Εθνικο Κέντρο ‘Ερευνας και Τεχνολογικής Ανάπτυξης

CPERI
Chemical Process and Energy Resources Institute

Καθ. Εμμανουήλ Κακαράς

Ομάδα εργασίας της Επιτροπής Ενέργεις της Ακαδημίας Αθηνών, 6 Οκτωβρίου 2017
‘‘Ενεργειακές Προοπτικές της Ελλάδας το 2030 με την προοπτική του 2050‘‘

Centre of Research and Technology Hellas

CPERI
Chemical Process and Energy Resources Institute

Prof. Emmanouil Kakaras

Working group of Academy of Athens Energy Committee, 6. October 2017
‘‘Energy perspectives of Greece in 2030, towards 2050 ‘‘

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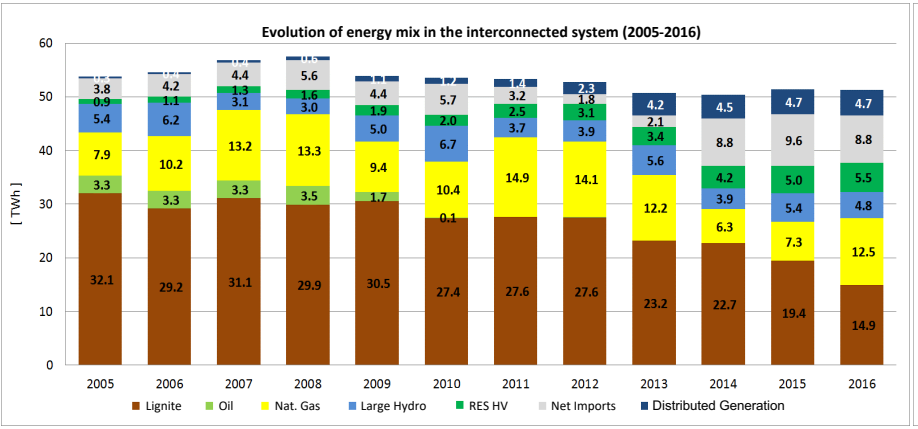
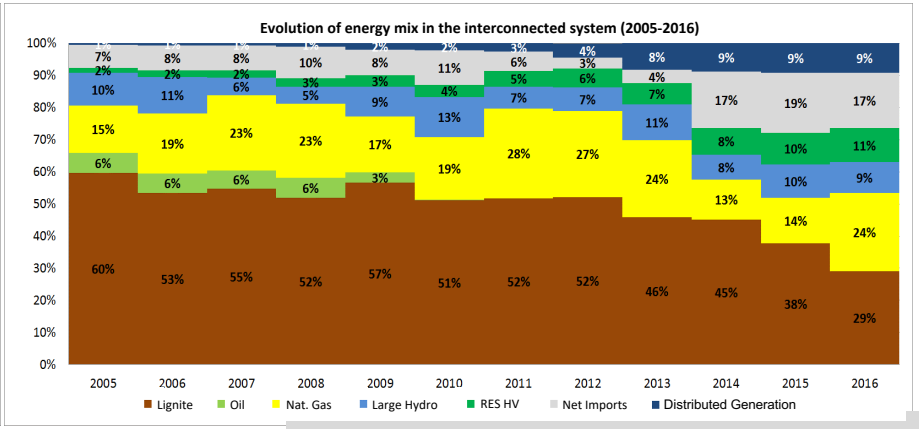
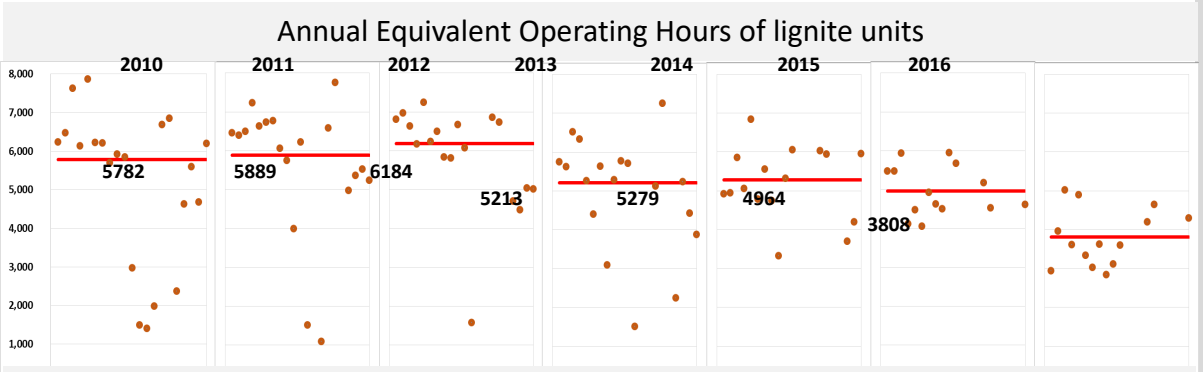
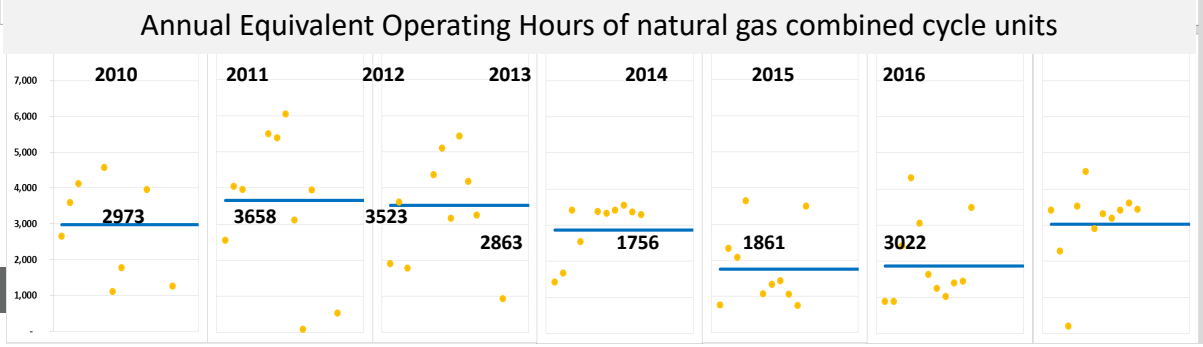
Evolution of energy mix in the interconnected system



