WELCOME

The opportunities for grid balancing and stabilisation arising from sector coupling

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Clean energy for EU islands
FORUM 2024

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Working group - The opportunities for grid balancing and stabilisation arising from sector coupling

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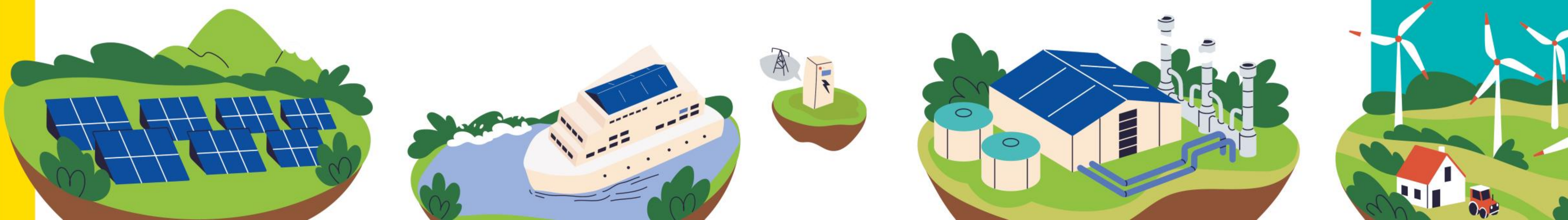

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Sector coupling

Virtual or physical combined operation of electricity generation and supply, with other centralised or distributed loads.

Examples of Loads

- ✓ Water and waste management infrastructures
- ✓ Charging infrastructure for EVs
- ✓ Heating and cooling loads (depending on the climate zone of each island)

Enablers

- ✓ Integration in energy investment planning
- ✓ DSM markets

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Limitations in RES Penetration

RES (especially Wind farms) are subject to output power limitations:

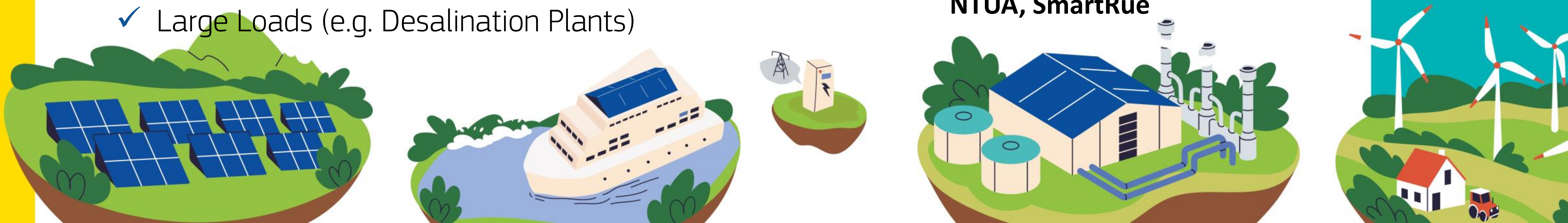
1) **technical minima** of thermal units

- ✓ Sufficient number of generators should be in operation to meet reserve requirements
- ✓ The cumulative technical minimum production levels cover a significant amount of load

2) **penetration level limit**, applied for stability purposes (e.g. 20-35% of the total demand). Different limits are imposed according to the island and the demand levels.

