«Energy Transition of the Island of Kastellorizo»

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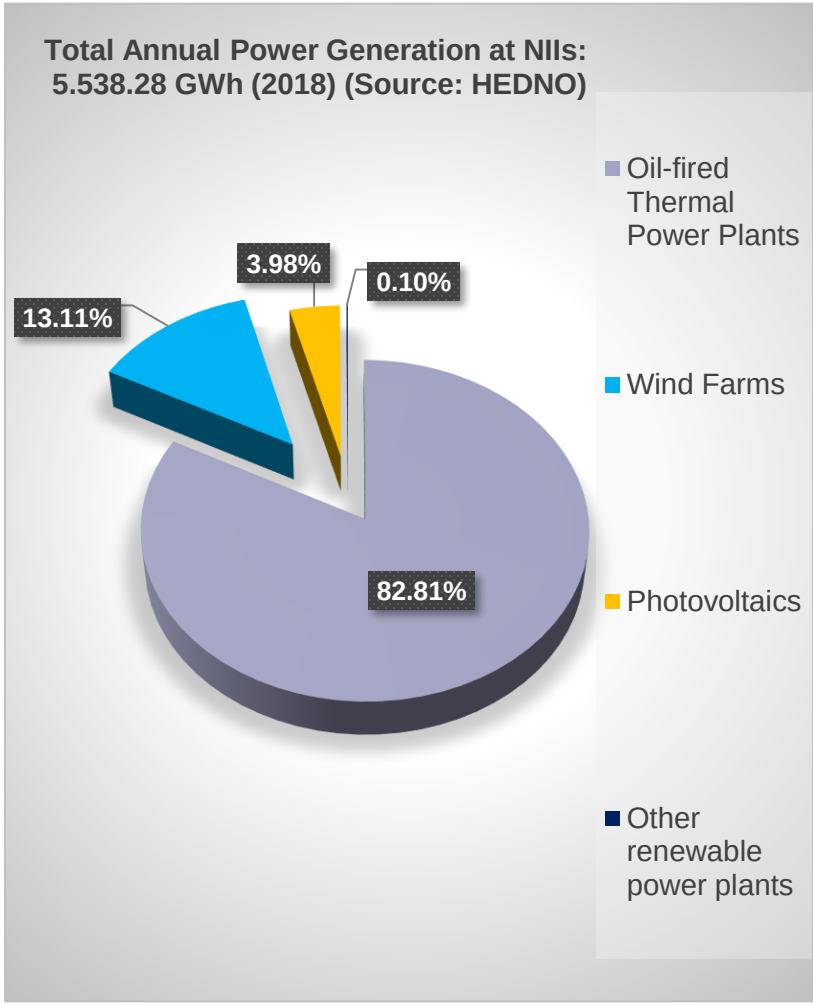
Renewable Electricity as the sole energy carrier in Non Interconnected Islands (NIIs)

