«Energy Storage and Island Systems»

SE Europe Energy Dialogue Athens 9-10 December 2020

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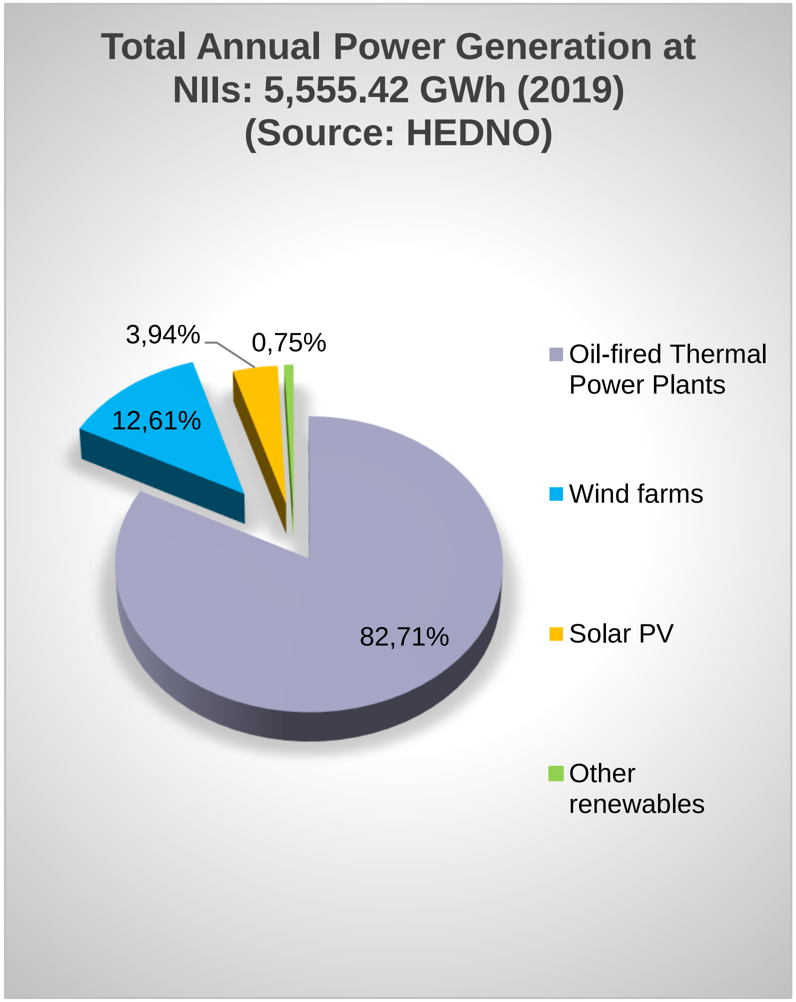
Presentation's Contents

- Renewable Electricity as the Sole Energy Carrier in Non Interconnected Islands
- The design of a New Energy system for the island of Kastellorizo
- IENE Study: "Feasibility Study of Energy Storage Systems' Integration in Crete" (M53)

Renewable Electricity as the sole energy carrier in Non Interconnected Islands (NIIs)

