Early-Operation Evidence from the First-ever Battery-based Hybrid Power Station in Greece on the Island of Tilos

URL: https://www.tiloshorizon.eu/
Email: dzaf@teipir.gr

University of West Attica – School of Engineers– Dept of Mechanical Engineers
Soft Energy Applications & Environmental Protection Lab

Dimitris Zafirakis, J.K. Kaldellis

4th International Hybrid Power Systems Workshop
22 - 23 May 2019
Crete, Greece

Contents

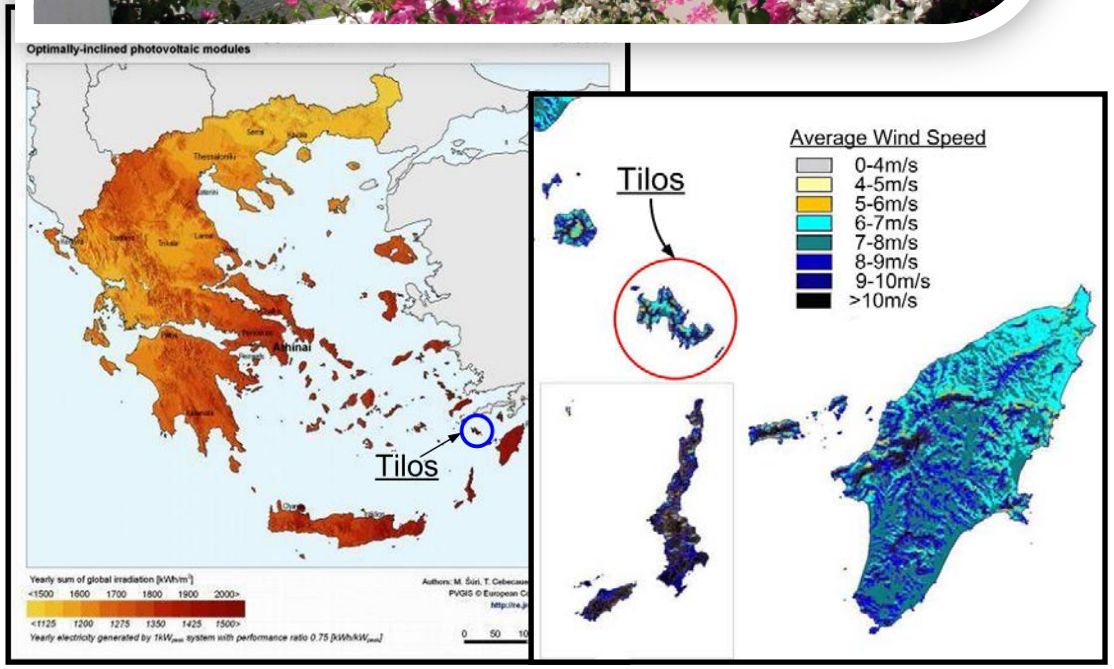
- Introduction
- Tilos Microgrid
- Demonstration Stage
- Key Exploitable Results
- Conclusions

INTRODUCTION

TILOS Project – General Info

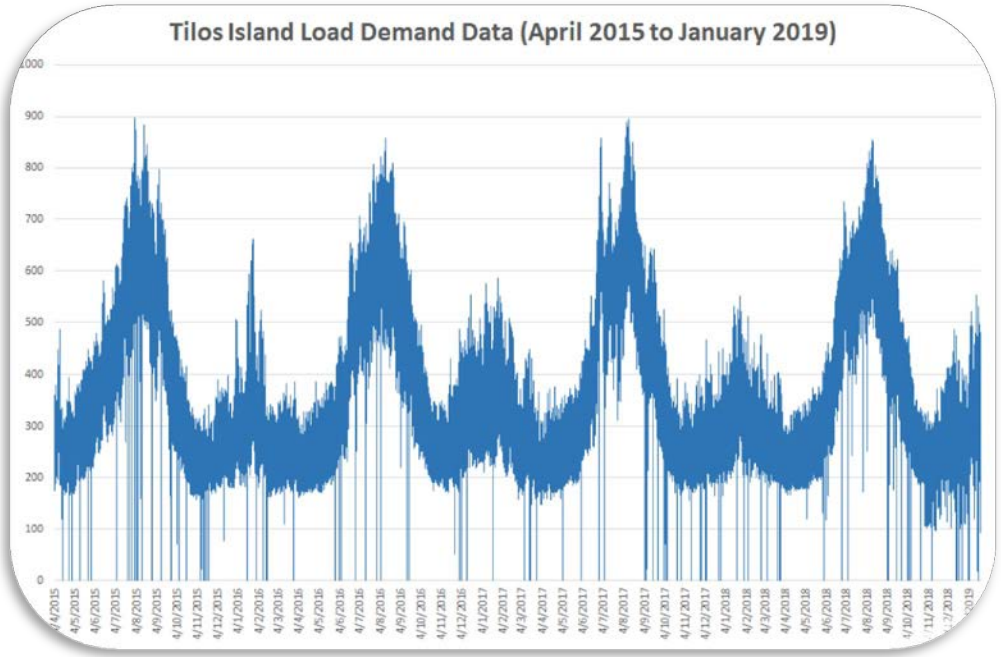
- **Framework**: Horizon 2020
- **Call**: Local / small-scale storage-LCE-08-2014
- **Score/Ranking**: 14/15 (1st among 80 proposals)
- **Budget**: 15M€ (11 M€ funding)
- **Consortium:** 13 partners / 7 European countries
- **Duration**: 4 years (2/2015-2/2019)

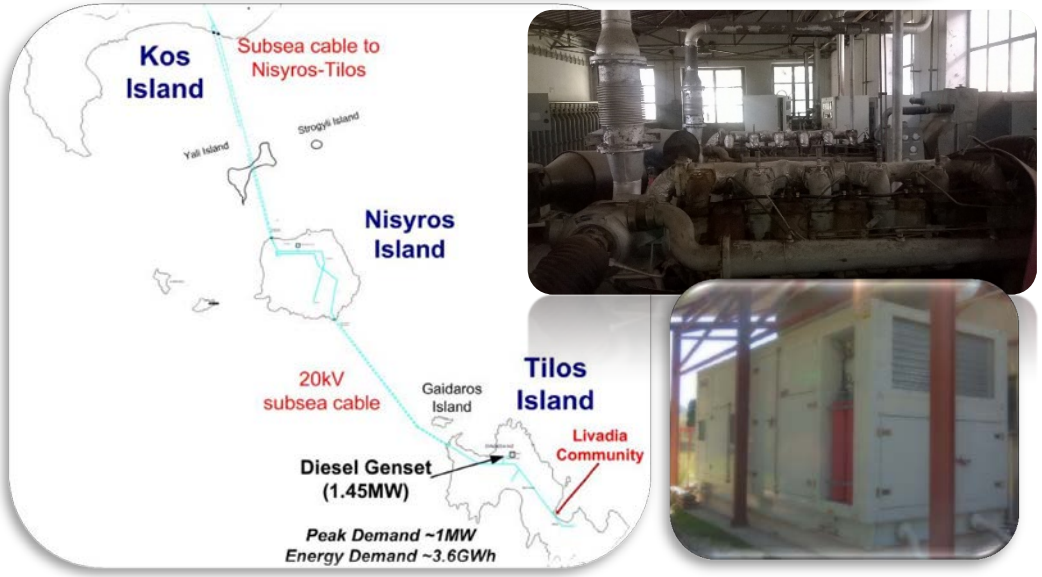
The Island of Tilos



- Small scale, remote Aegean Island; Belongs to the island complex of the Dodecanese
- Local population of ~**500 people**; More than **doubles** during the summer period
- Peaceful island with **environmentally-friendly** profile and culture
- **Medium-quality** wind potential – Average wind speed in the order of **6.5-7m/sec**
- **Excellent** solar potential; ~**1750kWh/m^2.a**

