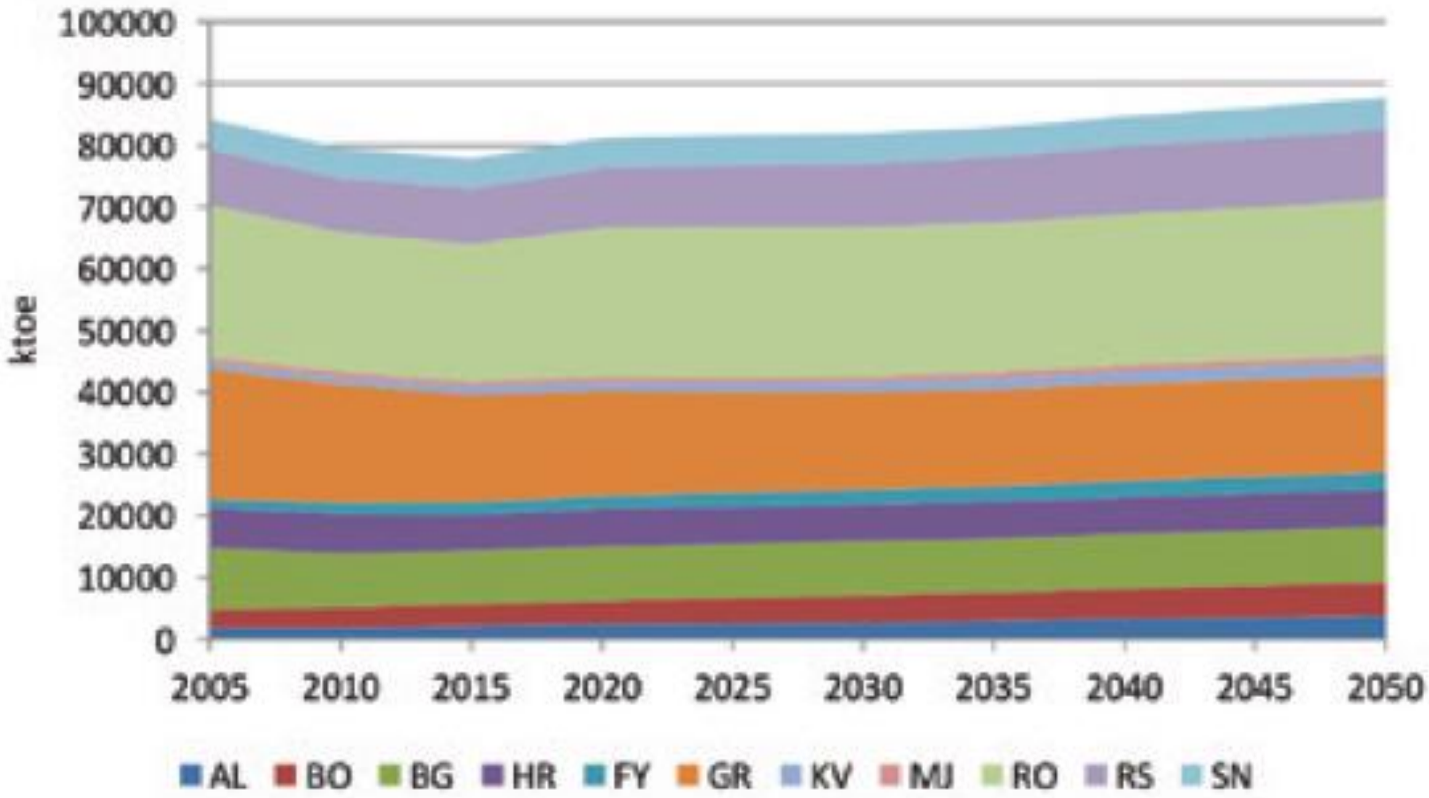
Source: IENE

SE Europe: Final Energy Demand, **Including Turkey** (2005-2050)



Source: IENE study "South East Europe Energy Outlook 2016/2017", Athens, 2017

SE Europe: Final Energy Demand, **Without Turkey** (2005-2050)