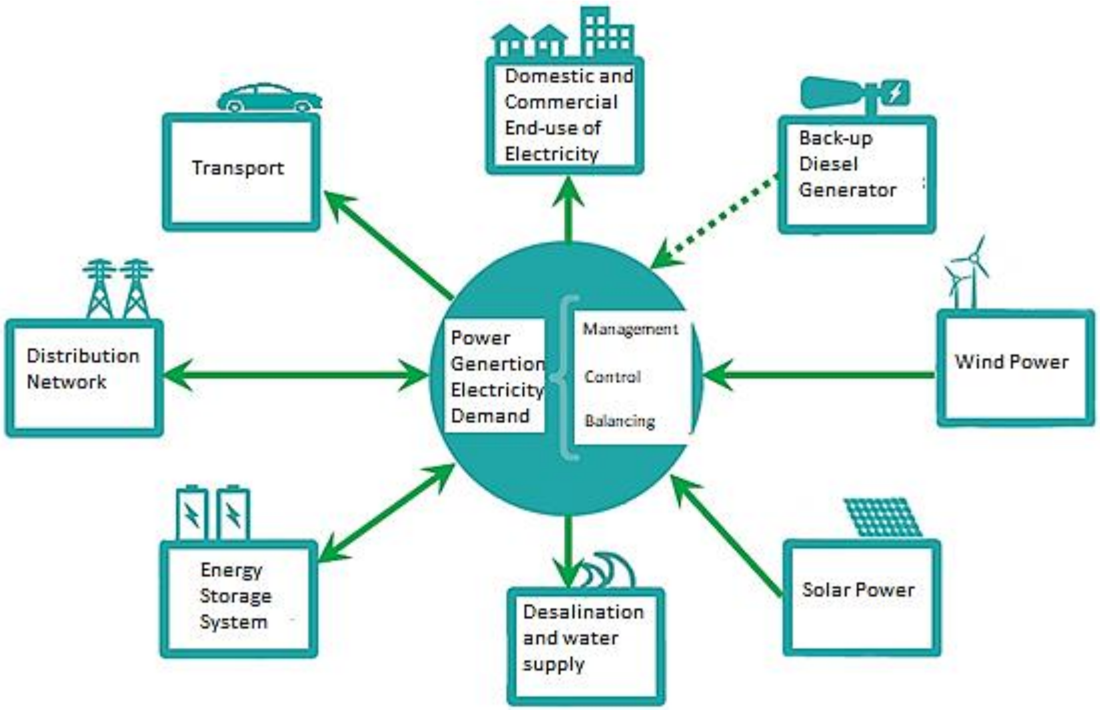
- Today, all NIIs are overwhelmingly dependent, by more than 80%, by oil-fired thermal power plants for power generation.
- EU Directive 2015/2193 for on the limitation of emissions of certain pollutants into the air from medium combustion plants is in effect, expected to lead to withdrawal of oil-fired power generating units from NII systems.
- Very high cost of operation for Autonomous oil-fired Thermal Power Plants in Small Non Interconnected Islands (Ag. Efstratios, Agathonisi, Anafi, Antikythera, Arkioi, Gavdos, Donousa, Ereikousa, Megisti, Othonoi)
  - Average annual full generation costs for 2019 amounted to €1,421.2/MWh on the island with the lowest demand (Antikythera) and €535.39 /MWh on the island with the highest demand (Megisti)
  - Average annual electricity generation costs for the last six years 2014 - 2019 range from €1,309.54 /MWh (Antikythera) to €466.75 /MWh (Megisti) respectively.
  - Average Monthly Variable Generation Costs range from €235.46 to €432.13 /MWh for 2019 and from €188 to €686 /MWh for the period 2014 - 2019. (While the average annual marginal price for electricity in the interconnected system was €64.35 /MWh in 2019)



Energy Transition of the Island of Kastellorizo

The design of a New Energy system for the island of Kastellorizo

- **High Penetration of available RES in the energy mix**: Solar and Wind power
- **Uninterrupted electricity supply for all consumers:** Domestic and Commercial Consumption
- **Uninterrupted water supply:** uninterrupted coverage of electricity demand for desalination facilities (flexibility through demand response)
- **Electric Mobility:** coverage of EV charging demand



- **Improvement of Energy Efficiency:** Utilization of non-electric RES (solar thermal) applications, more energy efficient end-use devices, more efficient lamps for lighting of public spaces.
- **Use of Energy Storage system:** to achieve high RES penetration while ensuring security of supply. Lithium-ion battery storage systems were the primary focus due to their continuously decreasing cost, fast response (immediate high power supply) and sufficient storage capacity**.**