The Island of Tilos

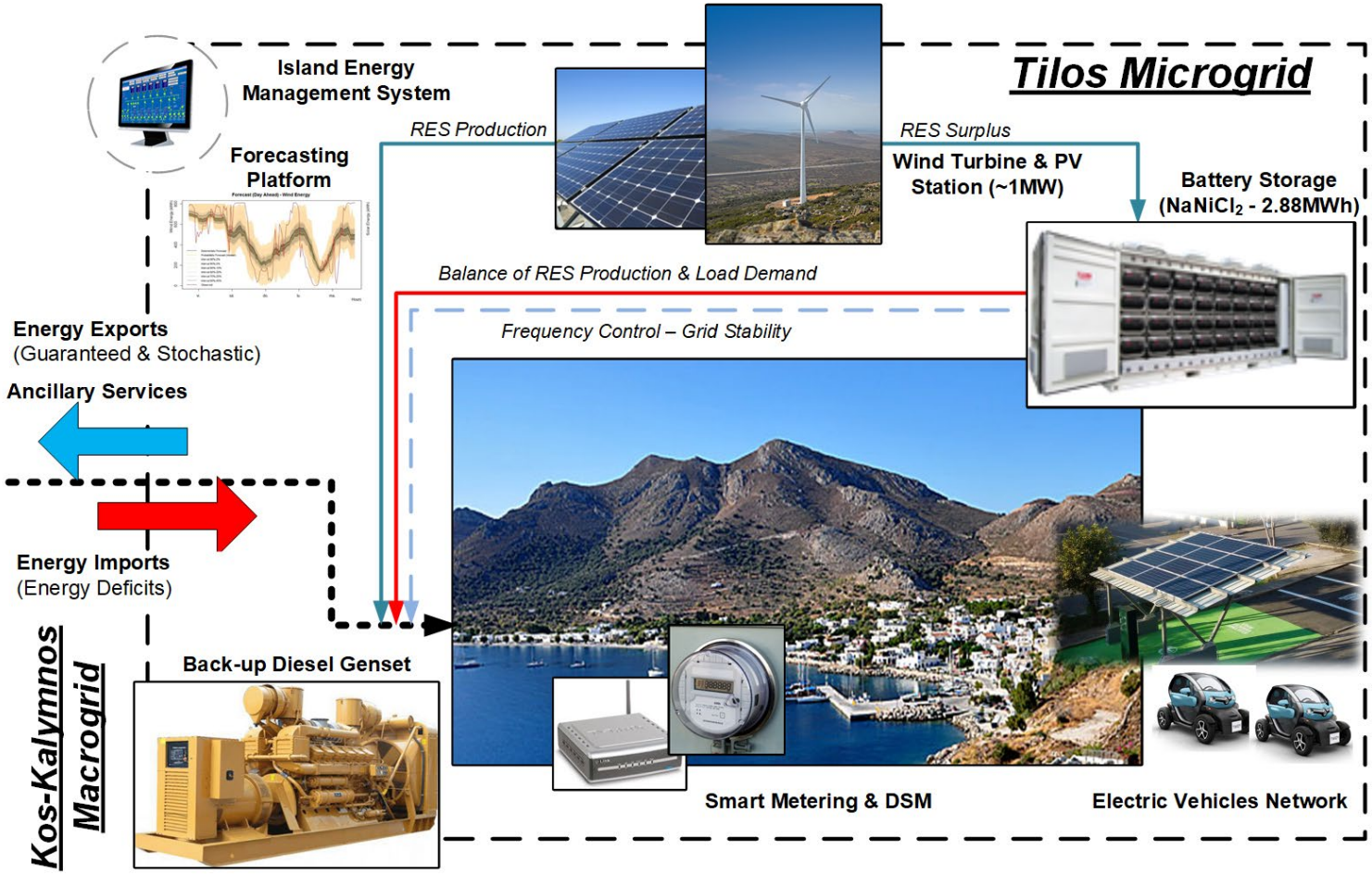


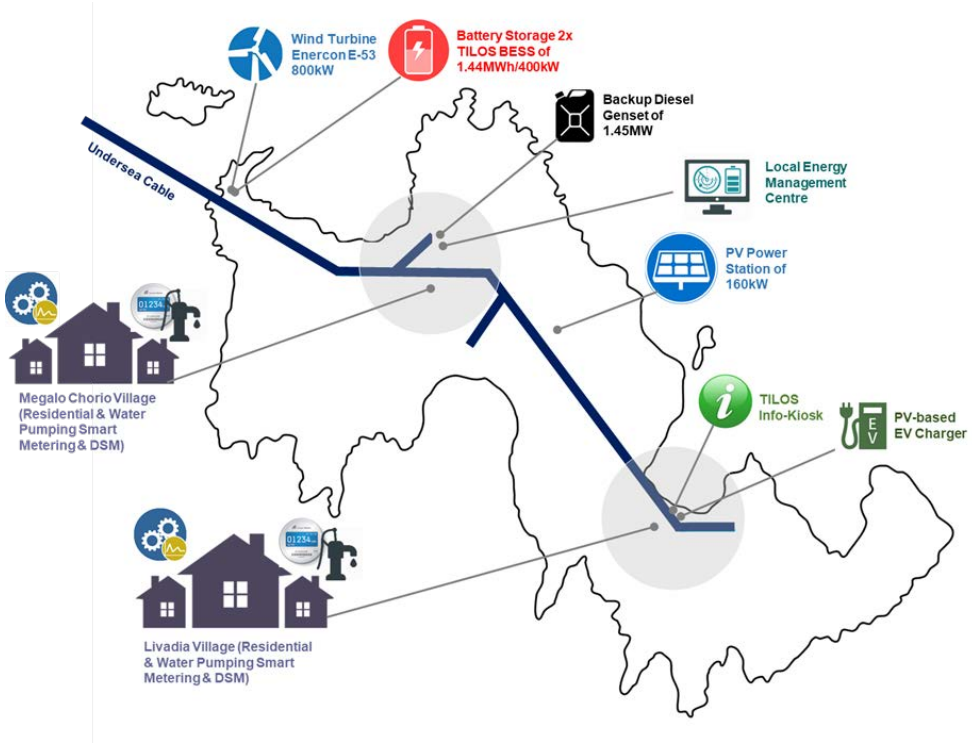


- Peak demand of Tilos close to **1MW**; Annual electricity demand of ~**3GWh**
- The island belongs to the **Kos-Kalymnos** electricity system (~100MW system)
- **Subsea interconnection** with Kos through Nisyros island; Tilos last in line (mainly oil-based supply: 85% oil vs 15% RES)
- Occurrence of faults from time to time causes **power cuts** that may last for tens of minutes up to a few hours
- Emergency **diesel genset** of PPC; Activated manually in the case of severe power cuts