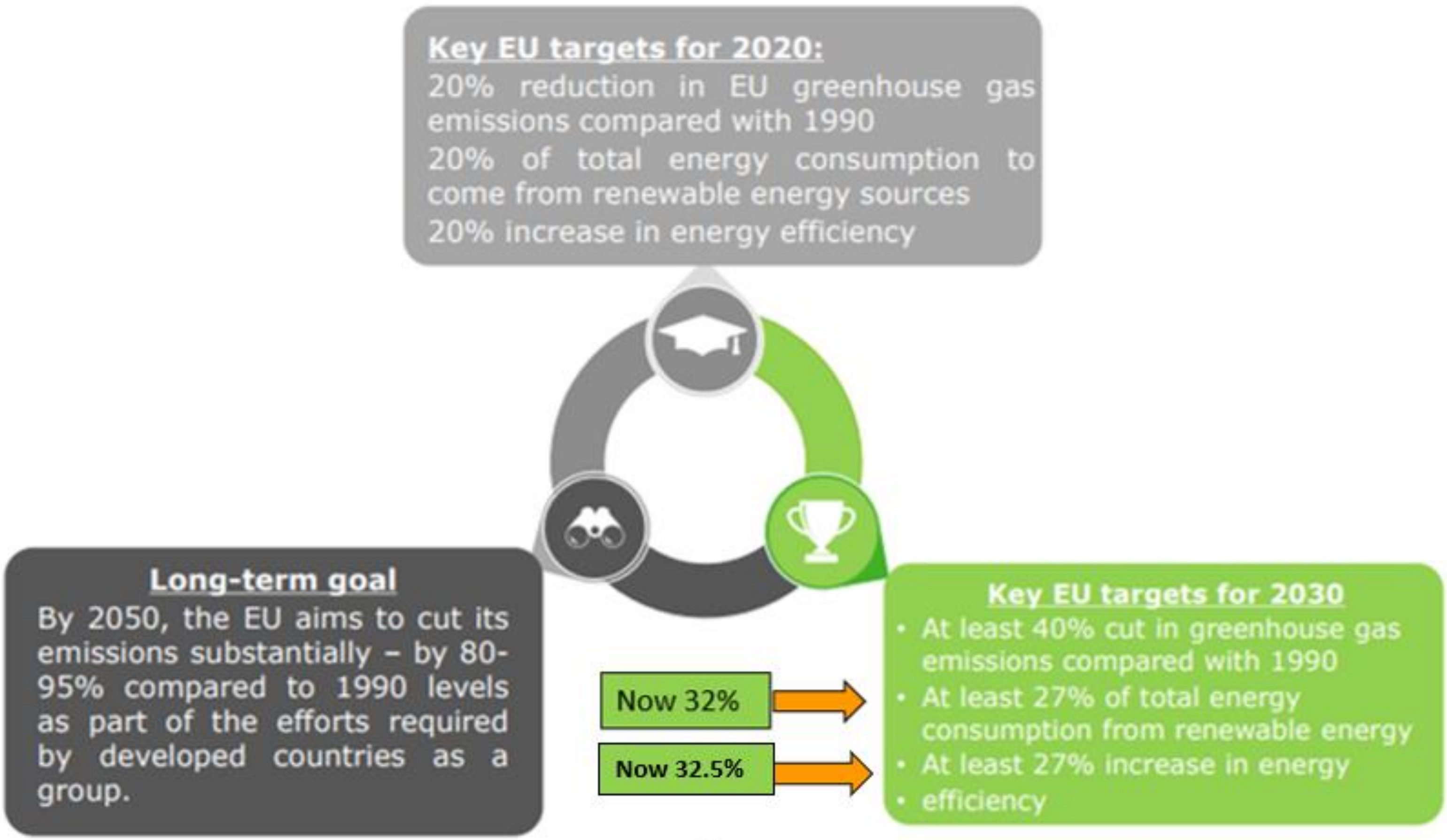


Source: IENE study “South East Europe Energy Outlook 2016/2017”, Athens, 2017

Key Regional Energy Issues

- Marked divergence between EU and SEE energy strategies
- SEE is more energy security vulnerable than the rest of Europe
- Energy supply diversification in SE Europe is less important than security of energy transportation and transmission (oil, gas and electricity)
- SEE's high hydrocarbon dependence
- Electricity's newcomer gas alters supply balance
- Lack of adequate electricity and gas interconnections
- Coal is and will continue for sometime to be relevant
- SEE's path towards decarbonisation is difficult and uncertain
- Nuclear remains a viable option for SEE power generation
- RES growth impeded due to policy failures, financial and regulatory framework and electricity grid constraints
- Energy poverty is emerging as a regional concern mainly related to deteriorating social conditions

EU Energy Policy Framework (2020, 2030 and 2050)



Source: European Commission

EU Energy Policy Framework: Revision of the Targets

- Latest thinking suggests that the **EC will revise upwards these targets**, while it is preparing to set even stricter limits for 2050.

- However, apart from the **self-flagellatory element** in EU's logic in its effort to curtail carbon emissions (which are falling steadily over the last decade), its current strategy, based entirely on the promotion of natural gas and Renewable Energy Sources (RES), backed by strenuous energy efficiency measures, **lacks boldness of purpose and a clear view of market operation**, especially with regard to the needs of adequate base load.

- **The provision of adequate base load is an absolute necessity,** if we are to achieve higher RES grid penetration.

- The present approach reveals **serious shortcomings in terms of energy security strategy**, as it promotes maximisation of gas consumption at a time when Europe faces a decline of indigenous gas resources.
  - All current scenarios indicate a growing gap between production and consumption which is to be filled in by expanded gas imports, mainly from Russia and through LNG.

EU Energy Policy Framework: How Does This Stand for SE Europe? (I)

- It seems that an **inverted pyramid arrangement** has been developed in SE Europe, compared to pursued official Energy Union policies and stated targets as economic development at all costs remains number one priority for most countries.

- The energy policy priorities in broad terms for SEE would appear as follows:
  - Further large-scale development of **coal and lignite resources** without any real recourse CCS/CSU provisions and plans
  - Further development of **electricity and gas interconnections in order to maximise cross border trade**
  - Promotion of **oil and gas exploration activities (onshore and offshore)** aiming towards maximizing production in the mid- and long-term
  - Further development of **renewables** in all application areas (i.e. solar, wind, biomass, hydro and geothermal) without necessarily aiming to adhere to specific targets (set by the EU)
  - Promotion of **energy efficiency**, focusing primarily on the building sector, incentivized by EU and green fund financing facilities
  - **Diversification** of supply routes and suppliers in order to secure future gas supplies
  - Reduction of CO_2 emission levels (least of priorities)

EU Energy Policy Framework: How Does This Stand for SE Europe? (II)

- In spite of EU's ambitious targets set for its member countries in the region (i.e. Greece, Bulgaria, Romania, Croatia, Slovenia and Cyprus) and for those in the West Balkans (i.e. Albania, Montenegro, Kosovo, Bosnia-Herzegovina, Serbia and North Macedonia) under the umbrella of EU-funded Vienna-based Energy Community, **progress towards decarbonization has been extremely slow to say the least**, with a number of countries actually proceeding with the construction of new lignite fueled plants (e.g. Greece, Kosovo, Bosnia-Herzegovina and Serbia).

- These countries continue to view their energy future aligned with the **continuing exploitation of their abundant indigenous coal resources which cover a substantial part of base load needs.**

- Although there is ample EU support for large-scale use of RES and energy efficiency schemes, **no such support or encouragement exists for the further use of nuclear generated power which could cover the region's growing energy requirements.**

Under Construction and Planned Coal Plants in SEE Countries (MW)*, as of January 2019

Country	Announced New Plants	Pre-permit	Permitted	Announced + Pre-permit + Permitted	Under Construction	Shelved	Operating	Cancelled (2010-2018)
Turkey	12,8	17,311	6,555	36,666	800	24,554	18,826	41,031
Bosnia & Herzegovina	2,38	0	1,7	4,08	0	0	2,073	1,02
Serbia	1	0	350	1,35	0	0	4,405	1,82
Romania	0	600	0	600	0	0	5,305	5,105
Kosovo	0	450	0	450	0	0	1,29	330
Greece	0	450	0	450	660	0	4,375	800
North Macedonia	300	129	0	429	0	0	800	300
Montenegro	0	0	0	0	0	0	225	1,41
Bulgaria	0	0	0	0	0	0	4,889	2,66
Slovenia	0	0	0	0	0	0	1,069	0
Croatia	0	0	0	0	0	0	210	1,3
Albania	0	0	0	0	0	0	0	800