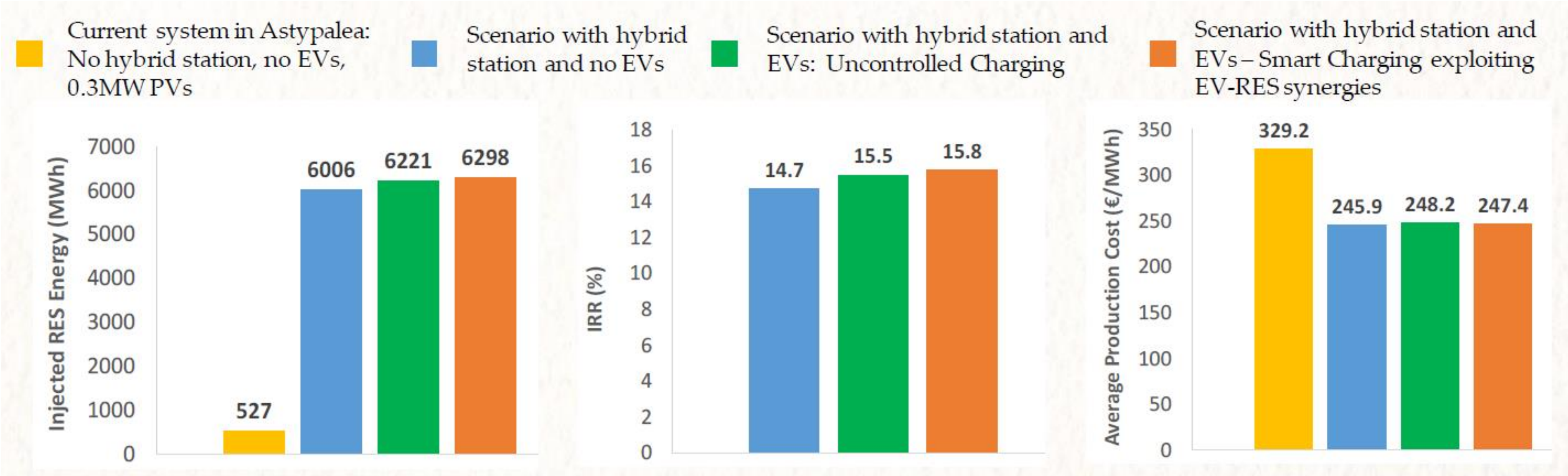
- ➢ Sector coupling and Demand Side Management (DSM) can facilitate higher RES penetration levels, while also offering services like frequency regulation.
- ➢ Different applications in islands:
  - ✓ E-Mobility
  - ✓ HVAC, Appliances
  - ✓ Large Loads (e.g. Desalination Plants)

Source: Prof. Nikos Hatziargyriou, NTUA, SmartRue



Astypalea: EVs and High RES penetration

- A hybrid station with 2.3MW PVs, 2MW Wind and a Battery capacity of 9.6MWh (bluebars) significantly increases the RES penetration levels and reduces the system's production cost
- The higher EV demand in the case of uncontrolled charging (green bars) can increase the RES energy supplied to the grid, while also increasing the IRR related to the Hybrid station investment
- A smart charging scheme that exploits EV-RES synergies (orange bars) can further increase the RES penetration and the IRR of the Hybrid station investment and decrease the system's production cost compared to uncontrolled charging.

