Network and power plant investments - country case study with high wind power penetration

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Agenda

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- Methodology
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  2. Application of the models
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Introduction

- High targets for electricity generation from renewables
  i. Share of 8,6 % in 1997
  ii. Share of 18% in 2020 envisaged (directive EU 28/2009)

- Wind energy promotion by Greek energy policy
  i. Tariff rules
  ii. Financial support for investors

- Large wind power potentials in Greece
  i. Cyclades and Aegean sea: over 8m/s in 40m height
  ii. Potential in the regions of Evia, Peloponnes and Thrace

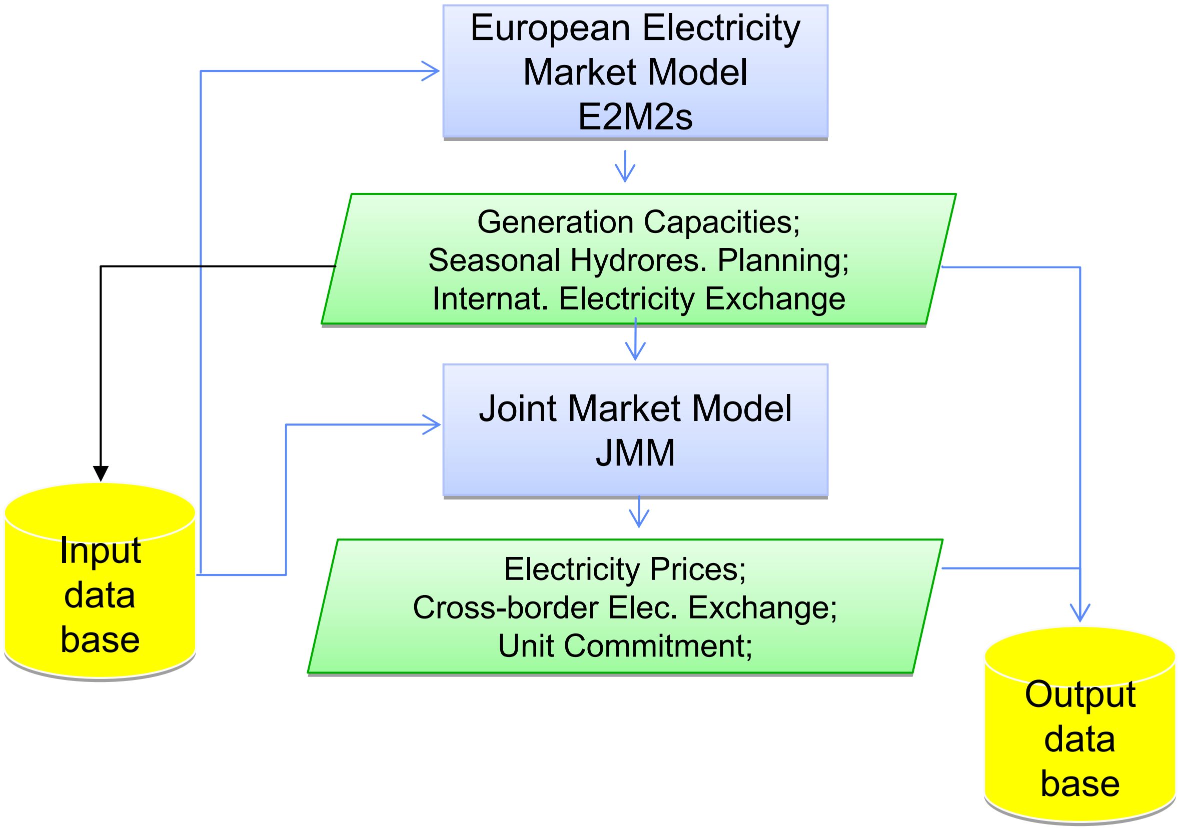
Introduction

- Challenges due to wind capacity expansion on conventional power system
  i. Increased residual load gradients
  ii. Increased flexibility requirements
  iii. Distance between wind sites and demand centers

→ Due to increasing wind power and its accompanying challenges, increasing importance of methods for evaluating impacts of wind power and integration measures

Joint Market Model (JMM) and European Electricity Market Model (E2M2s)

- E2M2s
  i. Market model with long time horizon to determine long term aspects of power system, esp. investments
- JMM
  i. Market model with hourly resolution to cover operational aspects of power system



E2M2s: General concept

Input:

Data on

- existing capacities for conventional power plants, renewables and storage
- fuel & CO_2-prices
- power plant efficiencies
- further technical parameters (availability, start-up costs)
- transmission capacities / susceptances
- load
- RES-E availability

Methodology:

Market operation corresponds to system optimisation

- Inclusion of DC load flow approach
- formulation as a cost minimisation problem
- LP-Model, encompassing several time steps

Output:

- marginal system costs = equilibrium level for electricity prices
- **investments in power plants**

E2M2s: Time resolution and scenario grid

- To represent different seasonal effects on RES-E potentials and electricity demand a full year is considered
- To limit calculation time the year is divided into 12 typical days
- To consider the temporal fluctuations of demand and RES-E the typical days are sub-divided into a two-hourly resolution
- Uncertainty covered by recombining decision tree
- Long run fluctuations covered by two hydro inflow scenarios
- Short run fluctuations covered by three wind generation scenarios

JMM: General concept

Input: Data on

- existing capacities for conventional power plants and storage
- boundary conditions (fuel prices, prices for emissions)
- power plant data (efficiency, availability, start-up costs)
- transmission data (susceptance, capacity)
- load
- RES-E injection