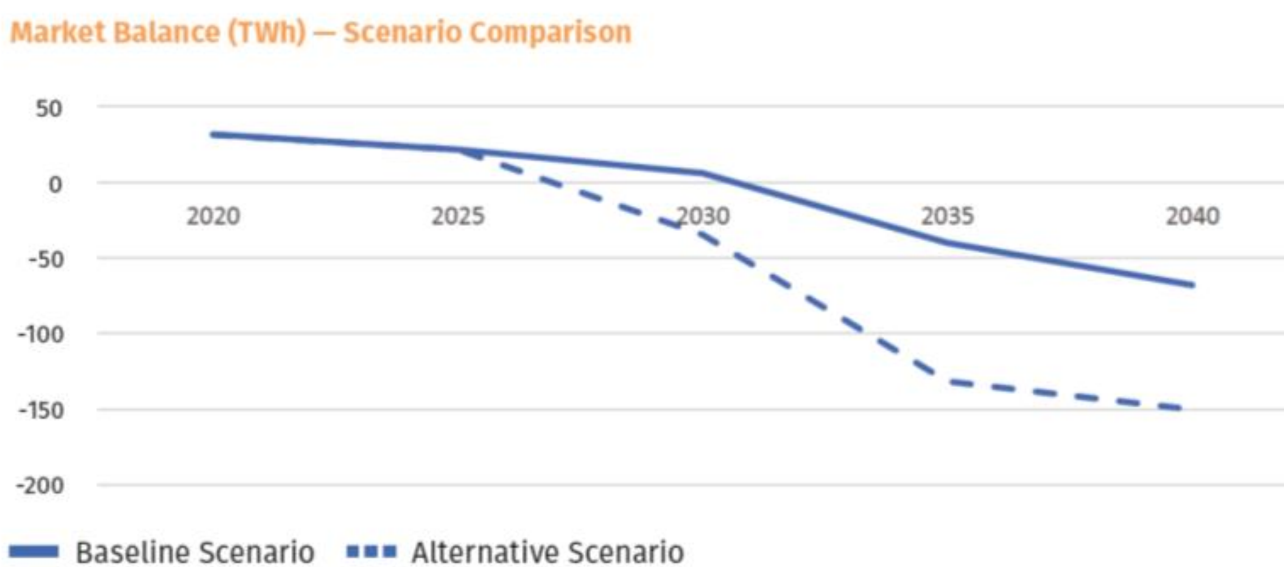
***Note:** Includes units 30 MW and larger

Sources: EndCoal, IENE

Electricity Market Balance in SE Europe

- As the New Nuclear Watch Institute's "The Electricity Market of SE Europe: The Impact of New Trends and Policies" report says "The conclusion of our alternative – 'New Trends and Policies'– scenario is that **SE Europe will experience annual electricity generation deficits from 2027 onwards; the onset of annual deficits is delayed until 2031 in the baseline analysis.**

- The market balance of the alternative forecast worsens over the duration of the forecast period. **After falling into deficit in 2027, the shortfall then reaches 35 TWh in 2030, 132 TWh in 2035, and 150 TWh in 2040.** As shown in the following Figure, the projected deficit at the end of the forecast is marked, 150 TWh is only slightly less than half of the actual generation forecast for 2020 (310 TWh)".



Source: New Nuclear Watch Institute

Nuclear Energy in the EC Strategy (November 2018)

EC Communication*:

"Renewables together with nuclear energy will be
the backbone of a carbon-free European power system"

EC in-depth analysis:**

- Nuclear will **remain an important component** in the EU 2050 energy mix
- Capacity of nuclear in 2050 – **between 99-121 GW**
- Share of nuclear in the electricity mix in 2050 – **ca. 15%**
- The consumption of **natural gas** is expected to be severely reduced by 2050 in all scenarios
- In the Baseline, **hydrogen** use develops only as a niche application for road transport and industry

Strategy refers directly to the study commissioned by FORATOM

** https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf*
*** https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf*

Present Situation of Nuclear Power Generation in SE Europe (I)

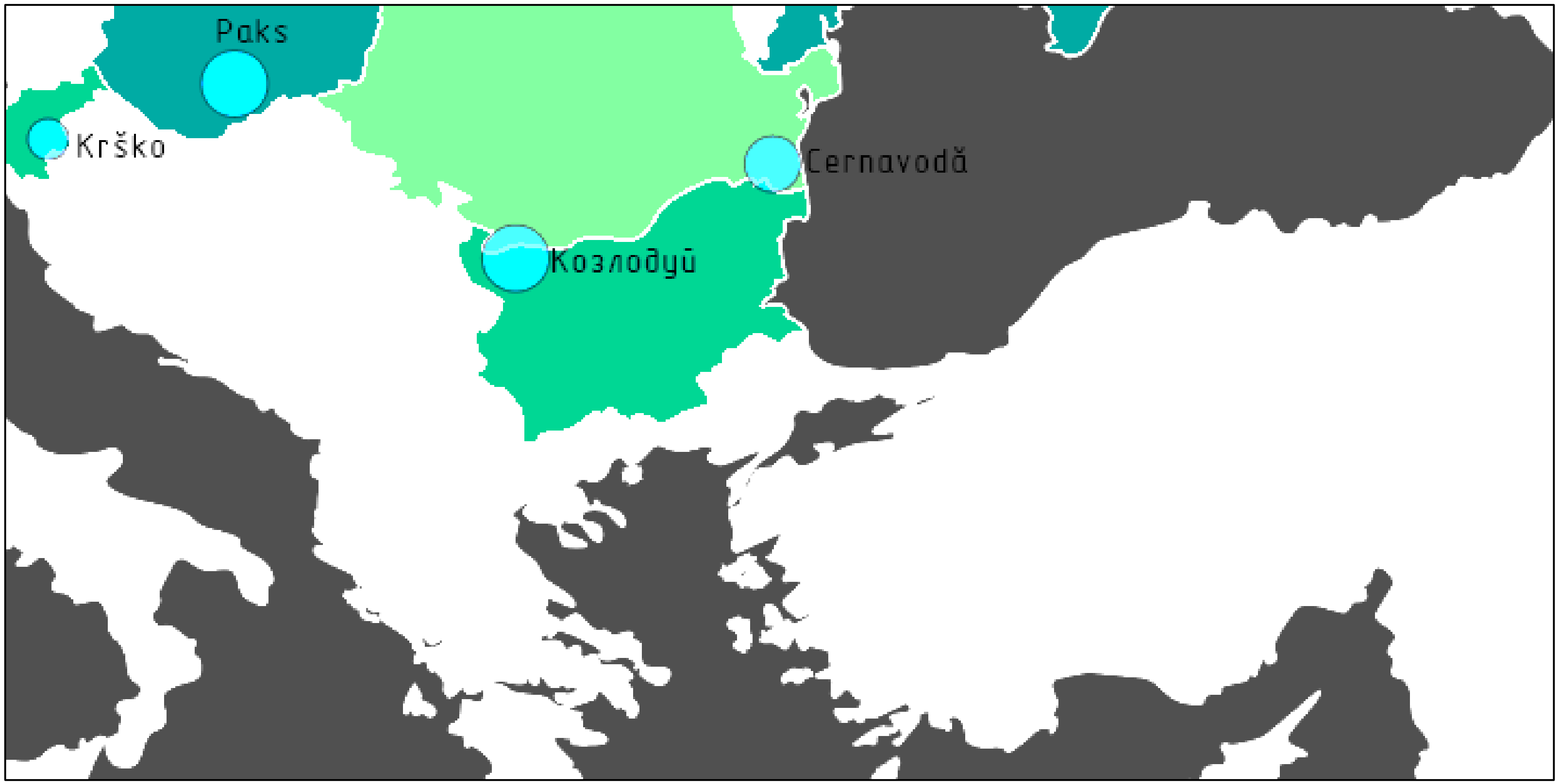
Table: Existing Nuclear Reactors in SE Europe

