Increasing the Share of Renewables in Turkey's Power System

Options for Transmission Expansion and Flexibility

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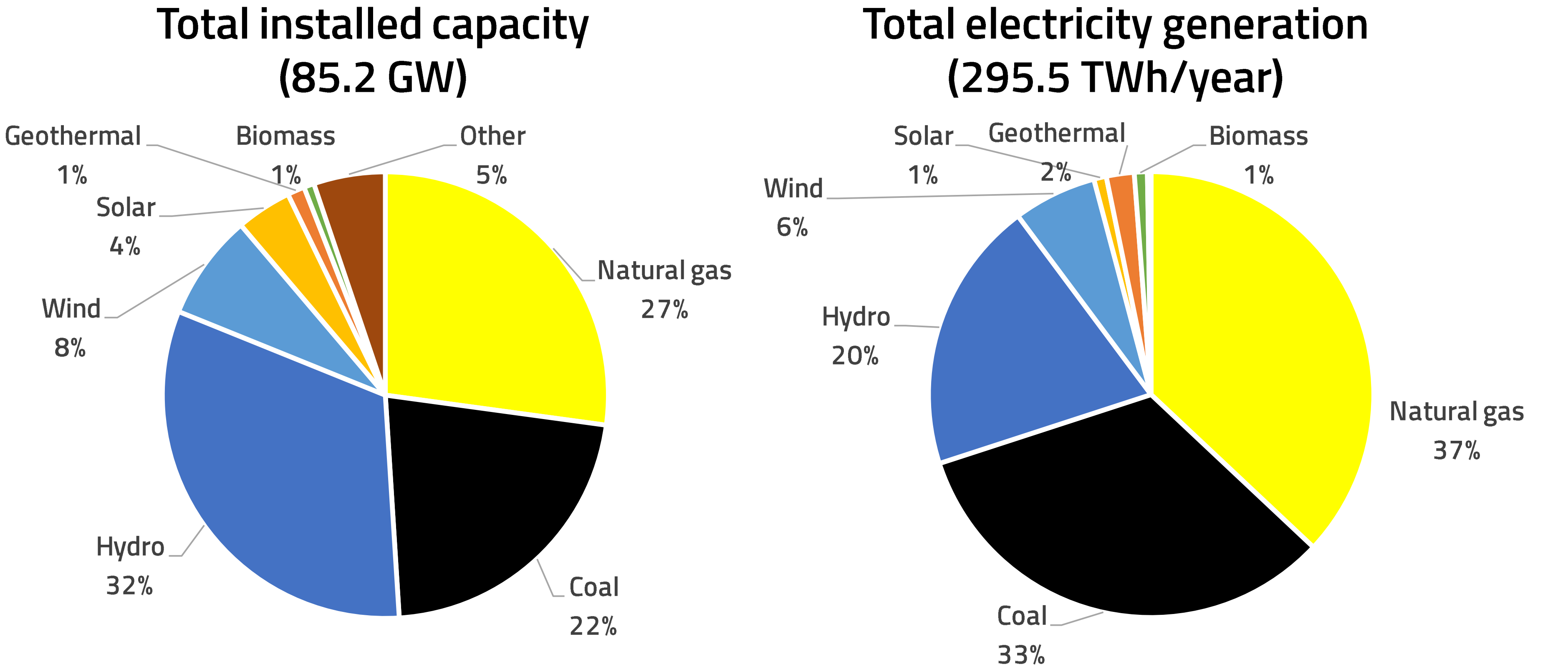
SHURA's objectives

- **Mission:** Contributing to the debate on Turkey's energy transition
- **Who we are:** A transparent platform stimulating discussion on Turkey's energy future among all interested stakeholders
- **What we do:** Energy sector think tank providing fact-based, unbiased and independent research and analysis, covering technology, economics and policies

Renewables represent 30% of total generation (2017)



Solar and wind represent 7% of total generation

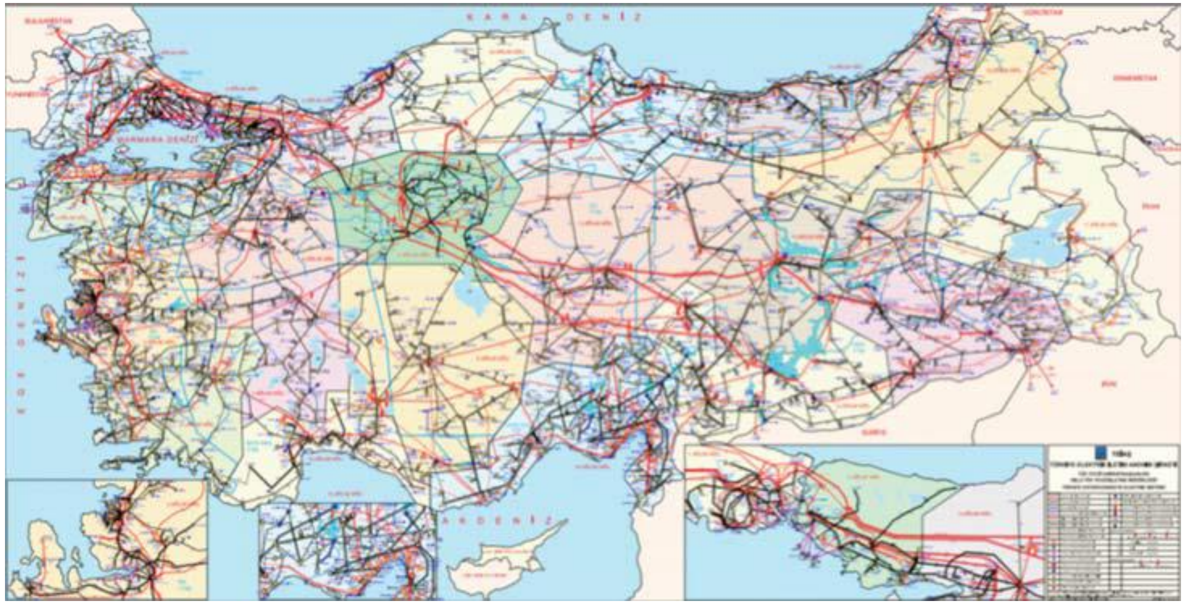
Renewables are around half of the total installed capacity. Geothermal 4th worldwide

Large share of supply from imported gas and coal

Source: MENR (2018)

Some characteristics of Turkey's grid

- 400 kV and important load flows through 154 kV as well
- State-owned TEİAŞ sole owner – planning with TYNDP
- 2% power trade
  - Synchronous with ENTSO-E (Greece and Bulgaria) – grid frequence stability and sharing of reserves
  - Controlled and unsynchronised with Georgia (HVDC), Iran, Iraq and Syria
- Winter and summer peak difference is 5% (high electricity use in residential, including for heating)
- But large load deviations happen, iron-steel
  - 8th largest steel producer in the world, 2/3 EAF route
  - Large share of electricity use in other sectors (textile, food, cement-grinding)
  - In 30 secs up to 900 MW load – balanced with ENTSO-E



Source: SHURA (2018)