Sizing Methodology for the RES – Energy Storage system for Kastellorizo Island I

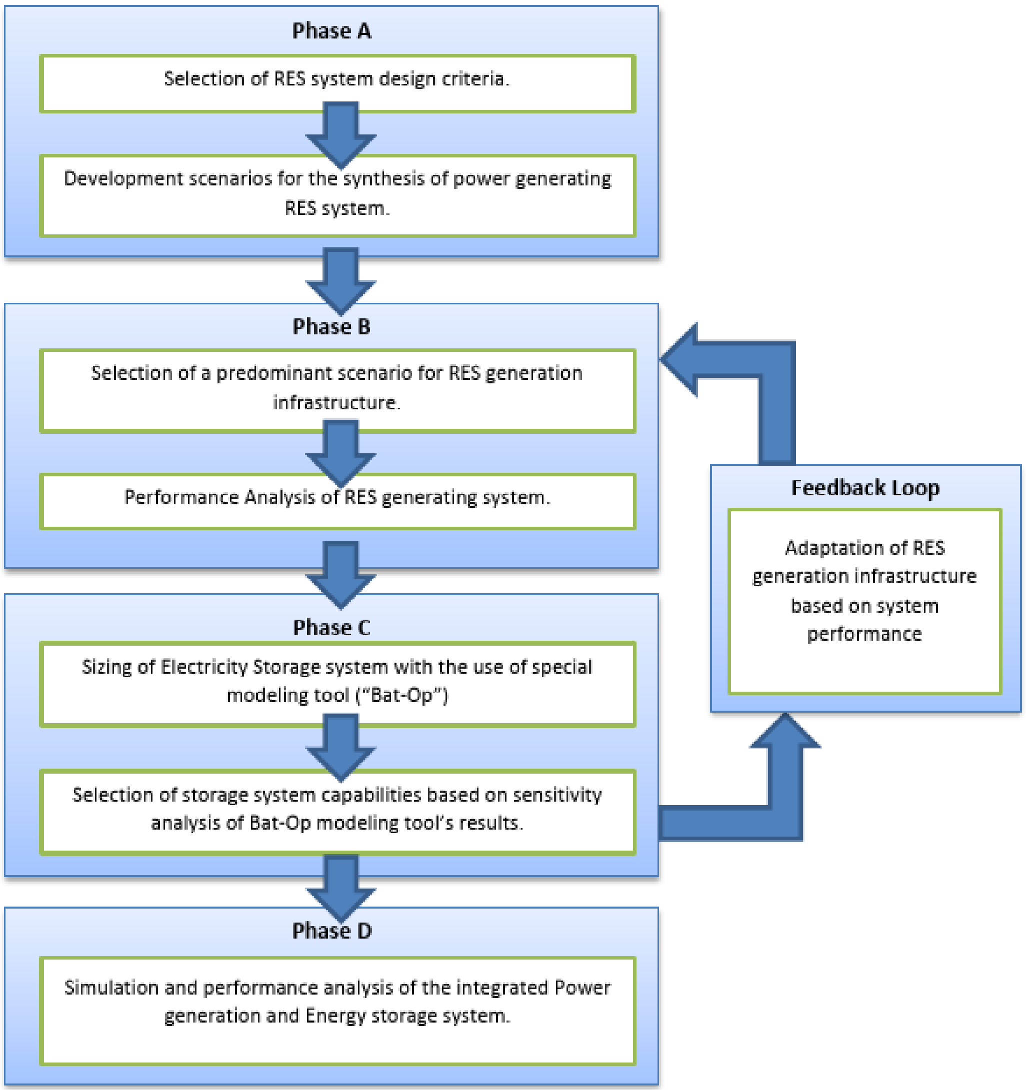


Figure 7.7 Flow diagram for the design process of the autonomous RES-storage system for the island of Megisti (Kastellorizo)

- Evaluation of available RES potential
- Selection of reference RES technologies
- Formulation of RES installed capacity scenarios
- Scenario Performance Analysis
- Sizing of Electricity Storage system with the use of special modeling tool ("Bat-op").
- System simulation and performance analysis

System's Performance Optimizations

- Demand Side management (DSM) performed for desalination energy demand.
- Reduction of electricity demand by replacing electric water heaters with solar thermal systems

Sizing Methodology for the RES – Energy Storage system for Kastellorizo Island II

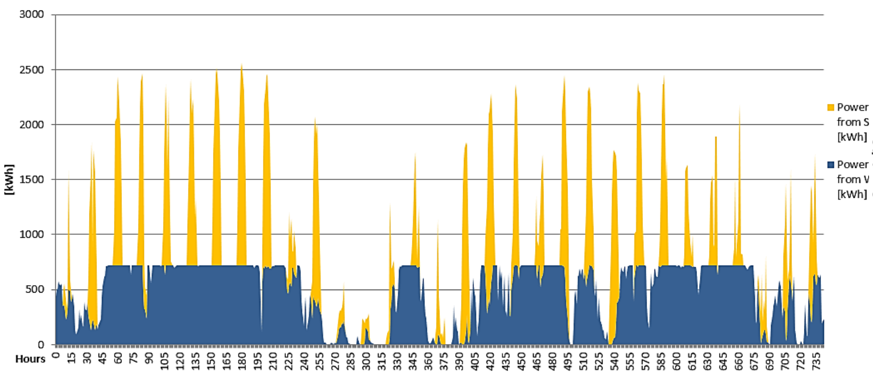


Figure E1: Hourly Power Generation from RES for the selected scenario in January [kWh]

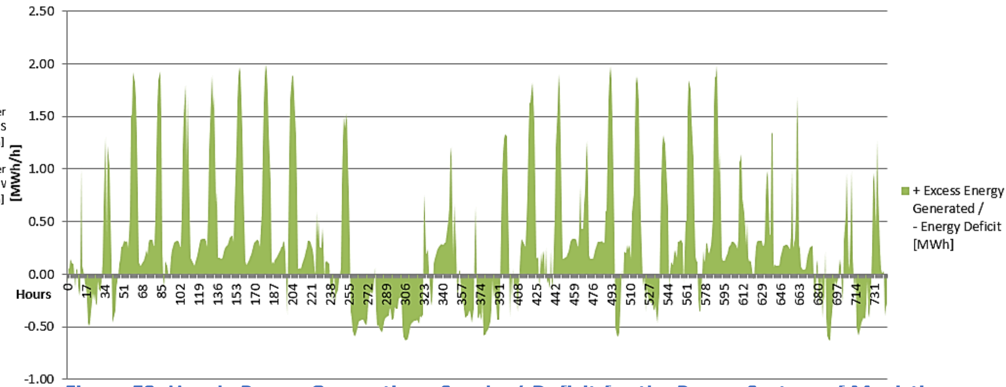


Figure E2: Hourly Power Generation +Surplus/-Deficit for the Power System of Megisti (Kastellorizo) (2025) for the selected scenario in January [MWh]