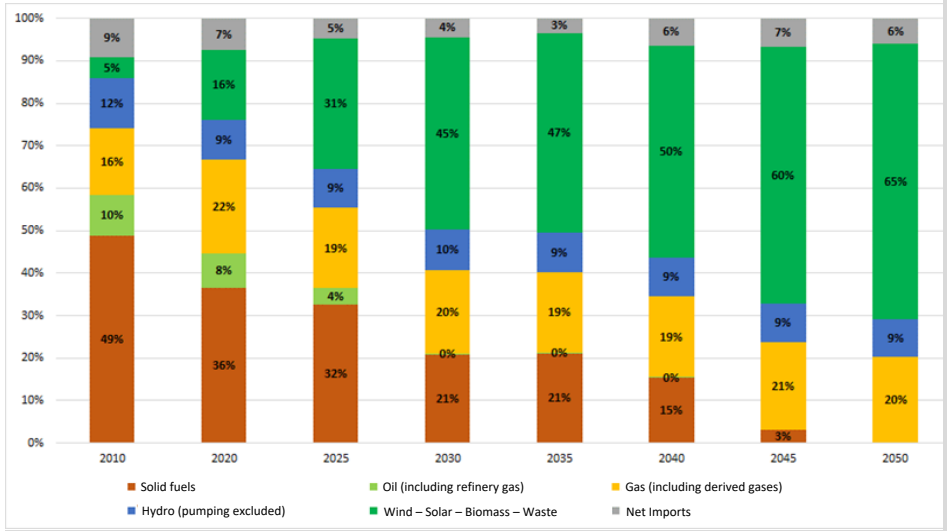


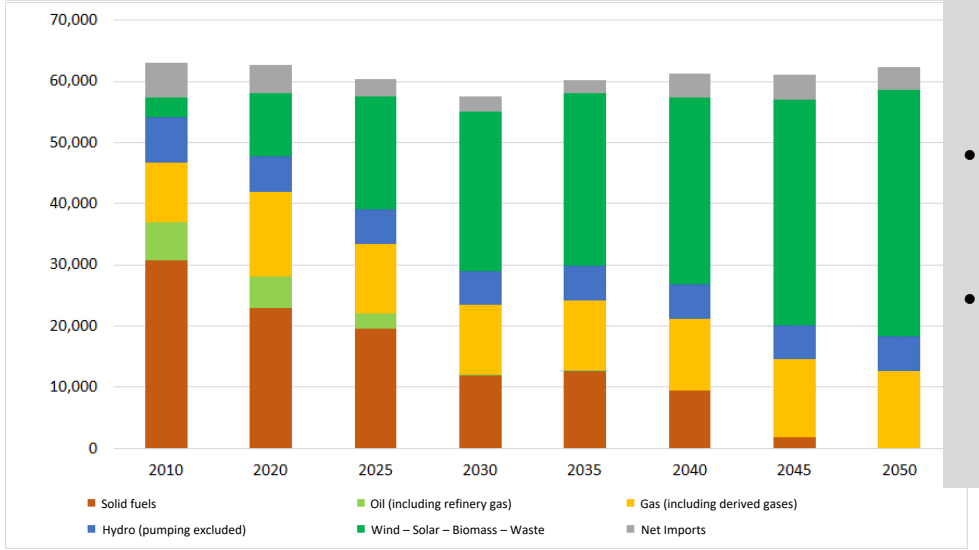




- Reduction of electricity demand of the interconnected system by 11% since 2008.
- Decrease of lignite share from 60% (2005) to 29% (2016)
- Lignite fleet's equivalent operating hours reached a minimum of less than 4000 in 2016.
- Natural gas share with fluctuations due to market regulatory provisions and fuel price fluctuations.
- High Voltage RES and CHP with significant market share, representing 11% and 9% respectively.

Forecast of Greek energy mix to 2050





- Lignite-fired power generation in Greece expected to be significantly limited after 2025 ("EU Energy, Transport and GHG Emissions - Trends to 2050" study)
- Lignite production share expected in magnitude of 36% in 2020, reduced to 21% in 2030, zero in 2050
- Accordingly, lignite plants capacity will be constantly decreasing its share to 15% of the total installed capacity in 2020, 12% in 2030 and 3% in 2050.
- No carbon capture and storage technology CCS foreseen.
- According to study binding targets for greenhouse gas emissions and RES for 2020 are achieved based on the policies agreed in the EU Member States by 2014.

"EU Energy, Transport and GHG Emissions - Trends to 2050" European Commission

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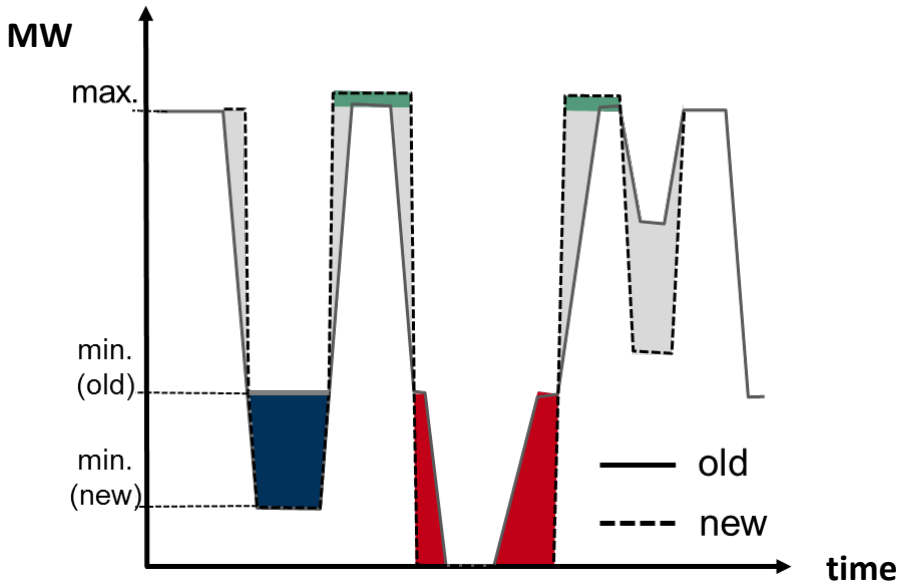
The new role of fossil plants: Projections to 2050