Methodology: Market operation corresponds to system optimisation

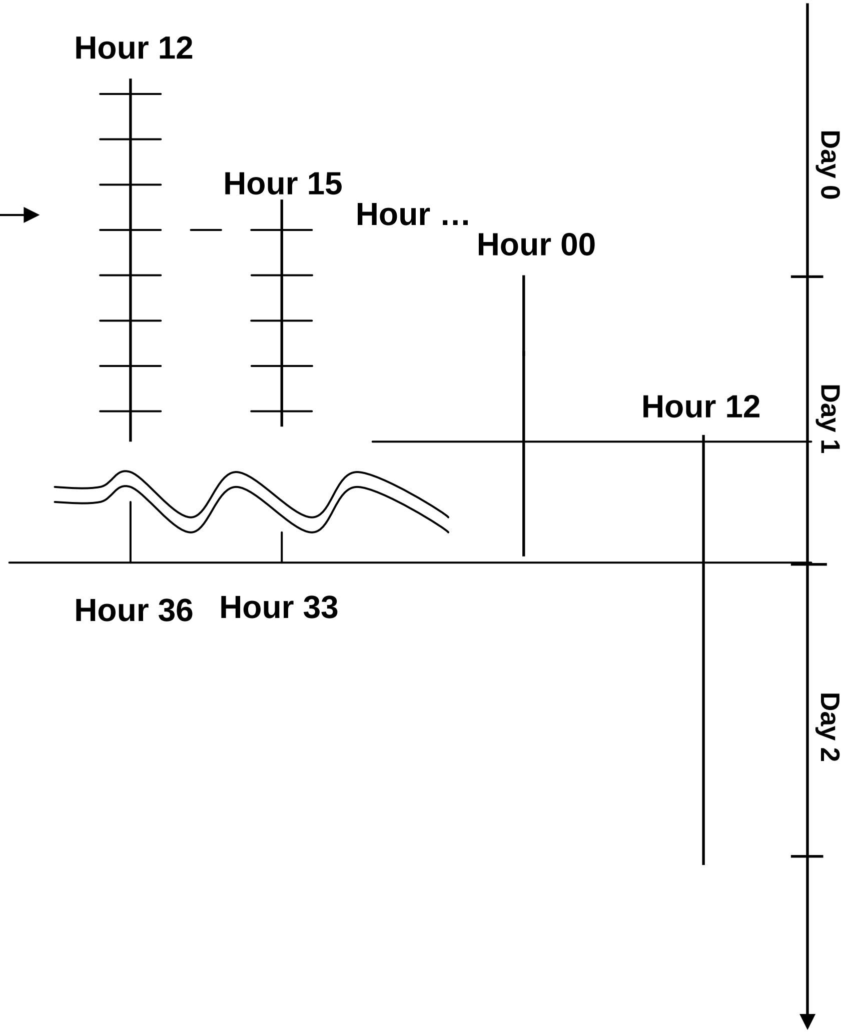
- formulation as a cost minimisation problem
- LP-Model, nodal model encompassing hourly resolution
- Inclusion of DC load flow

Output:

- marginal system costs = equilibrium level for electricity prices
- detailed **system operation cost**

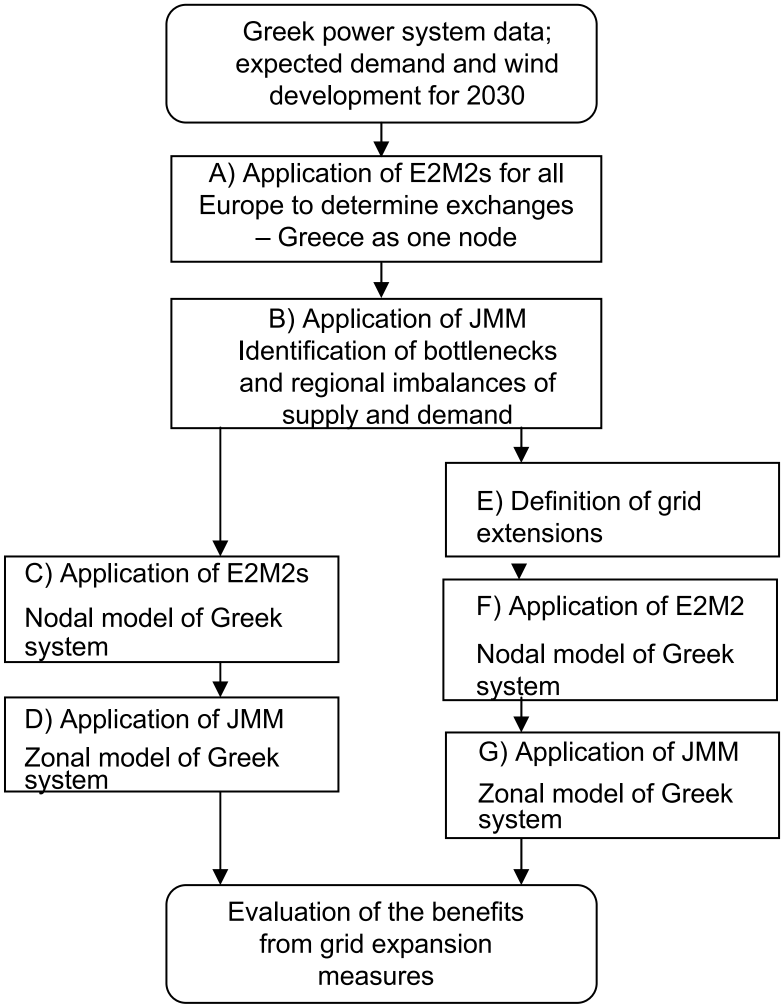
JMM: Time resolution

- Day-ahead-planning simulated - Optimization period up to 36 h
  i. Rolling Planning approach
- Within each optimization period, hourly time resolution
- Every 3 hours, a new planning (optimization) loop
- Transfer of new information on load and wind of each loop
- Transfer of values for intertemporal constraints between loops (esp. storage values)
- Consideration of one year (2030) with 2920 planning loops