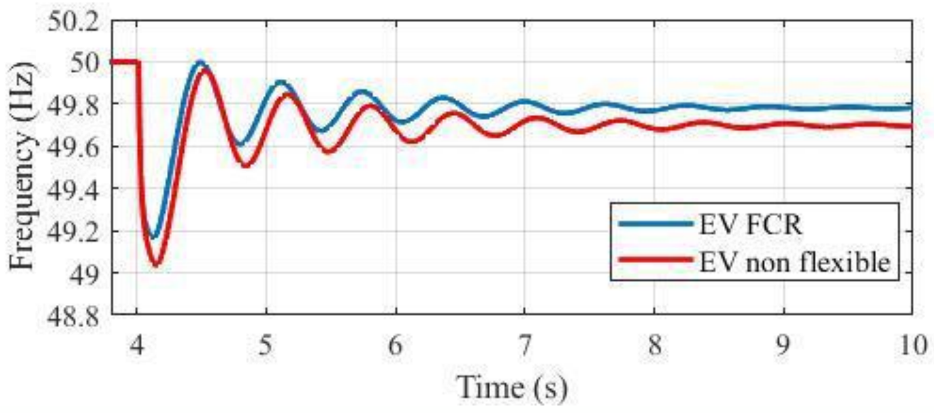


Source: Prof. Nikos Hatziargyriou, NTUA, SmartRue

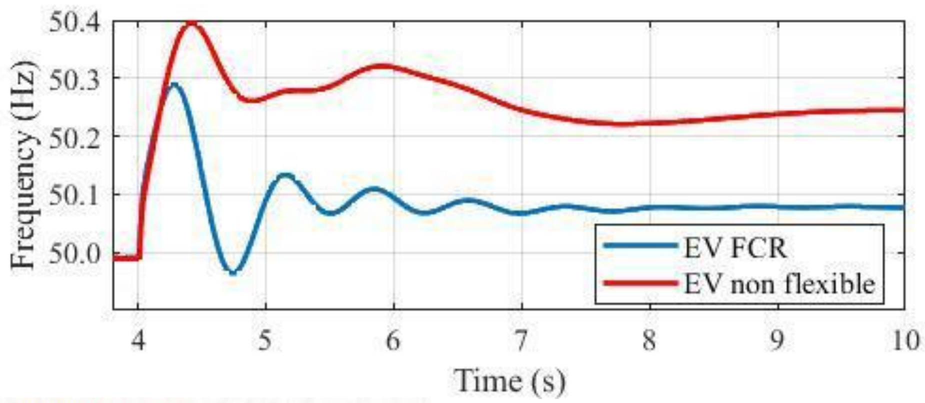
EVs for Meeting Technical Challenges

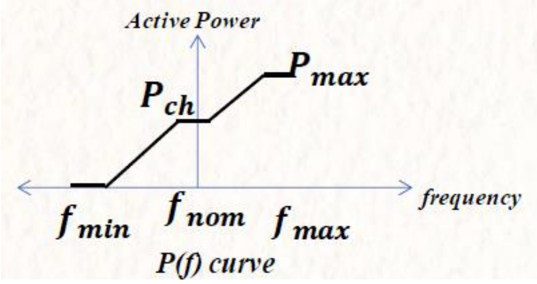
- EVs can alter their charging power to provide frequency containment reserves (FCR).
- In underfrequency reserves the charging power can be reduced and in overfrequency can be increased dynamically according to the frequency to provide FCR.
- Study in Astypalea network. Operating scenario:
  - Island demand:1,6MW and EVs charging:0,6MW
  - WT: 2MW, BES=-0.4MW, Diesel=0,6MW

- Contigencies
  - ✓ Disconnection of WT (underfrequency event)
  - ✓ Disconnection of central BES (overfrequency event)



Impact of EVs in underfrequency transients





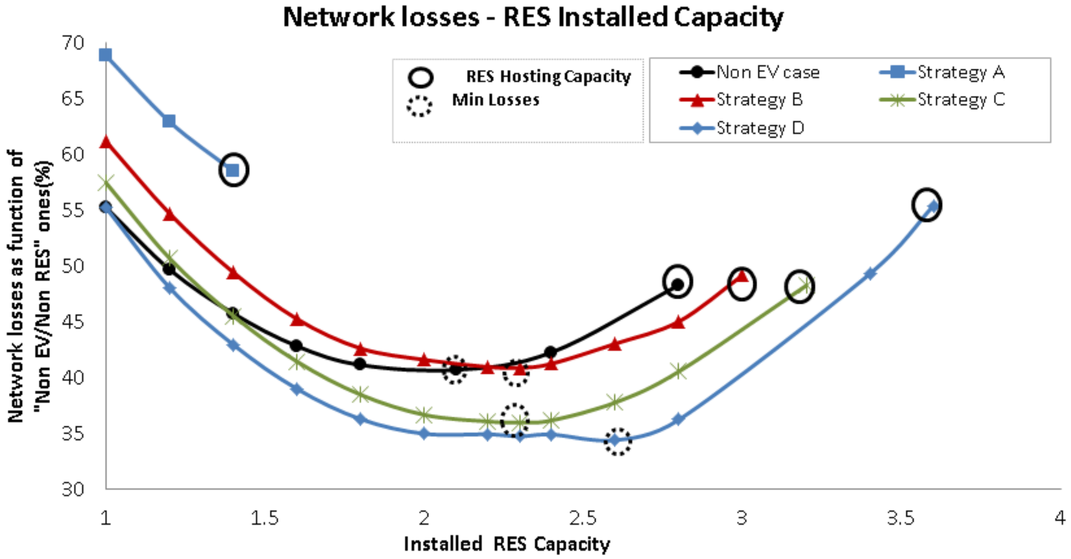
Source: Prof. Nikos Hatziargyriou, NTUA, SmartRue