Objective and scope

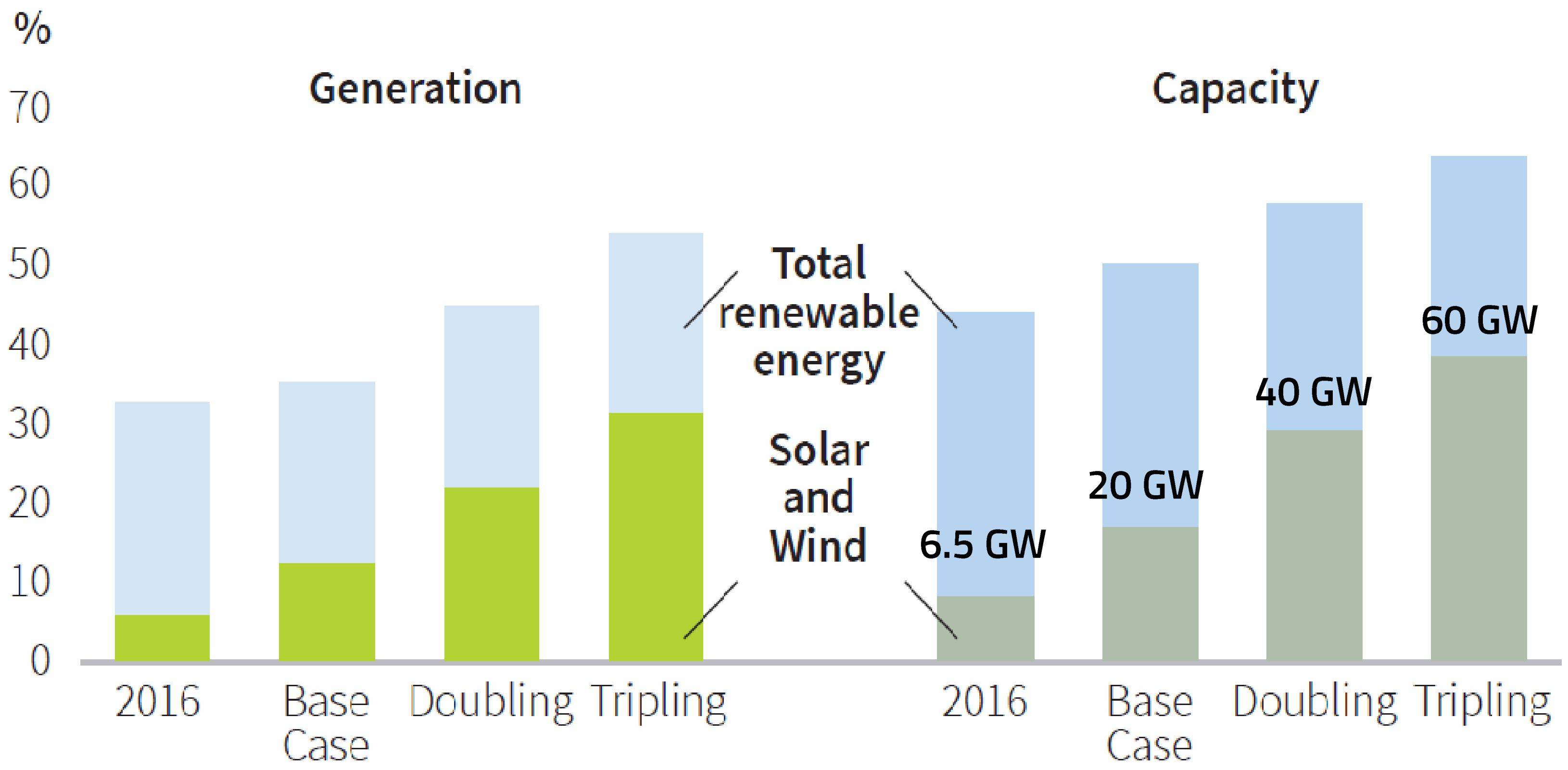
Objective of this study is to **assess the consequences of increasing wind and solar power generation in the Turkey's power system beyond the levels planned by transmission system operator's Ten Year Network Development Plan**

Addresses the following questions:

- Is additional transmission grid investment necessary, where and how much?
- How does the placement of new wind and PV installations affect the power system?
- How will a greater share of renewables affect reserve requirements, redispatch of conventional power generation and renewables curtailment?
- What are the benefits of increasing flexibility in the Turkey's power system?

Source: SHURA (2018)

Three distinct scenarios developed to assess wind and solar capacity to 2026



For each scenario, various strategy and flexibility options have been evaluated for grid integration

Source: SHURA (2018)

Key findings

- Turkey’s first of its kind renewable energy grid integration study
- Complements TSO’s network development and expands the time horizon
- Doubling the planned wind and solar capacity to 40 GW by 2026 without any major impacts on planning and operation possible.
  Supplies >20% of Turkey’s total electricity output
  - No additional transmission grid investments needed
  - Impacts on renewable curtailment and redispatch limited
- System friendly relocation of wind and solar capacity by considering areas with strong grids and high electricity demand enables tripling (60 GW) with limited additional invetments
- Findings are a first step in development of an inclusive roadmap for a low-carbon electricity system in Turkey by identifiying the priority areas for energy planners

Source: SHURA (2018)

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Data and Methodology
Scenarios and Strategies

	Strategies for RE Grid Integration	Simulation Cases			Parameters for Assessment of Result
Main Scenarios Resource Driven Allocation	Allocate Wind and Solar Generation by Resource Quality	Base Case **20 GW** Wind and Solar **Resource Driven**	Doubling (x2) **40 GW** Wind and Solar **Resource Driven**	Tripling (x3) **60 GW** Wind and Solar **Resource Driven**	• Transmission Investments (in Million Euros) • Redispatch Amounts (in TWh/year and % of total generation) • Wind and Solar Curtailment (in TWh/year and % of total generation) • Congestion Duration on Lines (in hours per years)
Strategy 1 System Driven Allocation	Reallocate Wind and Solar Generation by Balancing Resource Quality and Local Demand		Doubling **System Driven**	Tripling **System Driven**	
Strategy 2 Flexibility Options	Storage Systems (Pumped Storage and Battery) Wind and Solar Curtailment & Demand Response Flexible Thermal Units		Doubling Resource Driven* **Flexibility**	Tripling System Driven **Flexibility**	

Several strategies and flexibility options assessed for renewables grid integration

Source: SHURA (2018)

Hourly simulation of Turkey's power system

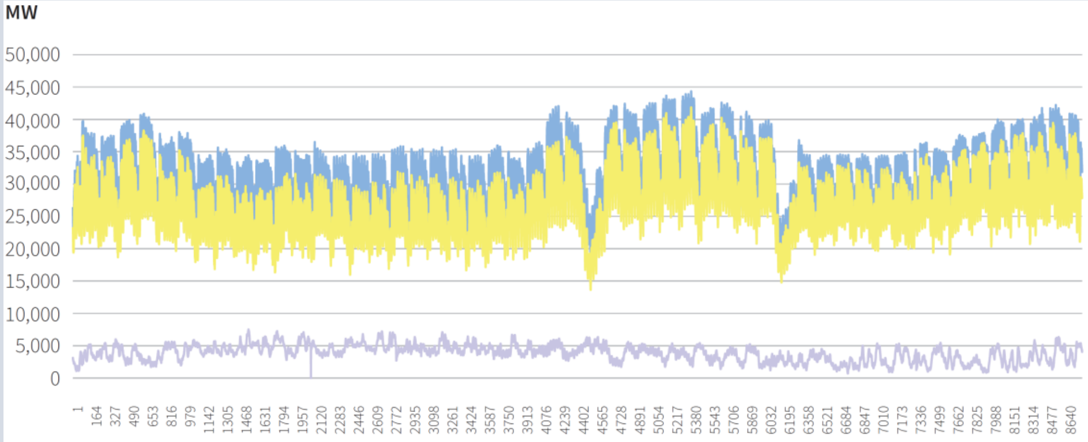
Network simulation

Grid simulation

Four key outputs:

Generation profile for each unit
Transmission grid investments
Wind and solar curtailment
Redispatch

Hourly simulation for demand, load flow and generation



Assessment of high voltage transmission grids (2016-2026)

Base Case and Doubling Scenarios: Regional distribution of demand and supply

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Renewables capacity increases in western regions with high demand and good resource availability, but total generation declines

Explained by the decrease in fossil fuel-fired generation, in particular gas

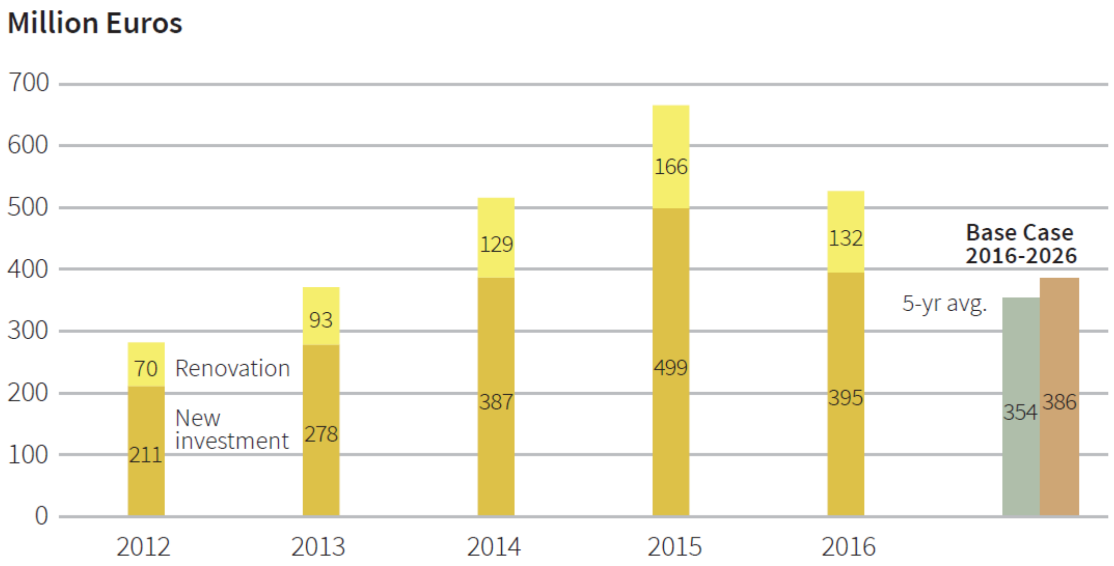
In southern regions with good solar resources, generation increases

Although Western Mediterranean region has good solar resources, with the sharp decline in thermal generation, total generation declines

Region Generations (TWh)	Base Case	Doubling	Demand
Trakya	23.0	22.1 ↓	65.9
N-West Anatolia	54.7	46.6 ↓	94.4
West Anatolia	94.8	93.0 ↓	62.7
Mid-Anatolia	29.9	34.7 ↑	49.8
West Mediterranean	22.6	29.0 ↑	29.8
Mid-Black Sea	35.1	34.2 ↓	22.6
East Anatolia	19.0	19.4 ↑	14.5
South-East Anatolia	63.4	68.3 ↑	62.5
East Mediterranean	76.1	71.3 ↓	37.3

Source: SHURA (2018)

Base Case and Doubling Scenarios: Transmission Grid Investment needs



Base Case and Doubling Scenarios

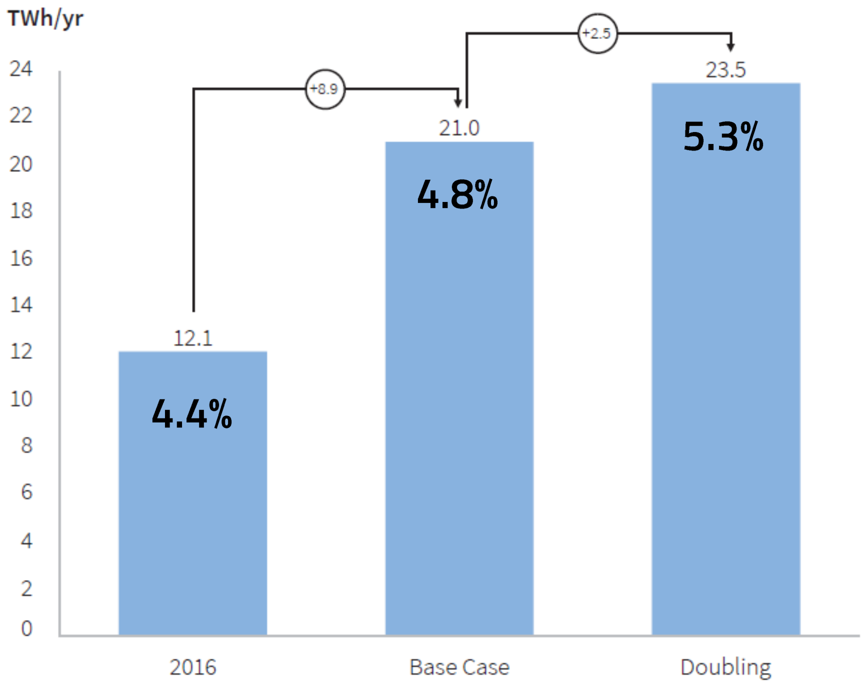
Additional 19,635 km transmission grid investments needed between 2016 and 2026

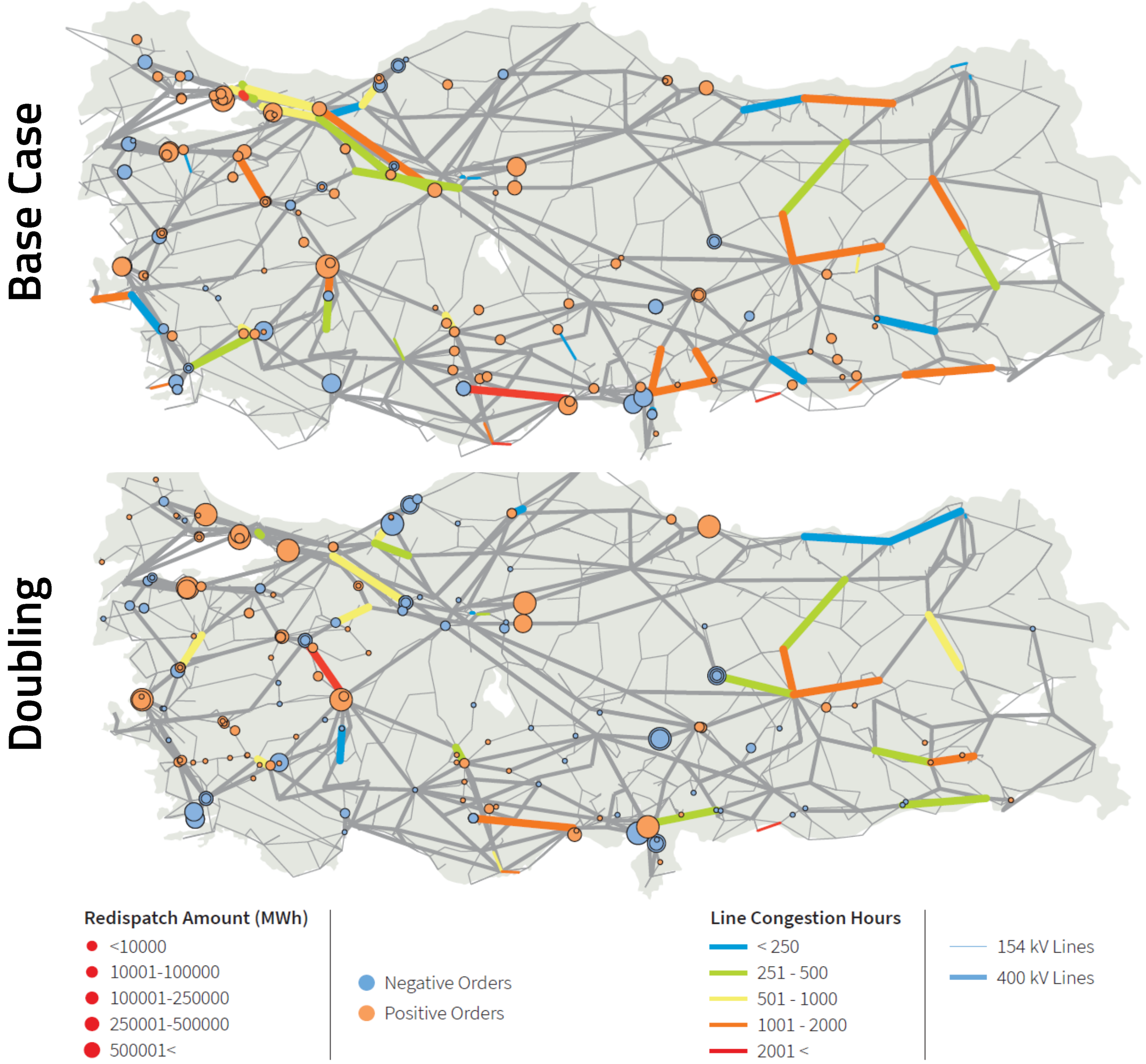
Investments in same magnitude and regions sufficient for secure and reliable grid operation in both scenarios

