DECARBONIZATION OF EUROPEAN ISLANDS. THE SCIENTIFIC EXPERIMENT OF TILOS

Prof John (Ioannis) K. Kaldellis
Soft Energy Applications and Environmental Protection Laboratory
Dept. of Mechanical Engineering, University of West Attica
e-mail: jkald@uniwa.gr

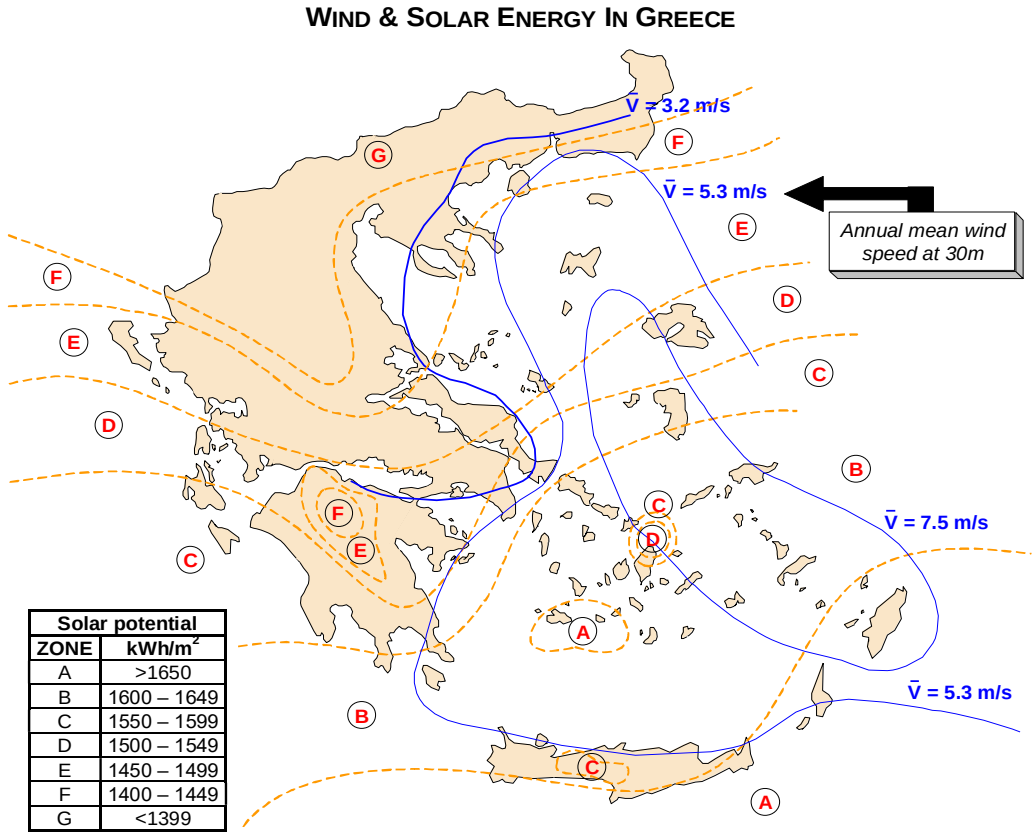
SUSTAINABILITY Masterclass
National and Kapodistrian University of Athens
6-9 November 2023, Athens, Greece

CONTENTS

Electricity Generation Status of Remote Islands

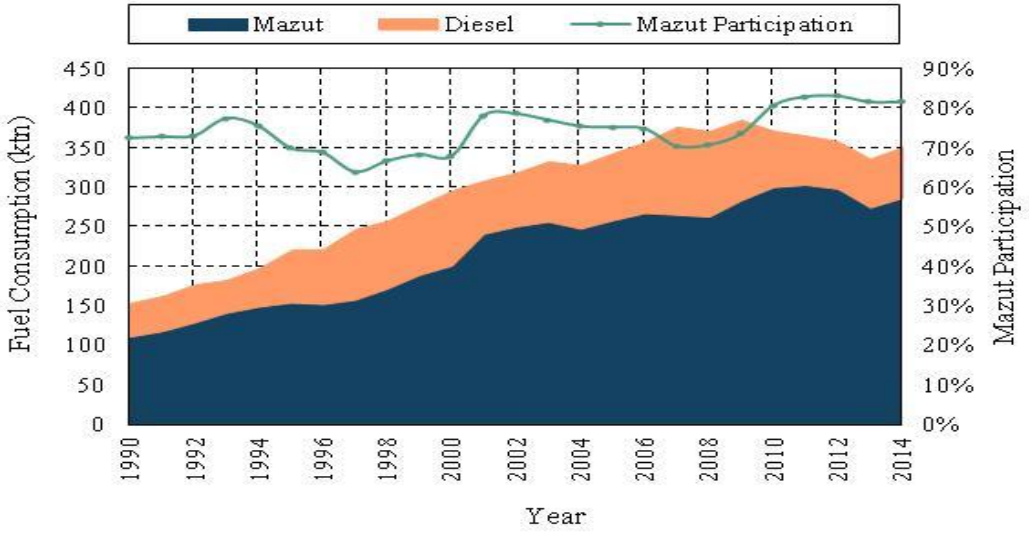
INTRODUCTION-POSITION OF THE PROBLEM

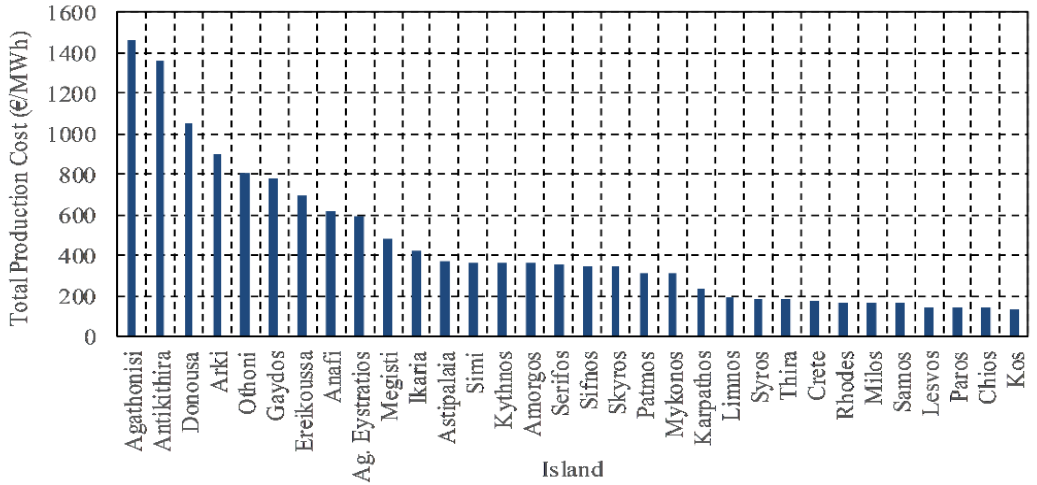
- The Aegean Archipelagos is a Greek-European area of the SE Mediterranean where several remote islands are located.
- Despite the excellent wind and solar potential of all these islands, their electrification is covered by more than 28 (APS) of various sizes, starting from 100kW up to several MW. Until now all these APS are operating using remarkable quantities of diesel or heavy oil.



INTRODUCTION-POSITION OF THE PROBLEM

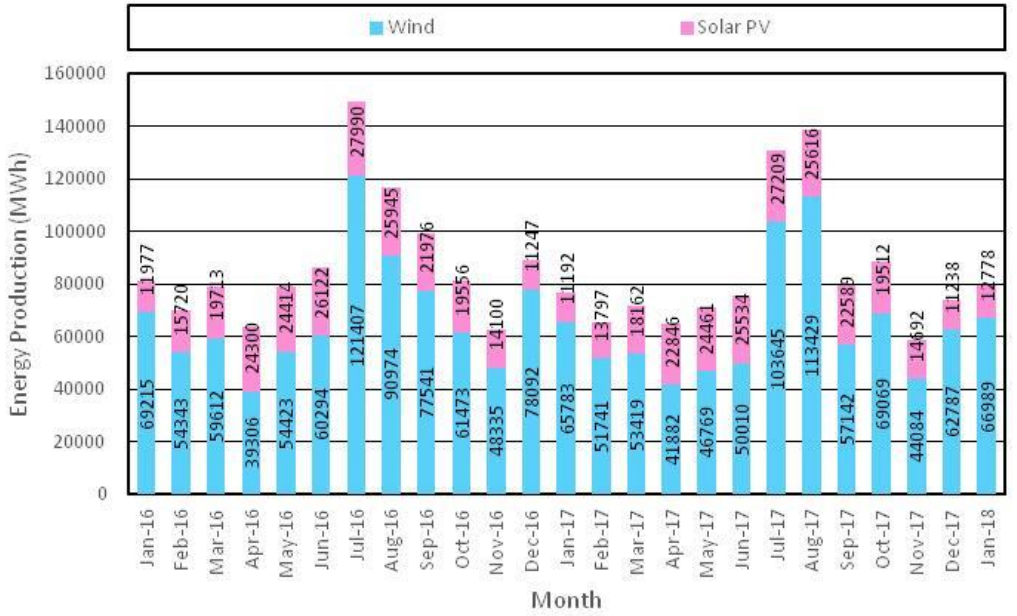
- The corresponding marginal production cost is extremely high, exceeding 1500€/MWh in certain small islands.
- The average electricity production cost for the entire Aegean Sea area varies between 250 and 350€/MWh, being almost five times higher than the corresponding cost of the mainland.