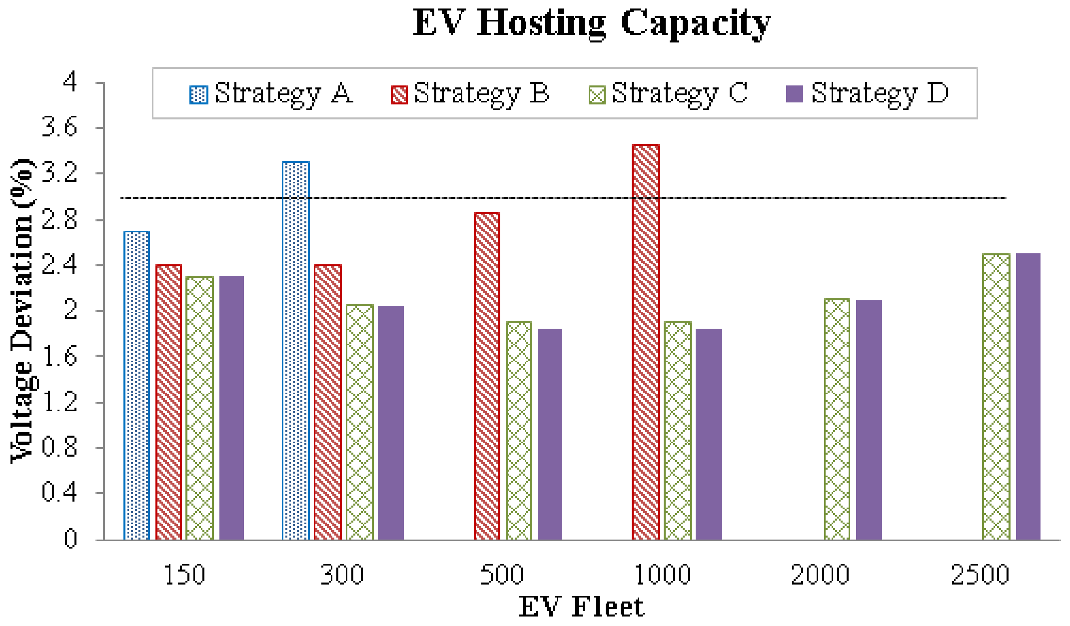
EV-RES Synergies

Rural MV distribution grid of Ikaria

Strategy A: Uncontrolled Charging
Strategy B: Controlled Charging – Dual Tariff
Strategy C: EV-RES Synergy scheme
Strategy D: EV-RES Synergy scheme & V2G

- ➢ A distribution grid with a certain number of EVs has a maximum RES hosting capacity.
- ➢ The upper diagram depicts the network's losses with 300 EVs
  - ✓ Smart charging methodologies, particularly exploiting the EV-RES synergies, decreases the network losses.
  - ✓ The maximum allowable RES integration defined according to the maximum voltage deviation - depicted with continuous circles.
  - ✓ EV-RES synergies increase the optimal RES integration (lowest losses) - depicted with dashed circles.
- ➢ The maximum allowable number of EVs is defined according to the maximum voltage deviation (diagram on the bottom)
- ✓ EV-RES synergies allow an increased number of EVs without violating the grid's technical limits.