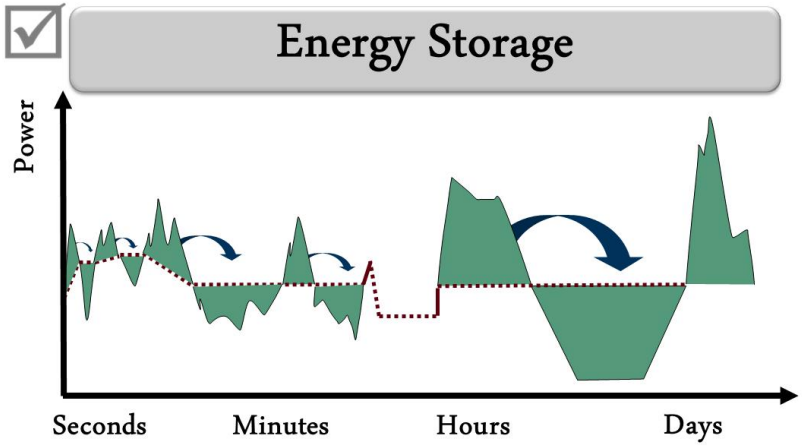
- Transition Phase (low RES):
  - Flexible, dispatchable thermal power generation to cover from required grid balancing up to full back-up in case of minimum RES penetration
  - Thermal power has provided and can provide the system flexibility in supply management till ~2030)

Expected trends:

- Increasing flexibility of existing coal plants
- Development of storage and advanced demand side management

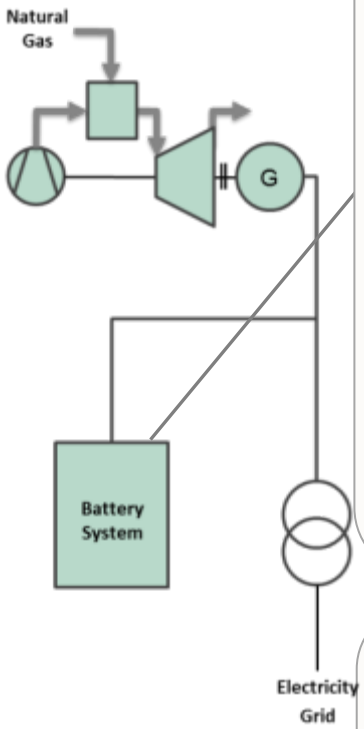
- High RES and decarbonisation targets towards 2050,
  - Fuel switch towards low carbon fuels: a) coal to biomass, b) coal to gas (CCGT) including CHP (wherever applicable)
  - Integration of power storage or thermal energy storage options in existing power plants



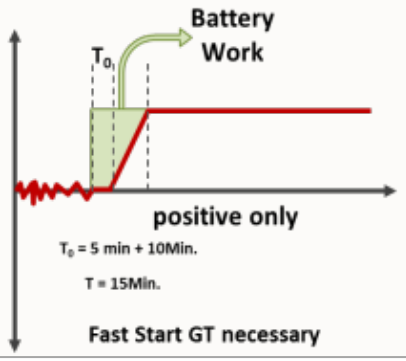


The new role of fossil plants:
Battery storage / thermal storage integration in existing plants

Battery integration in coal or gas plants (OCGT/CCGT)

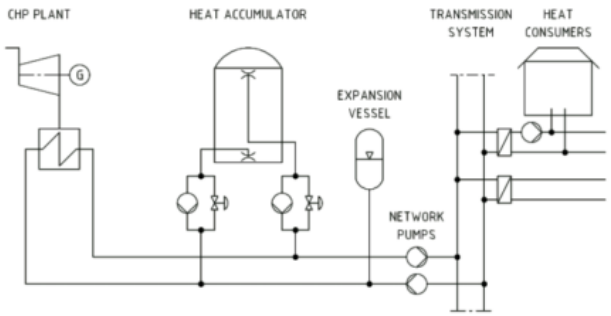


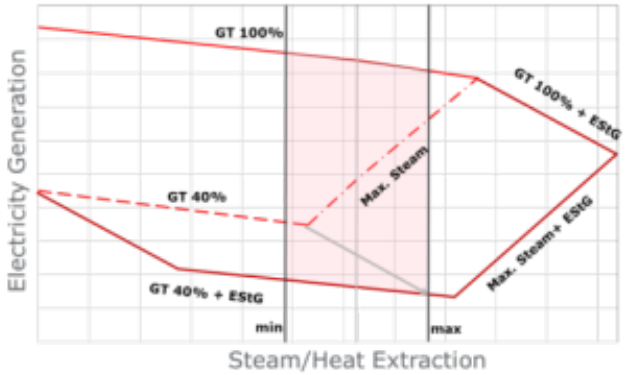
- ❑ Instant respond to request of grid operator. Increasing ancillary services (primary control)
- ❑ Reducing minimum load lower than environmental minimum load (battery charging during low priced hours)
- ❑ Increasing maximum load (battery discharging during high priced hours)
- ❑ Increasing ramp-rates



Thermal storage integration in CHP plants

- Large scale heat storage already a commercially available.
- Flexible CCGT or GPP with CHP in combination with electric steam generators for DSM give maximum flexibility to the grid and renewable energy sources
- Run the power plant between zero output vs. 100% load with the grid with constant heat supply