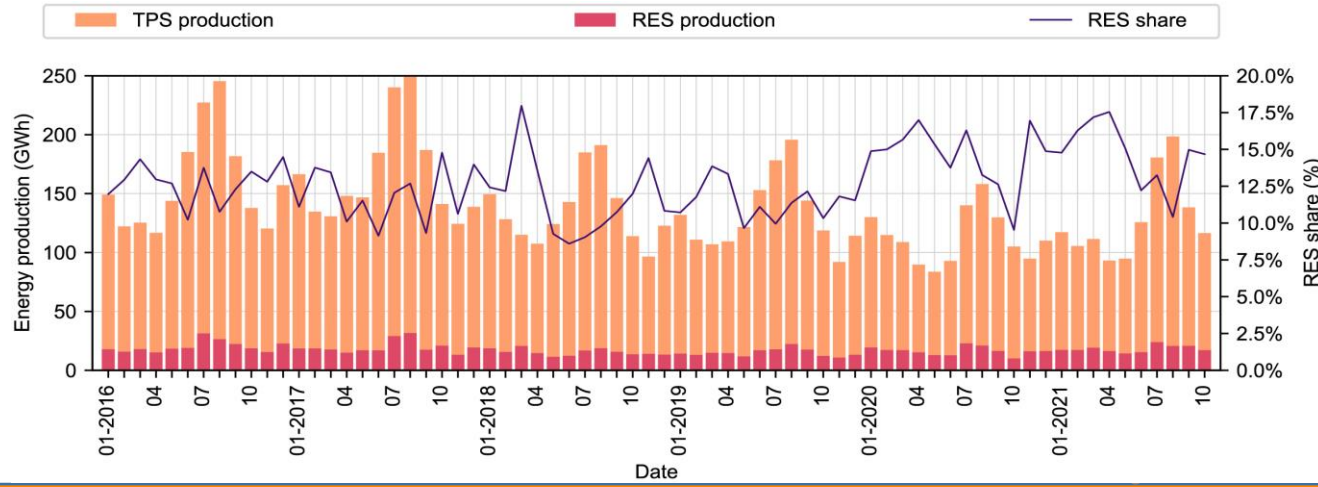


PROPOSED CLEAN-GREEN SOLUTION

- In the context of smart green islands we propose **since early 90's** to use RES-based hybrid power stations (mainly solar and wind) with energy storage and demand side management instead of oil-based APSs.
- Without energy storage and hybrid solutions the RES contribution cannot exceed 20%, mainly for local grid stability issues.

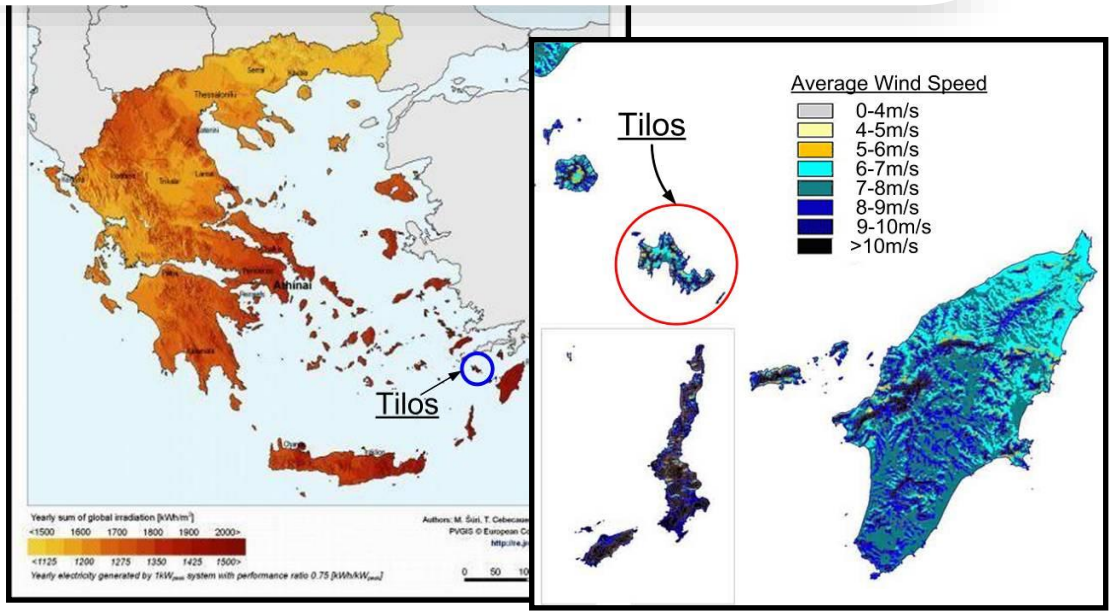


UNIWA (SEA & ENVIPRO Lab) proposed in 2013 a Hybrid Power Station solution for Tilos Island in the context of a Horizon 2020 projects, finally supported financially by EU.



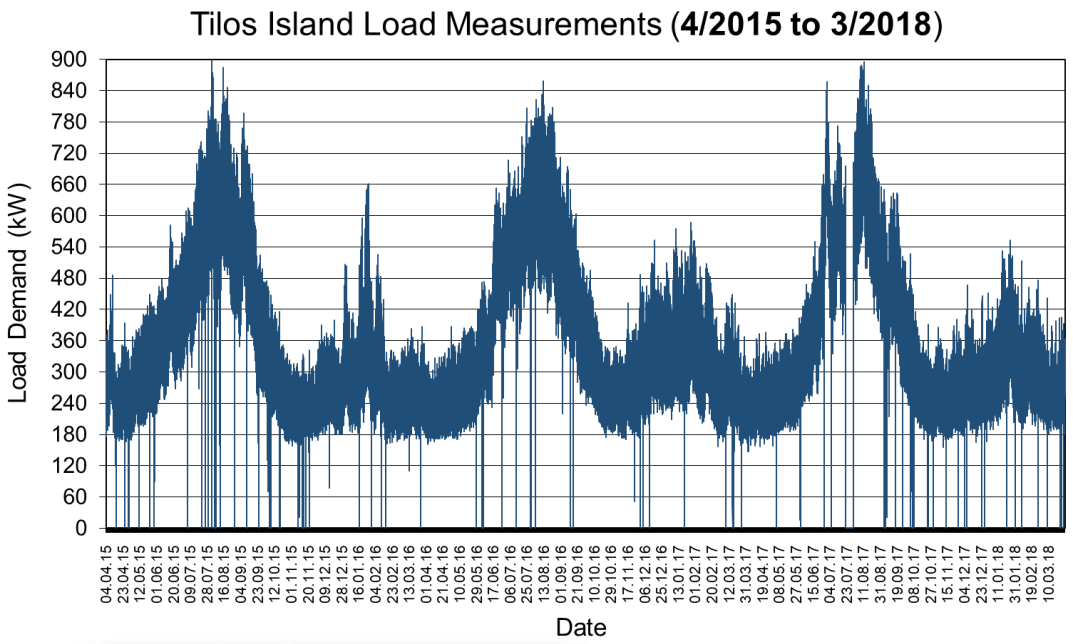
The Island of Tilos

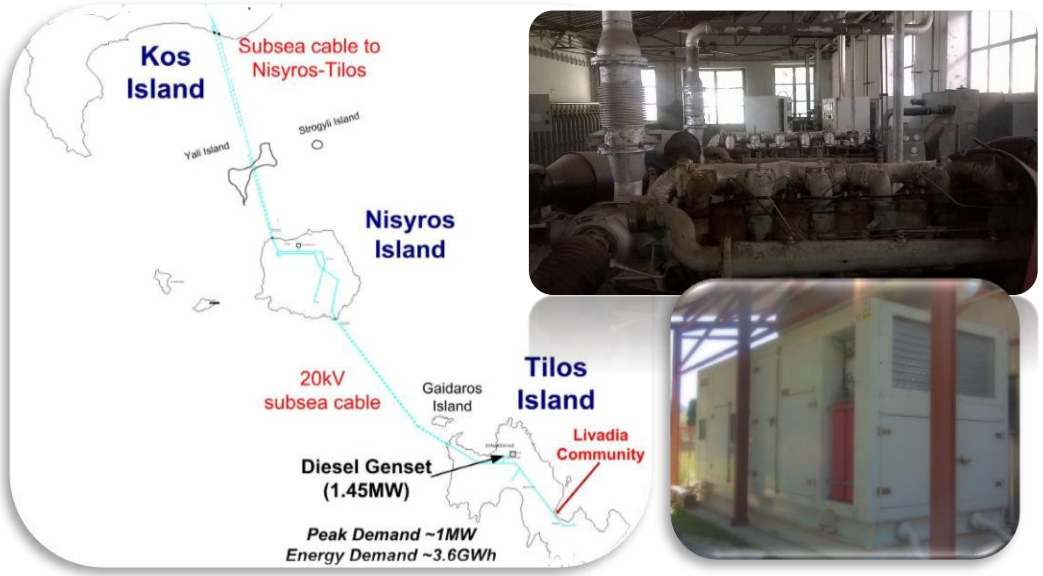
GENERAL INFO



- 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/m².a**

ELECTRICITY SUPPLY





- 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 Project

GENERAL INFO

INDUTRIAL PARTNERS	
1	FZSonick Energy Storage Solutions (IT)
2	Younicos AG (DE)
3	EUNICE Laboratories SA (EL)
4	EUROSOL P&M GmbH (DE)
UNIVERSITIES-RESEARCH CENTERS	
5	Commissariat à l' Energie Atomique et aux Energies Alternatives (FR)
6	Instituto Tecnológico de Canarias S.A. (ES)
7	Technological Educational Institute of Piraeus (EL) - **ΣΥΝΤΟΝΙΣΤΗΣ**
8	University of East Anglia – Business School (UK)
9	Universite de Corse (FR)
10	Rheinisch-Westfaelische Technische Hochschule Aachen (DE)
11	Kungliga Technica Hogskolan (SE)
NATIONAL GRID OPERATOR	
12	Hellenic Electricity Distribution Network Operator S.A. (EL)
ENVIRONMENTAL ORGANIZATION (NGO)	
13	World Wide Fund for Nature – Greece (EL)