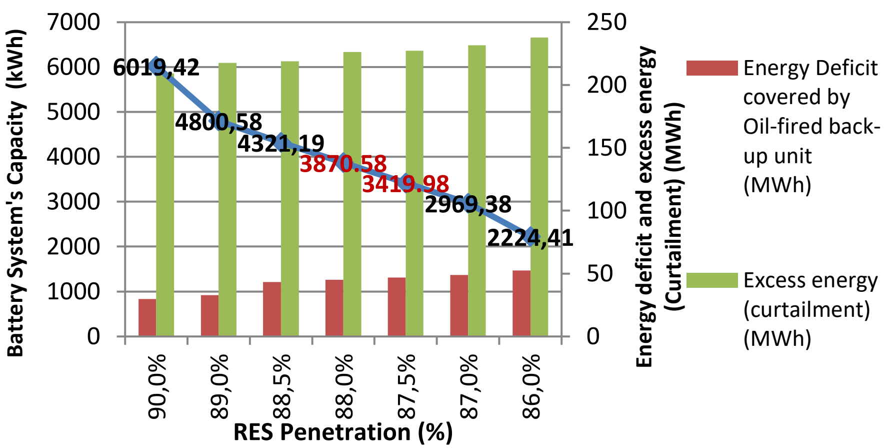


Figure E3: Results of the optimal required (minimum) system battery capacity, and the System's Deficits and Energy Curtailment [kWh] for specific RES penetration [%] using the Bat-Op software for January

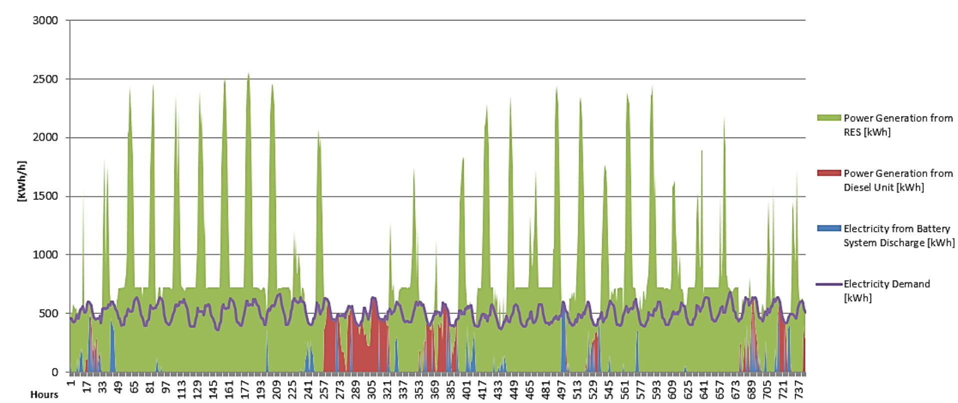


Figure E4: Performance of Integrated RES - Electricity Storage Power Sources for January

The New Energy System for the Island of Kastellorizo I

Proposed RES Power Generating Units

(a) Wind turbines (WT): 750 kW (3x 250kW)

(b) Photovoltaic Stations (PV): 2,300 kWp (monocrystalline PV)

(c) Back up diesel generators 1,000 kW (2 X 500 kW/600KVA)

(d) Li-ion Battery Energy Storage Systems 2 X 2.000 kWh/1.000 kW (C-rate 0.5)