Country	Reactor	Model	Gross Capacity (MWe)	Construction Date	Commercial Date	UCF for 2018
Romania	Cernavoda 1	CANDU 600 (PHWR)	650	1982-07-01	1996-12-02	89.0
Romania	Cernavoda 2	CANDU 600 (PHWR)	650	1983-07-01	2007-11-01	98.2
Hungary	Paks 1	WWER-440/213 (PWR)	479	1974-08-01	1983-08-10	91.5
Hungary	Paks 2	WWER-440/213 (PWR)	477	1974-08-01	1984-11-14	88.5
Hungary	Paks 3	WWER-440/213 (PWR)	473	1979-10-01	1986-12-01	78.9
Hungary	Paks 4	WWER-440/213 (PWR)	473	1979-10-01	1987-11-01	99.4
Bulgaria	Kozloduy 5	WWER-1000 (PWR)	1000		1987-11-29	89.21
Bulgaria	Kozloduy 6	WWER-1000 (PWR)	1000		1991-08-02	89.21
Slovenia	Krsko	WESTINGHOUSE 2-LOOP PWR	696	1975-03-30	1983-01-01	90.9

Note: Table is completely generated from PRIS data to reflect the latest available information and may be more up to date than the text of the report.

Source: IAEA - Power Reactor Information System (PRIS)

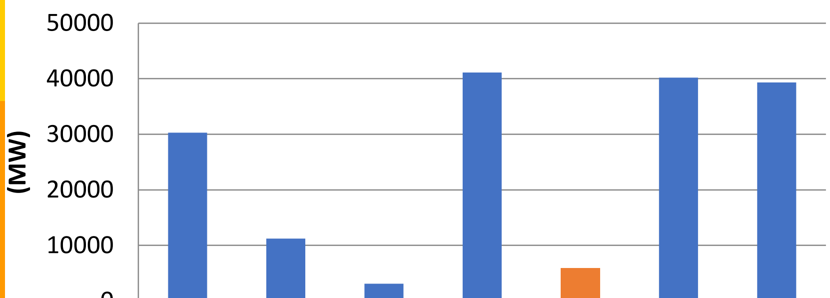
Present Situation of Nuclear Power Generation in SE Europe (II)



Source: Artemco.livejournal.com

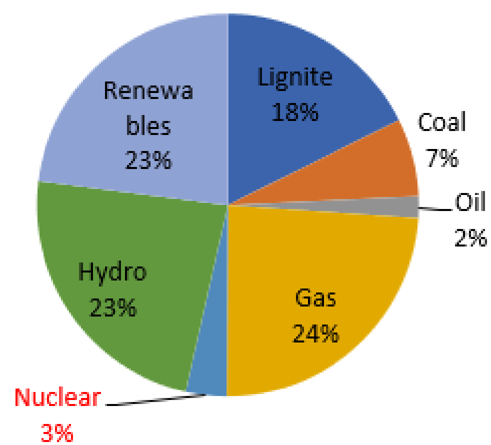
Present Situation of Nuclear Power Generation in SE Europe (III)

Installed Capacity for Power Generation in SE Europe (2019) (with Turkey)

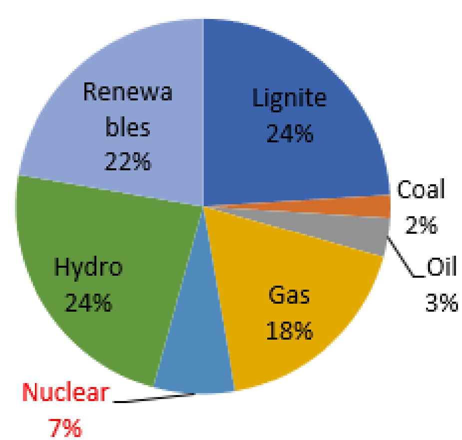


	Lignite	Coal	Oil	Gas	Nuclear	Hydro	Renew ables
MW	30281	11227	3119	41130	5900	40190	39346

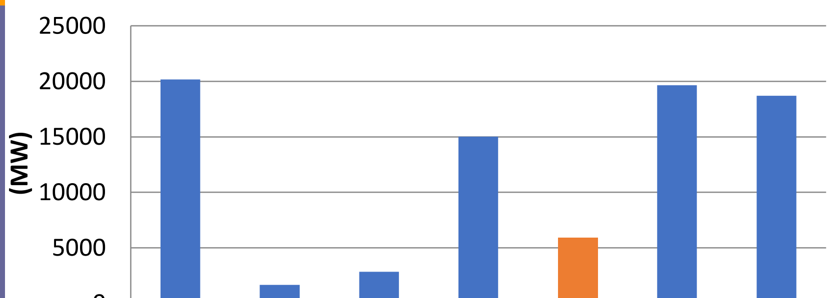
Installed Capacity for Power Generation in SE Europe (2019) (with Turkey)



Installed Capacity for Power Generation in SE Europe (2019) (without Turkey)



Installed Capacity for Power Generation in SE Europe (2019) (without Turkey)