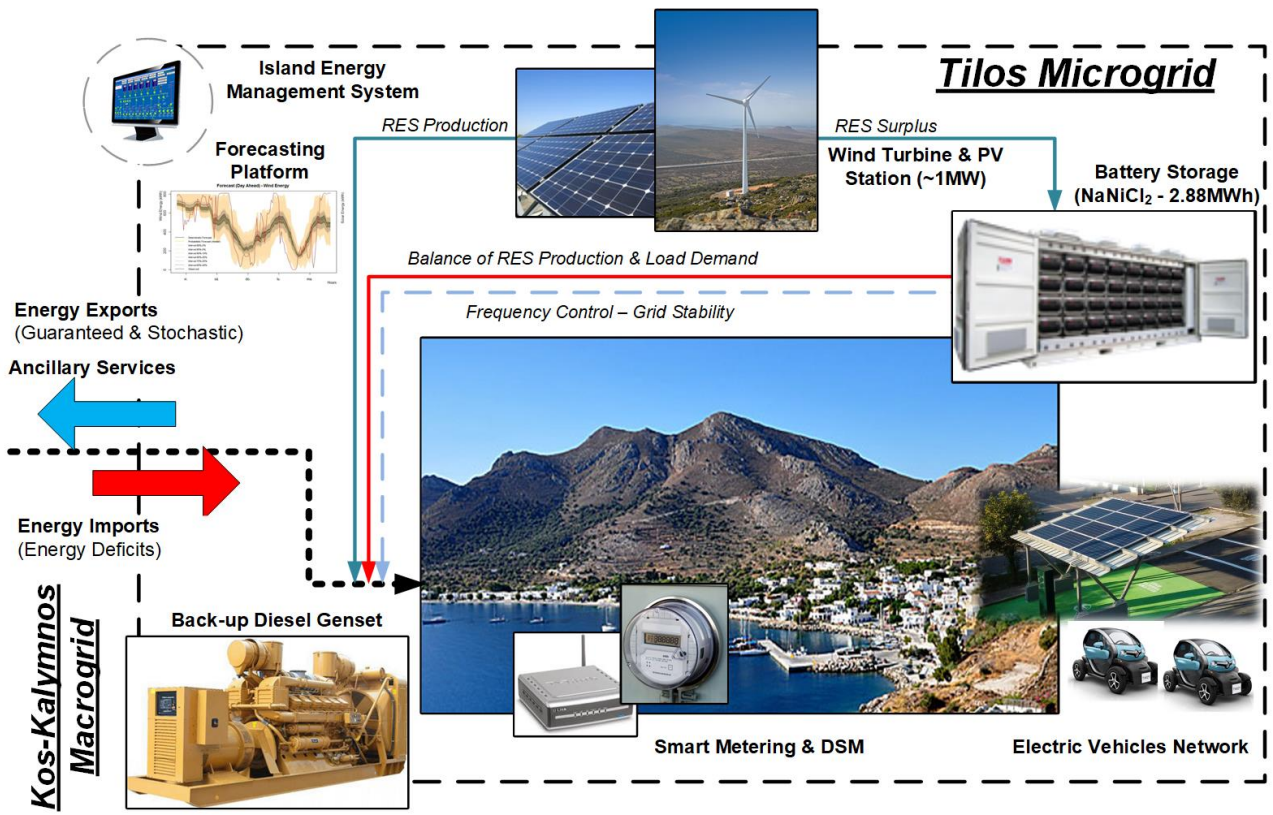
- **Framework**: Horizon 2020
- **Call**: Local / small-scale storage-LCE-08-2014
- **Score/Ranking**: 14/15 (1st among 80 proposals)
- **Budget**: 11 M€ of funding
- **Consortium:** 13 partners / 7 European countries
- **Duration**: 4 years (2/2015-2/2019)

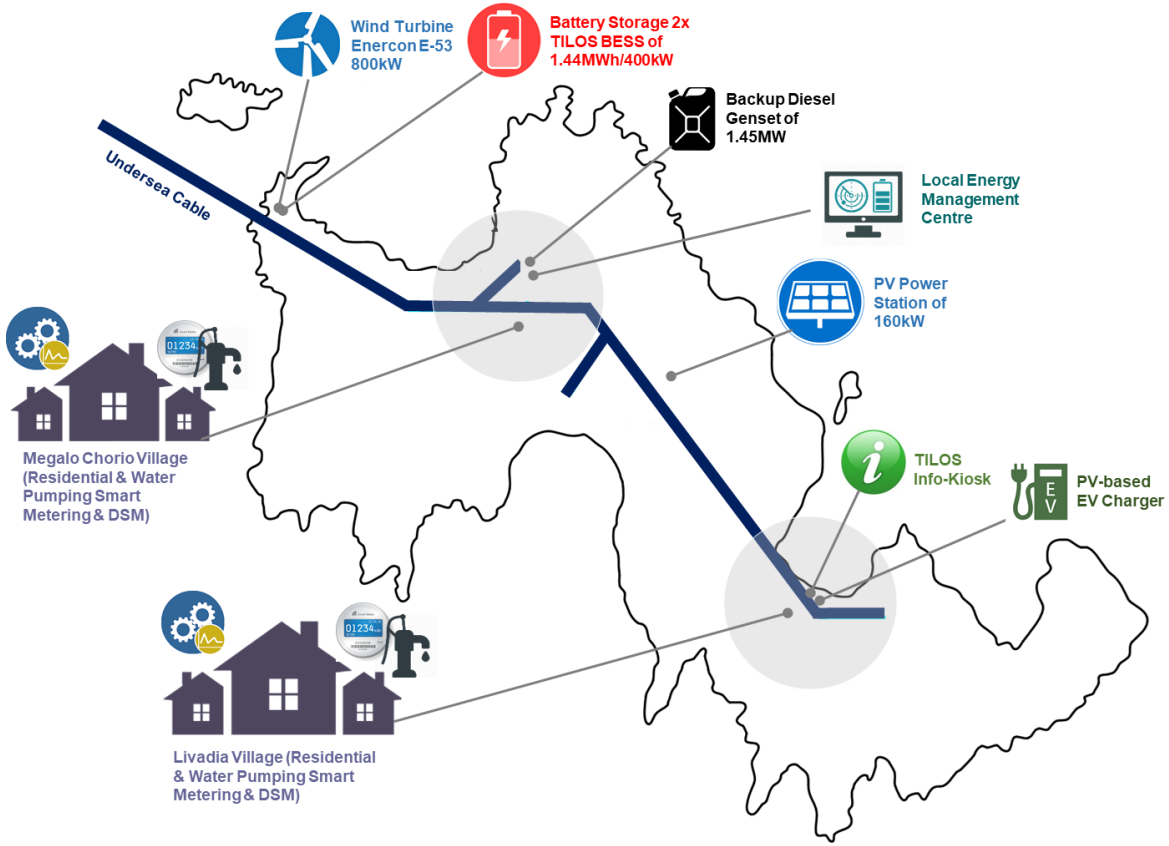
MAIN OBJECTIVES

- Development of a **Smart Microgrid** on the island of Tilos
- Development of a MW-scale **Battery-based Island HPS**
- Roll-out of **Smart Meters and DSM Panels**
- Development of an advanced **Forecasting Platform**
- Development of a two-level **Energy Management System**
- Achieve **High RES Penetration** & **Energy Exports** to Kos for **Peak Shaving**
- Encounter **Supply Security** issues for Tilos island