TILOS MICROGRID

TILOS Microgrid / Main Components





TILOS HPS – Wind Turbine

- One of the main elements of the TILOS Hybrid Power Station is the **Enercon E-53 wind turbine** of **800kW**
- Installed in **July 2017**, the wind turbine is located on the north side of the island, next to the **subsea cable junction**
- Annual energy yield of ~**2.1GWh** (30% CF), equal to **70%** of Tilos island annual electricity demand
- Supports both **energy autonomy** of Tilos and clean **energy exports** to the electricity system of Kos

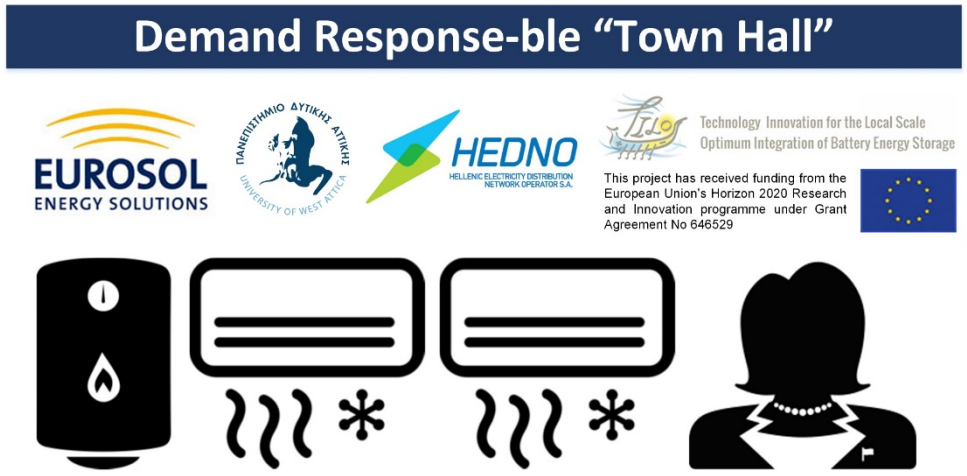
TILOS HPS – PV Station

- Small-scale **PV power station** of **160kW$_p$**, comprising of 592 solar panels of 270W$_p$ each @30 degrees tilt angle
- Located in the center of the island, between the villages of **Livadia** and **Megalo Chorio**
- Annual CF in the order of **19%**, expected to contribute with ~**265MWh** of clean energy on an annual basis, which is close to **9%** of Tilos island demand
- Offers a more **"dispatchable"** energy source that allows for better regulation of the HPS

TILOS HPS – Battery Storage

- The **BESS** of TILOS comprises of the **FZSoNick $NaNiCl_2$ Battery** and the **IDT Battery Inverter**
- Together they comprise a **multifunctional configuration**, for both **island** and **grid-connected** applications
- **High energy density** and **high-temperature** battery / remains unaffected from ambient temperature variation, suitable for Greek islands
- Battery capacity of **2.88MWh** (80% useful) ~12h of autonomy for Tilos; nominal power of **800kW**, close to island peak