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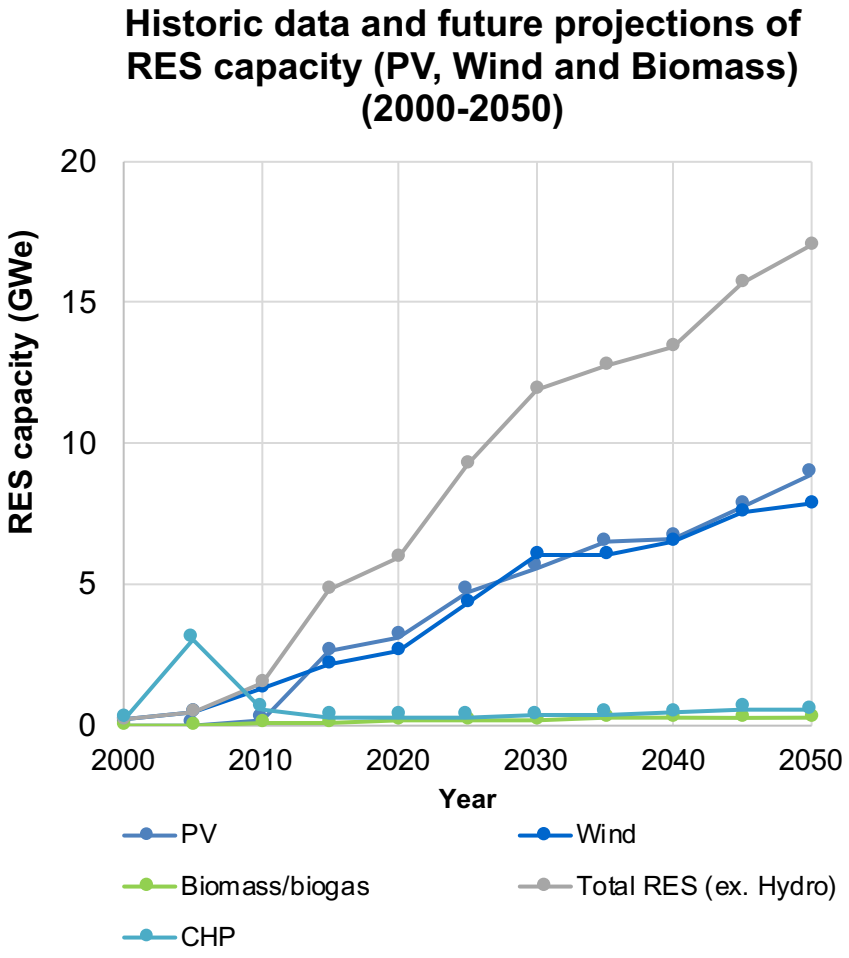
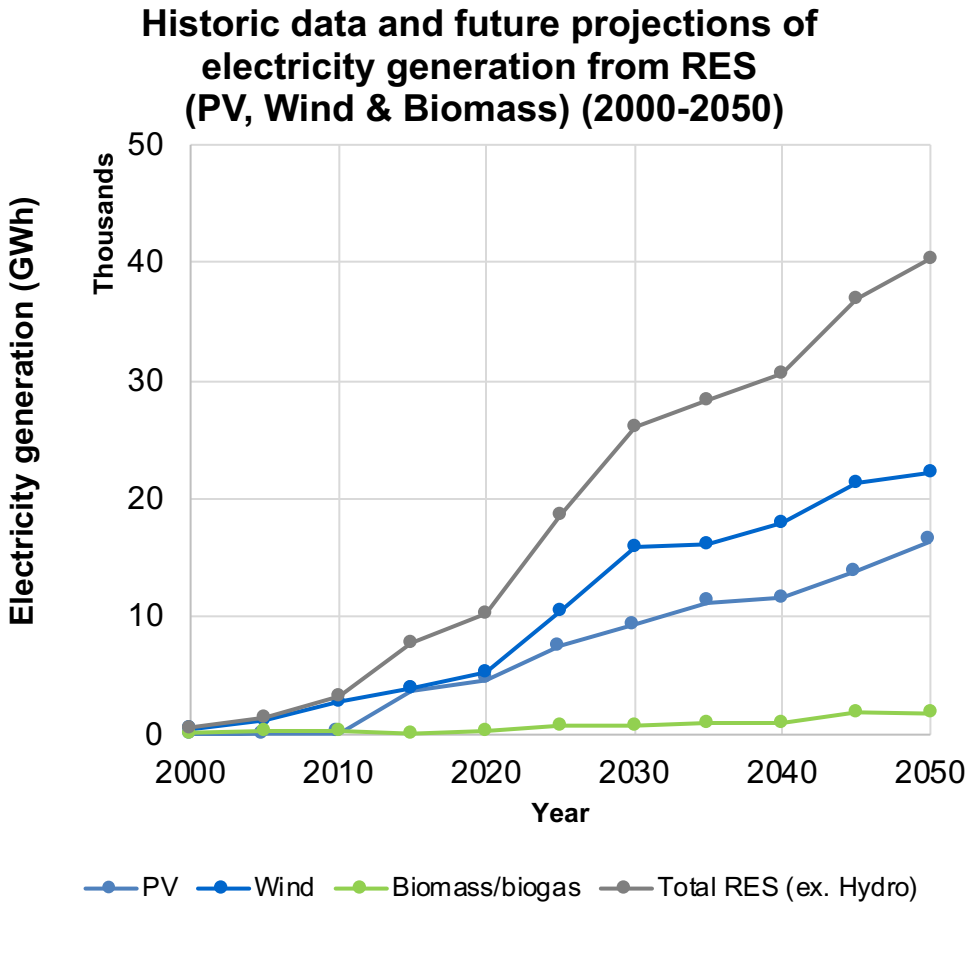
RES and CHP in Greece: Projections towards 2030-2050





Source: European Commission

RES and CHP in Greece Projections towards 2030-2050

CHP

- Percentage of CHP still one of the lowest among EU member states, despite a 40 years experience initially in the industrial sector (capacity, 570 MWe steady in the last years).
- Appropriate legal framework available, together with supporting mechanisms for independent producers.
- Lack of long term stability in the market environment, legislative framework, high natural gas prices, lowered feed in tariffs lead to difficulties in the further development of CHP

Considerations:

- Securing energy supply at a reasonable cost so as to be competitive and sustainable (20-year plan)
- Developing scheme for calculating the cost of base units exiting the day ahead programming.
- Proper interpretation / clarification of legislation on the formation of aggregators
  - One kind of RES (= an aggregator holds more than one portfolio)
  - All types of RES and conventional energy (= an aggregator owns a Portfolio with more than one type of RES and / or conventional form of energy source)

- ✓ **Dispatchable RES (Biomass, Biogas, Geothermal) and CHP** are key technologies in the new electricity market
- ✓ Aggregation of **Dispatchable RES** and **CHP** units towards offering balancing services and participating in different markets (day ahead, intraday, control reserve) constitutes a key factor for better RES integration in the Greek power system offering flexibility and securing energy supply