Microgrid Main Components

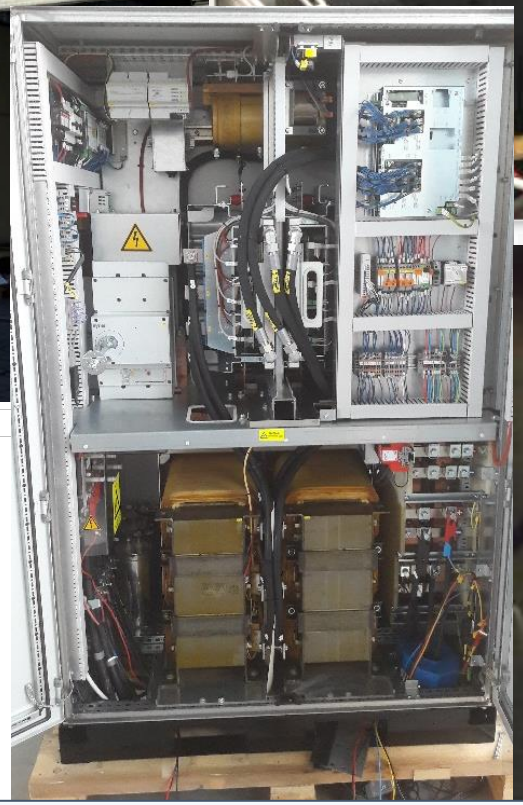
MICROGRID CONFIGURATION

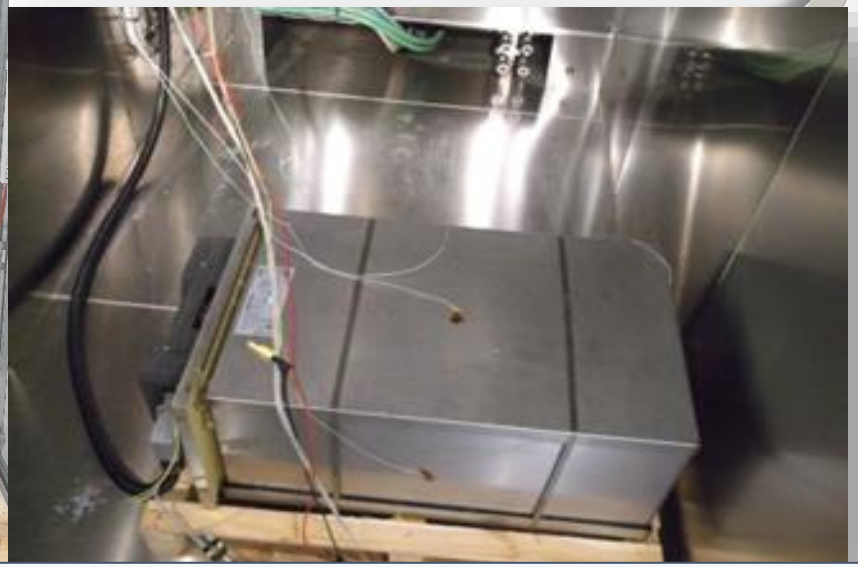




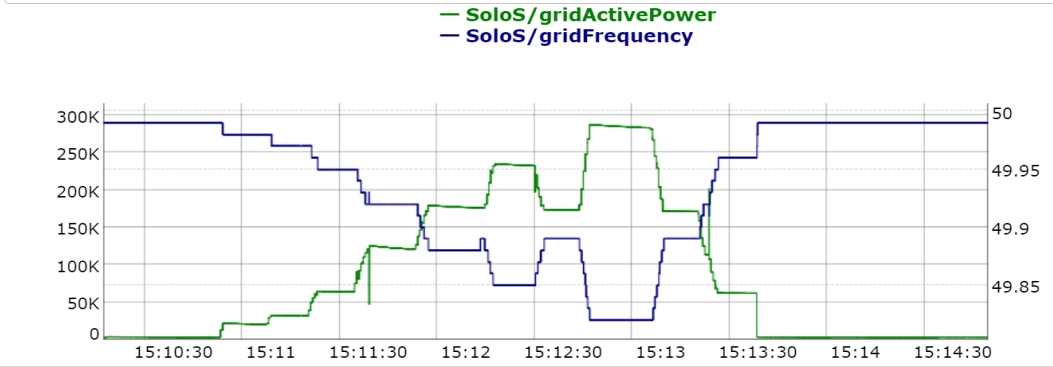
RES COMPONENTS INSTALLATION

BATTERIES TESTS



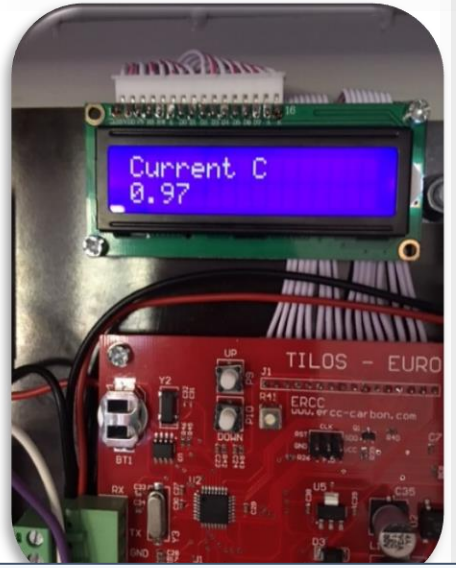


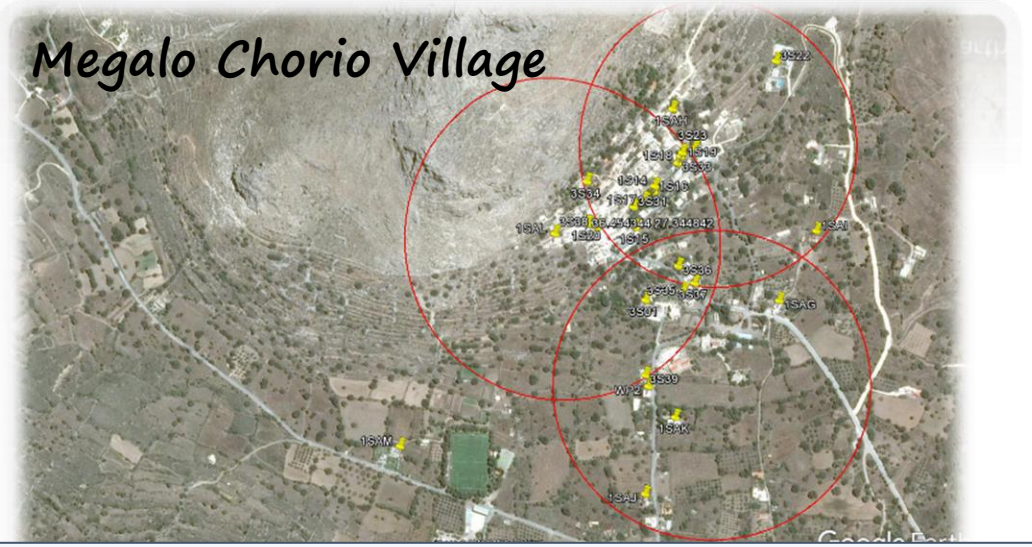
BPPM Main OSGi Web Console



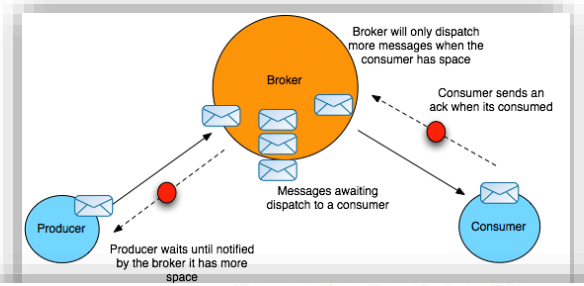
EQUIPMENT TRANSPORTATION

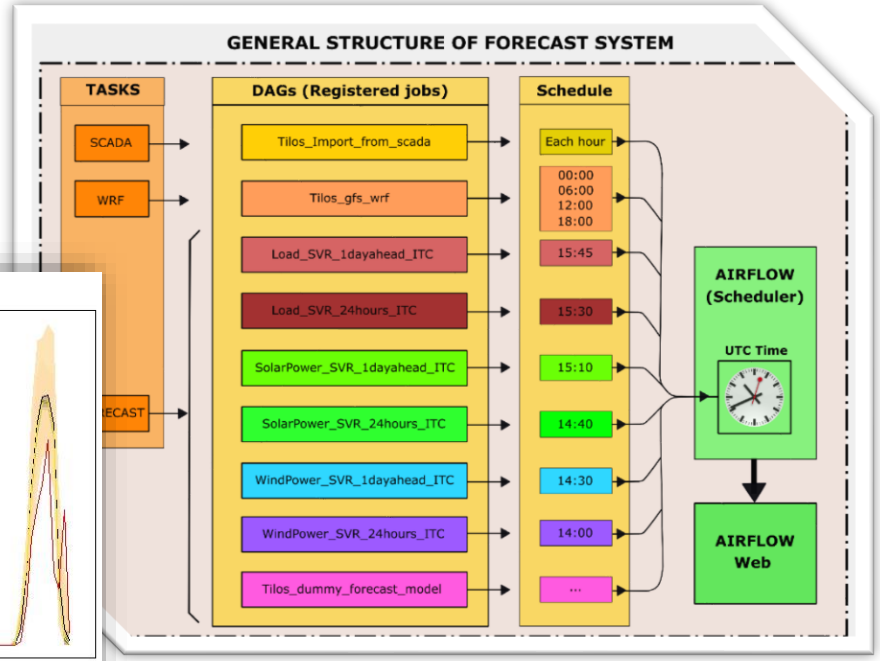
SMART METERS INSTALLATION

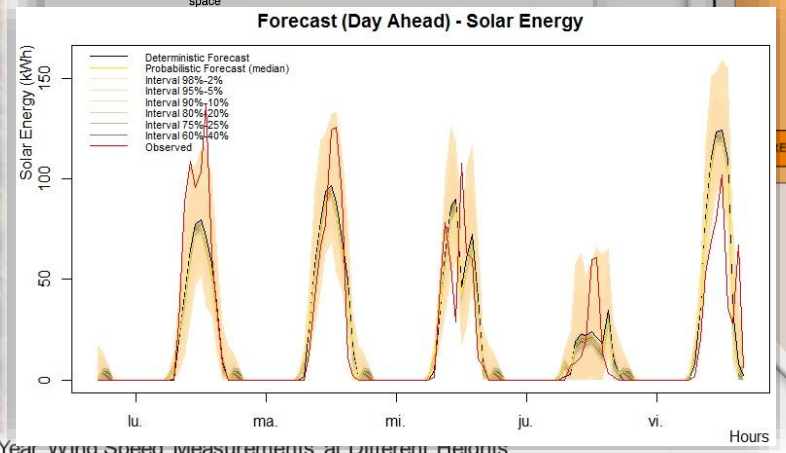


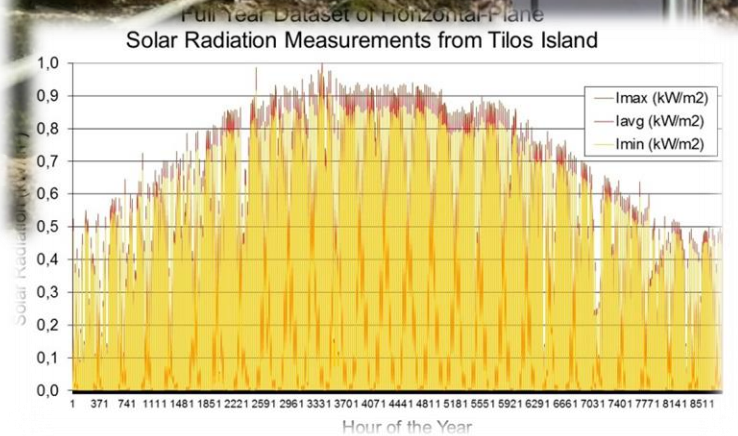


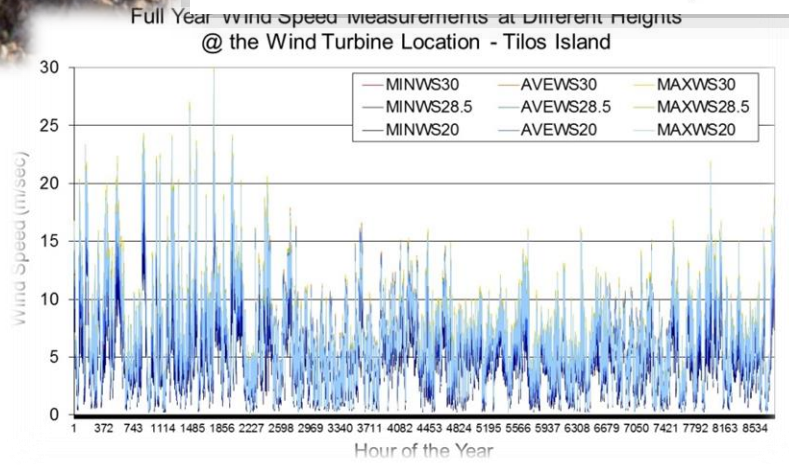
MEASUREMENTS & FORCASTING TOOLS

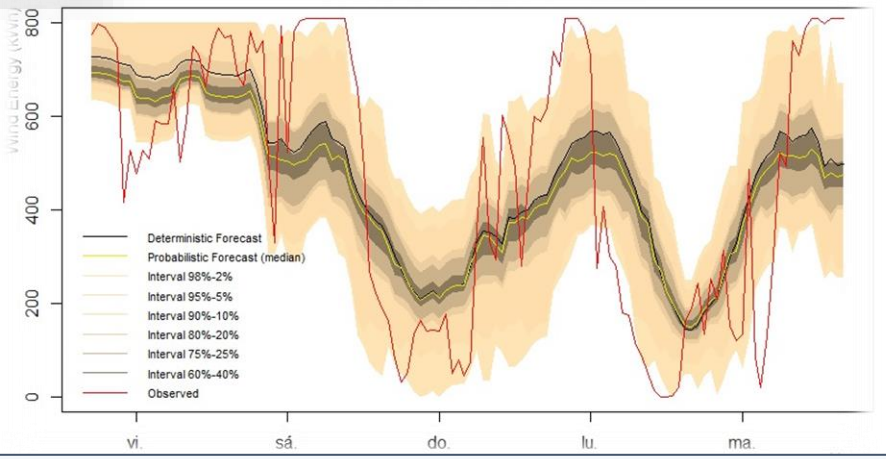




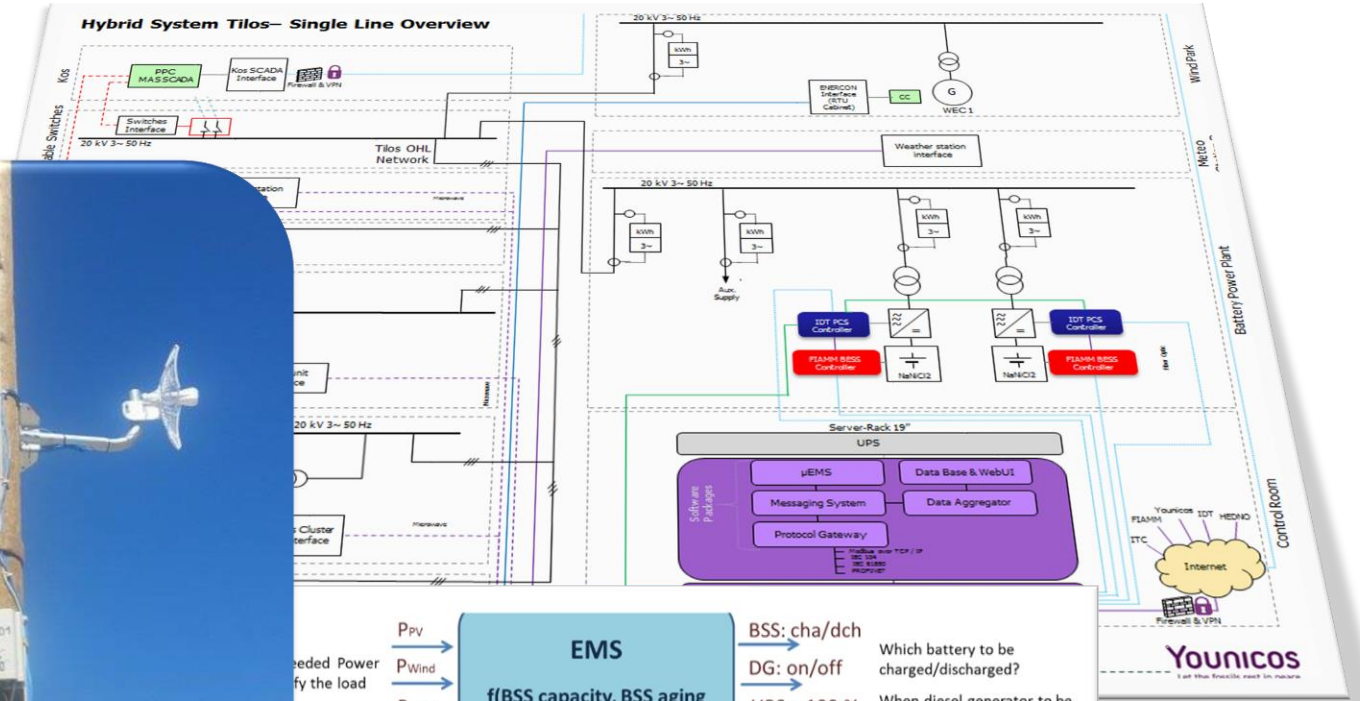


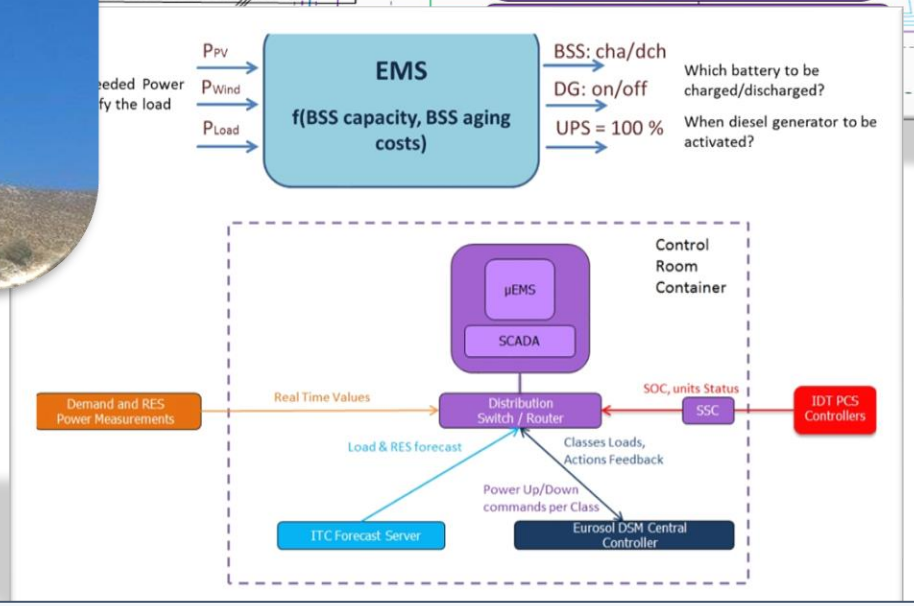






ENERGY MANAGEMENTS SYSTEM





HYBRID POWER STATION COMPLETE INSTALLATION

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 **~2GWh** (<30% CF), equal to **~65%** of Tilos island annual electricity demand
- Supports both **energy autonomy** of Tilos and clean **energy exports** to the electricity system of Kos

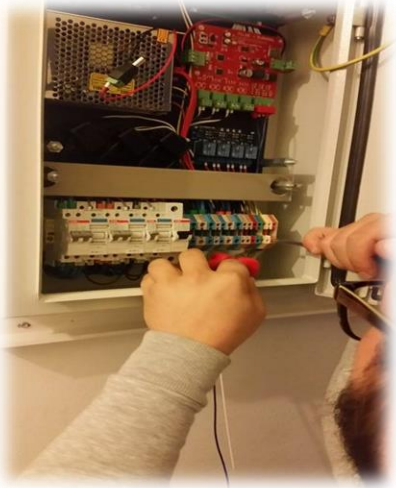
HPS – PV STATION

- 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 overall Tilos system

HPS – INTEGRATED BESS