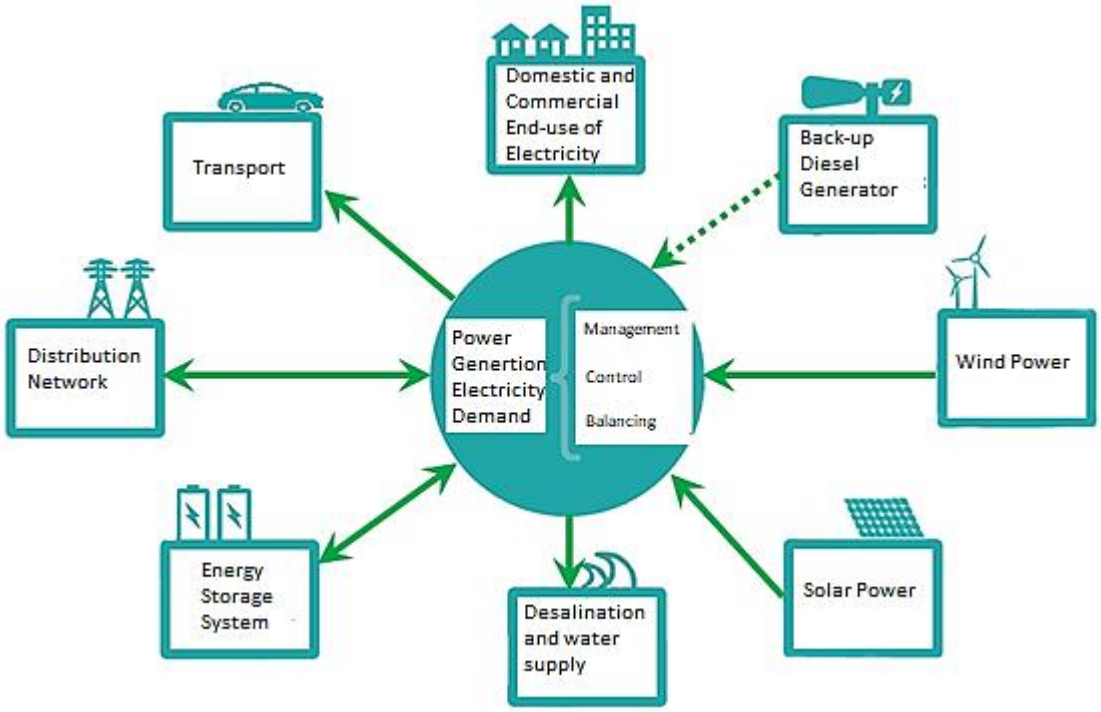
- Today, all NIIs are overwhelmingly dependent, by more than 80%, by oil-fired thermal power plants for power generation.
- EU Directive 2015/2193 for on the limitation of emissions of certain pollutants into the air from medium combustion plants is in effect, expected to lead to withdrawal of oil-fired power generating units from NII systems.
- Very high cost of operation for Autonomous oil-fired Thermal Power Plants in Non Interconnected Islands.
  - Average annual full generation costs for 2018 amounted to €1,387.5/MWh on the island with the lowest demand (Antikythera) and €483.4 /MWh on the island with the highest demand (Megisti)
  - Average annual electricity generation costs for the last five years 2014 - 2018 range from €1,283.9 /MWh (Antikythera) to €451.15 /MWh (Megisti) respectively.
  - Average Monthly Variable Generation Costs range from €239 to €443 /MWh for 2018 and from €188 to €686 /MWh for the period 2014 - 2018. (While the average annual marginal price for electricity in the interconnected system was €60.39 /MWh in 2018)