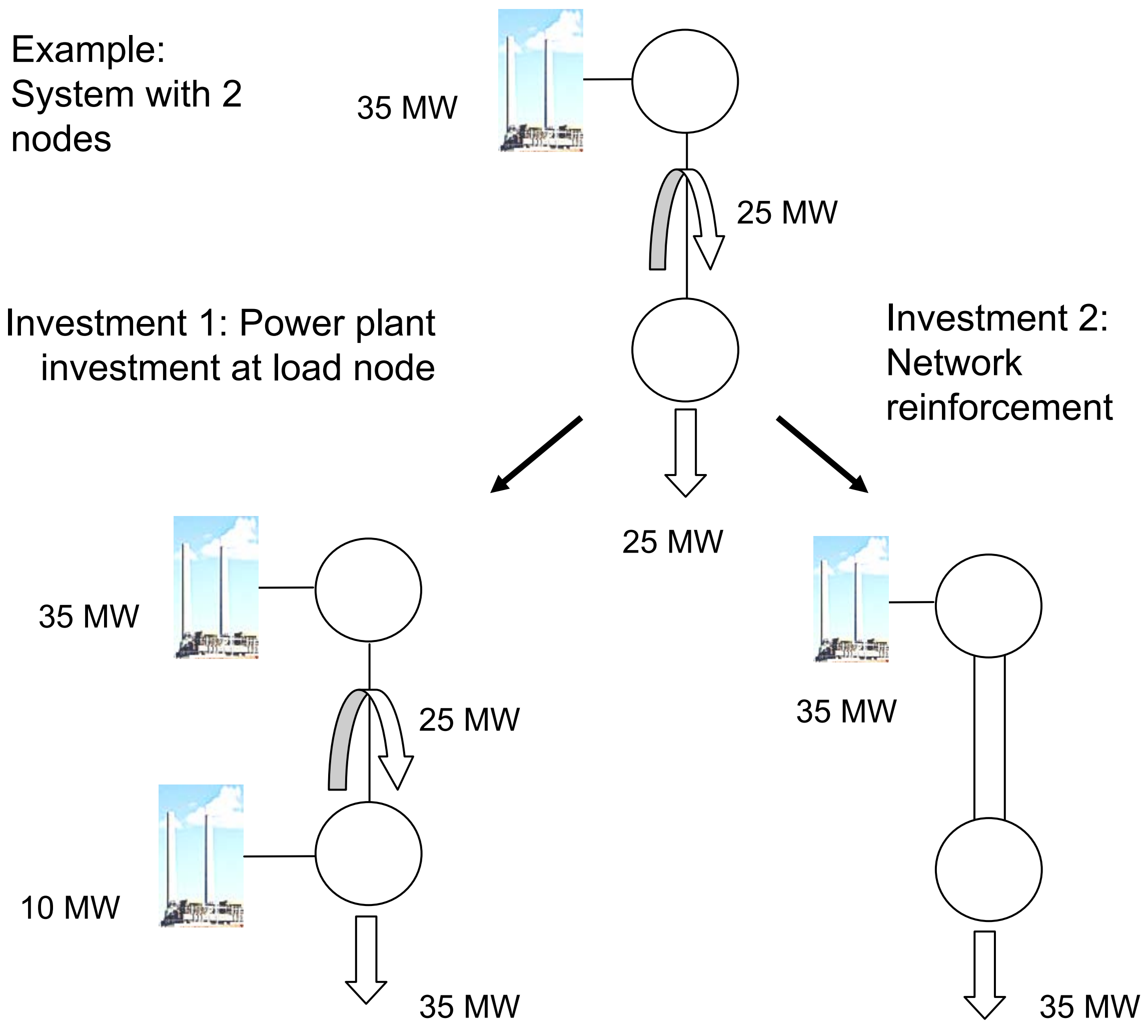


Application of the models

- Data collection process
- Application of E2M2s for all Europe to fix exchanges
- Application of JMM for definition of network extension scenario
- Detailed investment and operational cost analysis for scenario with and without network extension