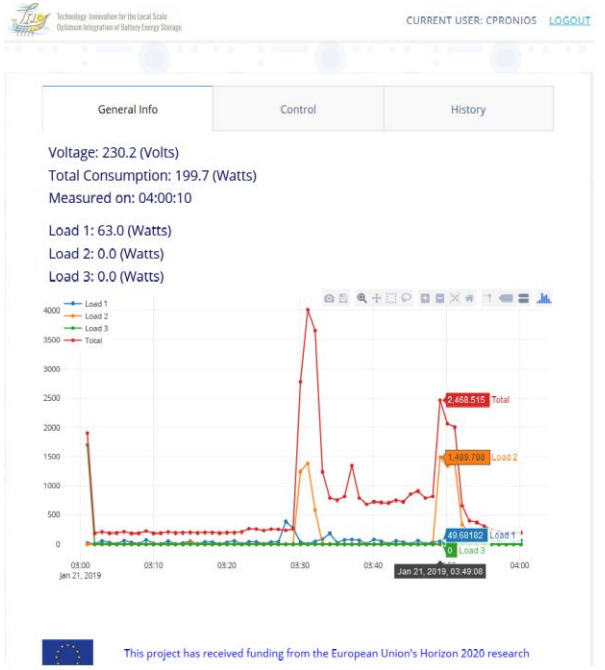
- The **BESS** of TILOS comprises of the **FZSoNick $NaNiCl_2$ Battery** and **IDT Inverter**
- Together they comprise a **multifunctional configuration**, for both **island** and **grid-connected** applications
- Battery capacity of **2.88MWh** (80% useful) ~12h of autonomy for Tilos; nominal power of **800kW**, close to island peak
- Before Tilos, the system went through two **FAT campaigns** in Berlin during 2017
- **SAT campaign complete** – Tilos: April 2018

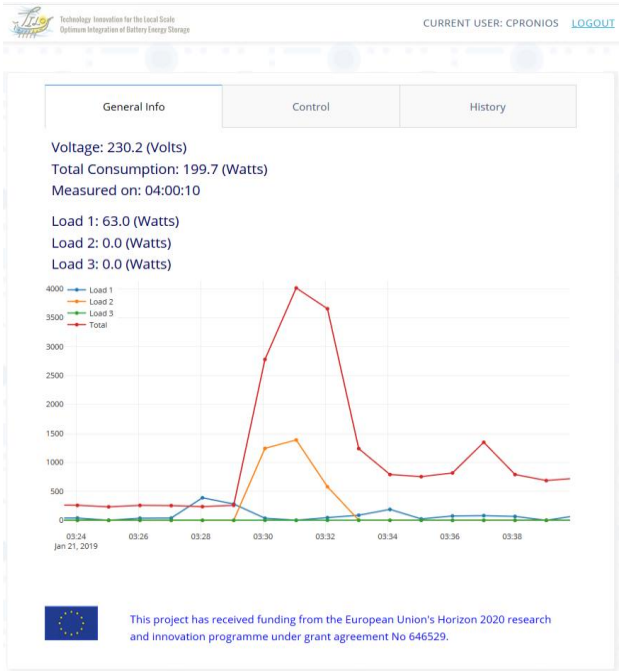
SMART METERING & DSM PLATFORM

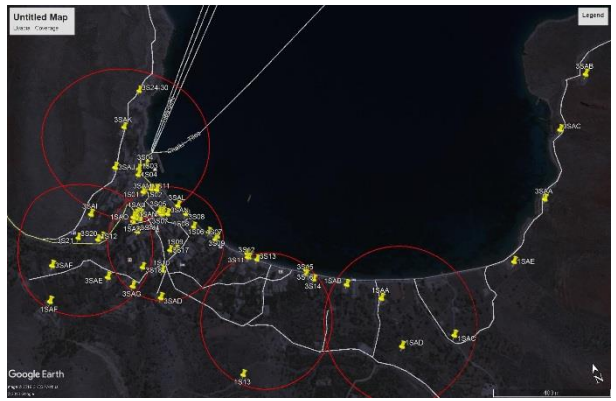


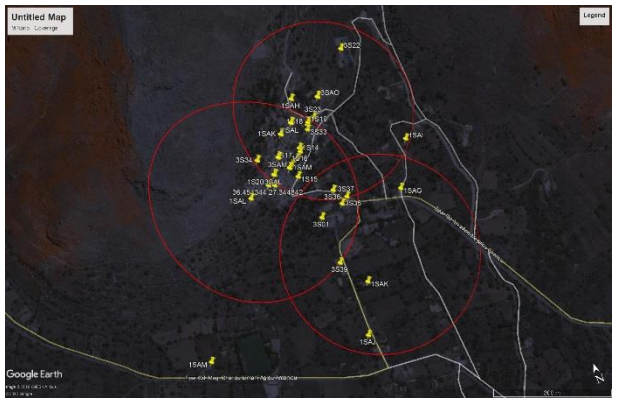
- TILOS SM & DSM Microgrid Platform is a **hardware / software platform** supporting **metering and control** of both community and individual, end-consumer loads
- Installation of **100 panels** integrating 3 loads per household and including **8 pumping stations** (water-energy nexus)
- By exploiting an adequate **pool of customers (15% of loads)**, the platform is able to deploy **DSM strategies** at the local, end-user level, and also at the global, **MG/aggregator level**
- Enables **improved RES penetration**, **operation** and also **provision of grid-supporting services**