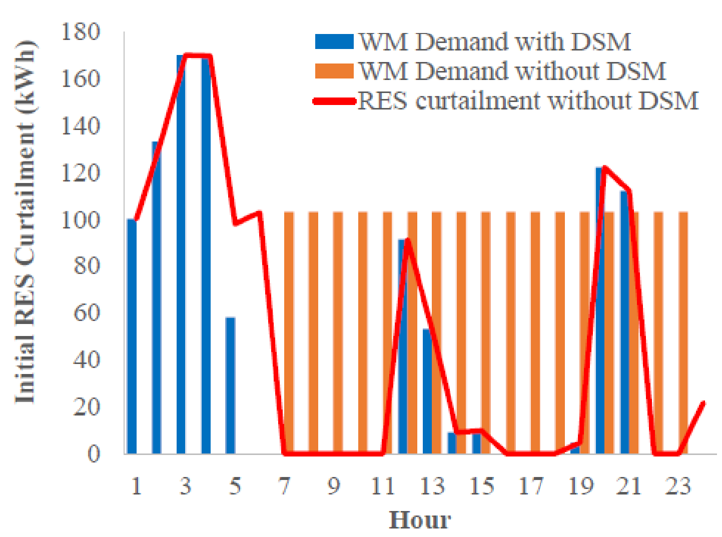


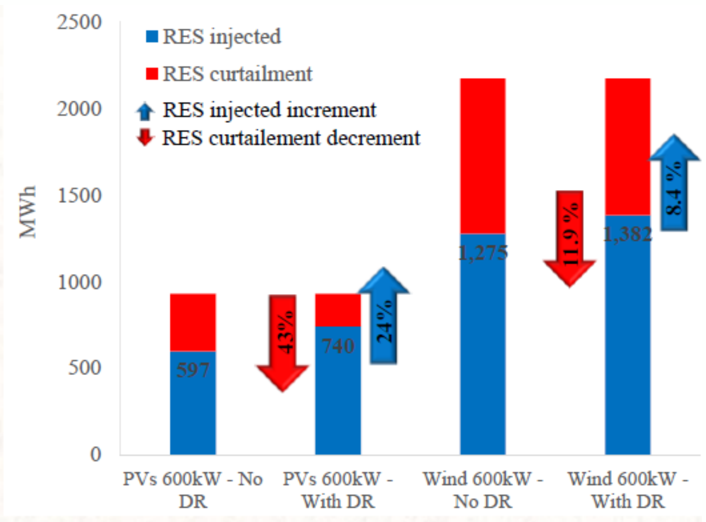
Source: E. Karfopoulos, N.Hatziargyriou, "Distributed Coordination of Electric Vehicles Providing V2G Services", IEEE Trans. on Power Systems, 2015

Source: Prof. Nikos Hatziargyriou, NTUA, SmartRue

Appliances

- DSM by home appliances, like HVAC or Washing Machines.
- DSM schemes have been evaluated in Kythnos by shifting Washing Machine (WM) demand to hours with increased RES production
  - ✓ Day Ahead Scheduling to identify hours with increased RES curtailment
  - ✓ WM demand is transferred towards these hours.