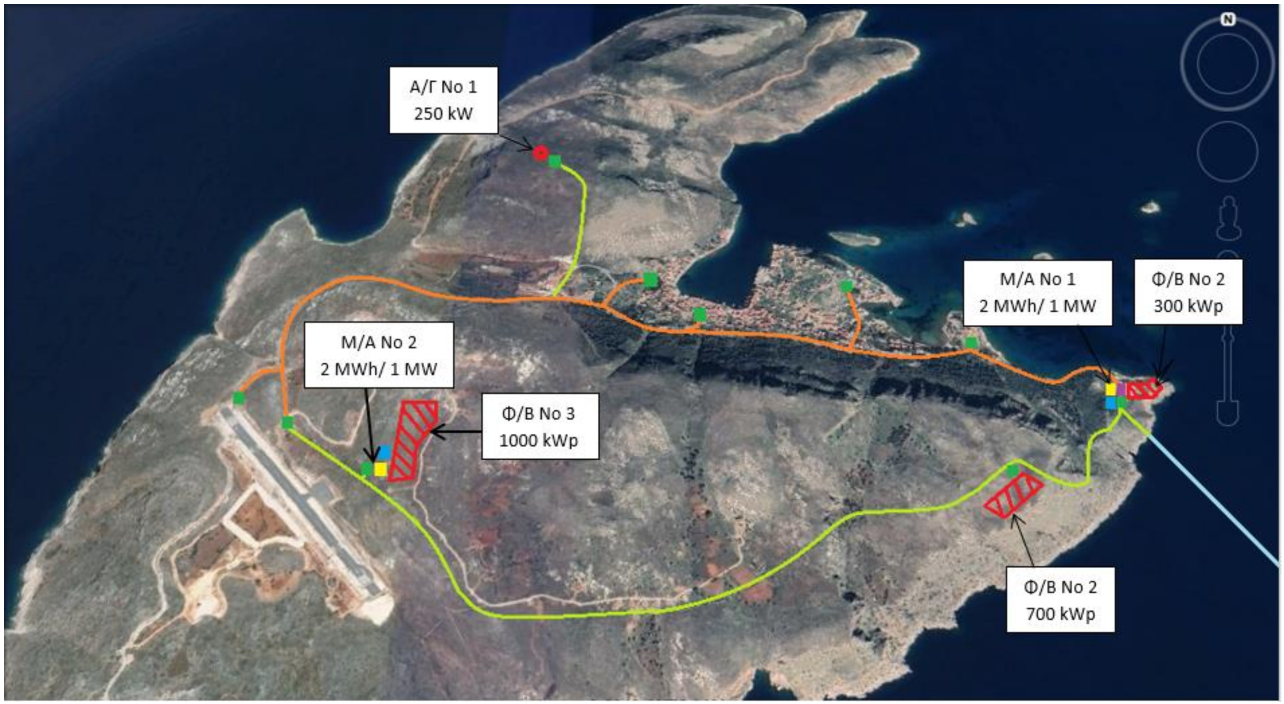
Annual Electricity Demand and Power Generation of the Proposed System

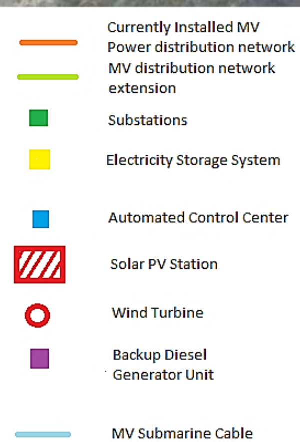
- Power demand: 4.722,3 MWh for 2025 (higher demand during the period June - October)
- Annual Windpower Generation: 4.165 MWh
- Annual Solar Power Generation: 3.882 MWh
- Energy from RES utilized to cover the demand : 3.974,95 MWh
- Electricity discharged from battery system : 433,49 MWh
- Energy Curtailment of the RES system: 3.638 MWh (including battery charge/discharge losses)
- Back-Up Diesel Generator: 312,9 MWh

RES Penetration

- **93.37%** annually, with energy storage and DSM techniques for electricity demand for water desalination

The New Energy System for the Island of Kastellorizo II



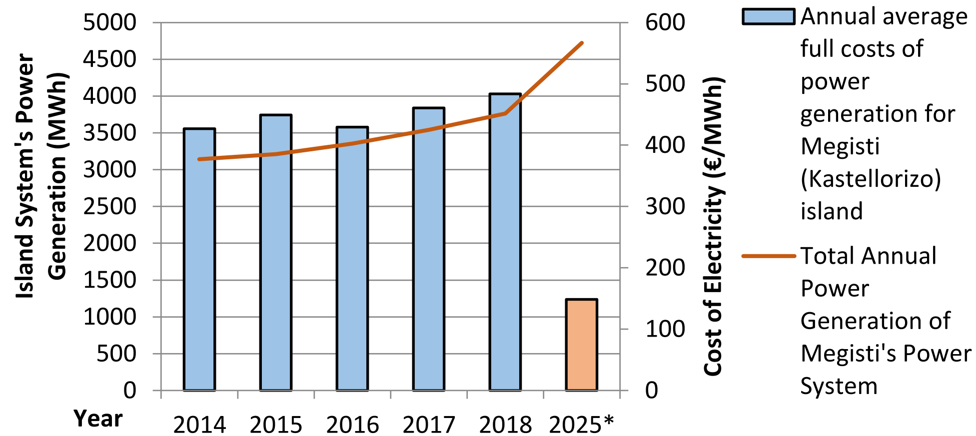


Economic Evaluation for Proposed Energy System

For the Economic Evaluation of the New Power System we utilized:

Levelized Cost of Electricity (LCOE)