SMART METERING & DSM PLATFORM

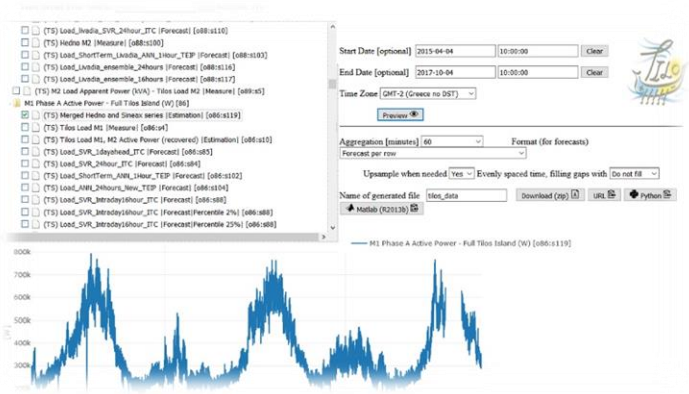


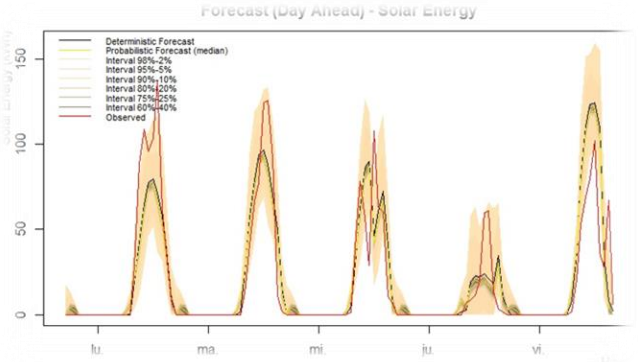


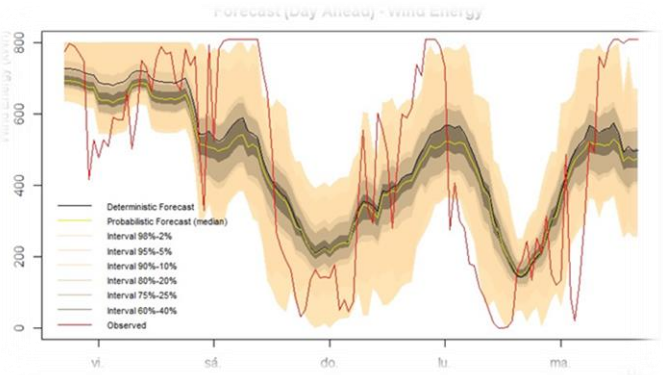




FORECASTING PLATFORM

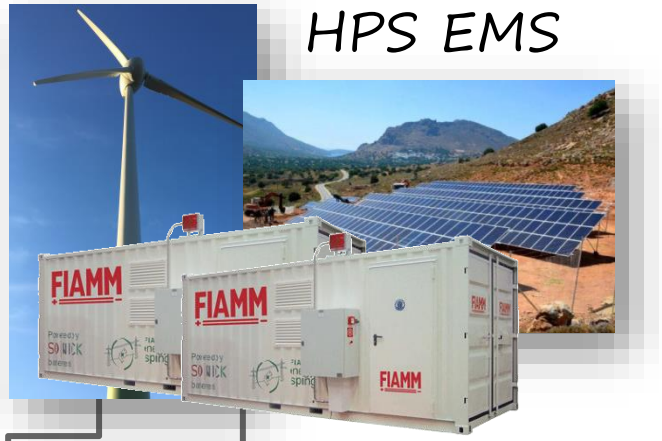






- TILOS **Forecasting Platform** is an exhaustive system which supports the **automatic execution** of forecasting models for the prediction of **load demand** and **RES power generation**, facilitating smart management of a microgrid
- TILOS FP manages the **automatic storage** of forecasting results and their dispatch to the different agents of the microgrid
- The FP is an **essential, integrated element** for the operation of the **TILOS EMS** (both **Hybrid Power Station** & **Island System**)

EMS ARCHITECTURE

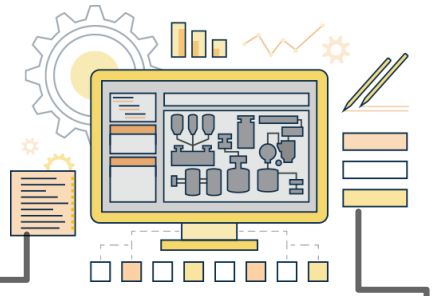


HPS EMS

"Regulated" version

"Island" version

HPS Server
Code for NIIs



High Level Island EMS

@PPC station – Activated during isolated operation

"Research" version

"Island" version

Diesel Genset

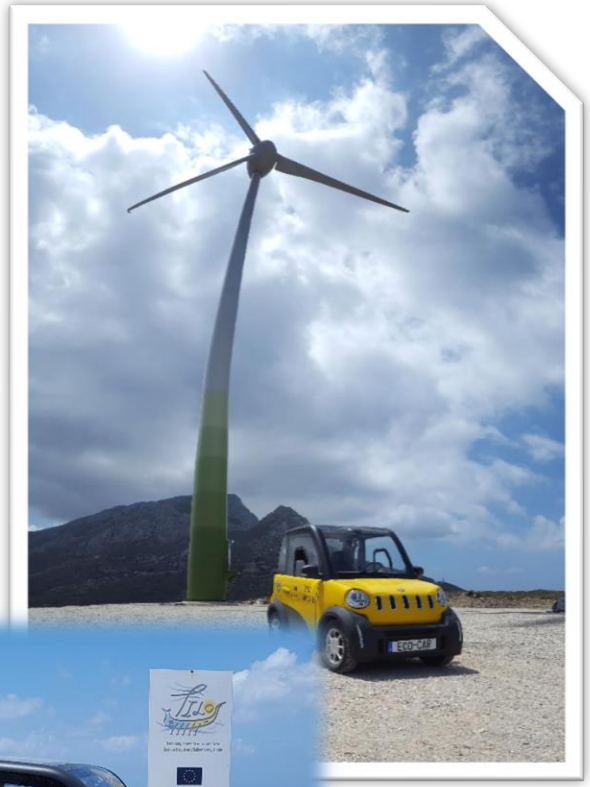
DSM Server

HL Island EMS
Server & HL Simulator

SOLAR EV CHARGING STATION

- **Roof PV system** of **4.93kW$_p$**, comprising of 17 PV panels Jinco Smart, 290W$_p$ each, and an ABB inverter (type UNO) of **5kW** capacity
- **EV charger** of type "EVlink Wallbox" of Shneider-Electric, with max charging power of **7.4kW** at **32Amps** and at **16Amps** for Type 2 compatibility
- **Net metering scheme** with annual energy yield of ~8MWh, able to cover the needs of **>4 EVs** on an annual basis (10.000km)
- Currently, the PV-roof energy yield is balanced between charging of **local Evs** (2-3 existing passenger vehicles) and covering the local **info-kiosk** electricity needs