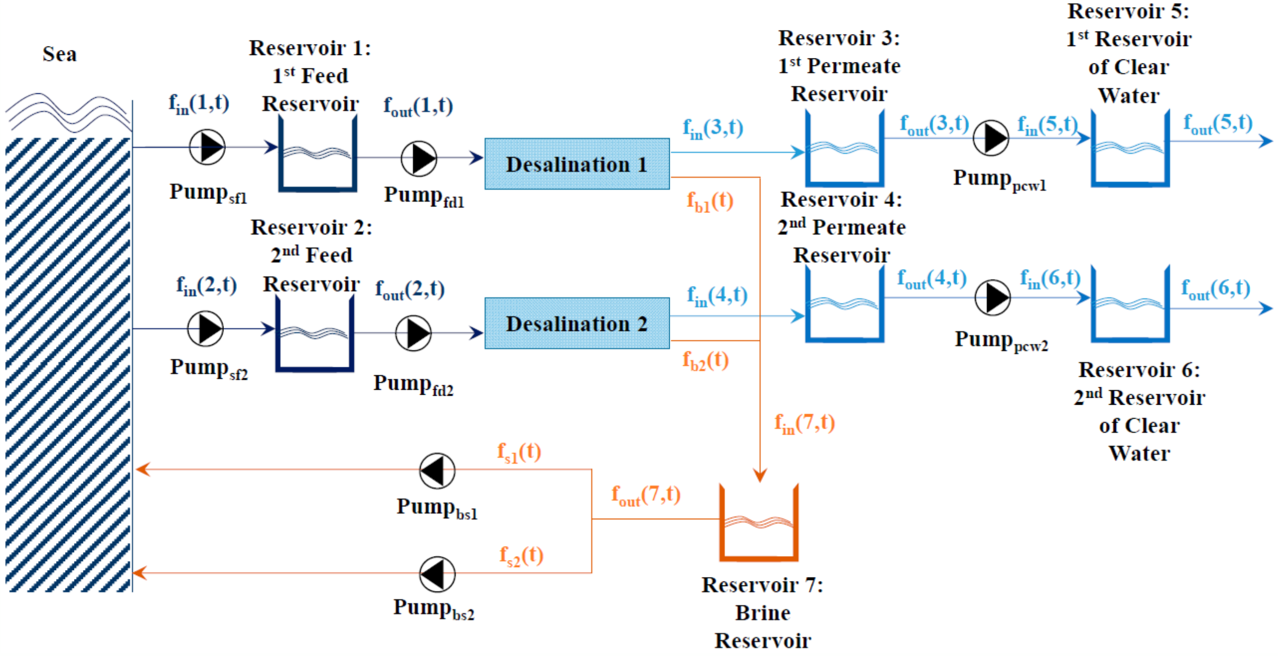
- The application of DR assuming that all the residential WMs participate in DSM has been evaluated for 2 scenarios:
  - ✓ Installation of 600kW PV
  - ✓ Installation of 600kW Wind Generator
  - ✓ In both cases, DSM can effectively achieve increase in RES penetration

Source: Prof. Nikos Hatziargyriou, NTUA, SmartRue

Large Loads

- Significant opportunities for DSM by larger loads, e.g. loads of a desalination plants or demand of hotels.
- Specific constraints should be considered in this case linked to the operation of each load.
- DSM capabilities of the desalination system in Kythnos have been evaluated
- In this case, the complex operation of a desalination system (comprising an increased number of pumps, water reservoirs, etc.), requests a careful design of the management scheme [1]
  - ✓ The constraints linked with the desalination system have been identified
  - ✓ An optimisation problem is defined to solve the optimal Day Ahead Scheduling of the desalination system.

Desalination system in Merichas (Kythnos)