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

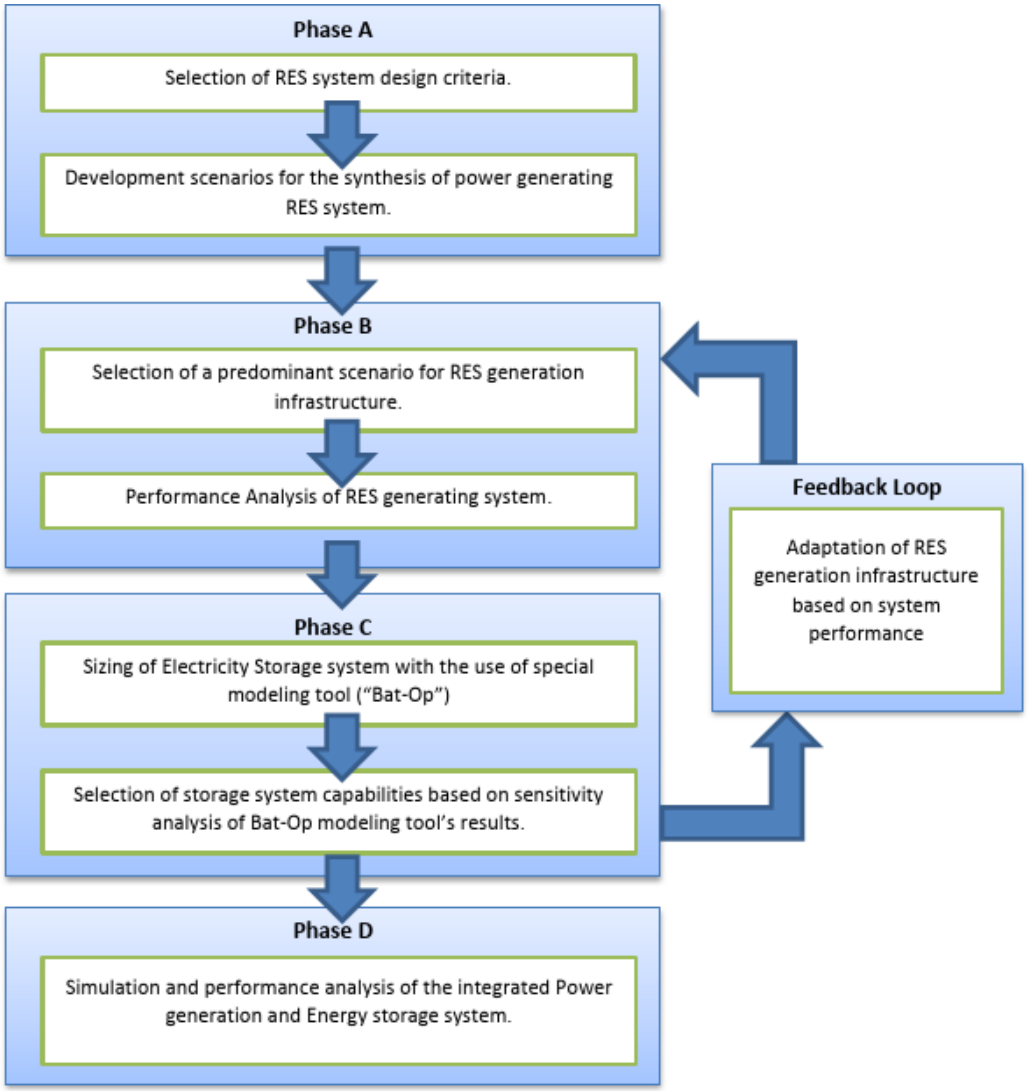


Figure 7.7 Flow diagram for the design process of the autonomous RES-storage system for the island of Megisti (Kastellorizo)

- 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

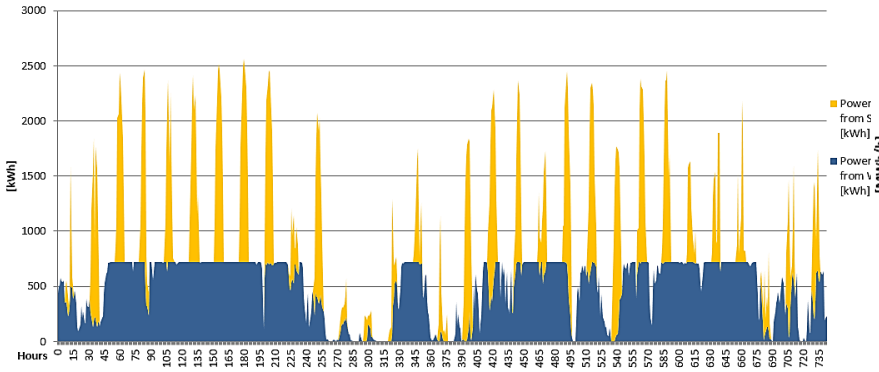


Figure E1: Hourly Power Generation from RES for the selected scenario in January [kWh]

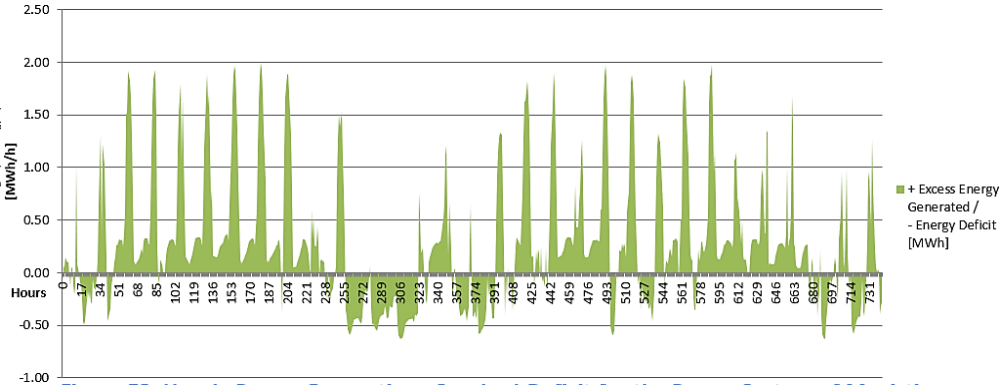


Figure E2: Hourly Power Generation +Surplus/-Deficit for the Power System of Megisti (Kastellorizo) (2025) for the selected scenario in January [MWh]