TILOS Smart Metering & DSM Platform

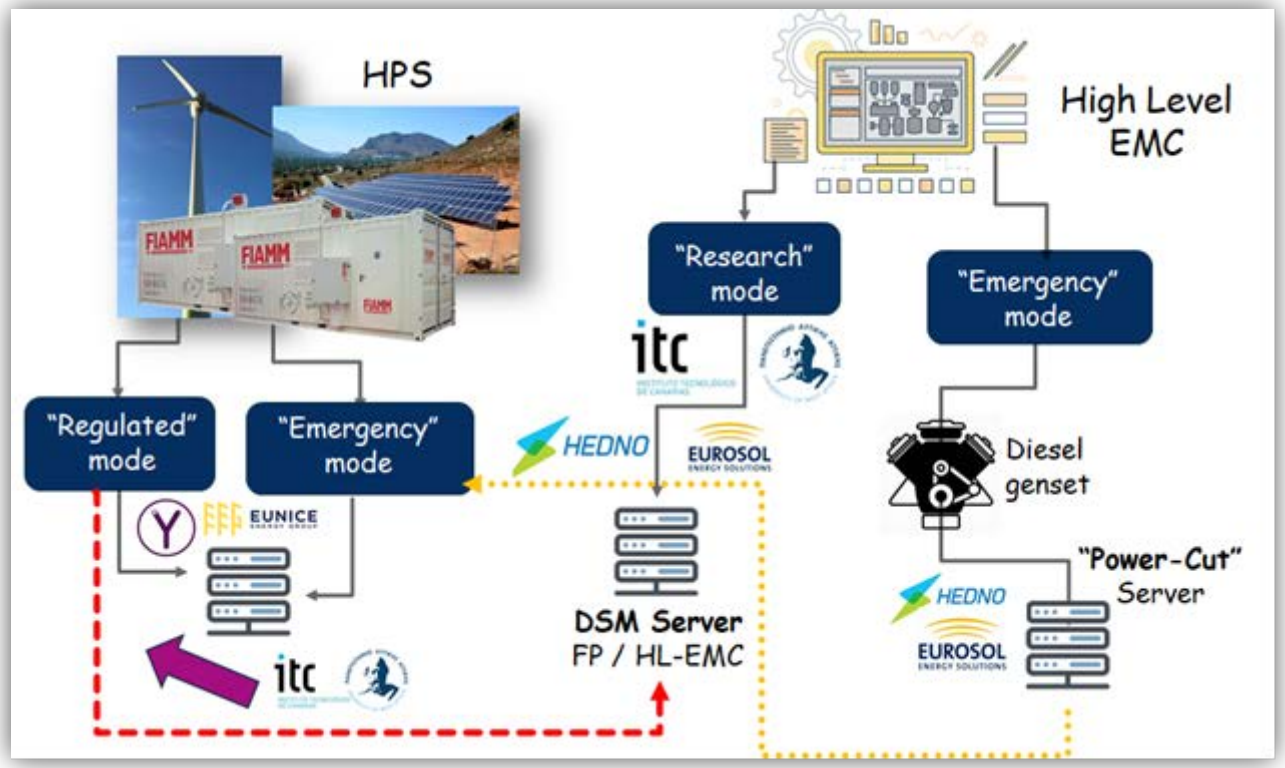


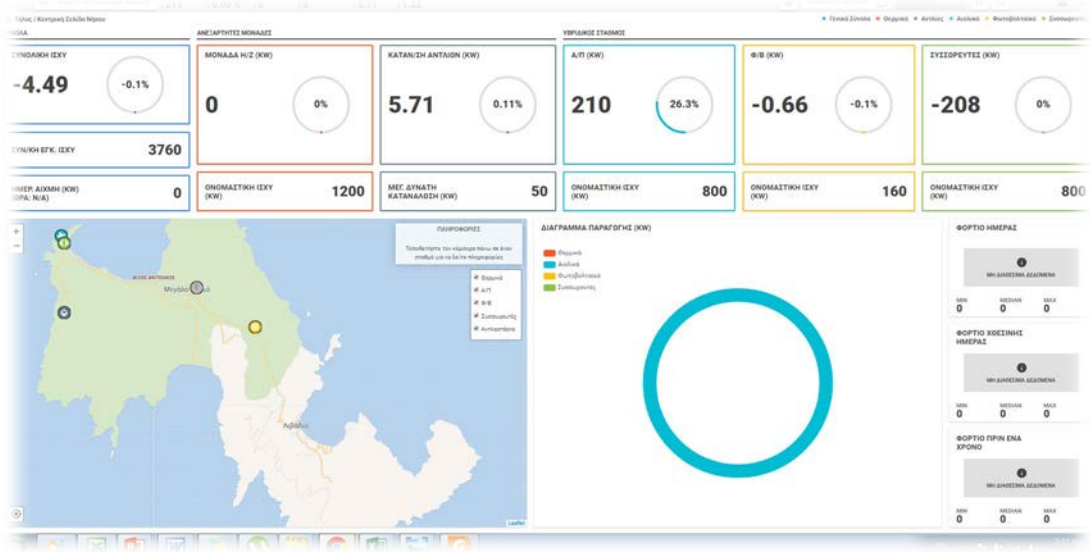
- TILOS SM & DSM Microgrid Platform is a **hardware / software platform** supporting **metering and control** of both facility-level and individual end-consumer loads

- **100 end-users** (mainly residential consumers) and **8 pumping stations –** Up to 3 controlled loads per end-user

- By exploiting an adequate **pool of customers (15%-20% of loads)**, the platform is able to deploy **DSM strategies** at the local, end-user level, and also at the global, MG/aggregator level

TILOS High-Level Energy Management Centre





http://195.251.95.11

- Offers an **upper level entity** that can **govern all microgrid components**, including the genset
- Commissioned in Jan 2019, **enabling isolated mode** of operation for Tilos
- Supported the **unbundling of roles** between different partners and actors onsite

DEMONSTRATION STAGE

Demonstration / Trial Period

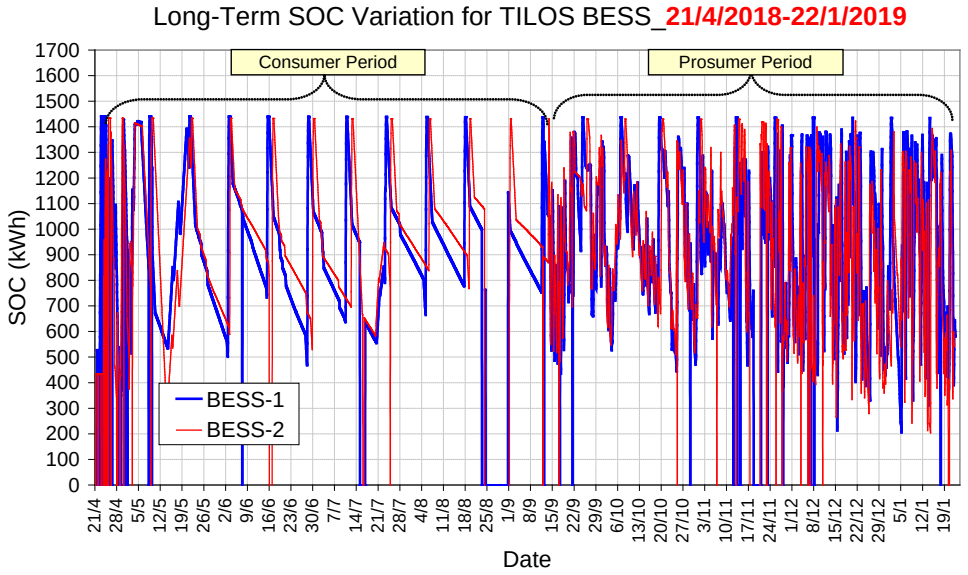
	2018									2019		
Activities	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**….**
BESS Commissioning												
HPS Consumer Mode												
Wind Turbine Commissioning												
PV Station Commissioning												
HPS Prosumer Mode												
HL-EMC Installation												
Island Testing in Berlin												
HPS Profile Testing												
HL-EMC Commissioning & Island Testing on Tilos												
Solar EV Station Commissioning												
HEDNO Commissioning Tests												
HPS Operational License												
HPS-only / Full-DSM Island Test												

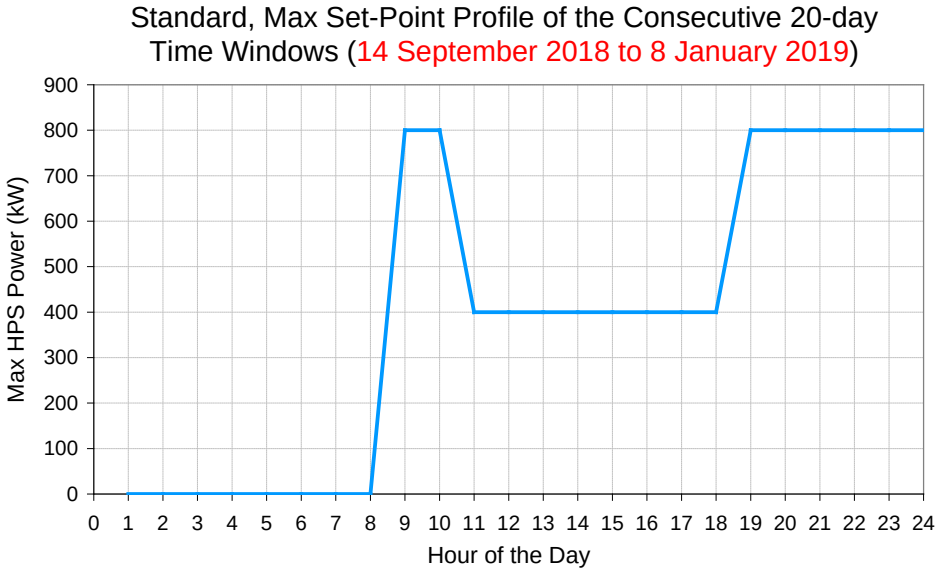
Trial Period Testing

- **PPA** issuance (Jan 2018)
- Two distinct periods: **Consumer & Prosumer**
- May-Sept 2018; Sept 2018-Jan 2019
- **Increased RES** penetration (daily, monthly…)

- **Profile Tests for the HPS**
  - **Std HEDNO profile**
  - Island load-following
  - Island load-following + Exports
  - RES following