Dispatchable RES and CHP the example of Germany

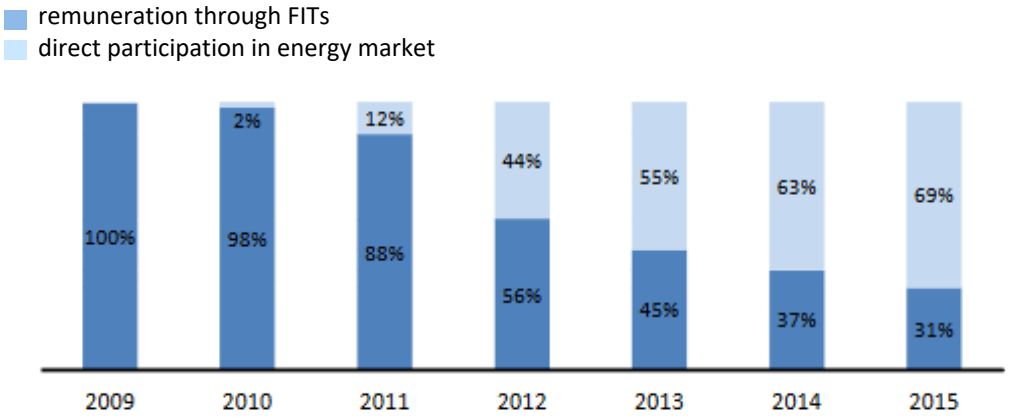
RES capacity in Germany has more than trippled in the last 10 years due to:

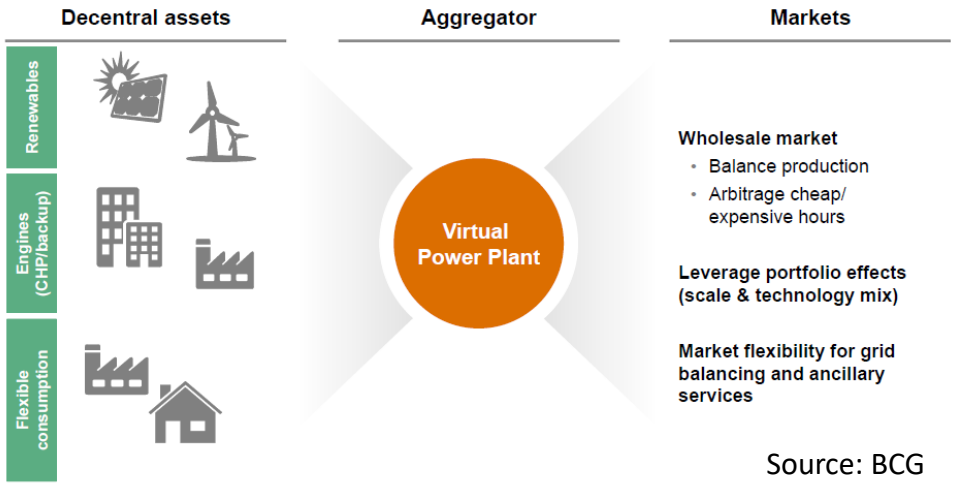
- gradual extinction of Feed In Tariff (FIT) schemes, forcing RES owners to participate in the regular el. market
- Revenues in majority of RES plants from el. Market participation. Control reserve market (primary, secondary, tertiary) → additional revenues.
- Aggregators aggressively entered the el. market and taken over the operation of a considerable percentage of RES capacity (particularly of smaller plants)
- Considerable savings in the operation of the whole market possible through pooling of assets and remote operation of

  a) renewable capacities, b) back-up plants or CHP plants as a virtual power plant

  OR of demand side management of large consumers.

Break down of produced energy from RES (GWh) according to payment schemes





Source: BCG

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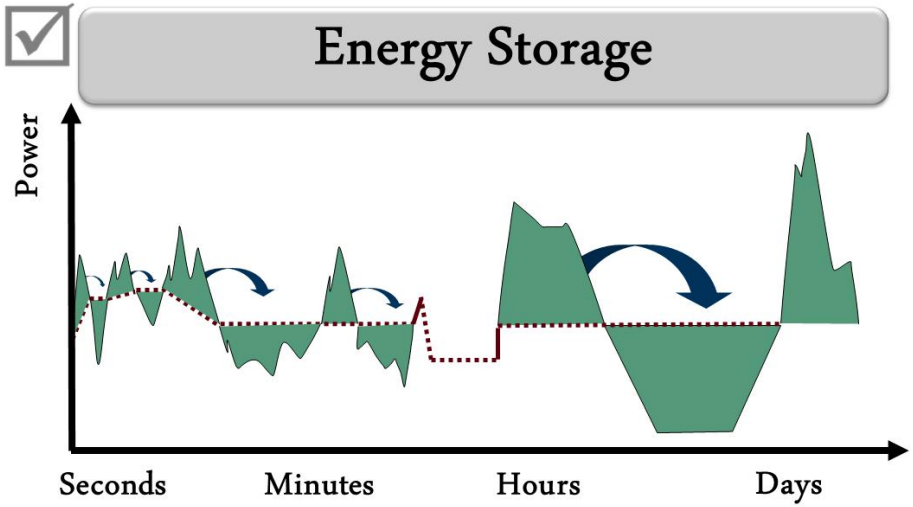
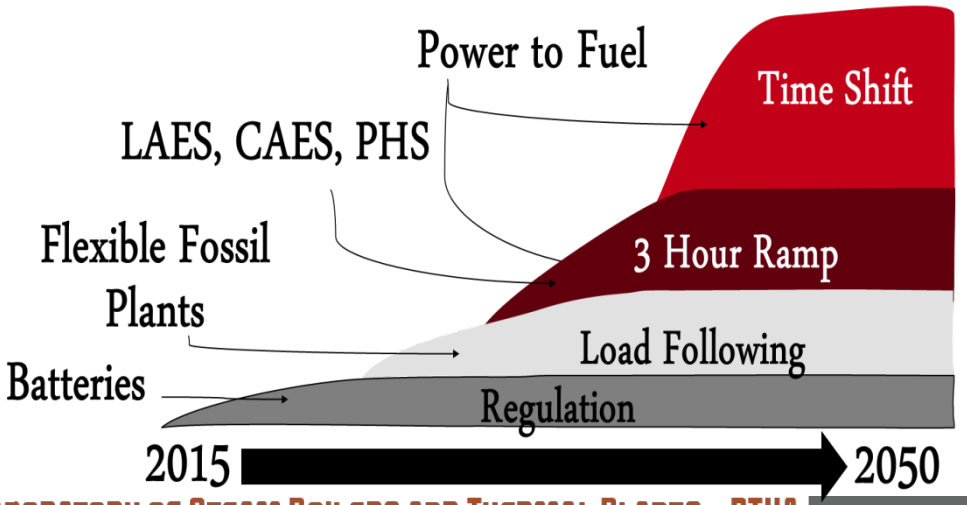
Energy Storage became a necessity



- Energy Storage is indispensable in a high RES system
- Energy storage Technology portofolio :
  - Power to Power
  - Power to Heat
  - Power to Fuel