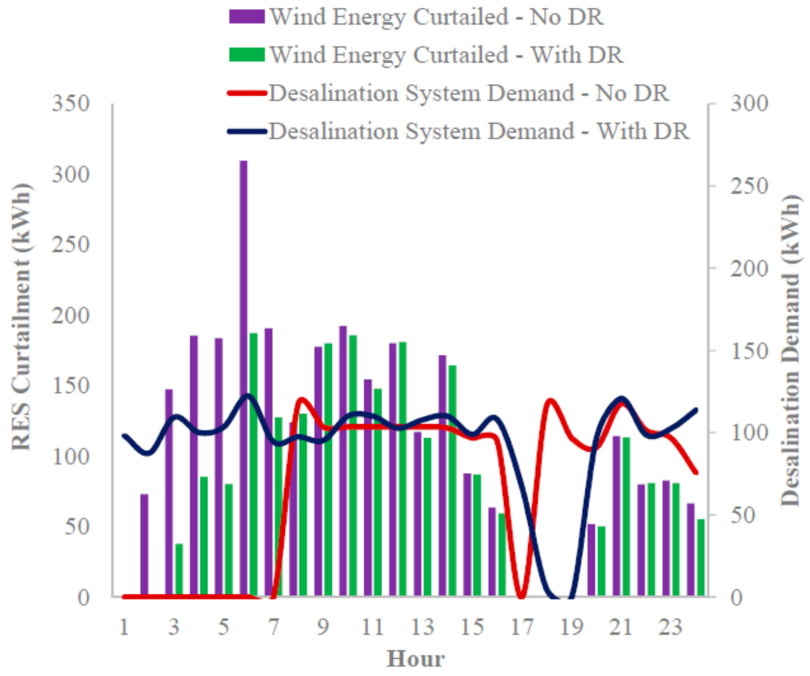


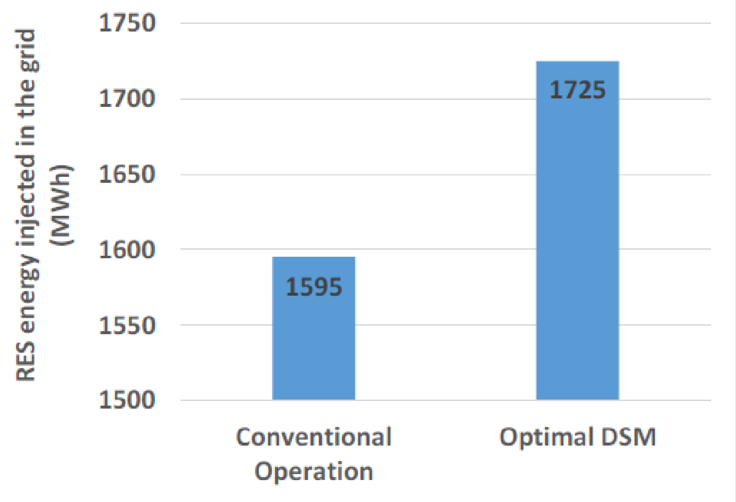
[1] Karakitsios, I.; Dimeas, A.; Hatziargyriou, N. Optimal Management of the Desalination System Demand in Non-Interconnected Islands.Energies2020,13, 4021. https://doi.org/10.3390/en13154021

Source: Prof. Nikos Hatziargyriou, NTUA, SmartRue

Large Loads

- The desalination system in Kythnos operates according to the level of water in each reservoir: when the water is lower than a specific level the relevant pump or desalination system is activated to increase the reservoir level.
- An optimal management of the desalination system has been applied to exploit RES:
  - ✓ The available volume capacity in all reservoirs is effectively exploited to schedule the system’s energy consumption during the day and offer demand response services to the system operator
  - ✓ The desalination demand is effectively shifted towards hours with increased RES curtailment allowing a significant increase in RES energy inje