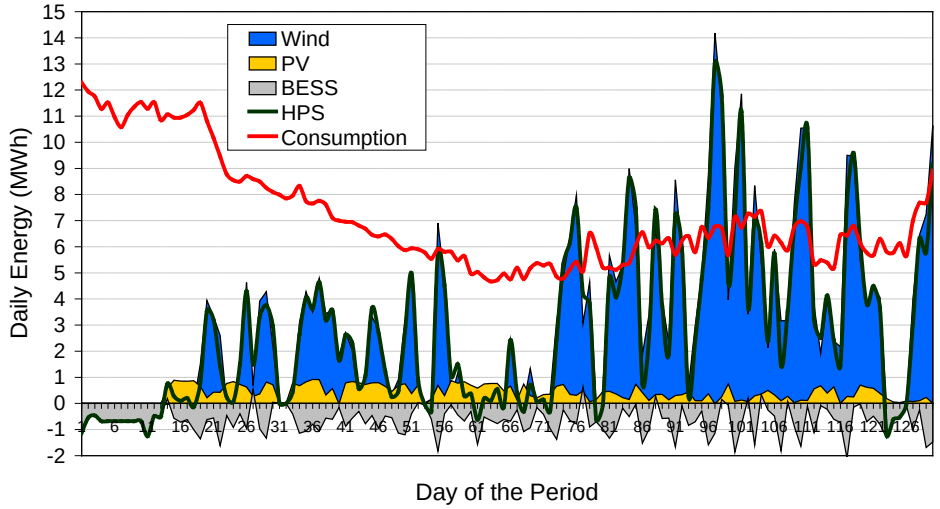
- **Island Tests** (isolated mode of operation)
  - Artificial black-out
  - Black-start with genset
  - Increased instantaneous RES shares
  - DSM contribution



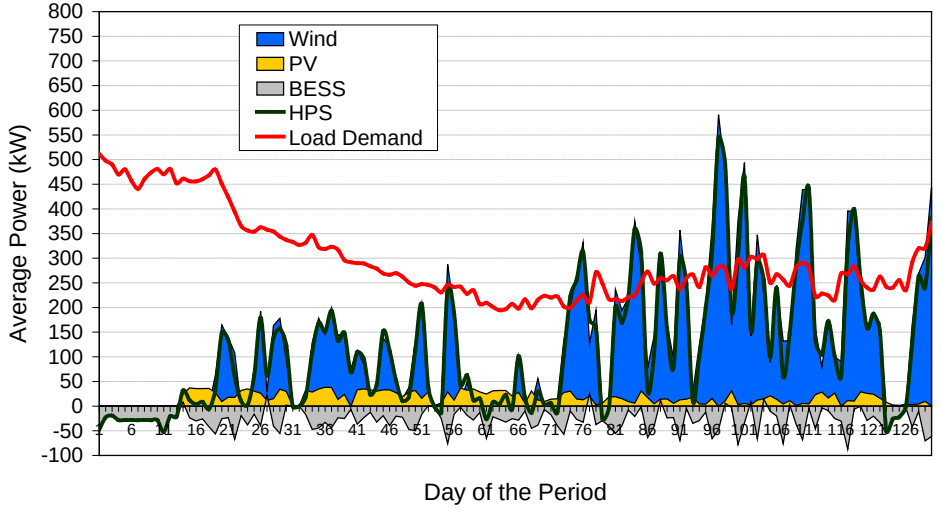


HPS / HEDNO Profile

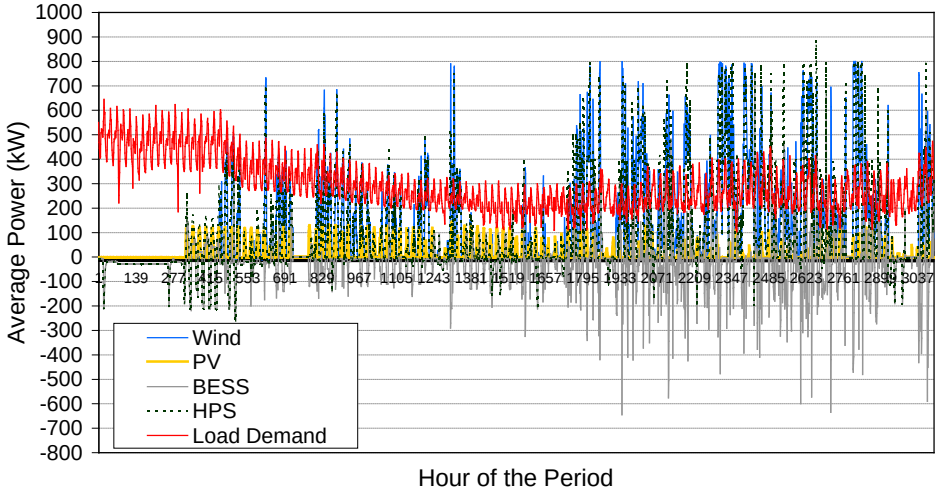
Comparison between the Daily HPS Generation & the Island Electricity Consumption (**1/9/2018-8/01/2019**)



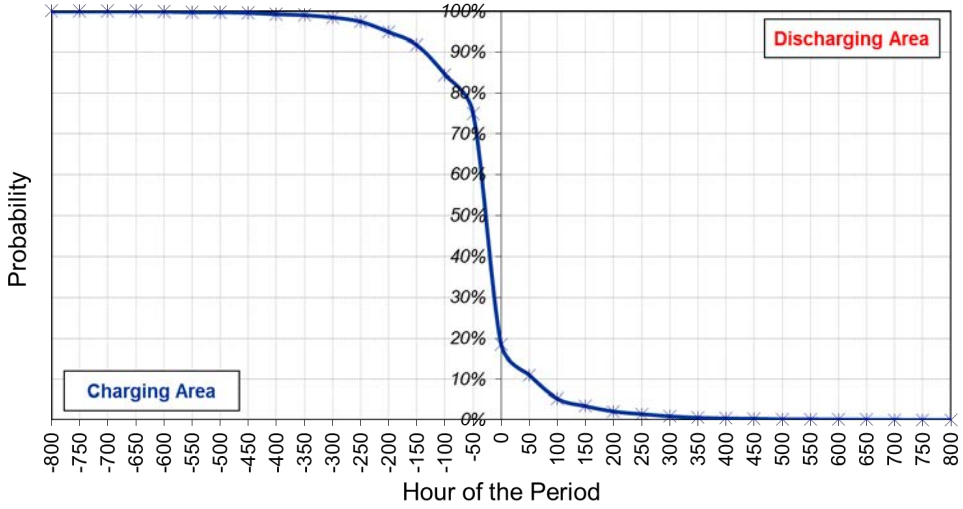
Comparison between the Daily Average HPS Power Output & the Island Load Demand (**1/9/2018-8/01/2019**)



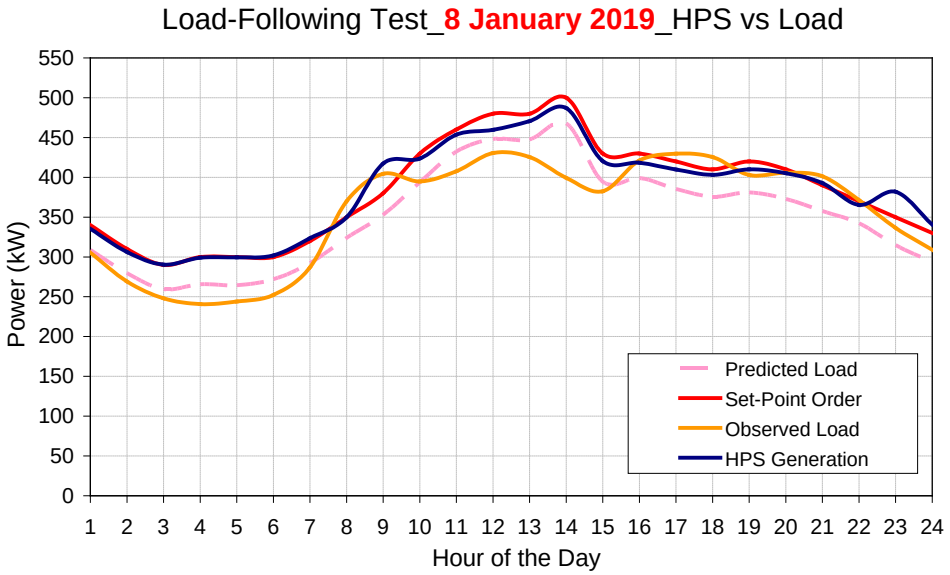
Hourly Logs of Tilos HPS Operation Vs Island Load Demand (**1/9/2018-8/01/2019**)