- Applications in Greece to be also categorised to:
  - Mainland – Grid Connected (CG)
  - Islands – Not connected to the Grid, autonomous operation



LAES: Liquid Air Energy Storage
CAES: Compressed Air Energy Storage
PHS: Pumped Hydro Storage

Energy Storage: Power to Power Technologies for Grid Side Management

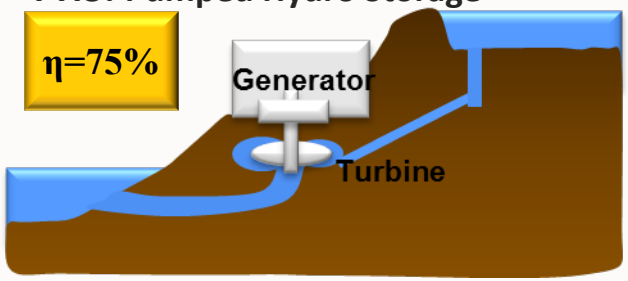
Storage Plants

-Power to Power
- LAES
- CAES
- Pumped Hydro
- Batteries
- Hybrid Systems

-Power to Fuel
- Hydrogen
- Methane
- Methanol
- Other Deriv. Fuels

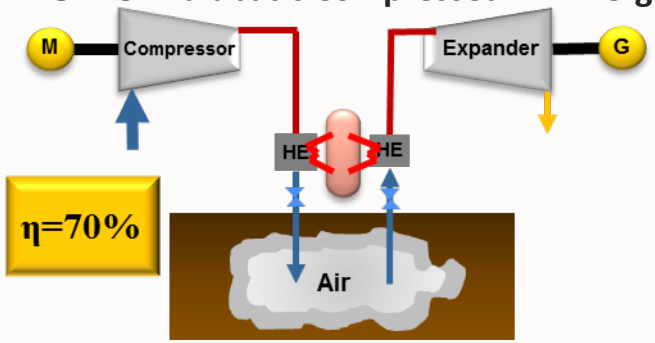
-Power to Heat
- Thermal Storage

PHS: Pumped Hydro Storage



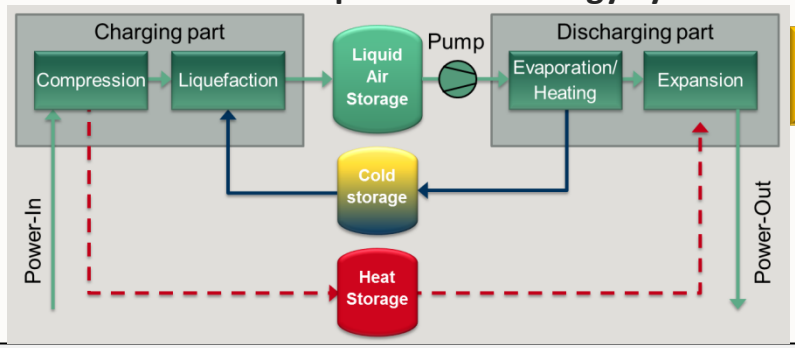
- Sfikia Station (CG)
- Nestos Station (CG)
- Amfilohia Project
- Amariou Project
- Ikaria Project

ACAES: Adiabatic Compressed Air Energy System



CAES with up to 55%
- Already Commercialised
- Natural gas use

LAES: Adiabatic Compressed Air Energy System



η=65%

Stand alone GT-LAES & integration to steam cycles

Energy Storage: Hybrid Systems and Demand Side Management

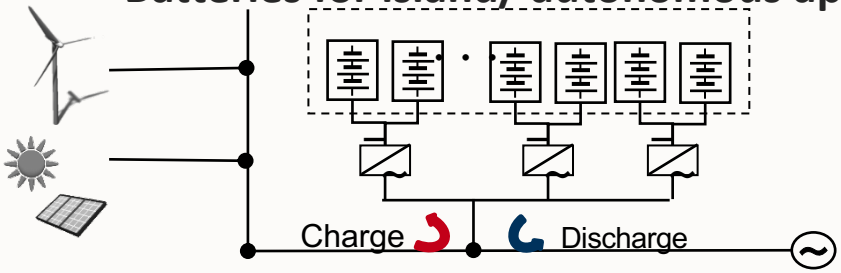
Storage Plants

-Power to Power
- LAES
- CAES
- Pumped Hydro
- Batteries
- Hybrid Systems

-Power to Fuel
- Hydrogen
- Methane
- Methanol
- Other Deriv. Fuels

-Power to Heat
- Thermal Storage

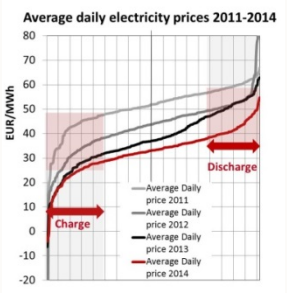
Batteries for island/ autonomous applications



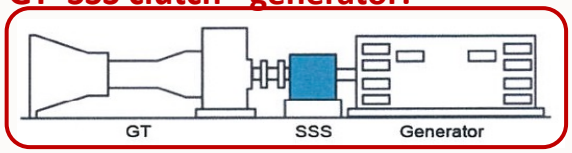
Replacing kWh or MWh of old Diesel engines is more profitable than batteries connected to CG

- *Tilos Project*

GTs + batteries or "SSS" clutch generator for Grid Management

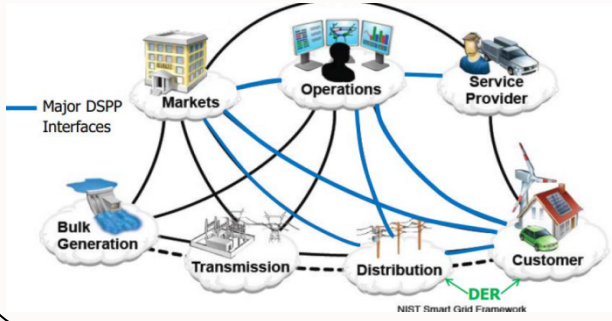


GT- SSS clutch - generator:



Use for reactive power compensation & grid stabilisation

Demand Side Management:



- Real Time Systems & Metering devices
- Distributed Controls & Demand Response
- Energy Efficiency

Large , Medium and Low Consumers:
Voltage Response, Demand Response, Local Generation and Storage (EV), Resiliency, Customer Services