SOLAR EV CHARGING STATION

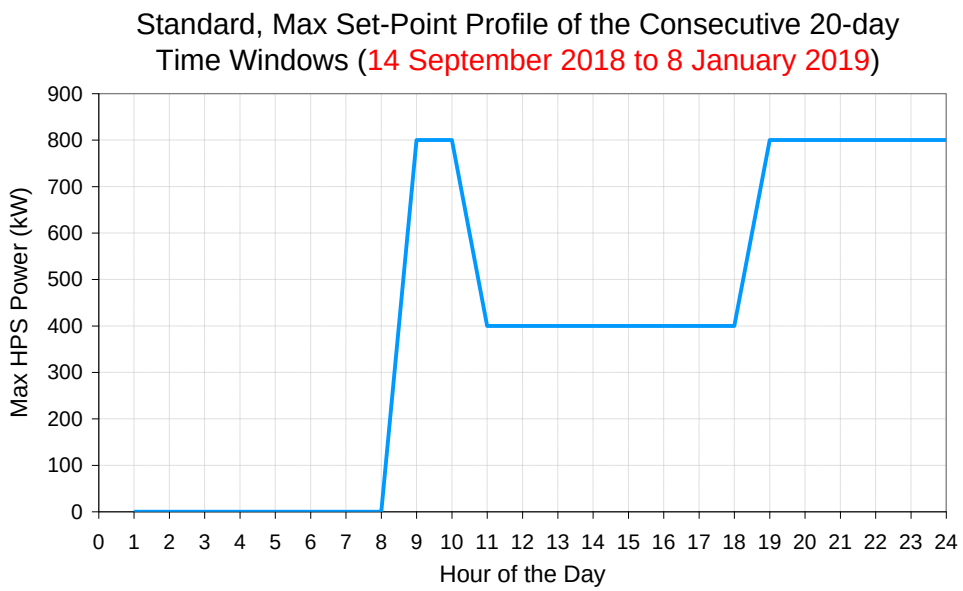


Demonstration Stage Main Results

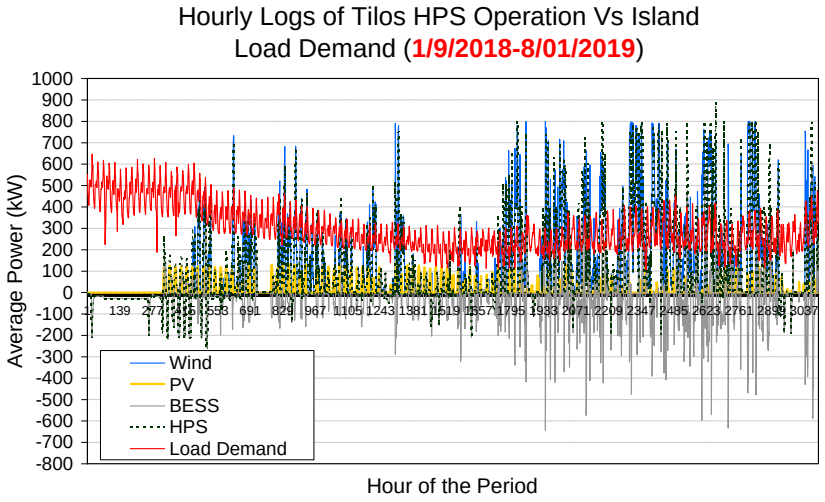
DEMONSTRATION STAGE TIMELINE

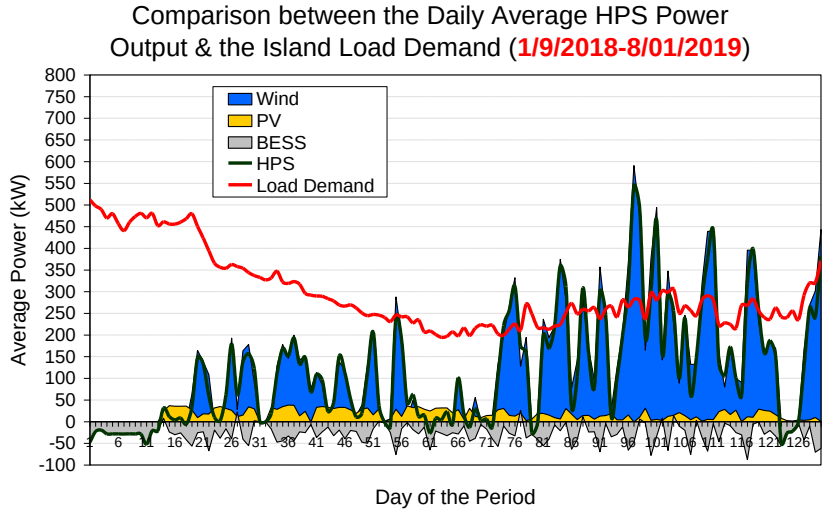
	2018									2019	
Activities	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**...**
BESS Commissioning	■	■									
HPS Consumer Mode		■	■	■	■	■					
RES Units Commissioning						■					
DSM Commissioning						■	■	■	■		
HPS Prosumer Mode						■	■	■	■		
HPS Profile Testing										■	
HL-EMC Commissioning										■	
Island Tests										■	
Solar EV Station Commissioning										■	

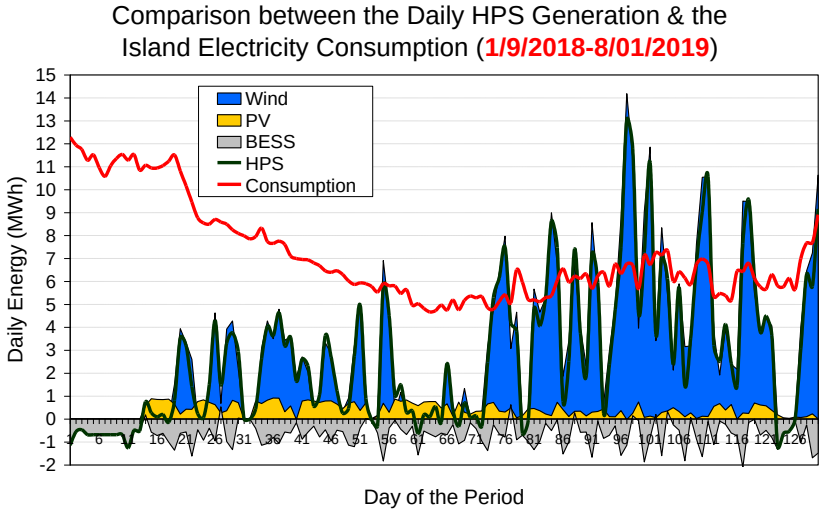
PROSUMER MODE RESULTS (1)



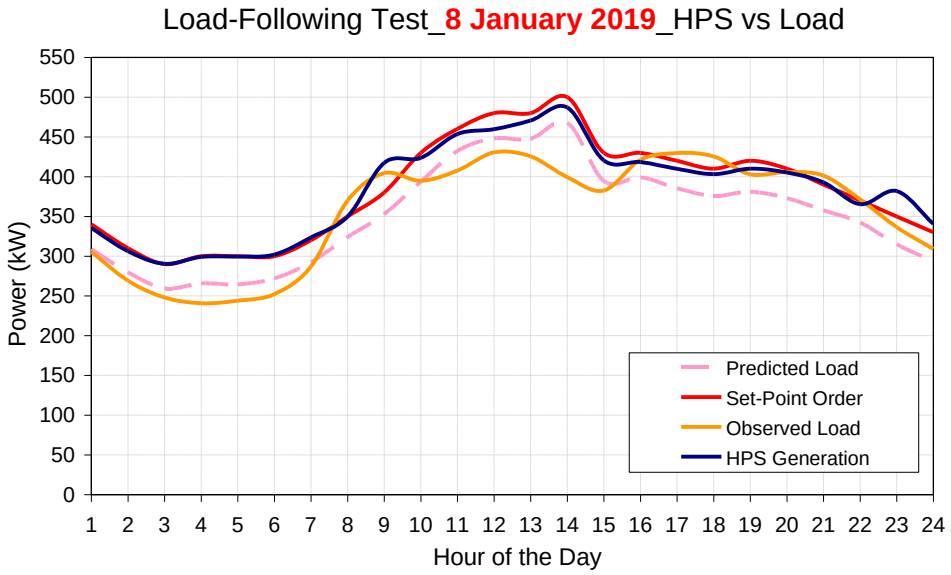
- Trial period subject to a fixed, **max power dispatch profile** on an hourly basis – max hourly power of **800kW/400kW/0kW** and max daily energy of **9.6MWh**
- Power / energy output of the HPS **compares favourably** with the local load demand, owing also to the winter period of testing – "exports" to the electricity system of Kos identified

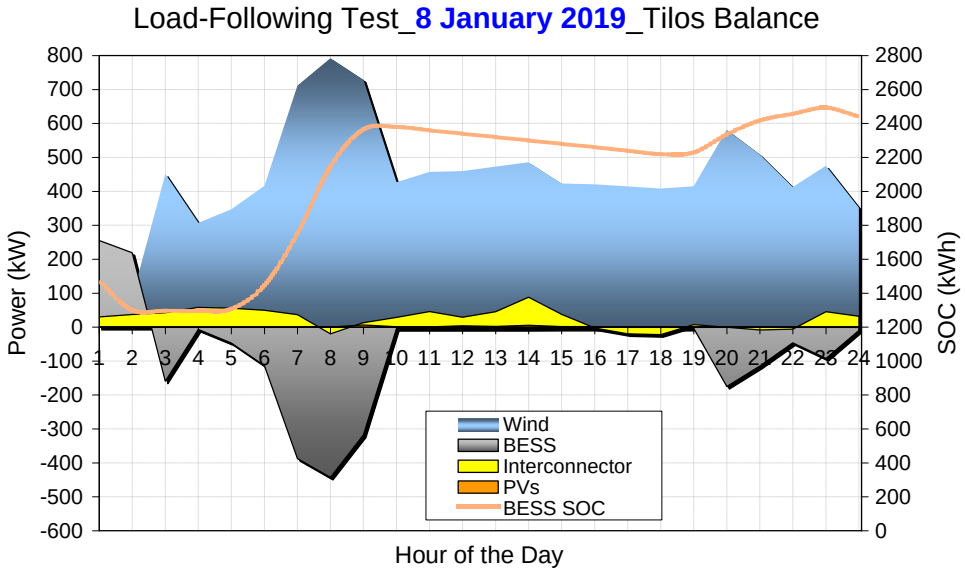






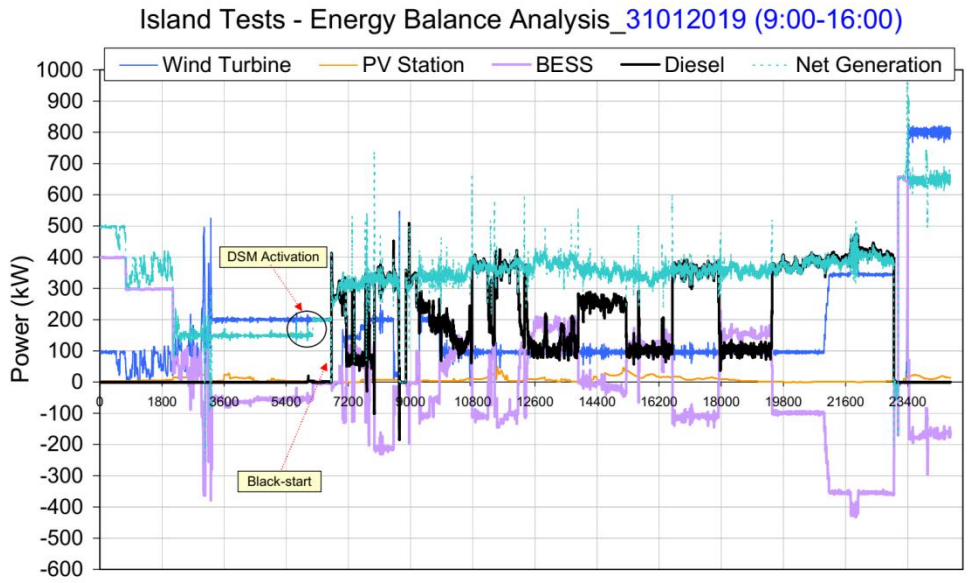
PROSUMER MODE RESULTS (2)