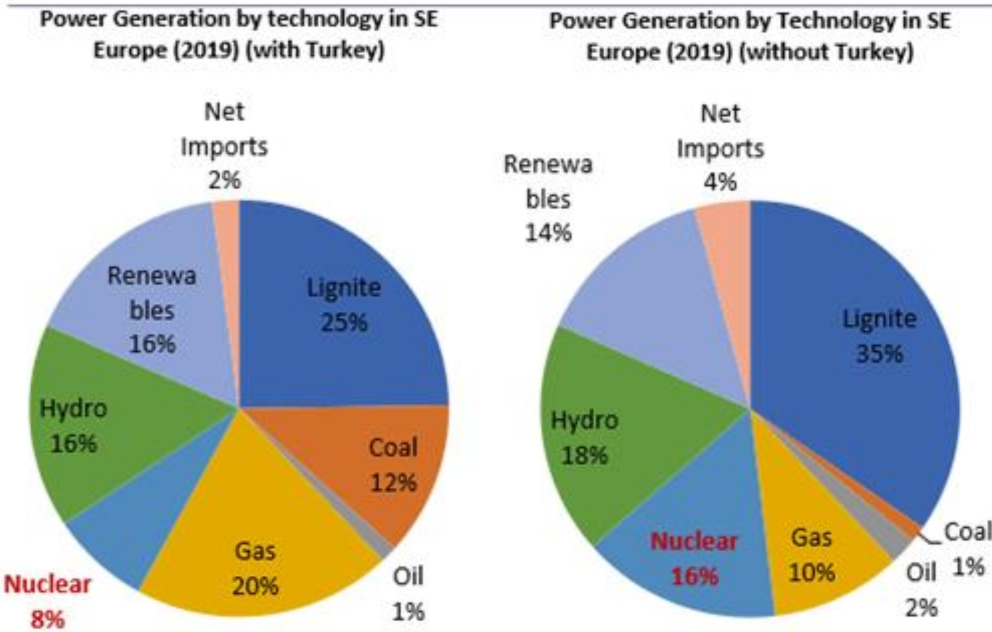


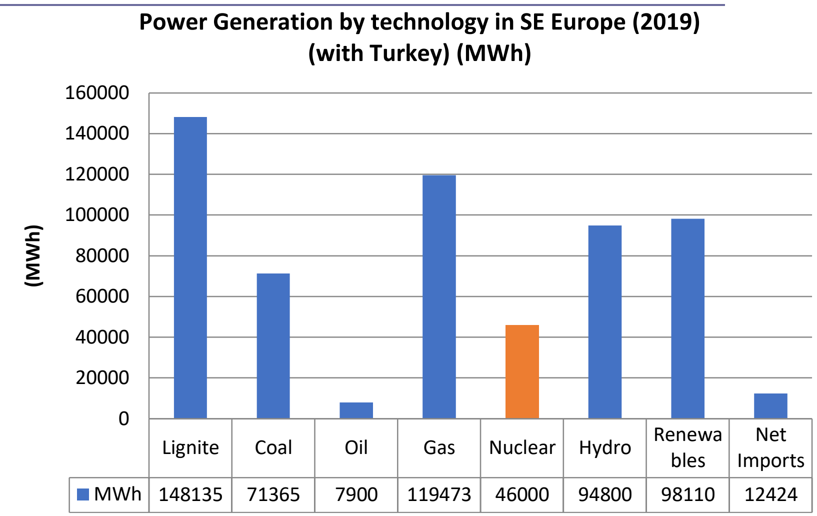
	Lignite	Coal	Oil	Gas	Nuclear	Hydro	Renew ables
MW	20163	1651	2831	15023	5900	19654	18712

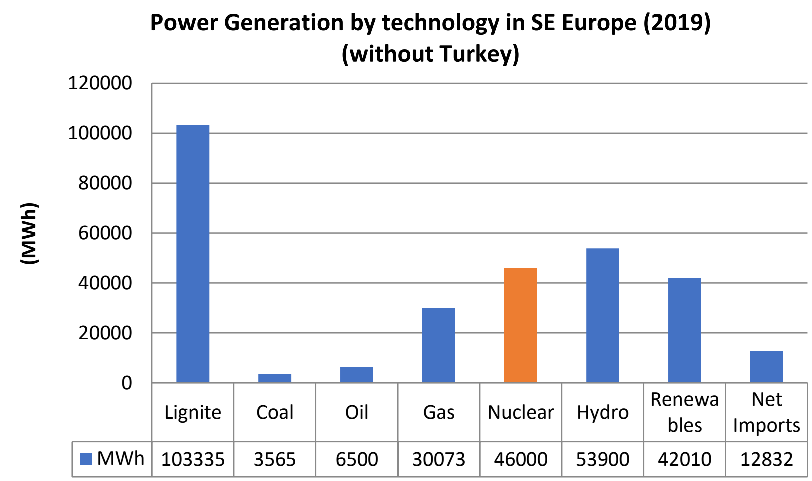
- **Total Installed Generating Capacity of 5,900 MW**
- **7% of installed generating capacity in SEE region is nuclear (3% with Turkey)**

Source: IENE

Present Situation of Nuclear Power Generation in SE Europe (IV)







- **16% of Power Generation in SEE region is from NPPs (8% with Turkey)**

Source: IENE

Future of Nuclear Power in SE Europe (I)

Table: Planned Nuclear Reactors in SE Europe

Country	Reactor	Model	Gross Capacity (MWe)	Expected Construction start year	Expected commercial year	Source
Romania	Cernavoda 3	CANDU 6	720	2022	2030	IAEA
Romania	Cernavoda 4	CANDU 6	720	2022	2032	IAEA[2]
Hungary	Paks 5	WWER-1200	1200	n/a	n/a	IAEA
Hungary	Paks 6	WWER-1200	1200	n/a	n/a	IAEA[3]
Bulgaria	KNPP-7/Kozloduy 7	PWR	up to 1200 MW	n/a	n/a	IAEA
Turkey	Akkuyu NPP - 1	WWER-1200	1200	2018	2023	IAEA
Turkey	Akkuyu NPP - 2	WWER-1200	1200	2019	2024	IAEA[6]
Turkey	Akkuyu NPP - 3	WWER-1200	1200	2020	2025	IAEA[6]
Turkey	Akkuyu NPP - 4	WWER-1200	1200	2021	2026	IAEA[6]
Turkey	Sinop NPP — 1	ATMEA-1	1120	2020	2025	IAEA[6]
Turkey	Sinop NPP — 2	ATMEA-1	1120	2021	2026	IAEA[6]
Turkey	Sinop NPP — 3	ATMEA-1	1120	2024	2029	IAEA[6]
Turkey	Sinop NPP — 4	ATMEA-1	1120	2025	2030	IAEA[6]

[1] https://cnpp.iaea.org/countryprofiles/Romania/Romania.htm
[2] https://cnpp.iaea.org/countryprofiles/Hungary/Hungary.htm
[3] *Note*: PWR — pressurized water reactor
[4] https://cnpp.iaea.org/countryprofiles/Bulgaria/Bulgaria.htm
[5] https://cnpp.iaea.org/countryprofiles/Turkey/Turkey.htm

Definition of Scenarios Used

	BaU	Full EU policy
Intensity of RES development		
WB	Low	High
Balancing of RES and trade		
WB	Conventional	Both
Lignite/coal plants		
WB	Persist, no ETS, poor refurbishment	Fast phase-out
Competition and prices		
WB and EU	Dominance and slightly underpaid electricity	Level-playing and fair prices
Market coupling		
WB and EU	No	Full
Interconnections and NTC		
WB and EU	Poor	Max

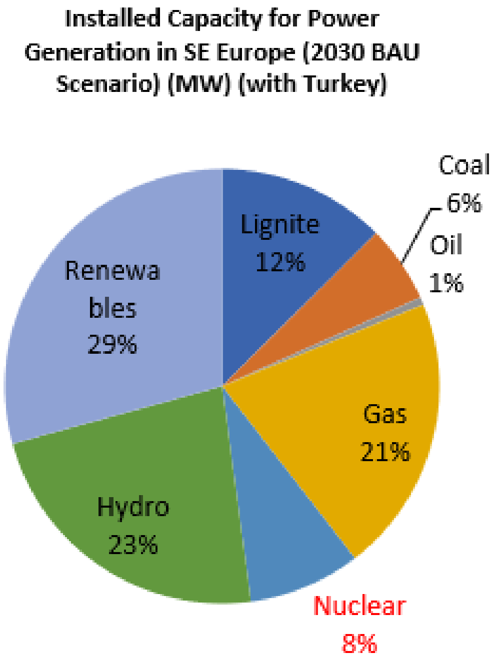
Notes: **(1) BaU scenarios** are based on joint data by IENE and E3M Lab. BaU and Full EU policy scenario data for Slovenia, Hungary, Croatia and Cyprus are projected by the respective National Energy and Climate Plans. For Turkey, the projection has been made based on currently implemented technologies and adaptation of the forecast of the BAU scenario presented by Kat et al. in Kat, B., Paltsev, S., & Yuan, M. (2018). "Turkish energy sector development and the Paris Agreement goals: A CGE model assessment". Energy Policy, 122, pp. 84–96.