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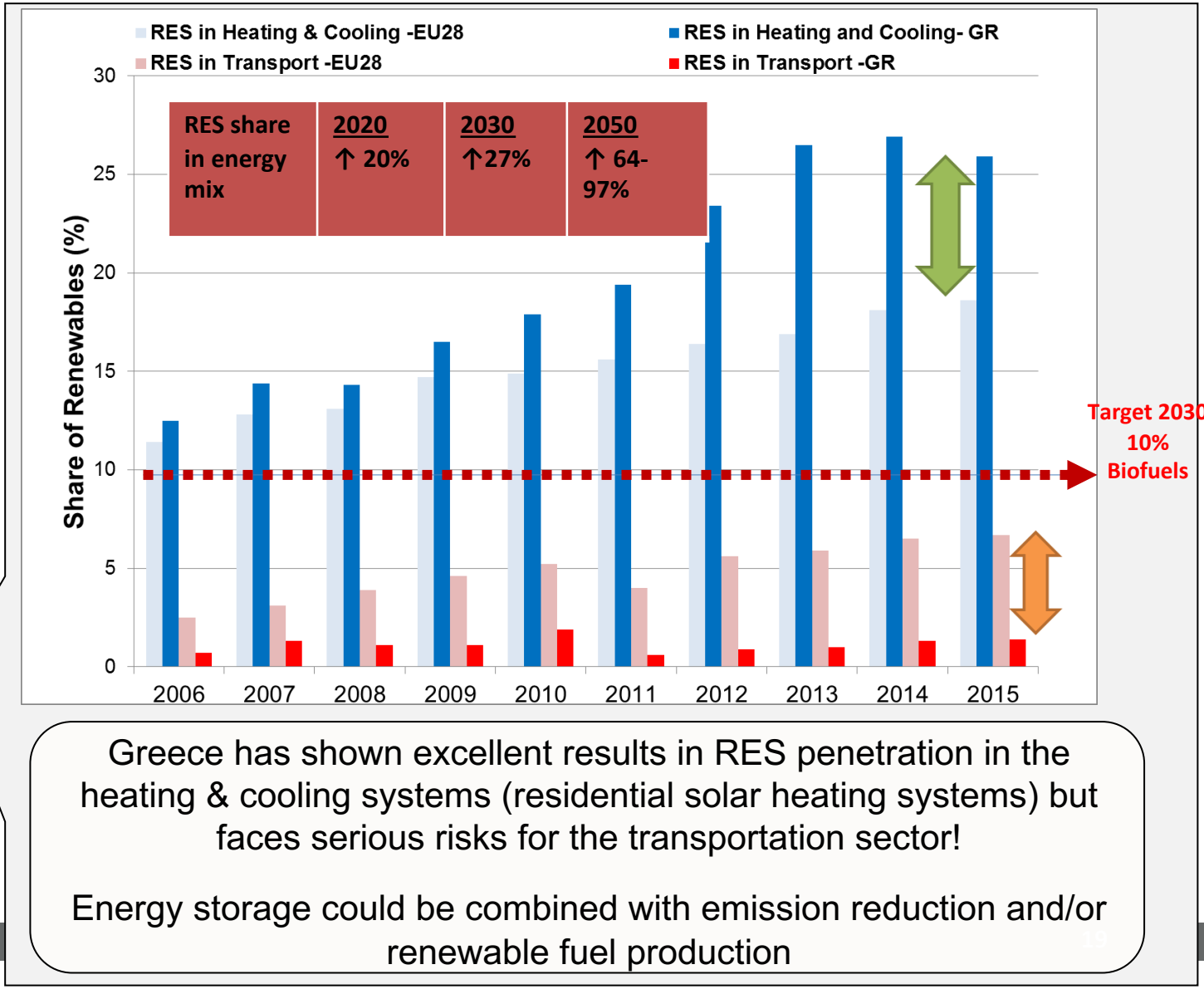
Energy Storage: Power to X

Storage Plants

-Power to Power
- LAES
- CAES
- Pumped Hydro
- Batteries
- Hybrid Systems

-Power to Fuel
- Hydrogen
- Methane
- Methanol
- Other Deriv. Fuels

-Power to Heat
- Thermal Storage



Greece has shown excellent results in RES penetration in the heating & cooling systems (residential solar heating systems) but faces serious risks for the transportation sector!

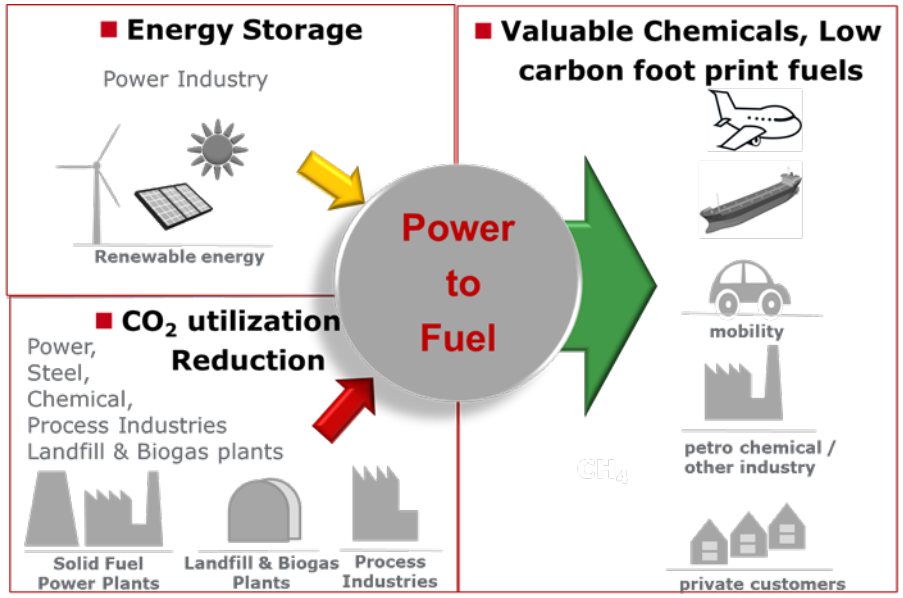
Energy storage could be combined with emission reduction and/or renewable fuel production