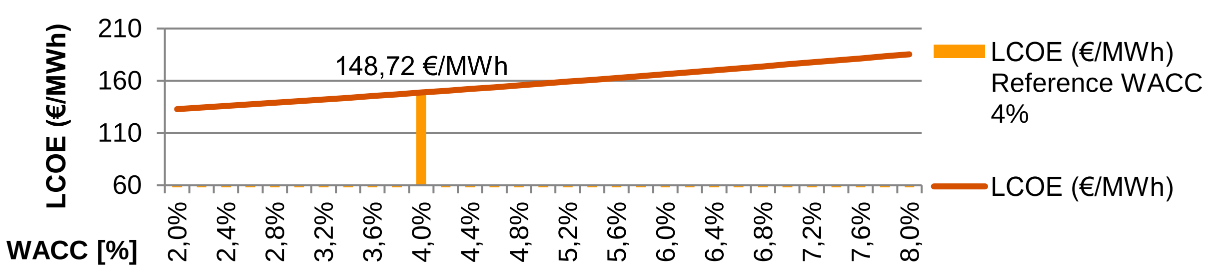
$$LCOE = \frac{CAPEX + \sum_{n=1}^{N} \frac{OPEX}{(1+r)^n} - \frac{RV}{(1+r)^{N+1}}}{\sum_{n=1}^{N} \frac{Y_o - (1-D)^n}{(1+r)^n}}$$



Cost of Electricity:

2018	2025 (WACC: 4%)	2025 (WACC: 7%)
483,44 €/MWh*	148,7 €/MWh	174,5 €/MWh

* average full cost of power generation for the current power station of Megisti (Kastellorizo)



Conclusions – Key points of the study

- The problem of high electricity costs and high greenhouse gas emissions of electricity supply in Kastellorizo Island can be addressed.

- This solution is characterized by high CAPEX (5.5m) but also by **very low running costs, stable generation costs over a long period of time and higher security of energy supply**.

- High installed capacity of RES (3.05 MW) for the island's proposed system compared to the current diesel power plant (1.45 MW).

- Energy Storage **mainly exploits the excess solar power generation of the day during the night hours**, a phenomenon that is mainly enhanced in the summer months,

- Required adaptations of the **legal framework** for NII energy systems, these should include specific studies for each island separately, focusing on security of supply, oil dependence, high RES penetration (70% - 90%) and thereby drastically reducing greenhouse gas emissions.

IENE Study: "Feasibility Study of Energy Storage Systems' Integration in Crete" (M53) (Collaboration with IPTO).

Scenarios

- Two reference years

2022 :

- Deployed Peloponnese – Crete AC interconnector
- Examination of two electricity demand profiles
- Assessment of BESS in an event of circuit disconnection at AC interconnector under a high electricity demand conditions

2030:

- Deployed DC interconnector Attica – Crete
- Examination of two electricity demand profiles
- Examination of two RES generation profiles
- Assessment of BESS with/without the deployment of Amari hybrid power station (pump storage unit)
- Assessment of BESS with/without the deployment of an efficient Gas-fired CCGT
- Assessment of BESS in an event of a DC pole disconnection at DC interconnector under various conditions

Analysis Methodology

- Crete UCED+S model developed by IENE – Mixed-integer linear programming tool. – Cost optimization (minimization)
  - Deterministic model
  - Thermal cycle of available thermal units (ramp-up/down, min up/down time, technical minimum output etc.)
  - Grid constraints: spatial constraints, spinning reserves etc.
  - RES generation
  - Electricity Demand
  - Costs: generation costs (variable, start-up/down costs, RES curtailment costs, cost of imported electricity (deterministic), etc.)
  - Battery operation constraints (set points, maximum DoD, roundtrip efficiency etc.)
- Crete UCED+S model : tailormade for the elaboration of the specific study.
- Scope of the analysis is:
  - The cost optimization and the reduction of oil use in Crete for 2022 with the integration of BESS
  - The reduction of the RES curtailment and cost reduction under various adequacy concerning circumstances for Crete in 2030 with the integration of BESS

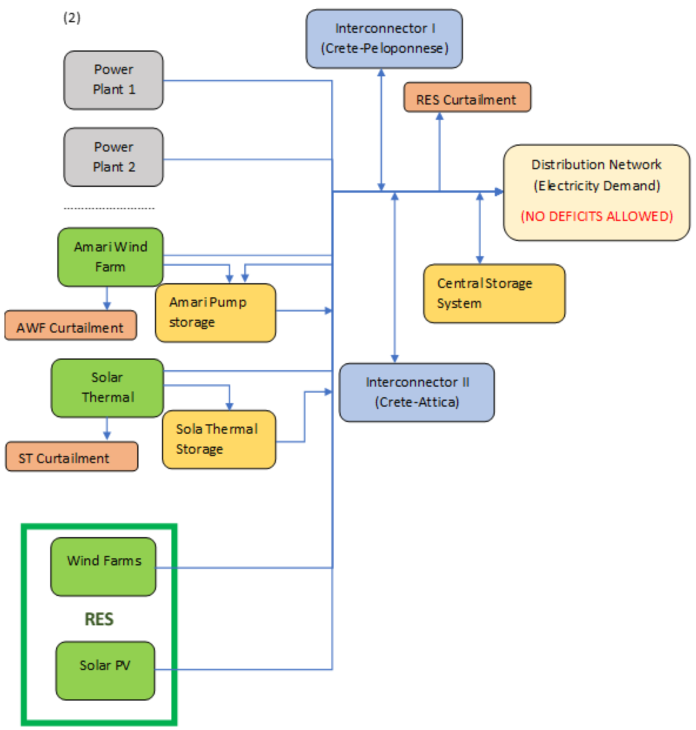


Figure 2 Nodal depiction of CRETE-UC+S model's function for the 2030 scenarios (Note: the display of thermal power plants in the nodal diagram (in grey) is indicative)