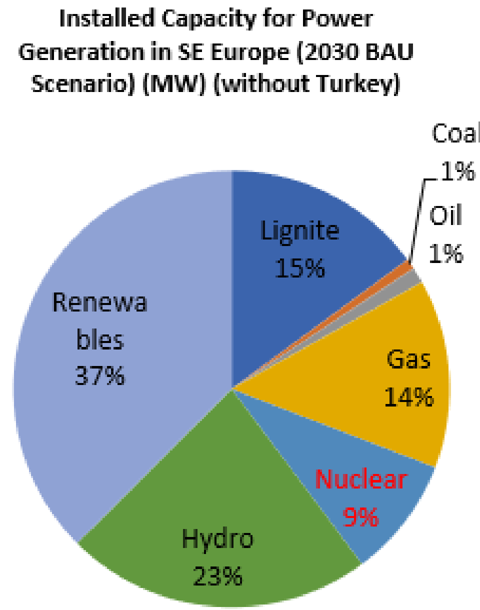
(2) Full EU policy scenarios: For Turkey, the projection has been made based on currently implemented technologies and adaptation of the forecast of the **Turkey's emission (TrEm) scenario** presented by Kat et al., which includes an emission restriction system, lower demand increase and phasing out coal-fired power plants by 2030.

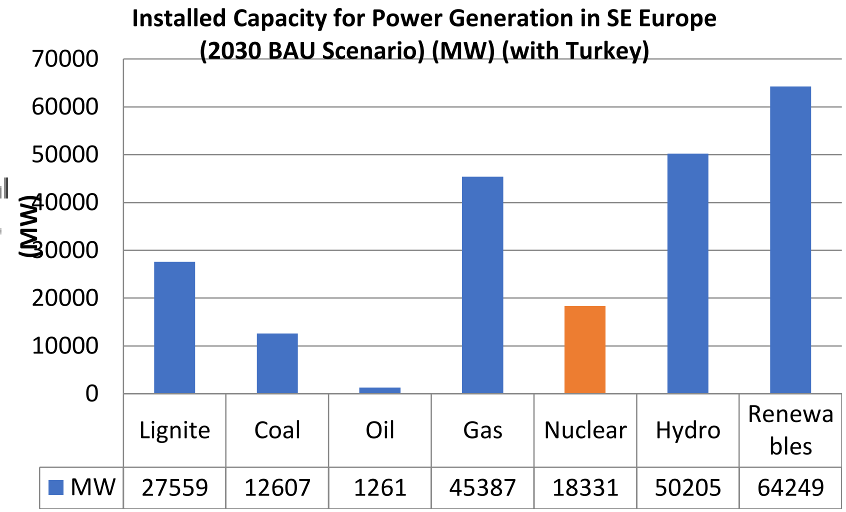
Source: IENE

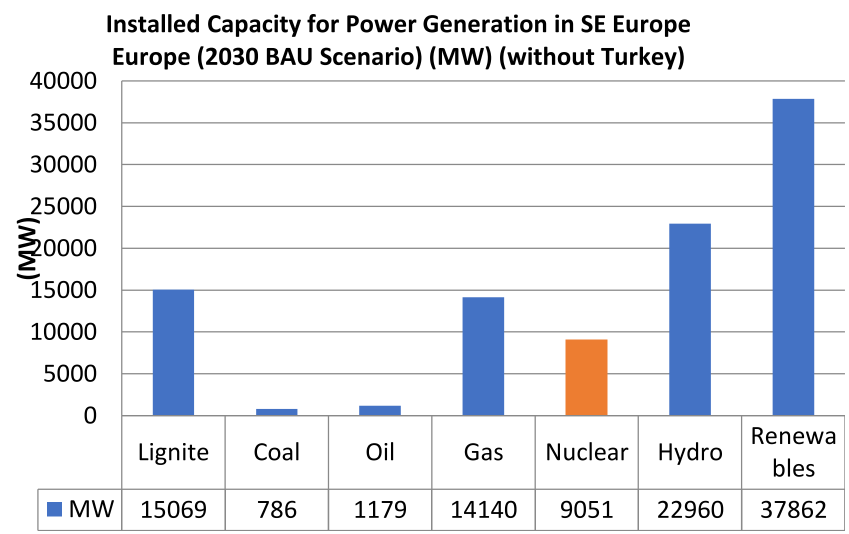
Future of Installed Capacity of Nuclear Power in SE Europe (I)