Annual average investment needs are equivalent to TSO's average between 2012-2016

Source: SHURA (2018)

Base Case and Doubling Scenarios: Congestions and redispatch



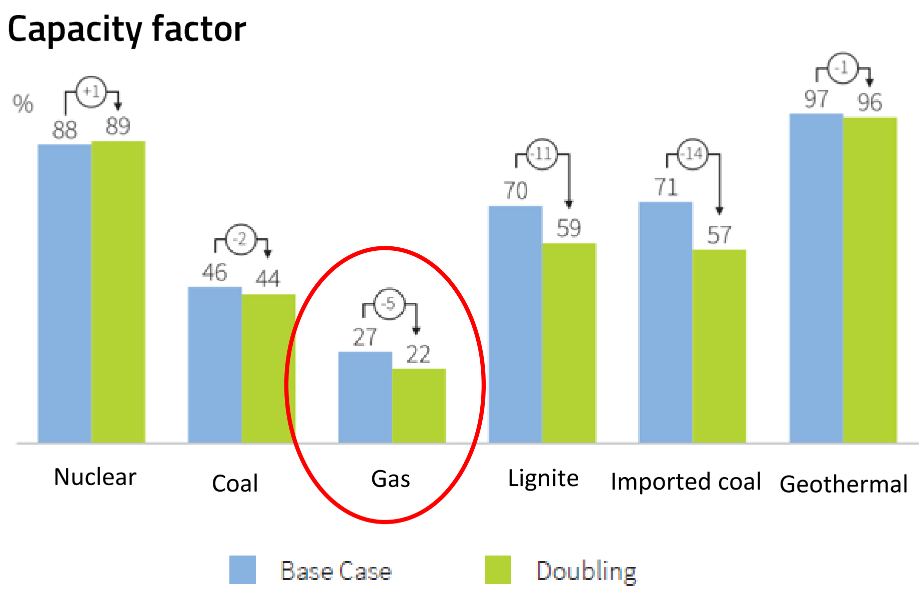


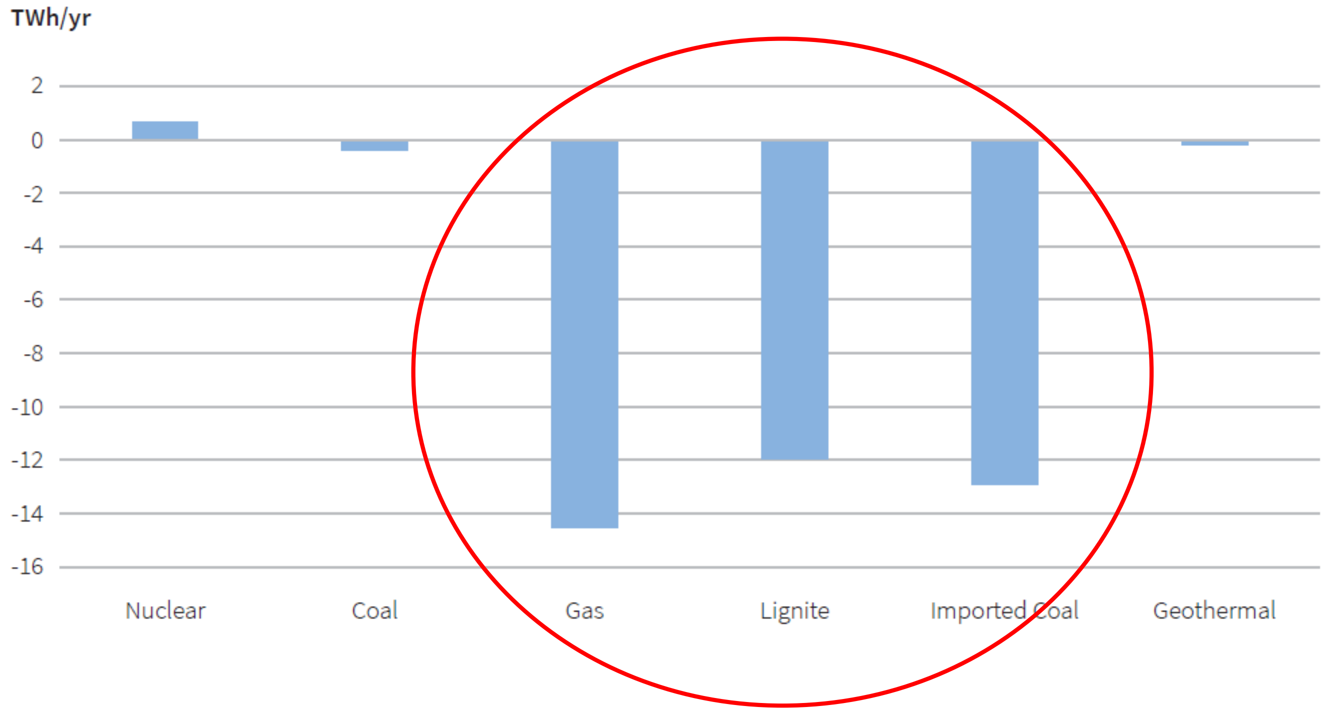
Redispatch volumes double from 2016 level of 12 TWh

Compared to total generation, redispatch shares are similar to today's levels (4.4% -5.3%)

Source: SHURA (2018)