Application of the models

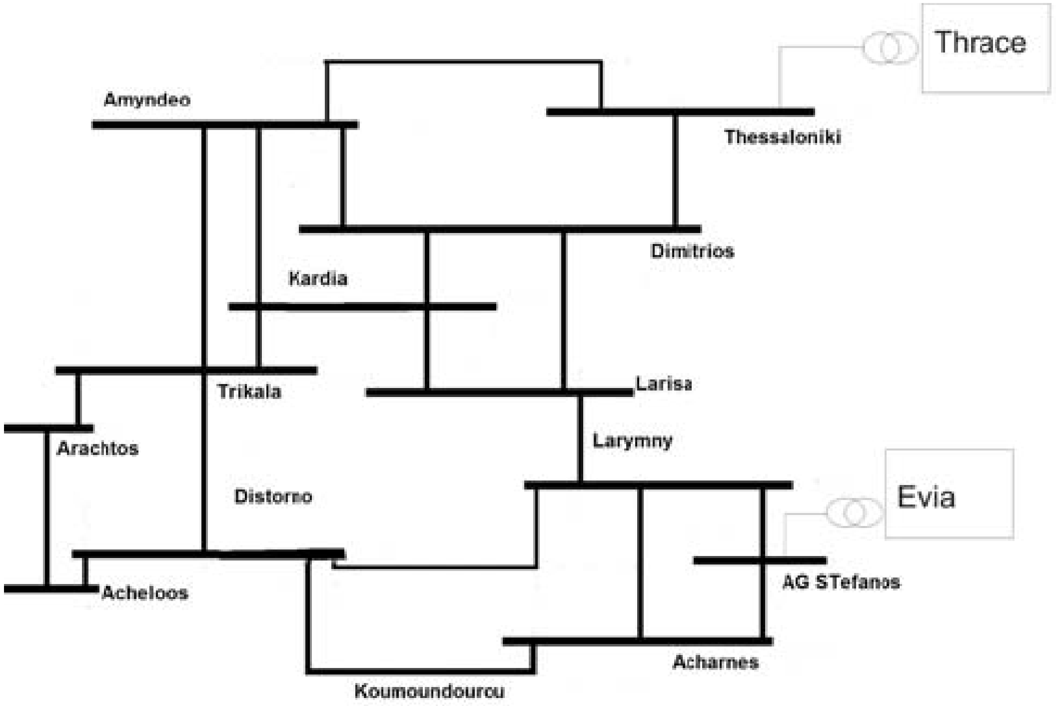


Aspects covered by each scenario:

- Regional load flows
- Consideration of international cross-border load flows

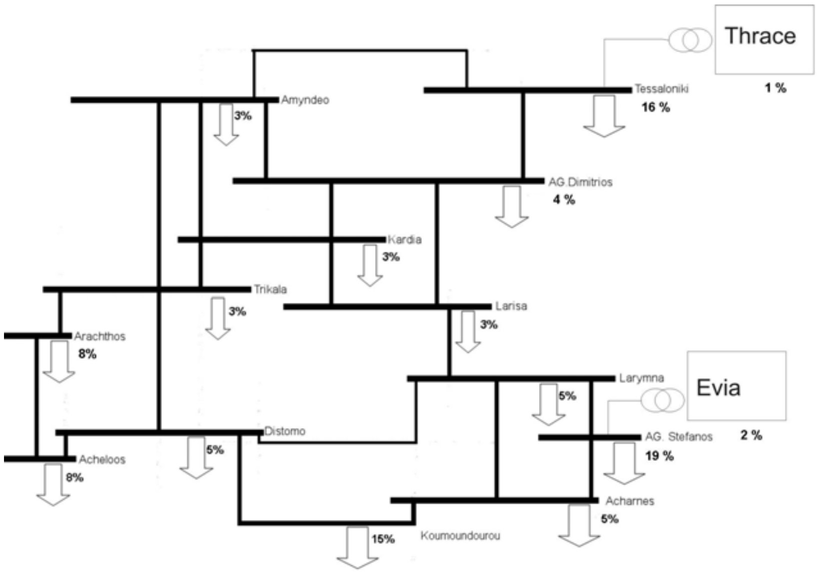
Power system data

- Consideration of the 400kV grid of Greece with 13 nodes plus EVIA and Thrace
- 150 kV subsystem of EVIA considered with 8 nodes
- 150 kV subsystem of Thrace integrated with 17 nodes
- Reinforcements of the 150 kV and 400 kV network have already been scheduled by HTSO

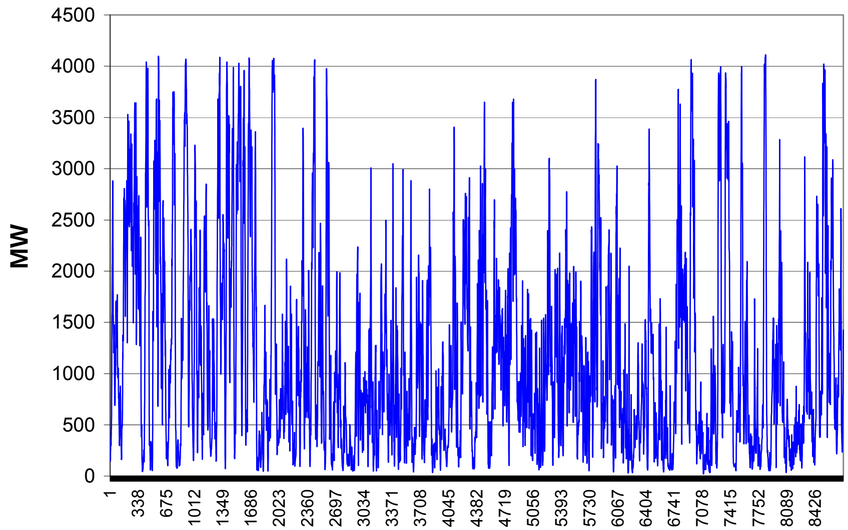


Power system data

- Load profile based on UCTE (now ENTSO-E) data
- Regional distribution of load according to population shares
- Total estimated installed wind power capacity in 2030: 6553 MW