BAU Scenario (2030) – Installed capacity





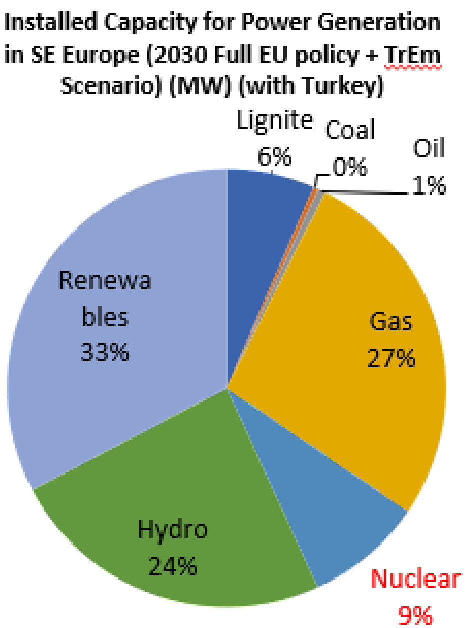


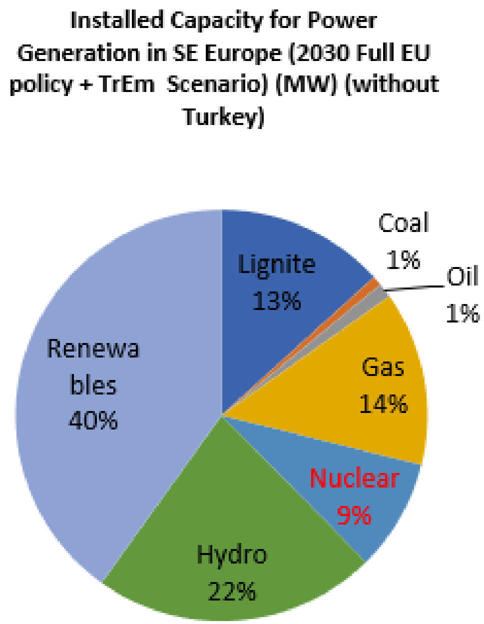


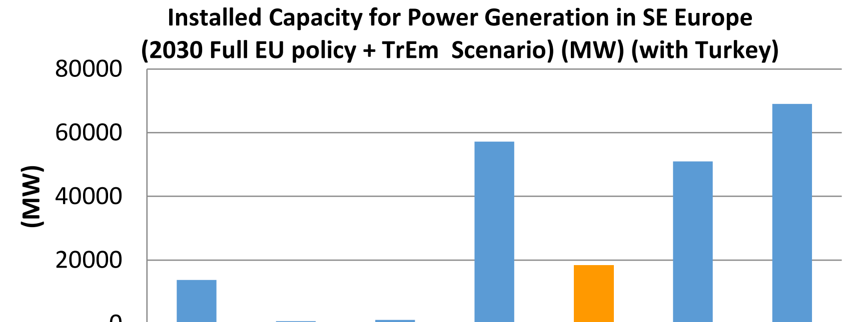
Source: IENE

Future of Installed Capacity of Nuclear Power in SE Europe (II)

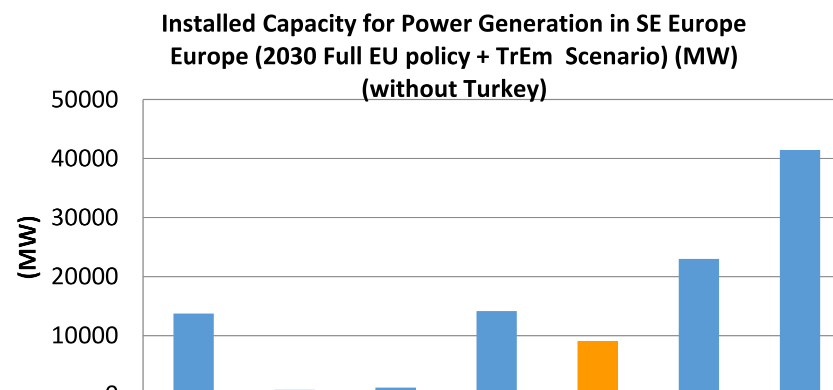
Full EU policy + TrEm Scenario – Installed capacity







	Lignite	Coal	Oil	Gas	Nuclear	Hydro	Renew ables
MW	13721	786	1179	57214	18331	50971	69047



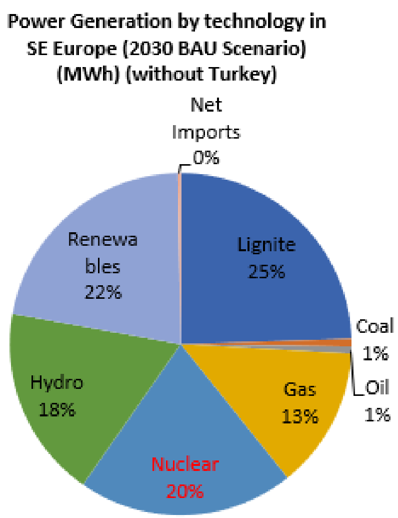
	Lignite	Coal	Oil	Gas	Nuclear	Hydro	Renew ables
MW	13721	786	1179	14140	9051	23002	41447

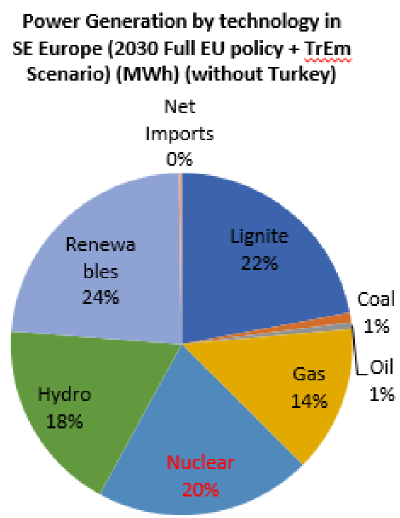
Source: IENE

Future of Power Generation in the SEE region (III)

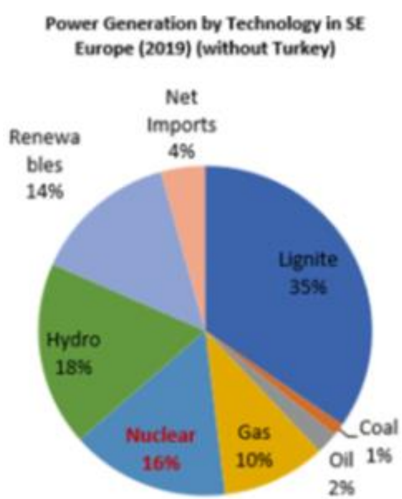
Comparison of BAU Scenario and
Full EU policy + TrEm Scenario (without Turkey)

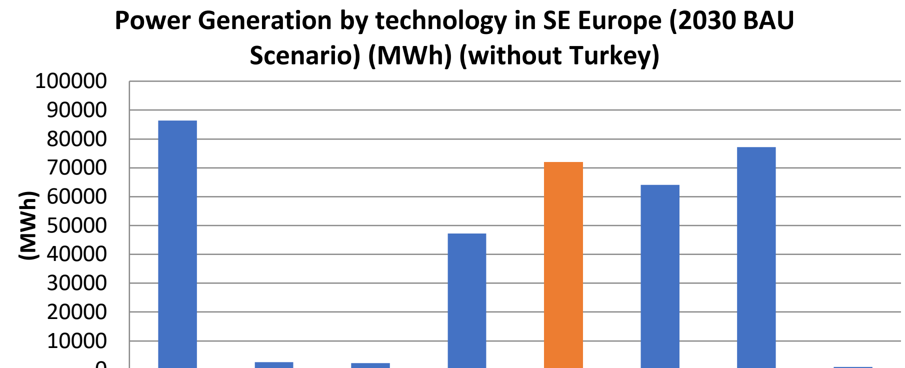
2030



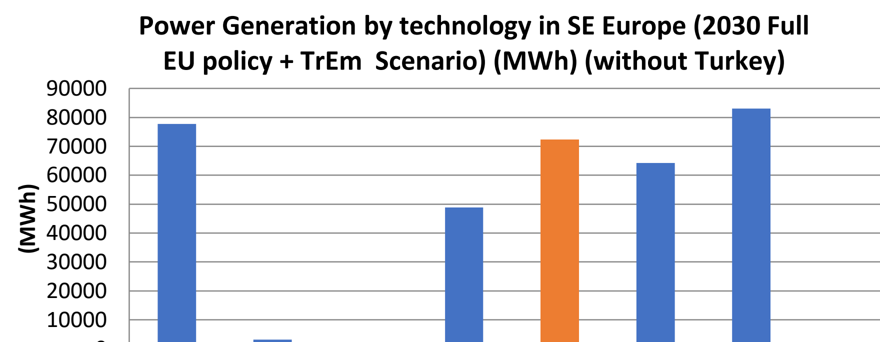


2019





	Lignite	Coal	Oil	Gas	Nuclear	Hydro	Renewa bles	Net Imports
MWh	86343	2602	2283	47206	72039	64062	77163	957