Base Case and Doubling Scenarios: Changes in generation mix





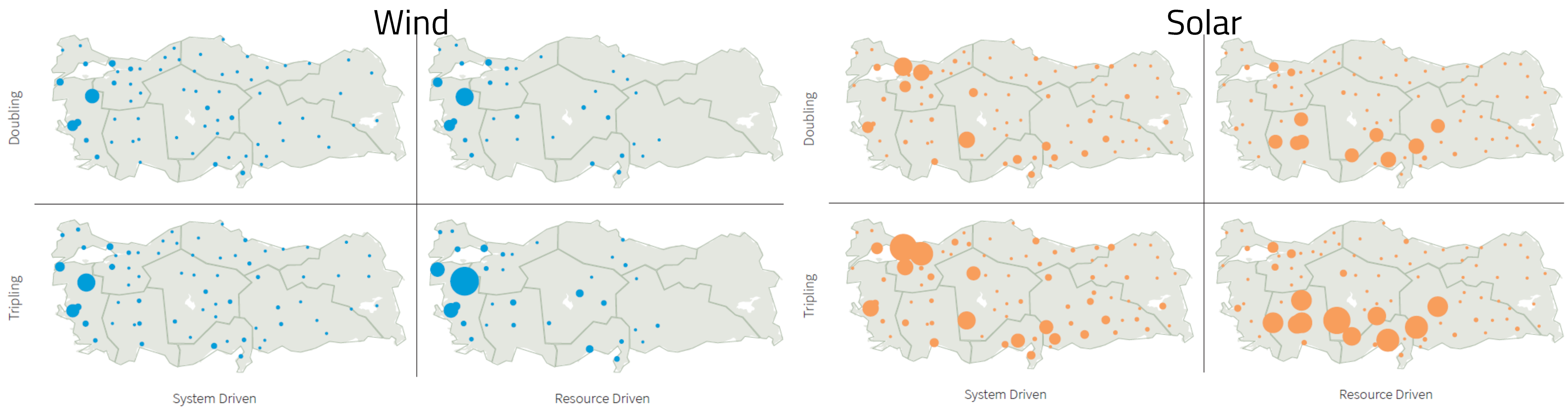
Generation from expensive reosurces decline as a result of higher share of renewables

Natural gas, imported coal and lignite generation decline significantly, meaning decline in capacity factors

To meet reserve needs and relieve highly congested grids, the decrease in gas assets is somewhat less

Source: SHURA (2018)

Tripling Scenario:
System friendly location of wind and solar

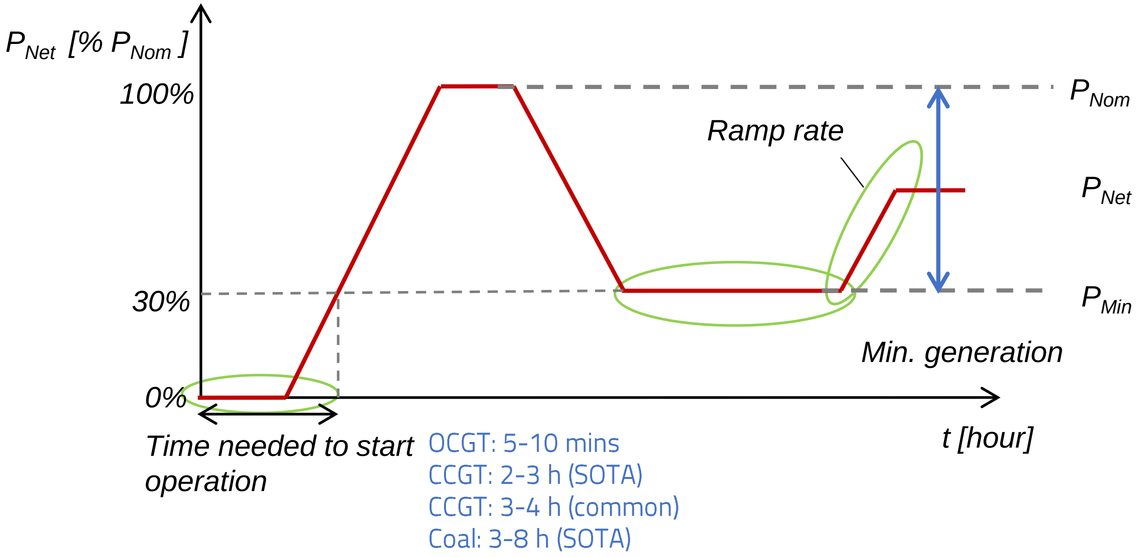


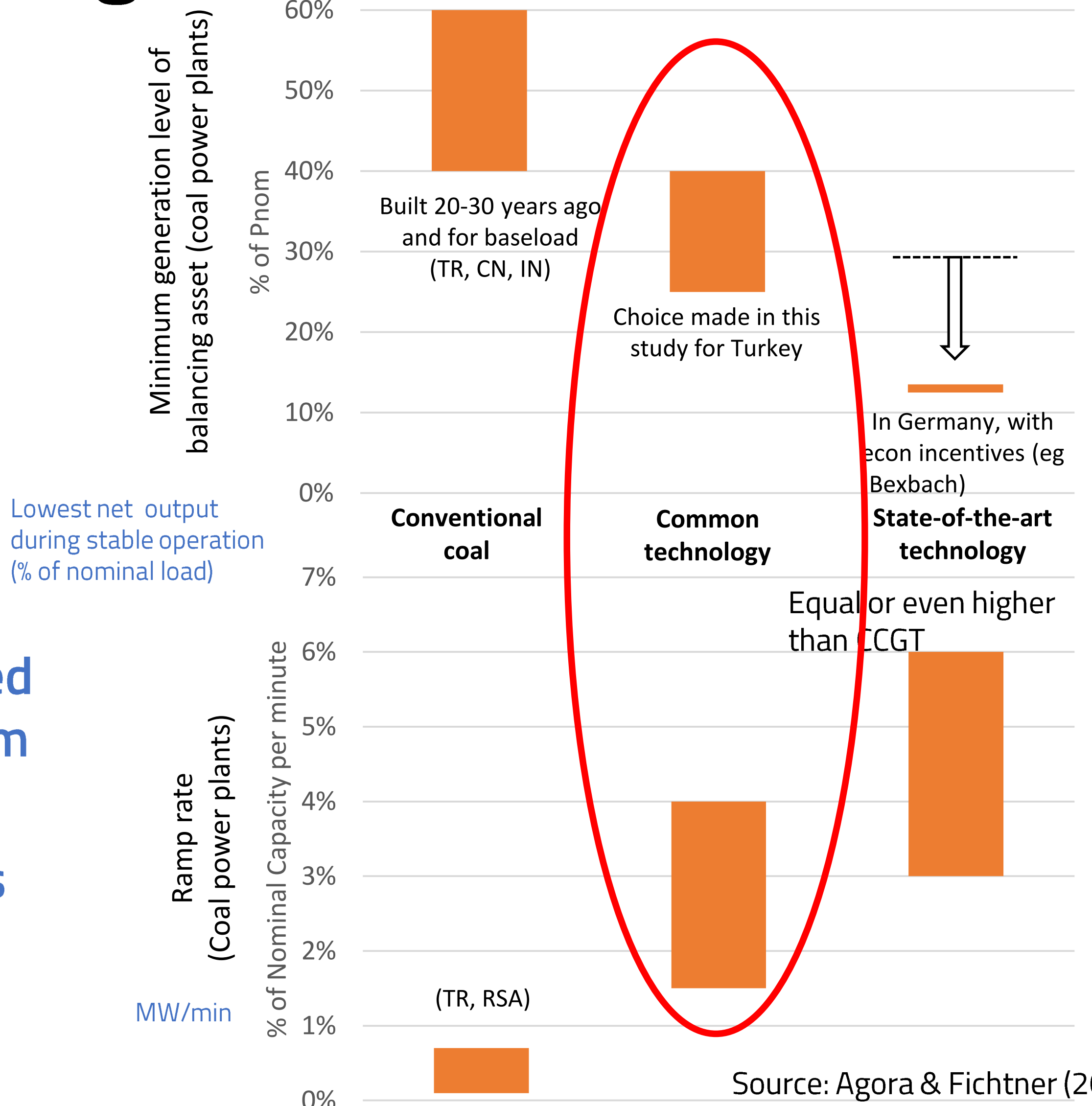
15 GW (out of 60 GW) wind and solar capacity is relocated to areas with more demand and strong grids (solar PV is impacted more – 10 GW)