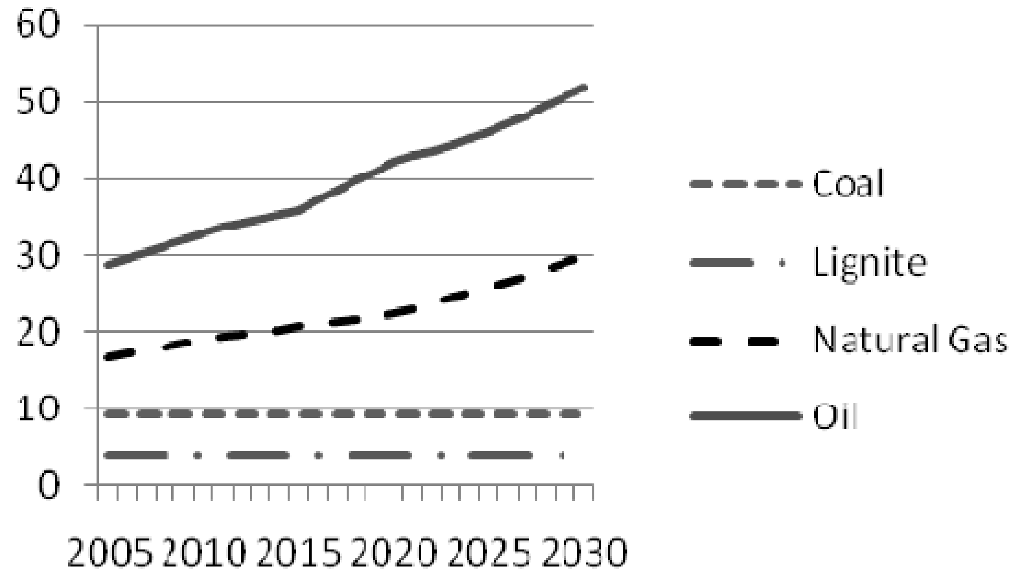


Windpower generation scenario for Greece - 2030



Power system data

- Boundary conditions are based on data by the EU[1]
- Stable prices for coal and lignite
- Strong increase of prices for natural gas and oil
- Linear increase of price for emission certificates from 25 Euro/ton to 60 Euro/ton

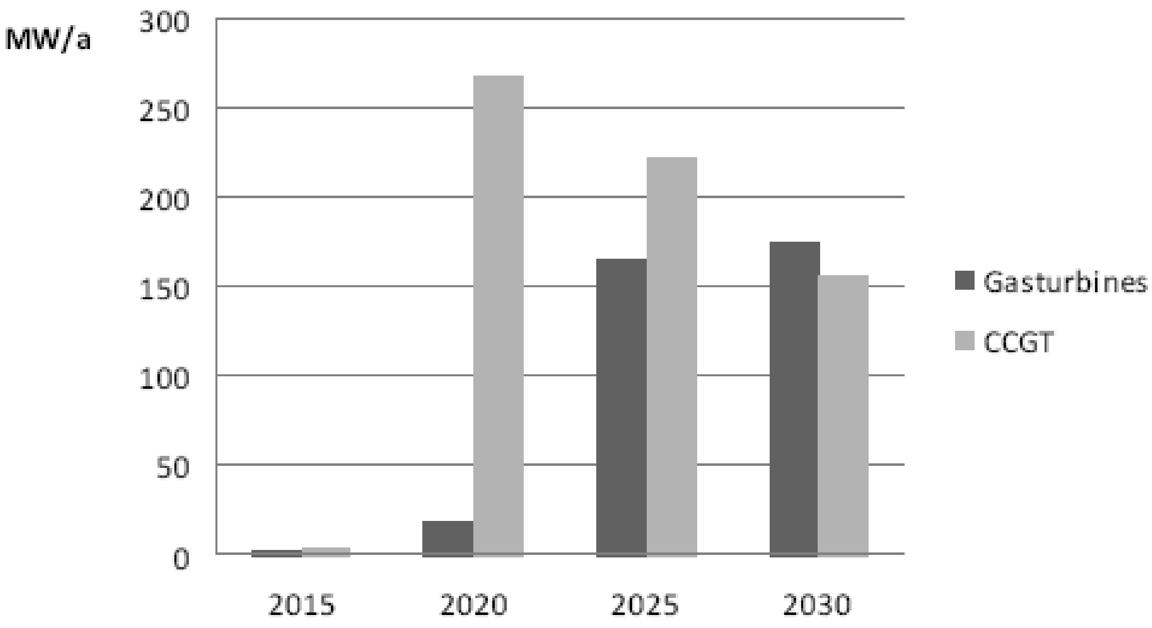


[1]European Energy and Transport Trends to 2030 – update 2005, European Communities, Luxembourg, 2006.
European Energy and Transport – Scenarios on high oil and gas prices, European Communities, Luxembourg, 2006.