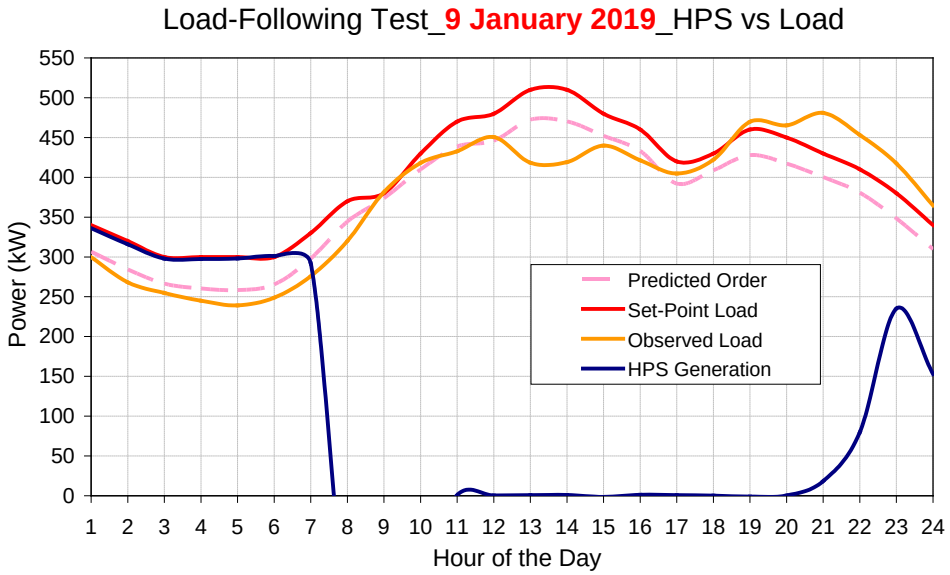


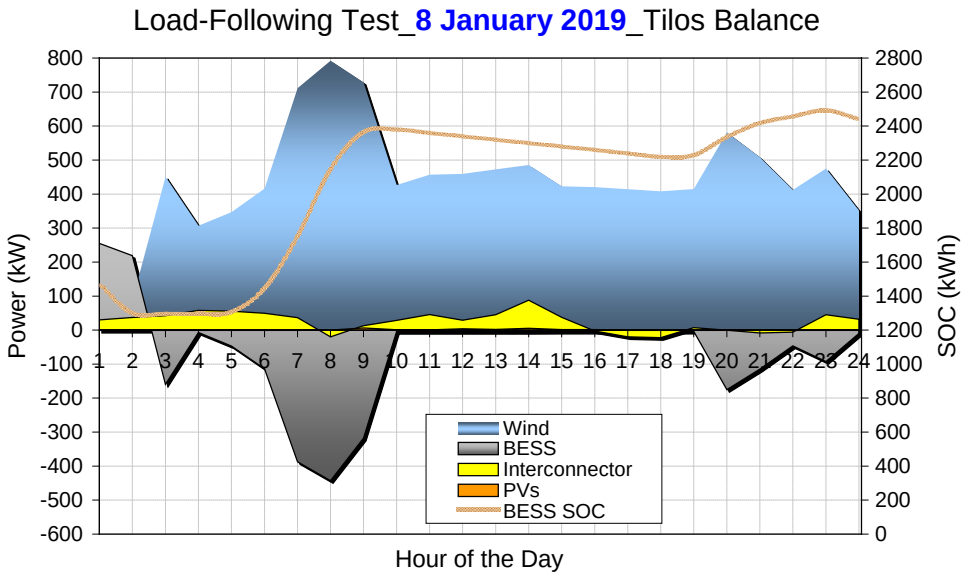
Duration Curve of Charging and Discharging Power for the HPS Integrated Battery System