A large share of curtailment and a quarter of redispatch is reduced

Capacity utilisation rates decrease by <10% which impacts the LCOE by max 12% (for solar PV)

Tripling Scenario:
Increasing flexibility of thermal generators



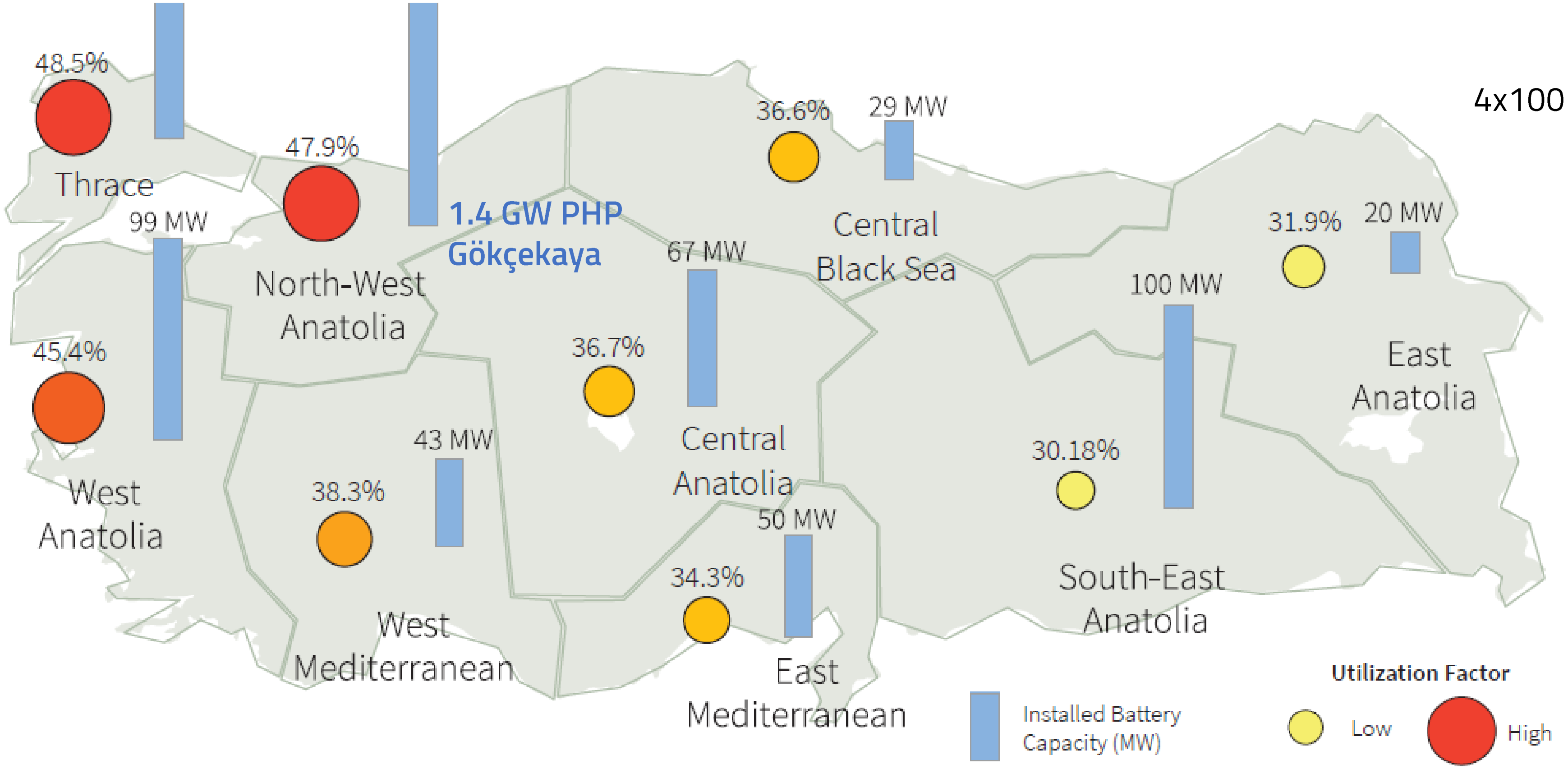


Operational issues because older assets cannot be used for spinning reserve, low ramp rates and high miminum generation levels

Modernising these assets with common technologies (average of the OECD)

Source: Agora & Fichtner (2017)

Tripling Scenario:
Capacity utilisation factors of battery storage



300 MW of battery storage &
4x100 MW of pumped hydro power reserved
for frequency control

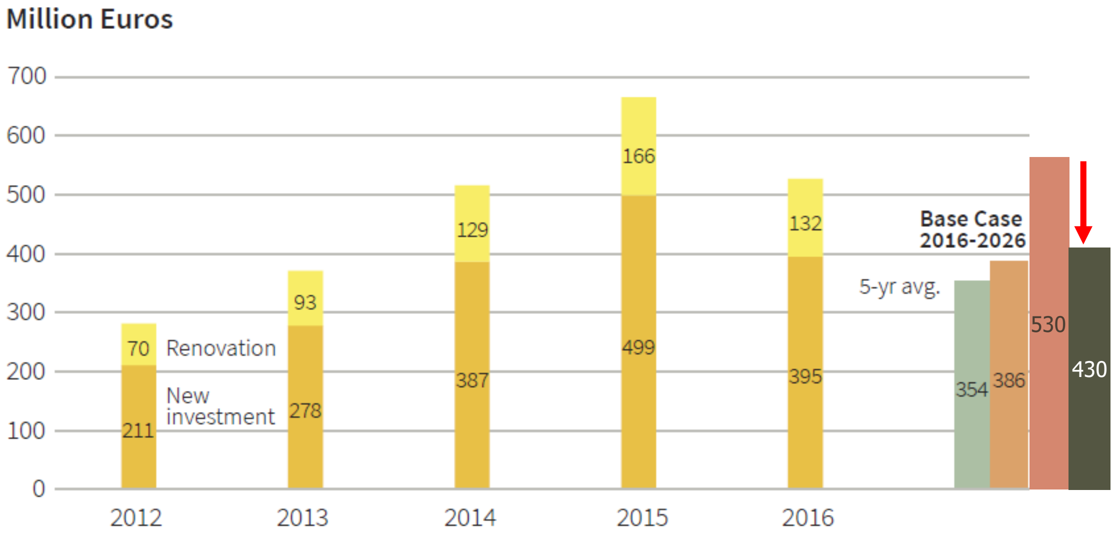
Reserve initially provided
by gas and hydropower plants

Utilisation = charging + discharging time in total

Storage enabled by 600 MW distributed battery storage (can be connected at different voltage levels) & 1.4 GW pumped hydro makes an important contribution to grid integration

Source: SHURA (2018)

