

# Integrating Hybrid Off-grid Systems with Battery Storage: Key Performance Indicators

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## Introduction

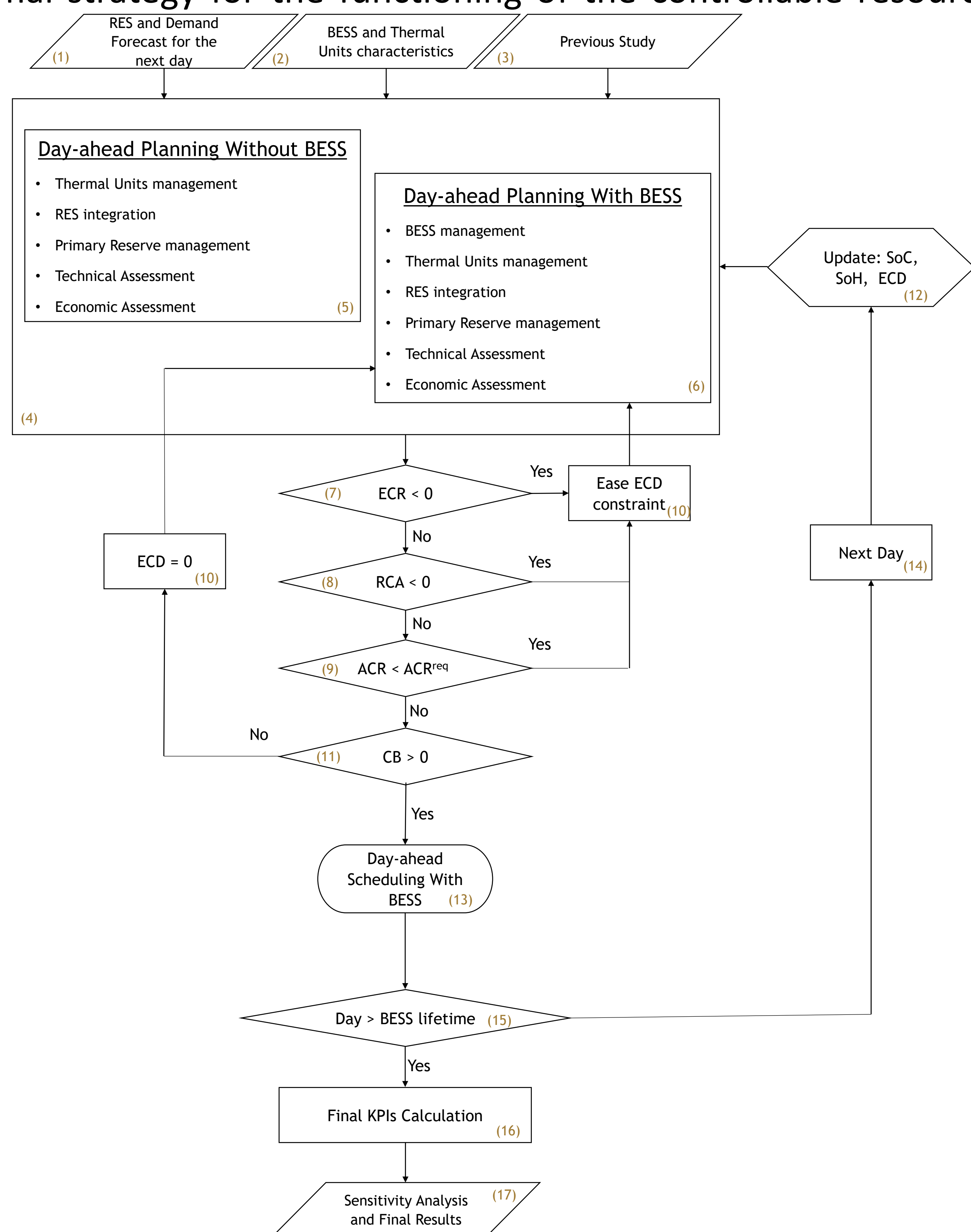
This work proposes a set of Key Performance Indicators (KPIs) to assess the integration of hybrid off-grid systems with Battery Energy Storage Systems (BESS). Furthermore, considering these KPIs, a methodology is developed, consisting in day-ahead planning of operation, in order to reduce the Operational Expenditure (OPEX) of off-grid systems and maximize their share of Renewable Energy Sources (RES).