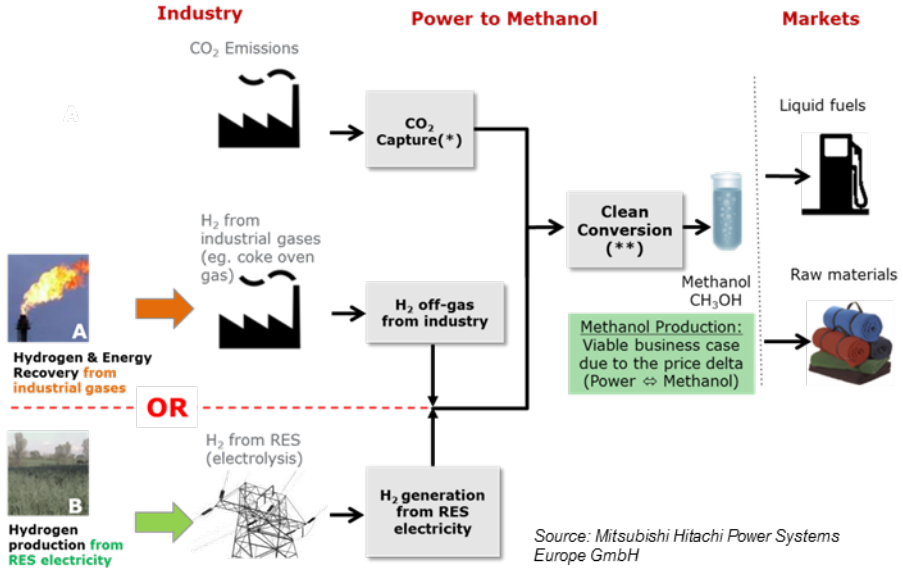
Power to X: Focus on Power to fuel **for the production of low carbon fuels !!!**

1. **Power to Hydrogen:** Use of H_2? A) Fuel cells with overall conversion ~30-44%
   B) Blending with NG, but grid specs!!!!
   η=70-80% No CCU

2. **Power to Gas:** Use of CH_4? Blending with NG, replacing fossil NG using existing infrastructure
   η=50-60% With CCU
   Remark: Heat also available, LCOE ~300% of fossil NG

3. **Power to Methanol:** Use of CH_3OH? Auto-Mobility, Marine sector, after conversion to Gasoline also in aviation sector, Chemical production
   η=50-60% With CCU
   Remark: High market/business potential due to high MeOH prices





Power to X: Focus on Power to Heat

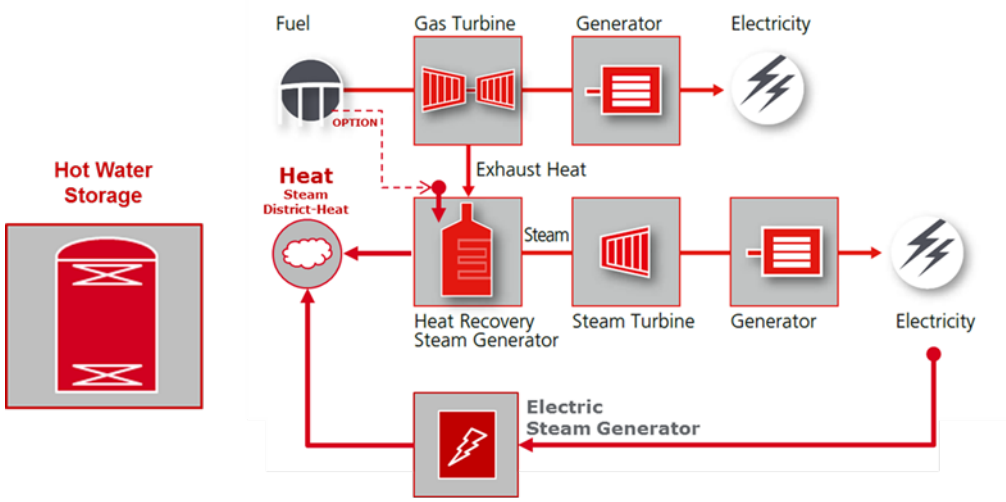
Energy storage with Power to Heat: Converting RES electricity to heat

-Use of electric steam generators at GT and CCGT plants

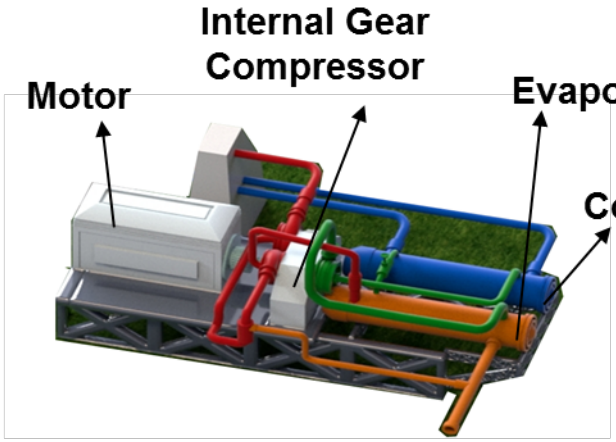
- Use of heat pumps for:
  a) Warm water for commercial use and district heat
  b) Steam production

-**Contribution to EU Targets:**

-Energy Efficiency, CO_2 reduction and avoidance of energy curtailment due to energy storage



Source: Mitsubishi Hitachi Power Systems Europe GmbH



High Temperature Heat Pump
Source: Mitsubishi Hitachi Power Systems Europe

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Conclusions

- Lignite production share will be in the magnitude of 36% in 2020, reduced to 21% in 2030, while it will be absent in the 2050 energy mix (Removed capacity ~4 GWe)
- Natural gas plants (modern CCGTs) in several cases already more cost competitive than aged lignite plants. Their share towards 2030 and 2050 is expected to remain stable at ~ 20%
- RES share is expected to increase up to 65% by 2050 mainly with wind and solar plants. The active participation of Biomass, Biogas and CHP units is necessary to ensure competition between RES in the new electricity market offering flexibility and securing energy supply.
- Energy storage becomes a necessity in high RES systems. PHS and LAES can be used for grid management in mainland, while batteries can be applied with RES on the islands. Batteries in combination with GTs can provide services for primary and secondary control.
- Greece's targets on biofuels implementation require immediate measures. Power to Fuel could both act as an energy storage and renewable fuel production reducing the GHG emissions.

Aknowledgements

- Dr. Michalis Agraniotis (MHPSE)
- Dr: Efthymia Ioanna Koytsoumpa (MHPSE)
- Prof. Sotirios Karellas (NTUA)
- Dr. Dionisios Giannakopoulos (CERTH)
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- Christina Chatzilaou (NTUA)