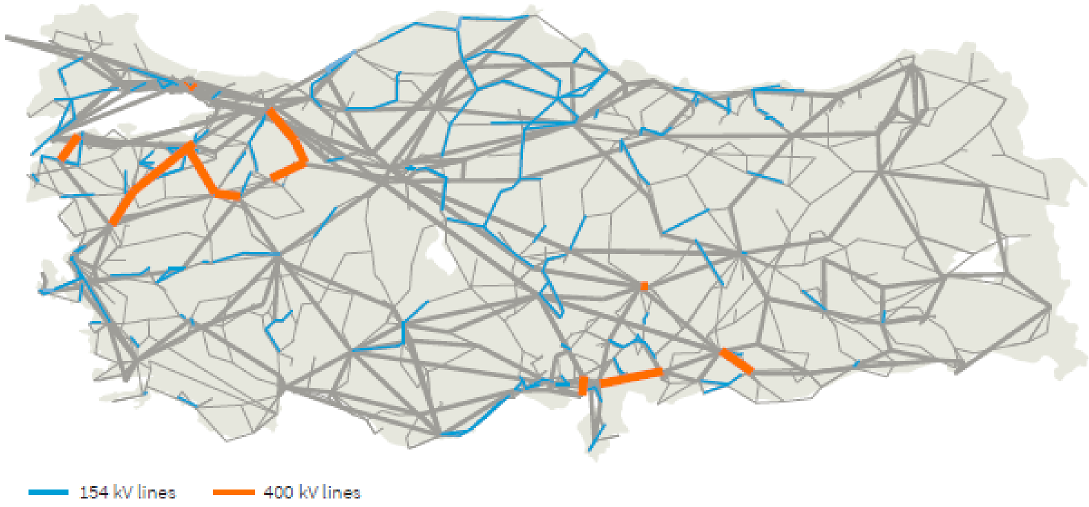
Tripling Scenario:
Additional investment needs



Additional investment needs that are needed for secure and reliable operation of the grid is reduced by EUR 100 million per year

Tripling Scenario – resource-driven

Tripling Scenario – system-driven



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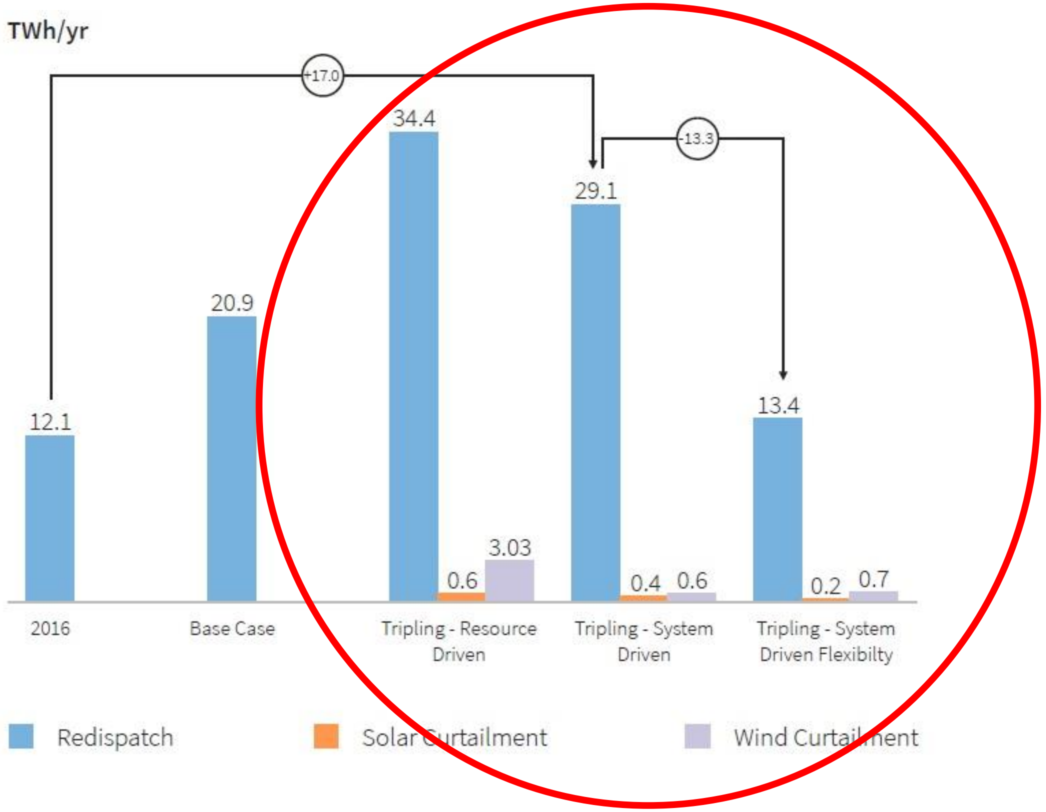
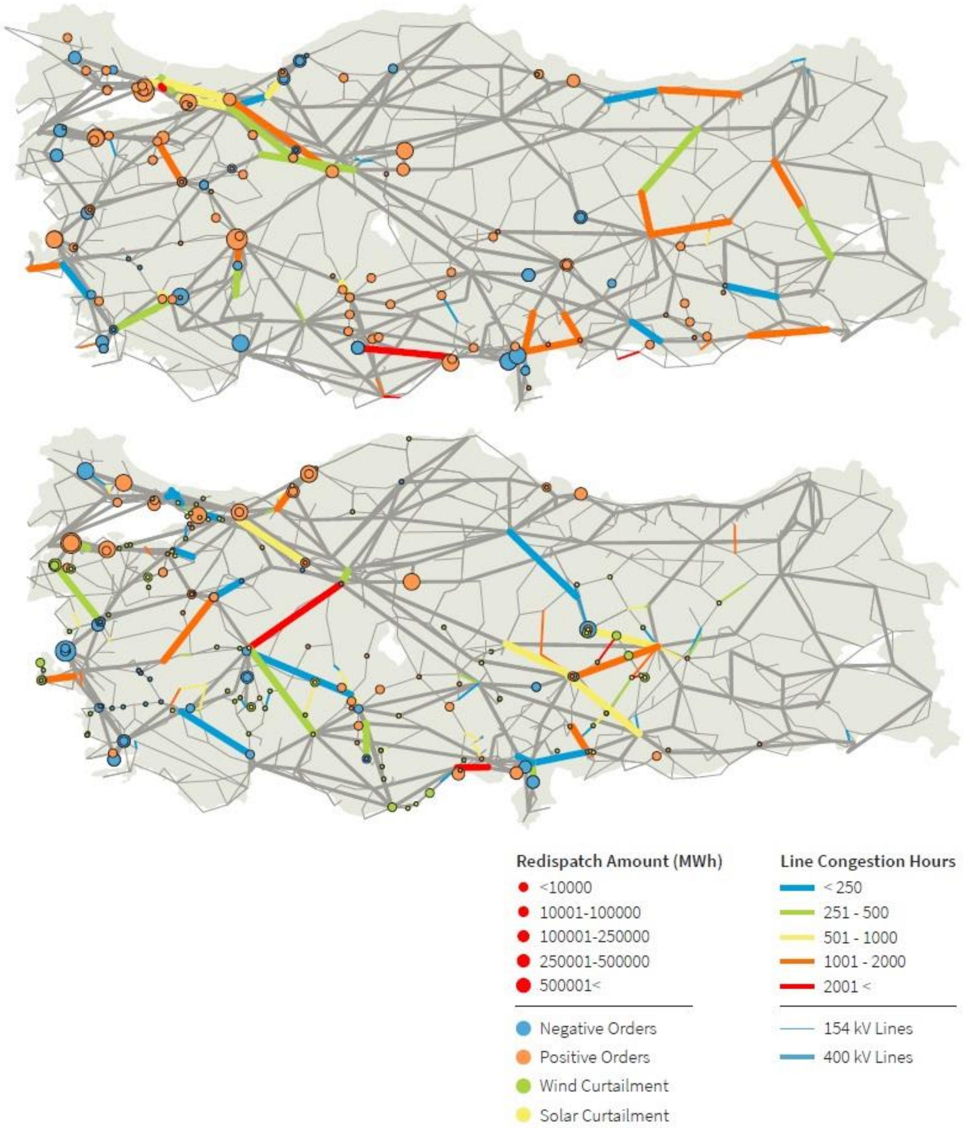
Tripling Scenario: Congestions, curtailment redispatch