## Key Performance Indicators

Operational KPIs	Planning KPIs
ECR – Emissions Cost Reduction	LCOE – Levelized Cost of Energy
ACR – Average Cost Reduction	LCOS – Levelized Cost of Storage
RCA – Renewable Curtailment Avoidance	LBOS – Levelized Benefits of Storage
CB – Cycle Benefits	NPV – Net Present Value
SoH – State of Health	PT – Payback Time

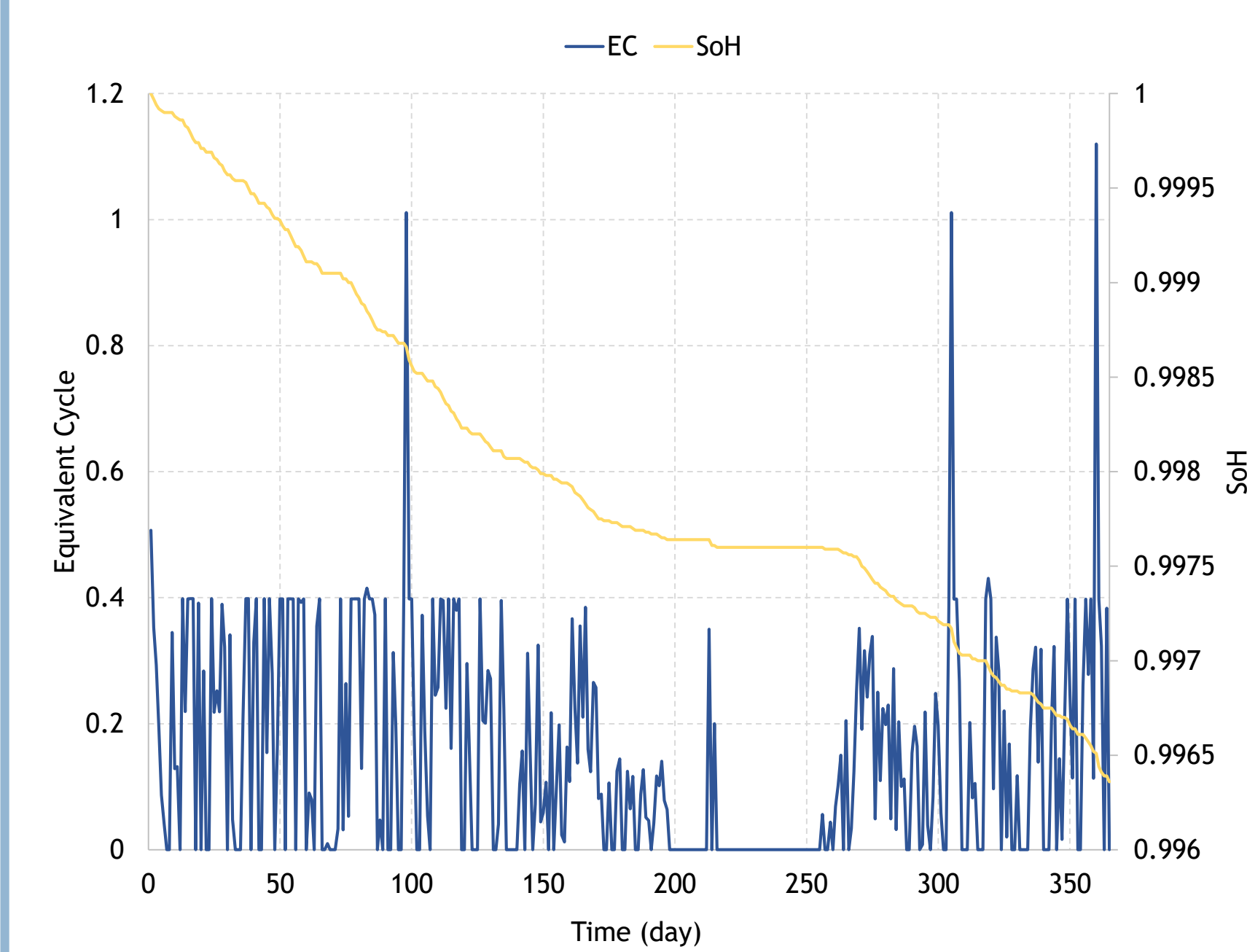
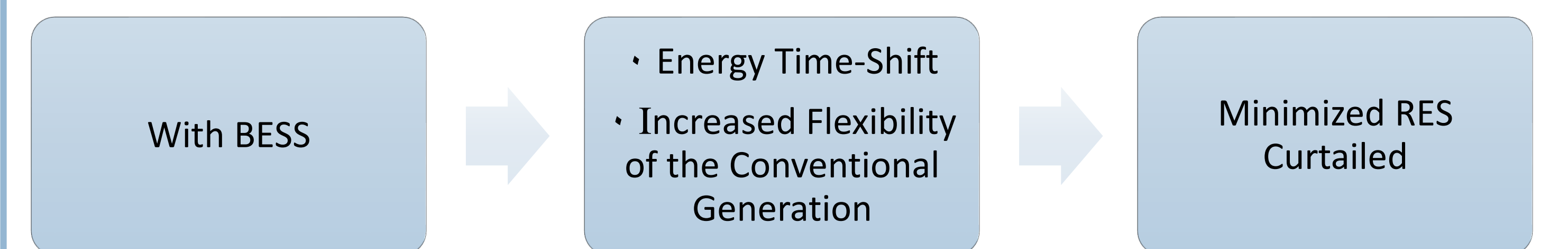
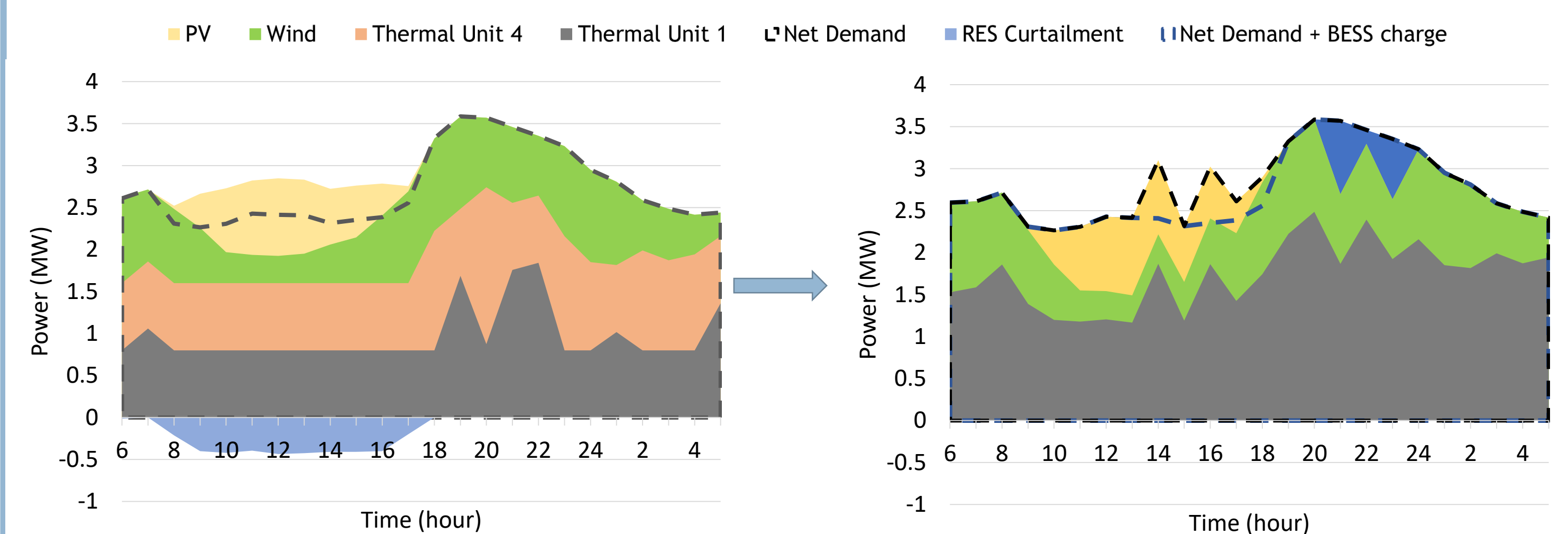
## Methodology