Results: Power plant capacity extension

- Scenario 1 excludes network investments
- Only investments in gas turbines (GT) and combined cycle gas turbines (CCGT)
- Overall invested generation capacity of approx 1 GW
- Main sites of investment are Arachtos, AG Stefanos and Distorno

Scenario 1: Power plant investment



Results: Investment cost scenario 1

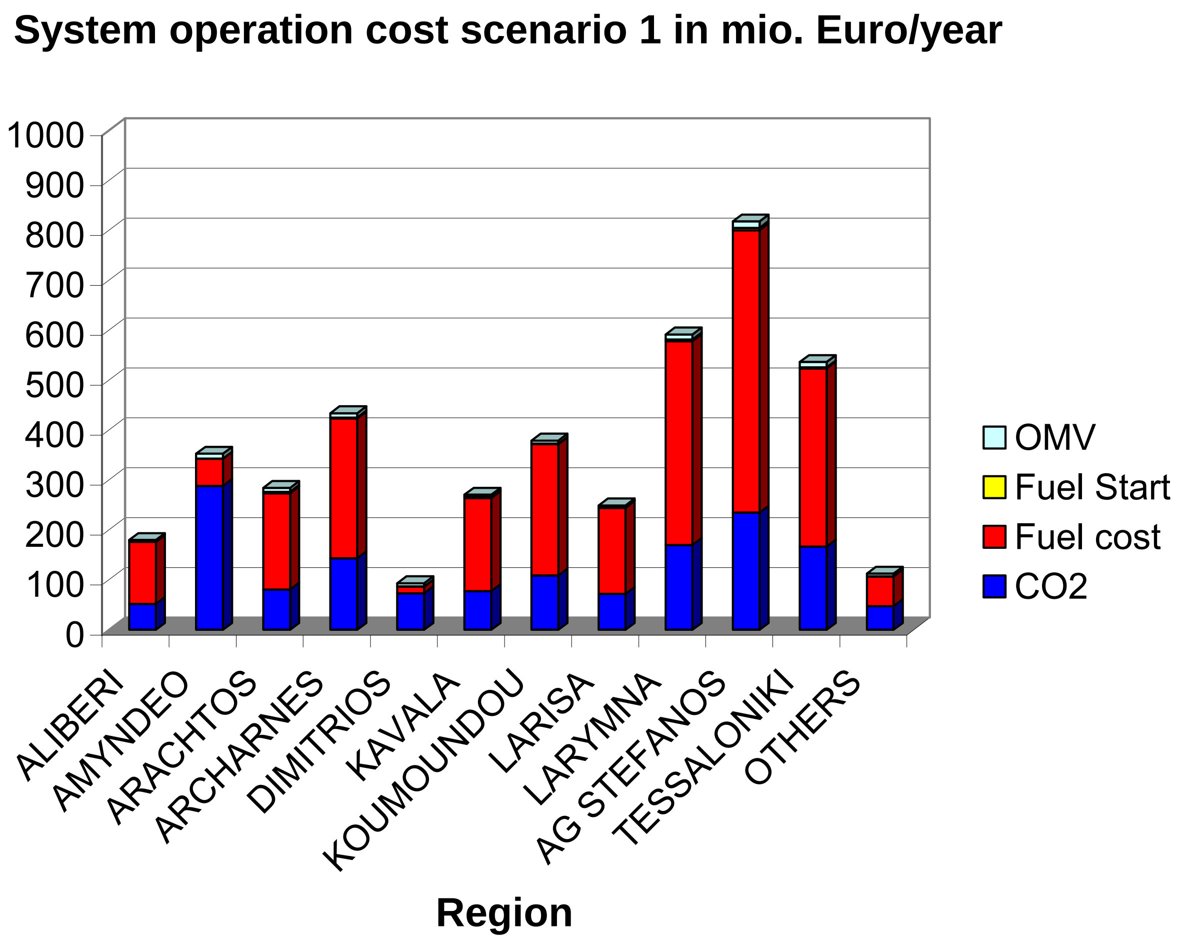
- Largest part of investments in combined cycle gas turbines
- Investment in gas turbines are increasing until 2030
- Investment in combined cycle gas turbines are decreasing until 2030

Year	Annuity of investments in Gas Turbines in mio. €/a	Annuity of investments in Combined Cycle Gas Turbines in mio. €/a
2020	0.812	22.316
2025	7.203	18.507
2030	7.674	12.969

→ Higher wind power penetration in 2030 reduces full load hours of more capital intense combined cycle units

Results: System operation cost in scenario 1

- Main cost factors are fuel cost and CO_2 cost
- For regions with lignite production, namely Amyndeo and Dimitrios, emission cost exceed fuel costs



Results: Network expansion for scenario 2

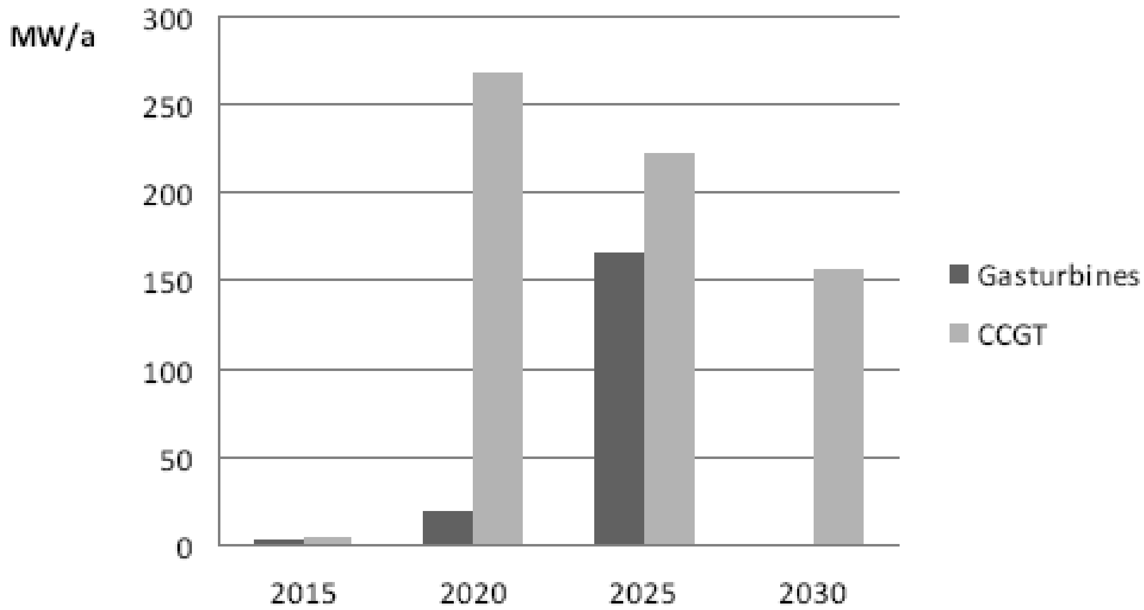
- Definition of transmission grid expansion for scenario 2
- Number of hours with usage at limit as criterion for component selection
- Most expansion measures are related to the link of the 150 kV system of EVIA and THRACE to the 400 kV main grid