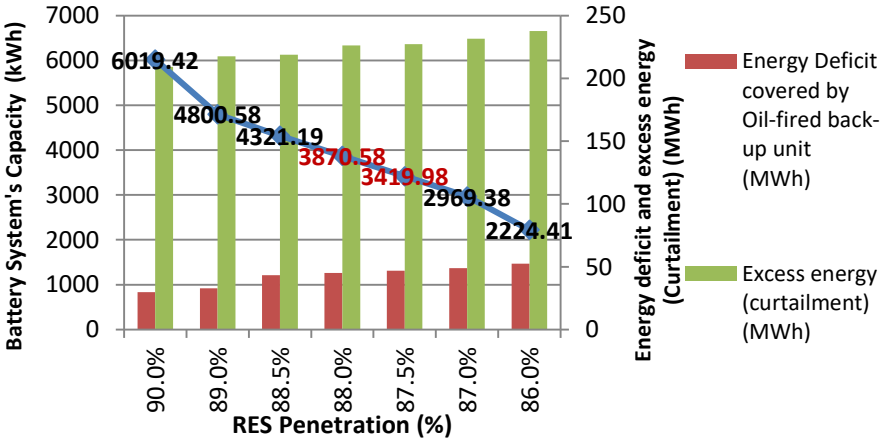


Figure E3: Results of the optimal required (minimum) system battery capacity, and the System's Deficits and Energy Curtailment [kWh] for specific RES penetration [%] using the Bat-Op software for January

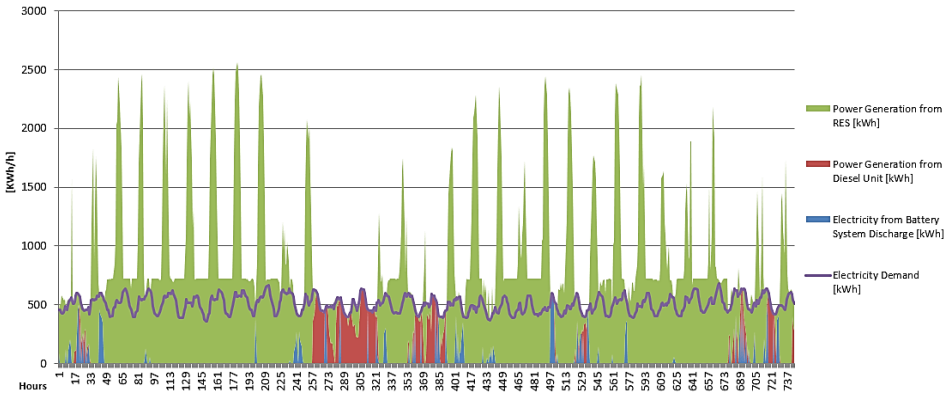


Figure E4: Performance of Integrated RES - Electricity Storage Power Sources for January

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)

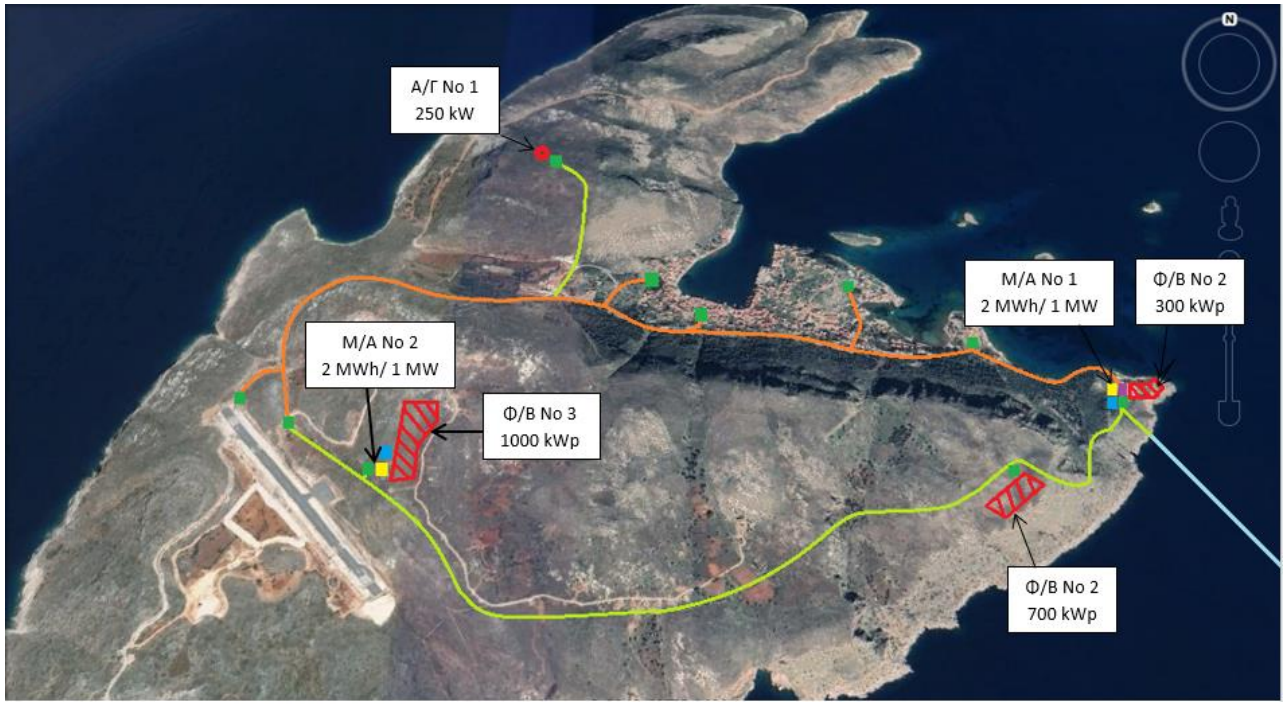
Annual Electricity Demand and Power Generation of the Proposed System