The objectives are achieved through a technical-economic analysis based on the Operational KPIs in order to define the optimal strategy for the functioning of the controllable resources.



## Results

The developed methodology is assessed and validated on a case study of a real island grid with renewable energy sources, considering a planning horizon of 10 years.



During the summer the system performs few or no equivalent cycles per day. Due to the fact that the consumption is much higher than the production.

The vast majority of equivalent cycles are performed in the remaining seasons of the year because the potential to obtain economic benefits is higher.

Operational KPIs	
Renewable Curtailment Avoidance (MWh <sub>integrated</sub> /MWh <sub>excess</sub> )	1
Average Cost Reduction (€/hour)	37,4
Emissions Cost Reduction (€/day)	13,4
Cycle Benefits (€/day)	1 143,4
State of Health (%)	96,2

Planning KPIs	
Levelized Cost Of Energy (€/kWh)	0,169 ↓ 1,23%
Levelized Cost Of Storage (€/kWh)	0,988
Levelized Benefits Of Storage (€/kWh)	1,21
Net Present Value (€)	371 587
Payback Time	8 year

The KPI RCA has the maximum possible value because all the renewable energy excesses in the off-grid system is integrated.

The cycles are very profitable economically, which makes KPI CB a positive value.

The improvement of LCOE may represent a reduction in the cost to be paid by end consumers.

The effective economic benefit of the BESS is the difference between the LBOS and the LCOS, which is 0,222€ for each kWh injected.

## Conclusions

- Integration of BESS in off-grid systems provides technical improvement in the conventional generation system.
- In off-grid systems with relatively low installed capacity of RES, the performance of cycles is quite reduced, however, the provision of primary spinning reserve results in economic benefits.