BESS integration in 2022 – Indicative results

- BAU22 Scenario: Reduction of oil use in Crete
  - 100MW/400MWh : -5.6% power generation from oil units
  - 100MW/400MWh: -73.2% of thermal units start ups

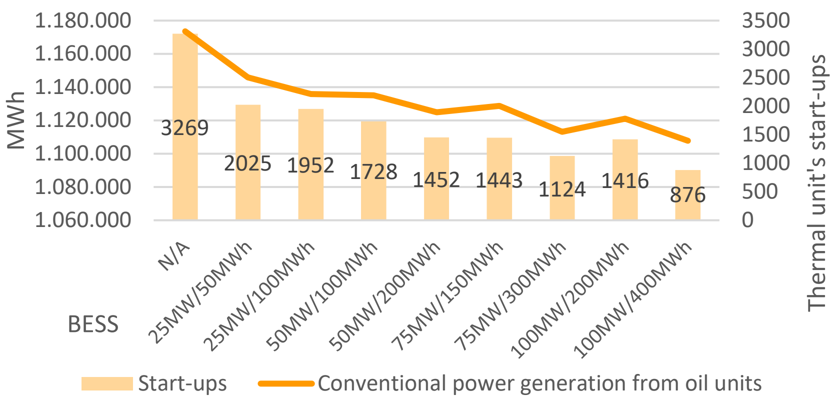


Figure 5 Power generation from conventional oil units in Crete for BAU22 scenario after the integration of various BESS.

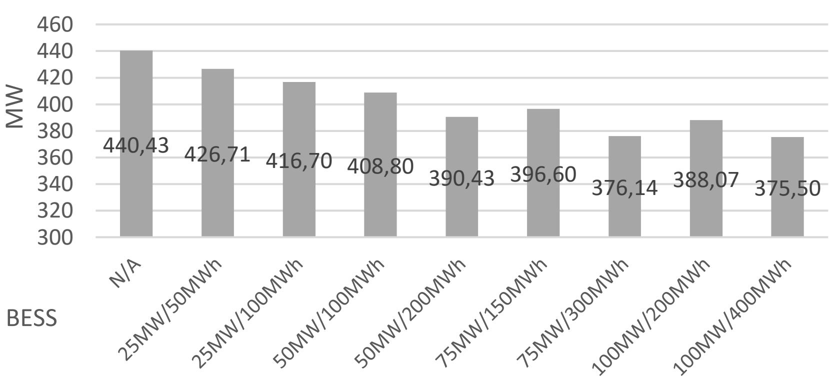


Figure 4 Annual maximum hourly average load demand covered by conventional oil units in Crete for BAU22 scenario after the integration of various BESS.

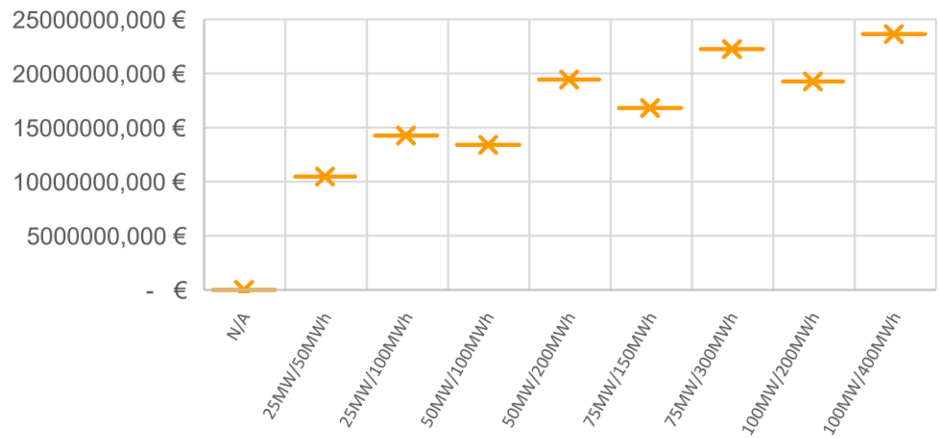


Figure 2 Economic benefit for the integration of various BESS in the system of Crete under all examined scenarios