Description	Node 1	Node 2
Line	Iasmos	Komotini
Line	Kavala	Thessaloniki
Line	Arachtos	Trikala
Line	Aliberi	Stefanos
Line	Aliberi	Arguros

Results: Power plant capacity extension

- Scenario 2 includes network investments
- Overall invested generation capacity of approx 820 MW
- Approx. 170 MW less investment in gas turbines in AG Stefanos

Scenario 2: Power plant investment



Results: Investment cost scenario 2

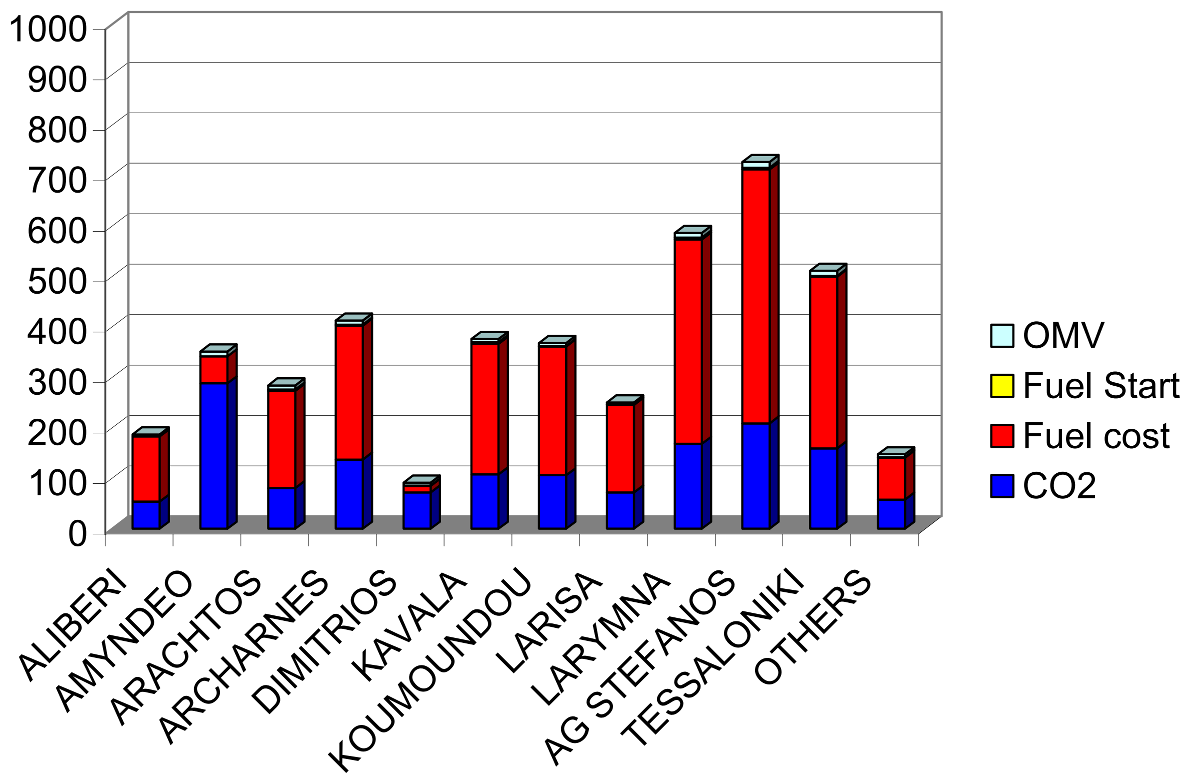
- Dominant investment type is combined cycle gas turbines
- Increased interconnection Stefanos - Aliberi makes wind power capacity and gas units of Evia better available for main 400 kV grid
- Annuity of network investment cost is 9,39 mio. Euro

Year	Annuity of investments in Gas Turbines in mio. €/a	Annuity of investments in Combined Cycle Gas Turbines in mio. €/a
2020	0.813	21.192
2025	7.251	17.917
2030	0.000	13.696