- 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



Currently Installed MV Power distribution network

MV distribution network extension

Substations

Electricity Storage System

Automated Control Center

Solar PV Station

Wind Turbine

Backup Diesel Generator Unit

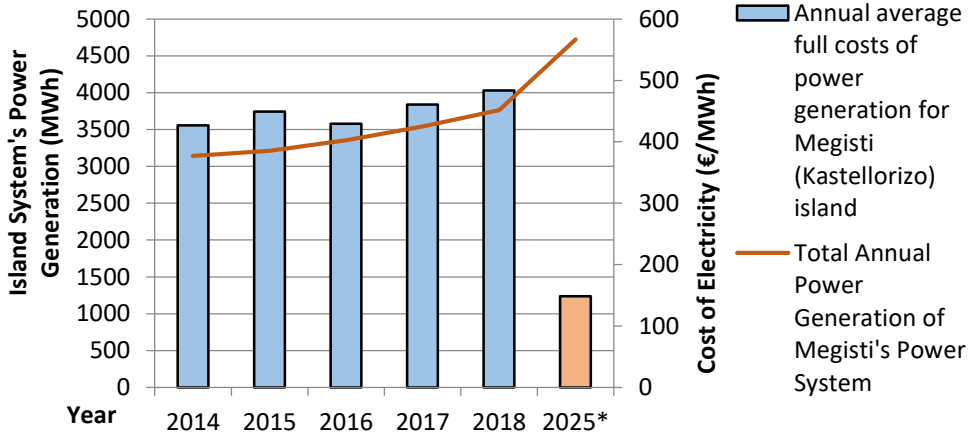
MV Submarine Cable

Economic Evaluation for Proposed Energy System

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

Levelized Cost of Electricity (LCOE)

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



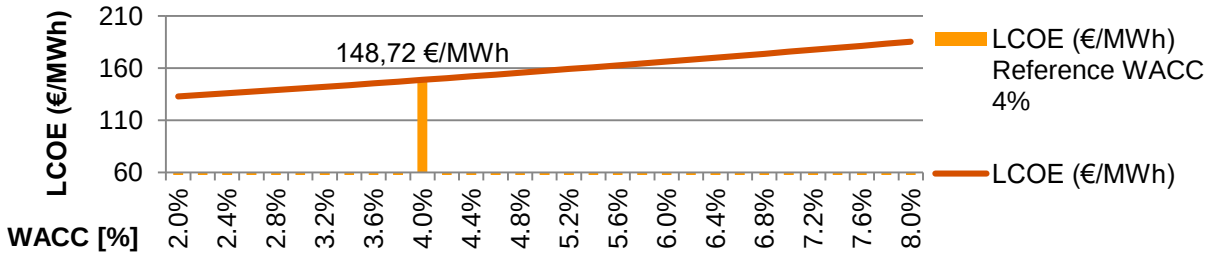
Cost of Electricity:

2018 .
483,44 €/MWh*

2025 (WACC: 4%)
148,7 €/MWh

2025 (WACC: 7%)
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). Li-ion Battery Energy Storage deals with the problem of intermittent generation from RES by utilizing excess RES generation covering timely for low RES performance and therefore increases penetration of RES (93.37%). The high solar potential and the steady moderate wind profile indicated PV and Wind Turbines as the main generating units of the island.
- 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, in which wind turbines in their rated output cannot meet the increased night demand, while it also contributes covering electricity demand during short periods of low wind and cloudiness.
- Regarding the 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.

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Thank you very much for your attention!

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