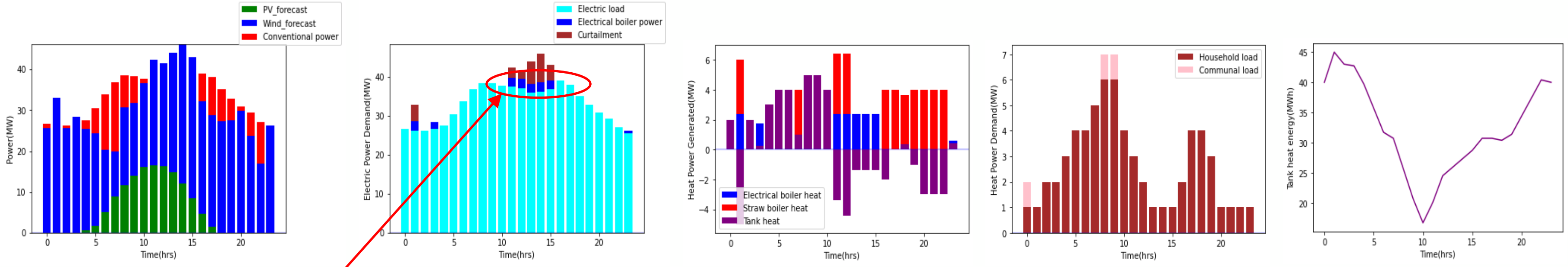




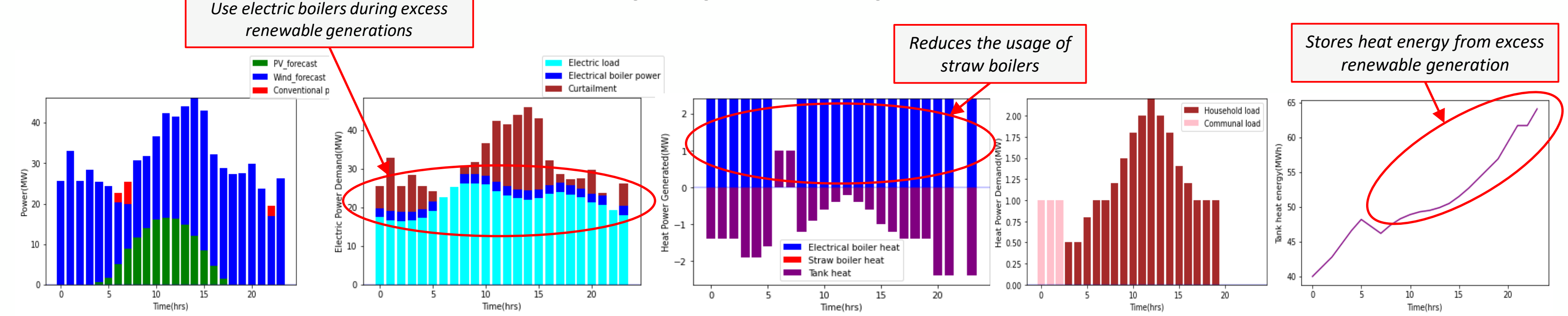
Source: Prof. Nikos Hatziargyriou, NTUA, SmartRue

Bornholm district heating application

The objective is to **utilise the flexibility of the district heating network** to **reduce renewable curtailment** in the electrical system and **reduce the use of conventional generation**.



Case 1 - High RES generation and high demand



Case 2 - High RES generation and low demand

Bornholm application

- The implementation of co-optimisations leads to the following advantages:
  - **Reduces renewable curtailment** during excess renewable generation
  - **Reduces the usage of straw boilers** by utilising the electric boilers
  - **Stores the heat energy** in the hot water tank during excess renewable generation
  - Effective utilisation of hot water storage and flexible heating demand to **minimise the operating cost**.

Table 1.1: Reductions in renewable curtailment, straw cost and emissions per day

Cases	*Case 1 (High load – High RES)*			*Case 2 (Low load – High RES)*		
Optimisation	*Independent*	*Co-optimisation*	***Change***	*Independent*	*Co-optimisation*	***Change***
Renewable Curtailment	42.7 MWh	25.9 MWh	**39.2 %** ▼	224.8 MWh	174.5 MWh	**22.4 %** ▼
Fuel cost of Straw boiler (EUR)	1146	846	**26.2 %** ▼	902	0	**100 %** ▼
CO_2 emissions from Straw Boiler (ton)	23.04	17.01	**6.03** ▼	18.14	0	**18.14** ▼
Gain in energy in the hot water tank (MWh)	0	0	-	0	23	**23** ▲

Approximate operational cost of Straw Boiler = 17.9 EUR / MWh
Approximate emissions of Straw Boiler = 360 kg CO_2 / MWh

Port infrastructure

- Island ports and marinas can be seen as polygrids as they include multiple loads that can be optimised:
  - Shore side electricity
  - Cranes
  - Berth electricity pillars
  - Lights
  - EV chargers
  - Desalination
  - **Combined with offshore RES**