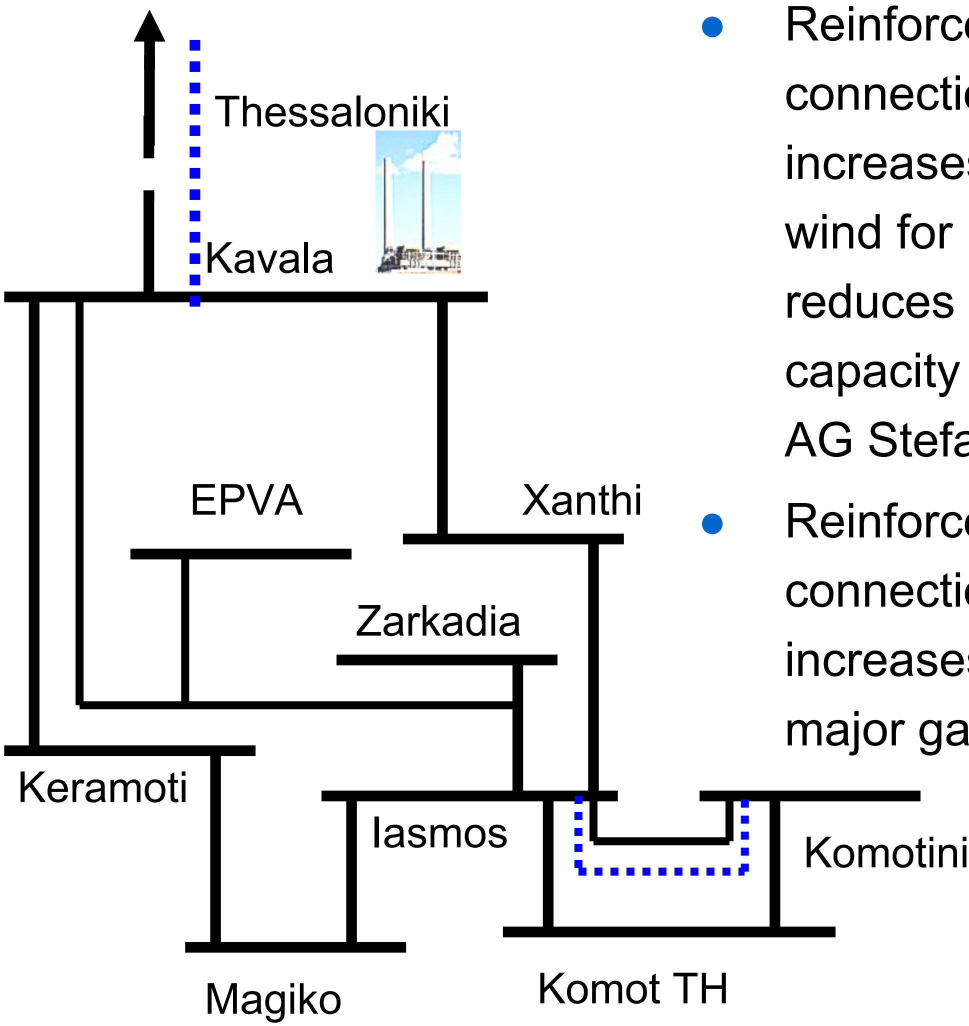
Results: System operation cost in scenario 2

- Overall system operation cost savings of 5 mio. € in comparison to scenario 1 relatively small
- System operation cost in Kavala (part of the Thrace loop) increase, due to higher usage of combined cycle gas units there

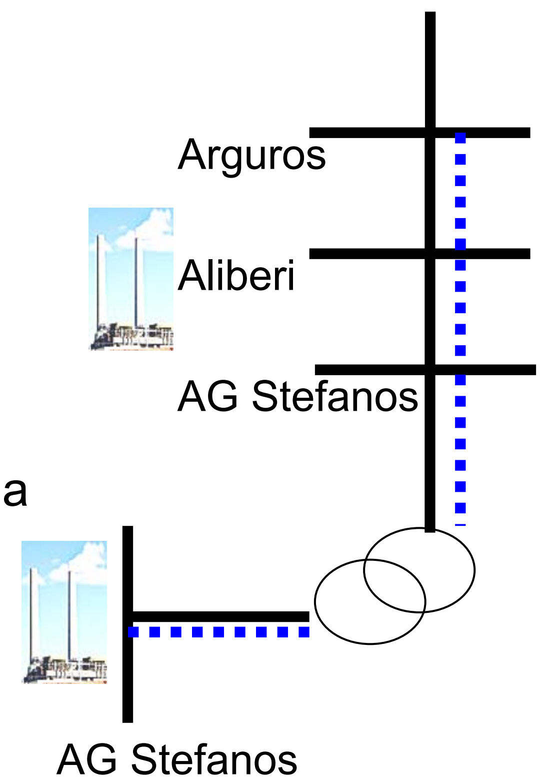
System operaiton cost scenario 2 in mio. Euro/year



Results: Network investment effects on power plant investments and system operation



- Reinforcement of connection to EVIA increases availability of wind for main grid and reduces gas turbine capacity investment in AG Stefanos
- Reinforcement of connection to Thrace increases operation of major gas units in Kavala



Summary

In the hypothetical case, there are

- 0,8 mio. Euro higher annualized investment cost in scenario 2 (with network extension)
- 5 mio. Euro lower yearly system operation cost in scenario 2
- Overall cost savings of 4,2 mio. Euro per year in the case of network extension
- Only conventional power plant investments in natural gas technologies
- Depending on the boundary conditions and the type of network investments results might be different

Conclusions

- The market models E2M2s and JMM can be used to evaluate different power system extension alternatives from an economic point of view with consideration of wind power integration
- Adequate network investment lead to
  i. Reduced power plant investment
  ii. Lower system operation cost
- Network investment had low impact on overall system cost, but larger impact on regional allocation of system costs

Thank you for your attention!

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