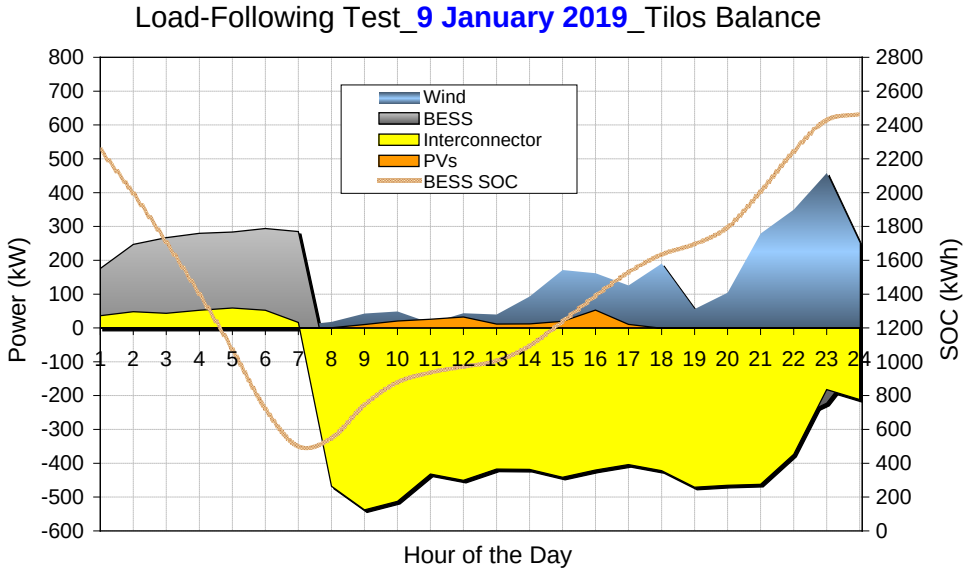


HPS / Load-Following







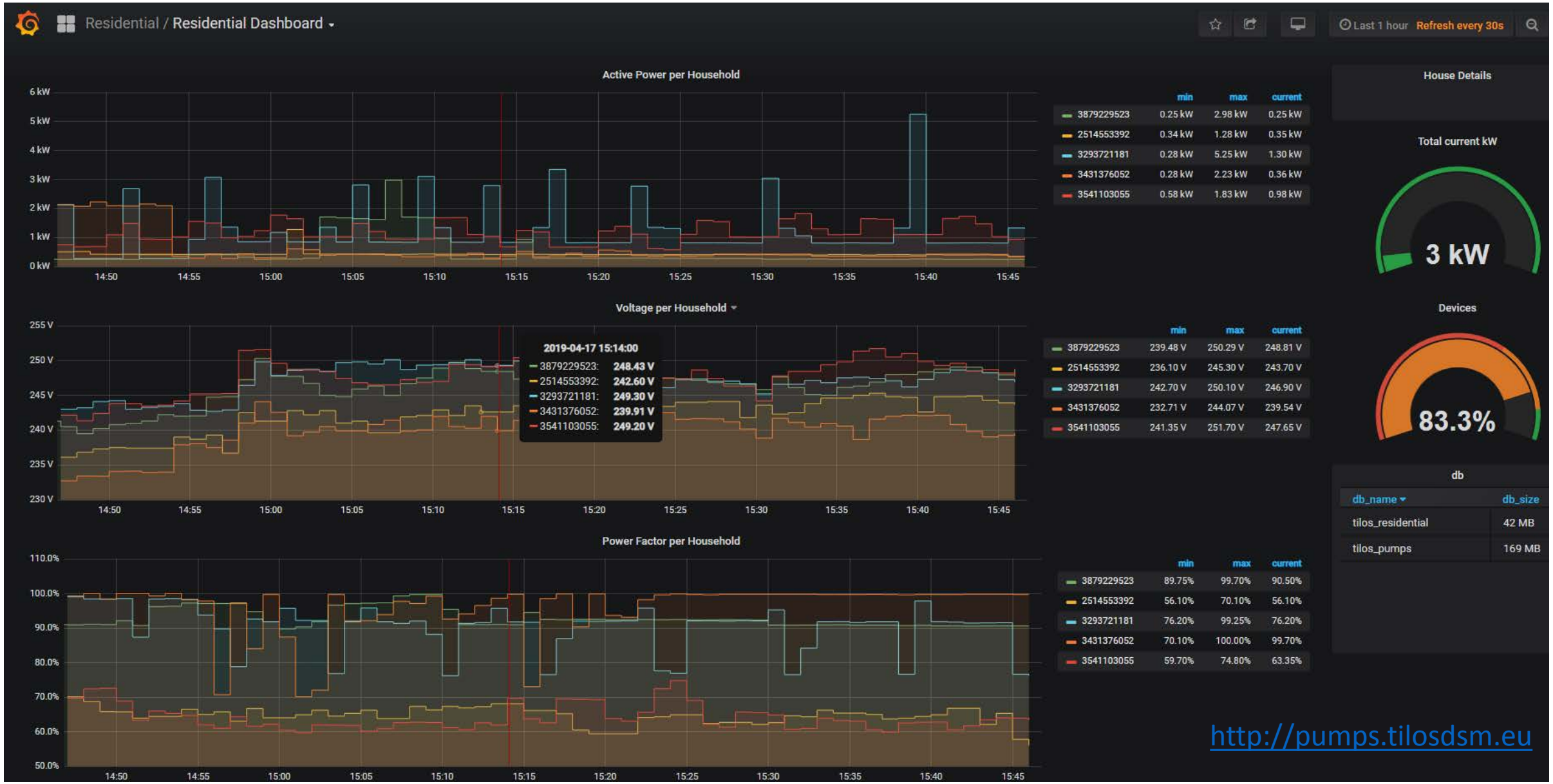


DSM / Pumping Stations

Pumps DSM

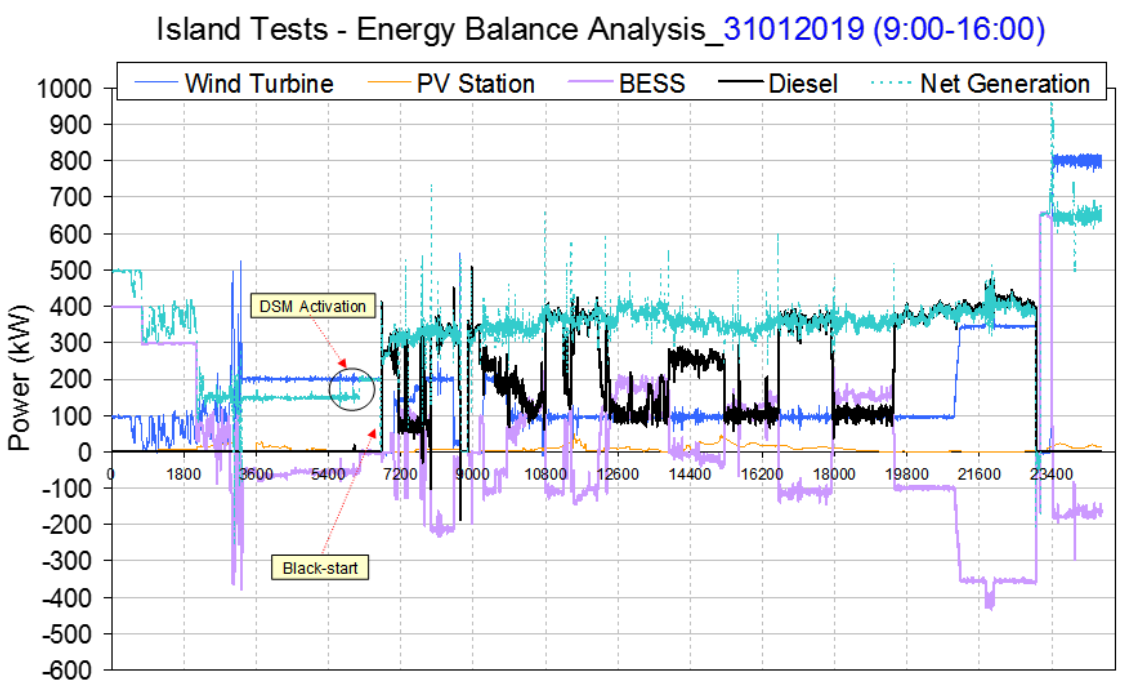
ID	DSM Availability	Rated Power	DSM Power	Current Power	DSM Down Capacity	DSM UP Capacity	Winter Op Hours	Summer Op Hours	Name	Feeds to
1	true	10.00 kW	10.00 kW	15.91 W	0 W	10.00 kW	8.00	4.00	Athymies	L
2	true	15.00 kW	15.00 kW	20.03 W	0 W	15.00 kW	4.00	0	Mikro Xorio	L
4	true	8.00 kW	8.00 kW	5.82 W	0 W	8.00 kW	6.00	4.00	Fraxtis	L
5	true	5.50 kW	5.50 kW	17.17 W	0 W	5.50 kW	4.00	0	Loupies	M
7	true	5.50 kW	5.50 kW	0 W	0 W	5.50 kW	8.00	4.00	Ag. Thekla	M
8	true	5.50 kW	5.50 kW	5.23 kW	5.50 kW	0 W	-	-	Potamos	-