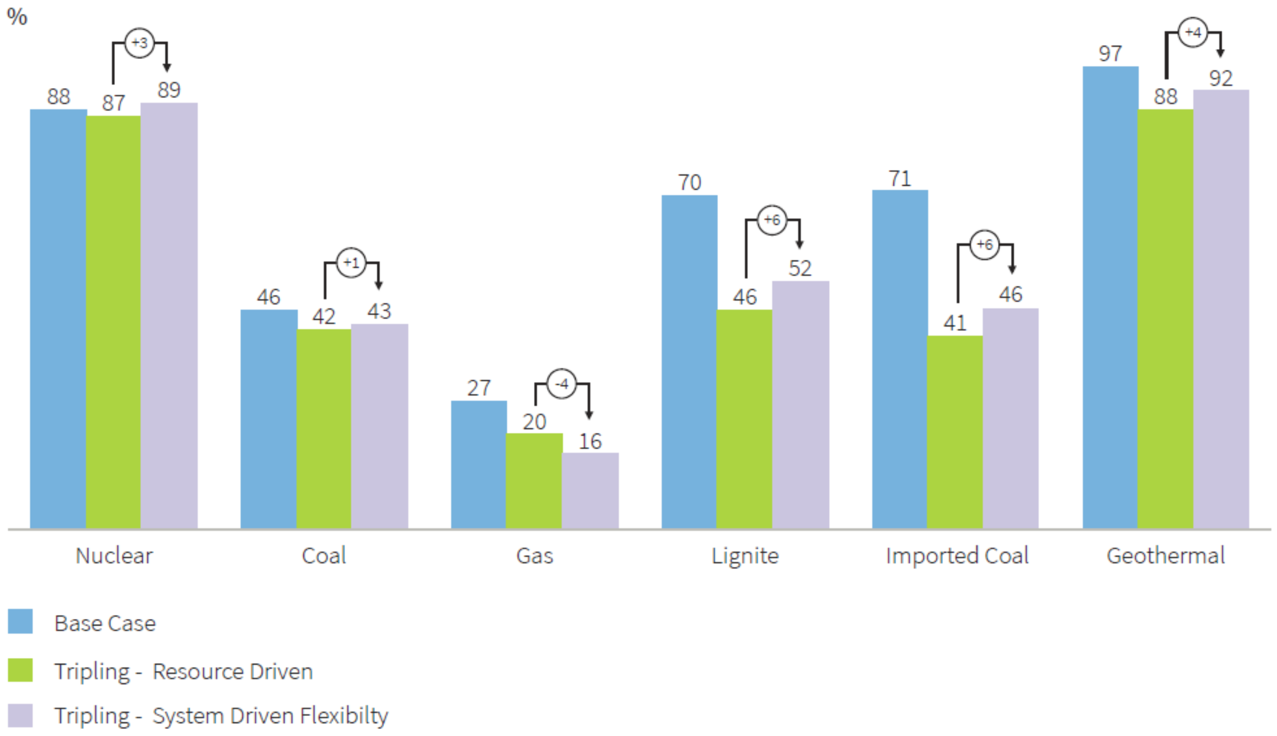
Base Case scenario

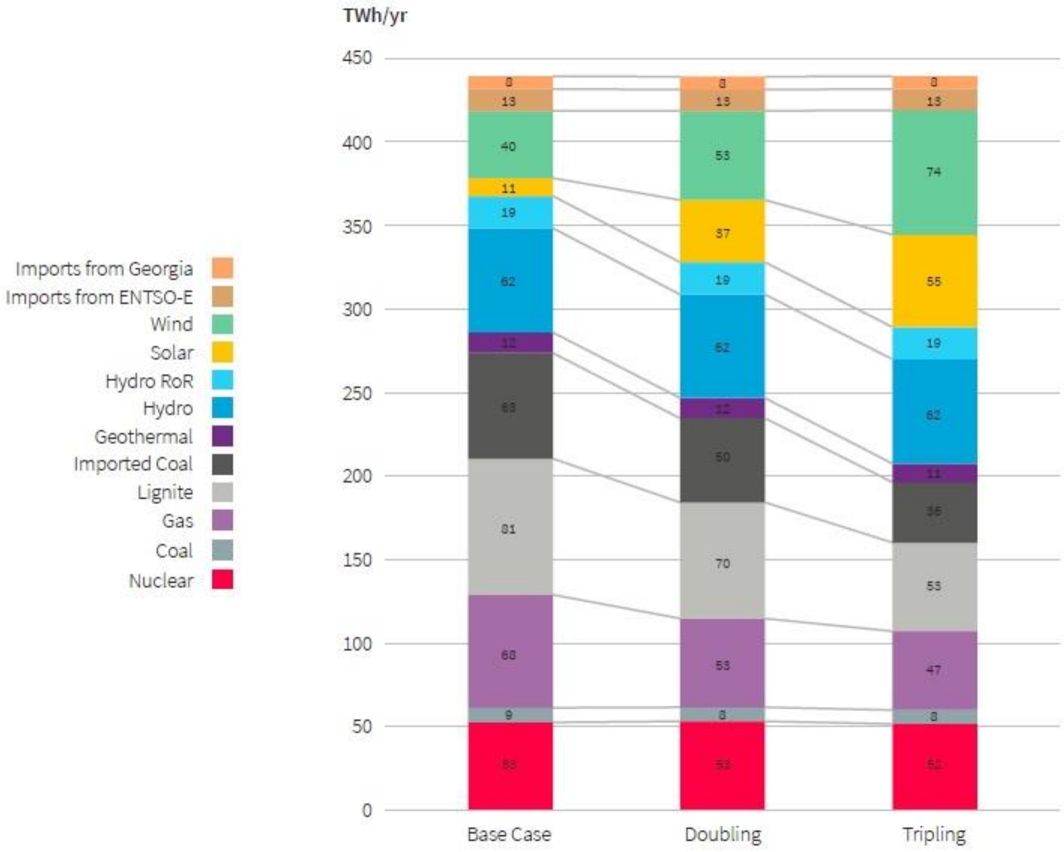
Tripling Scenario – system-driven and flexible



A flexible more system reduces further curtailment and redispatch

Tripling Scenario:
Changes in generation profiles





As flexibility and reserve requiremnets are provided by battery storage, the need for gas reduces significantly

Conclusions and next steps

- The analysis shows the **impacts, benefits and challenges** of higher wind and solar share on the transmission grid
- Without the need for additional grid investments and flexibility technologies, **wind and solar can supply more than 20% of the total electricity output**
- Flexibility technologies and a system-drien approach can **reduce additional investments in transmission grids by 100 million Euro per year**
- This study **provides the basis for a low-carbon economy roadmap** that covers the various actors of the energy system including energy system planners, system operators, investors and financers

Source: SHURA (2018)

Thank you!

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