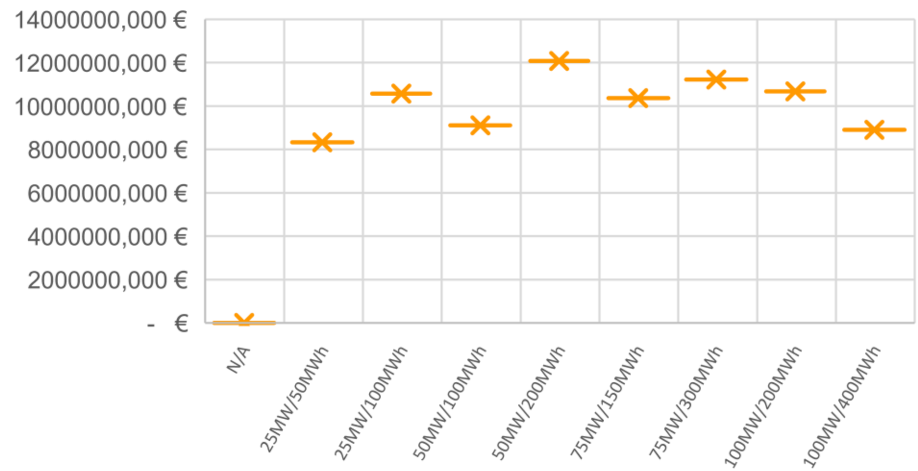
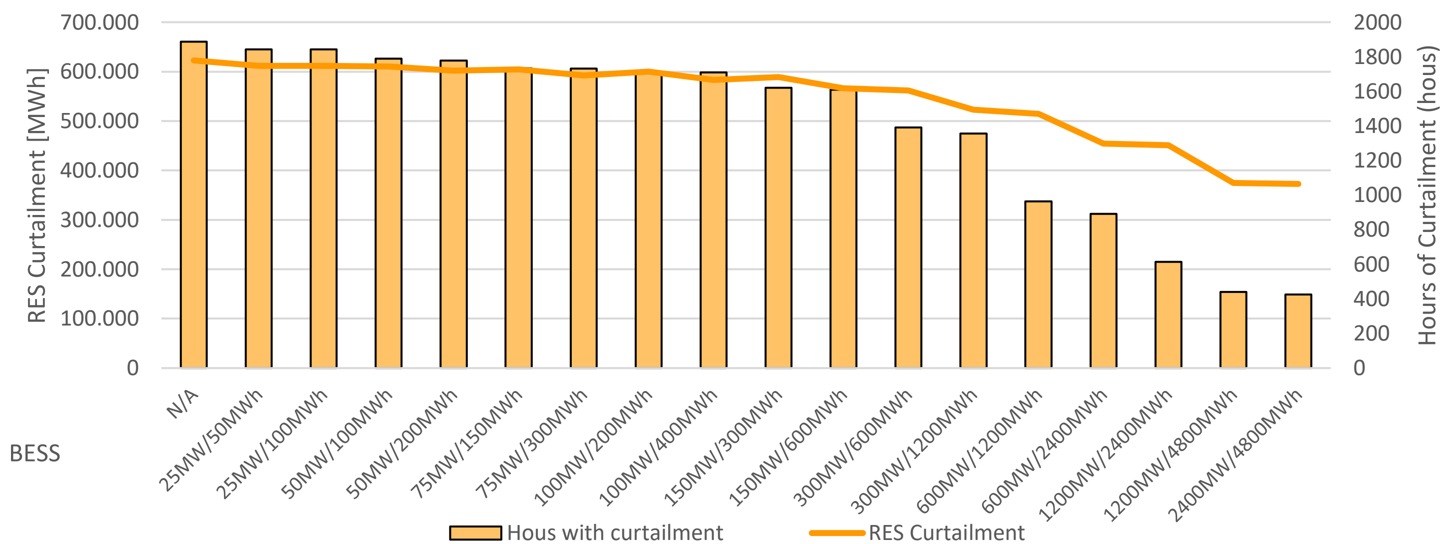


Figure 3 Economic benefit after depreciation for the integration of various BESS in the system of Crete under BAU22 scenario

BESS integration in 2030 – Indicative results

- Central BESSs' integration is economically infeasible due to very high investment capital costs.
- Economic feasibility occurs under circumstances of:
  - In an event of one pole disconnection at DC cable interconnector Attica-Crete (2 months) for BESS storage capacities ranging from 50MWh - 100MWh for BAU scenario and for any integrated BESS storage capacity under increased demand conditions
- RES Curtailment occurs only under a high RES integration scenario that includes aggregated RES capacity of 2,550 MW in Crete (RES curtailment of 9.17%, at 622 GWh/year). In this case there utility value of BESS but still BESS integration remains economically infeasible.



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Thank you very much for your attention!

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