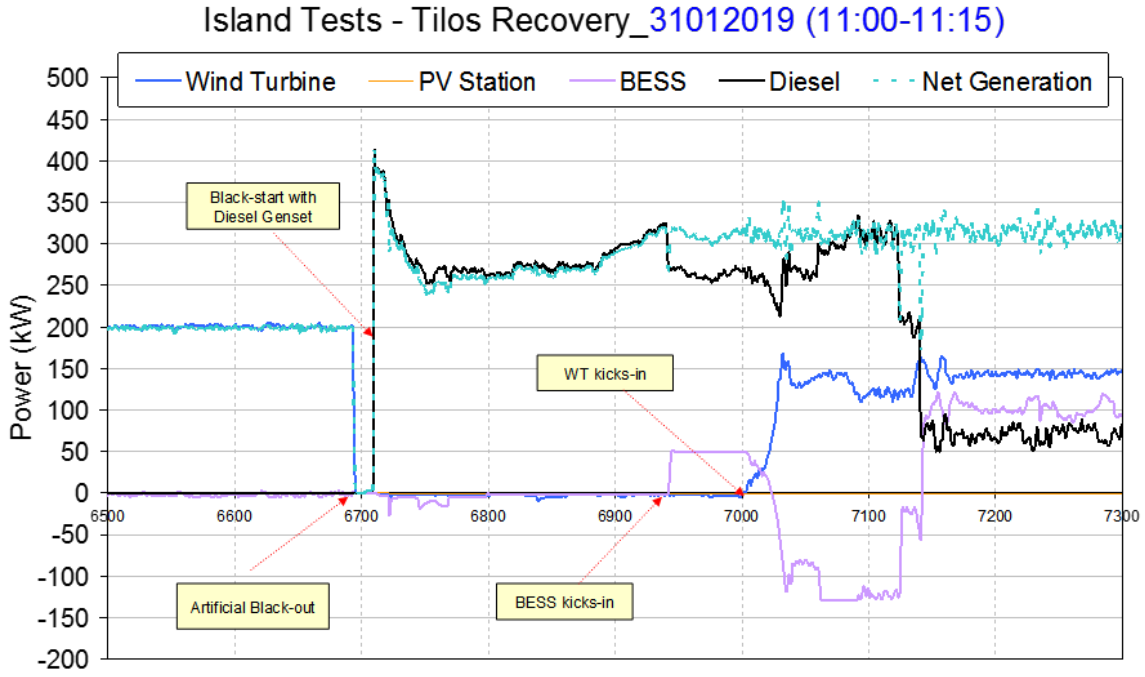
DSM / End Users



http://pumps.tilosdsm.eu

Island Tests





- Artificial **black-out and almost immediate recovery** via the diesel genset, followed by the introduction of the HPS, which received set points from the HL-EMC
- Instantaneous **RES shares >80%**
- Smooth continuous operation with the activation also of the DSM side during periods of RES excess, designating **interoperability aspects** between the different components

KEY EXPLOITABLE RESULTS

Key Exploitable Results

1. The integrated **prototype Battery Energy Storage System** which comprises the core element of the Tilos HPS and smart microgrid, offering also a solution tailored to the Greek regulatory framework

2. The **first-ever battery-based Hybrid Power Station in Greece** and issuance of all relevant permits, including the first-ever PPA, which disrupted the local energy market and paved the way for system replication

3. The integrated, end-to-end, **SM & DSM platform and prototype DSM panel**, and roll-out of 100 DSM panels in residential, commercial and community loads of Tilos

4. The first-ever, **Solar-based EV Charging Station** on a Greek island, introducing green electromobility in Tilos

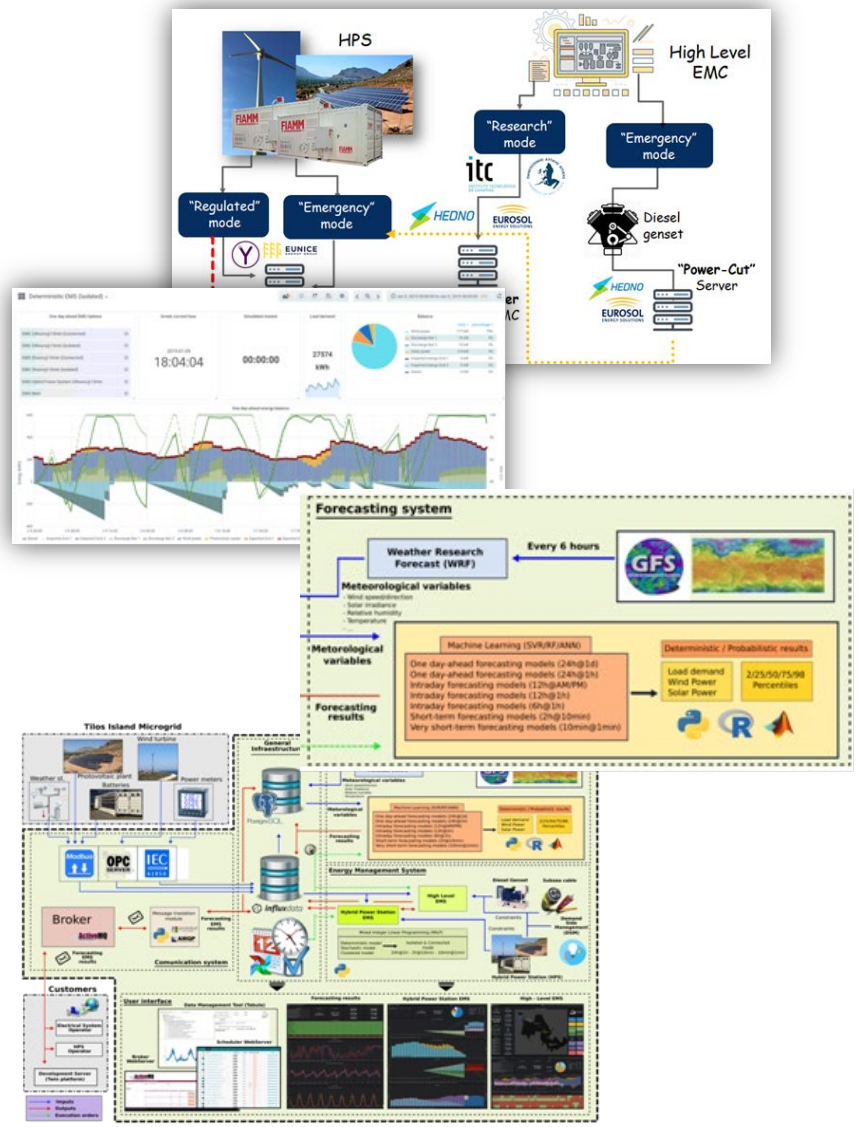
Key Exploitable Results

5. The **High-Level Energy Management Centre** governing all components of TILOS microgrid and comprising an expandable infrastructure that can incorporate additional vectors and modules

6. A **multi-layer EMS** which enables operation of the Tilos HPS in line with the Greek regulation framework and as an HL-EMC-governed component during island system operation

7. The **advanced forecasting system**, comprising different forecasting techniques and models for wind power generation, solar power generation and load demand

8. The **Microgrid Management Platform** comprising an advanced smart microgrid energy management platform, which incorporates also the forecasting platform of TILOS and which allows for the optimal dispatch of all agents of the Tilos microgrid



CONCLUSIONS

Key Issues

- Different features of **battery storage (vs PHS)** introduce several challenges

- Topics to elaborate on:
  - Dispatching principles → Day-ahead hourly dispatch offer
  - Ancillary services remuneration → (RAE consultation)
  - HPS tariff scheme → Unique tariff
  - Different scale islands → Grouping & different treatment
  - Demand response from end-users → Aggregated services
  - Recovery from power cuts → Emergency plans' advancement

Thank you

for your Attention