	Lignite	Coal	Oil	Gas	Nuclear	Hydro	Renewa bles	Net Imports
MWh	77747	3154	2283	48849	72315	64232	83047	897

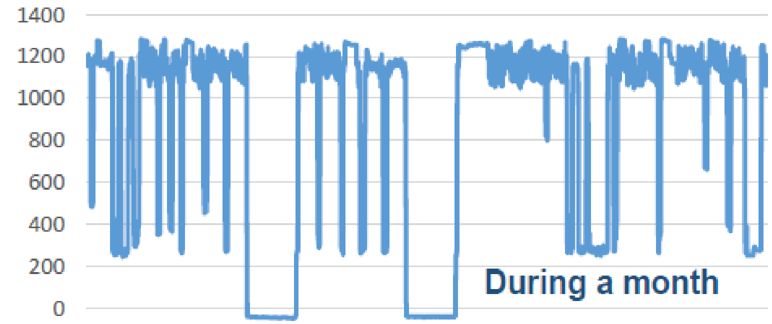
Source: IENE

Flexible Operation of NPPs is Possible

- The first NPPs were originally designed for base load
- In the early 80s, a decision was taken to improve French NPPs Load Following capabilities, leading to studies, modifications and administrative authorizations
- Modifications implemented by EDF:
  - Mechanical design: surge line, spray line, charging line
  - Introduction of a new core control mode (grey mode)
- Hence, Flexible Operation has been successfully implemented at EDF NPPs for 35 years with manageable impacts
- The following frames portray in great accuracy EDF's experience on NPPs' Operational Flexibility
- Achieving NPP Operational Flexibility is especially important in the case of SE Europe as we shall be aiming towards higher RES penetration.

What is Plant Flexibility ?

Power variations commonly observed



- Load following : large load variation program agreed in advance with the grid operator
  - 2 large variations/day,
  - Down to 20% Pn,
  - ramp up / ramp down 30 min.
- Frequency control : minor automatic load variations aimed at controlling grid frequency (50 Hz+/- 0.5Hz in Europe)
  - primary frequency control (2% Pn, up to 7%), short-term adjustments
  - secondary frequency control (5% of Pn), adjustments within 15 min

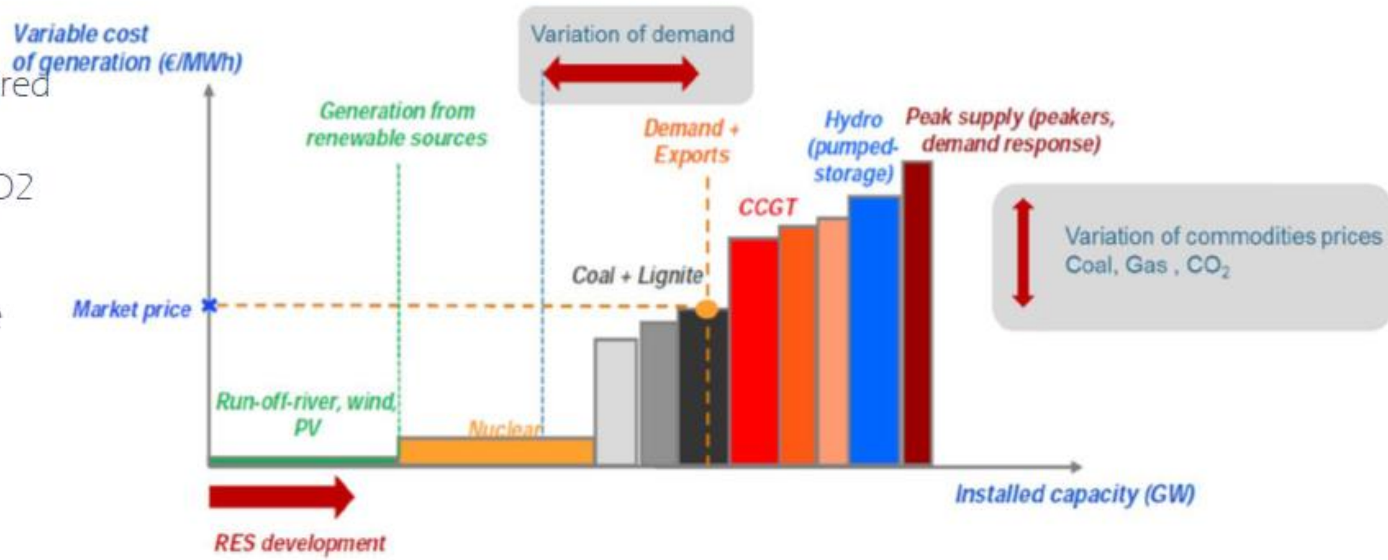
- If the plant was not flexible : 1-day shut-down, but generation at peak hours made by gas

Source: EDF

Flexible Operation at EDF

Market Price setting and merit order

- Flexible operation of nuclear fleet
  - offers a low-carbon alternative to the fossil-fired capacity
    - => Reduction of CO2 emissions
  - saves the fuel when the market price is low for future use
    - => Cost-effective



Source: EDF

IENE Study on SEE's Nuclear Option (I)

- IENE has embarked on a major research project with the aim of establishing the following:

(a) If there is adequate room for expanding NPP capacity in the SE European countries in view of latest EU targets

(b) Can power generation from NPP in SEE contribute significantly to achieving lower Greenhouse Gas emissions and will also be capable of replacing a significant part of present-day lignite and coal use?

(c) Will increased NPP generation enhance the use of Renewables and facilitate further their penetration in the region's energy mix?

(d) The IENE study will seek to quantify the above and also provide solid economic data on required CAPEX and operational costs

IENE Study on SEE's Nuclear Option (II)

- This IENE Research Programme will further examine:
  - The impact in terms of reduced CO_2 emissions, under different scenarios, from increased use of NPP
  - Power stability requirements and impact from higher RES penetration
  - The increased use of RES in tandem with higher input from NPP. What are the repercussions in terms of increased NPP capacity and where new NPP shall operate?
  - The relative costs from higher RES use and higher NPP operation

- This Programme will also seek to:
  - Review the outlook of new NPP in SEE in view of latest developments
  - Draw a realistic roadmap for increased nuclear generated electricity in SEE
  - Examine the state of electricity infrastructure in SEE (national grids, cross border interconnections) in relation to anticipated increased NPP use

INSTITUTE OF ENERGY
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Thank you for your attention

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