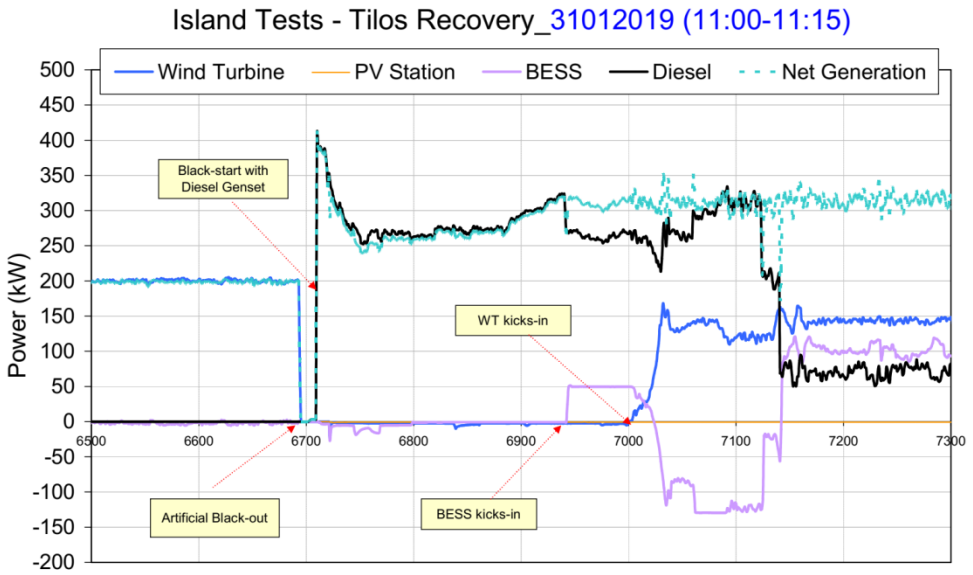




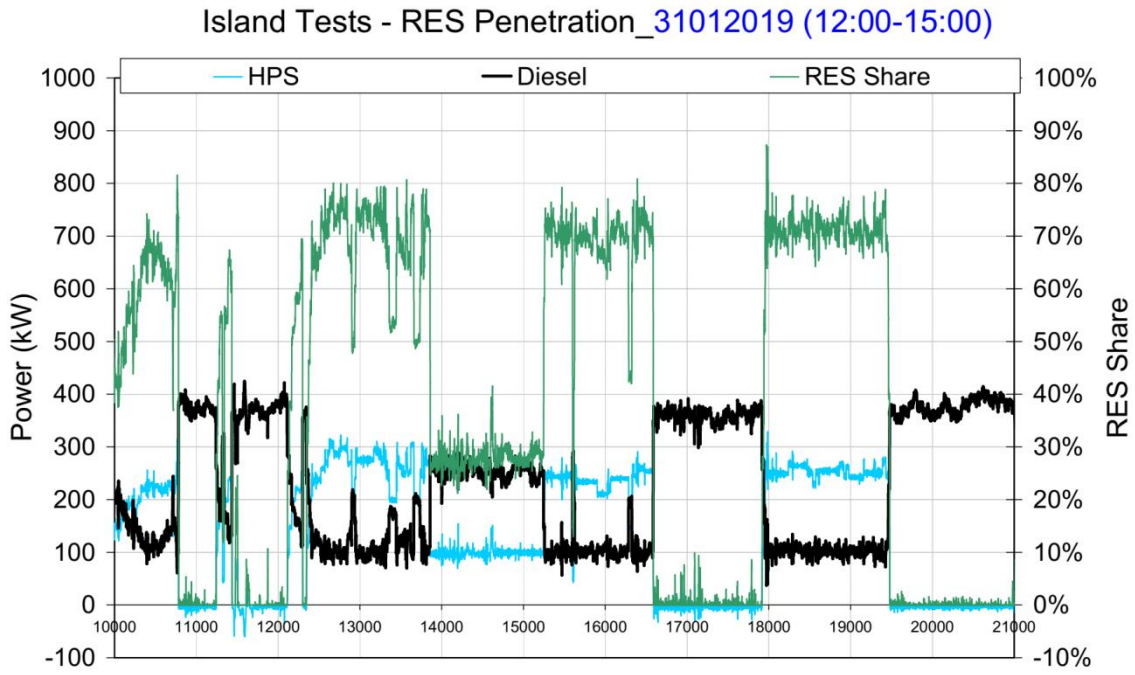
- **Profile testing** implemented:
  - Load-following profile
  - RES-following profile
  - RES/Load+Peak Exports profile
- **Day-ahead forecasting** of island **load demand** and **RES production** was used to **schedule** the operation of the HPS, depending on the implemented strategy
- The **BESS component** was used to **offset** any appearing deviations
- The HPS has proven **fully capable** of responding to **RES/load deviations**, with **forecasting models** acting as a **complementary component** to the use of the **BESS**

ISLAND TESTS

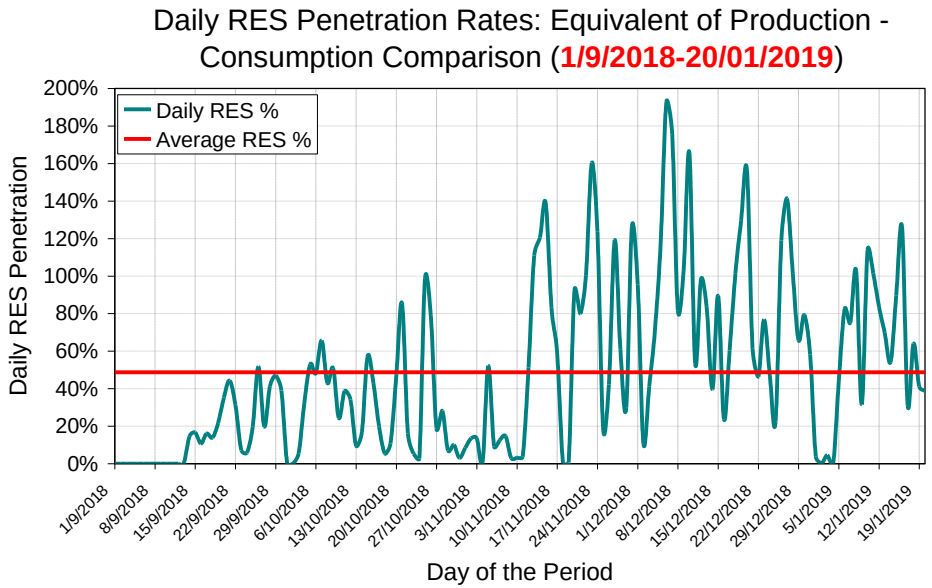


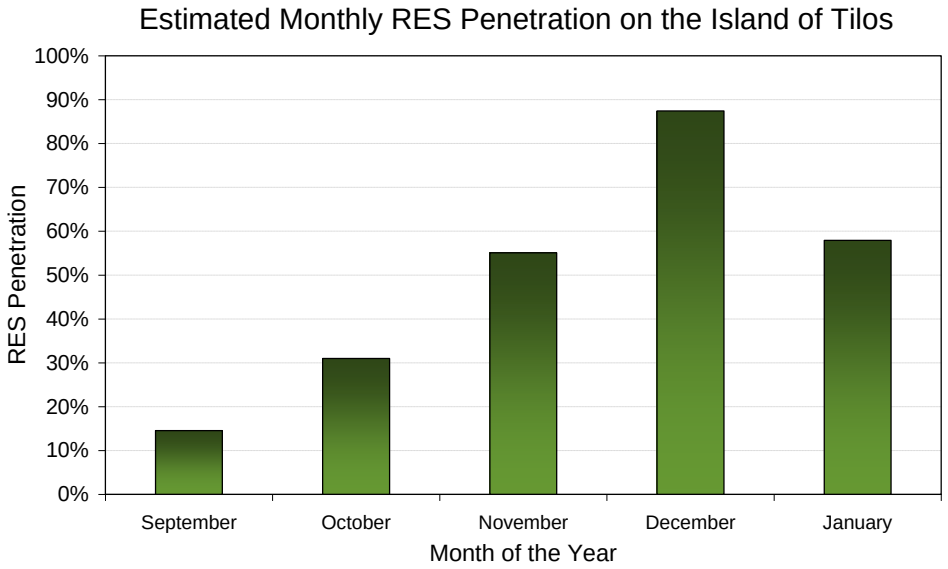


- Island tests executed through **Tilos isolation** from Kos
- All microgrid components, incl. the genset, **governed** by the **High-Level Energy Management Centre**
- **Increased RES penetration** challenged, employing also DSM community loads (excess RES exploitation) – **exceeding 70%**



OVERALL RES SHARES ACHIEVED





- Increased shares of **RES contribution** recorded following September 2018 (start date: **14/9/2018**) despite the execution of several trial tests and the adoption of **sub-optimal conditions** of operation
- The HPS was able to cover the local demand for **several days of the period**, supporting also "exports" to the system of Kos
- Monthly RES shares that **even approached 90%** during December and **well exceeded 50%** during November and January

Local Population Support-EU Awards

Continuous INVOLVMENT OF LOCAL POPULATION

WWF

HORIZON 2020

Για τις απαντήσεις σας, σημειώστε το κουτάκι το οποίο αντιστοιχεί στην σωστή απάντηση ή συμπληρώστε το κενό. Εάν δεν είστε βέβαιος/α για κάποια ερώτηση, προχωρήστε στην επόμενη. **Η συμπλήρωση του ερωτηματολογίου δεν θα σας πάρει περισσότερο από 15 λεπτά, και θα μας βοηθήσει να καταλάβουμε καλύτερα τις ενεργειακές σας ανάγκες.**

Σας ευχαριστούμε για τον χρόνο σας!

ΑΤΟΜΙΚΑ ΕΡΩΤΗΜΑΤΟΛΟΓΙΑ

α/α ερωτηματολογίου____

Προσωπικά στοιχεία

1. Κατοικώ στην Τήλο από το (ημερομηνία):_____
2. Ηλικία: έως 20 ετών ☐ 20-40 ετών ☐ 40-60 ετών ☐ Άνω των 60 ετών ☐
3. Φύλο: Άνδρας ☐ Γυναίκα ☐
4. Είδος απασχόλησης

Μισθωτός ☐ Ελεύθερος επαγγελματίας ☐ Συνταξιούχος ☐ Άλλο _____

Συνήθειες

ανάλωση;

οτελεσματικής εξοικονόμησης ενέργειας, προϋπόθεση ατανάλωσης ενέργειας και η ανάλυσή της;.....

ς συσκευές που πιστεύετε πως καταναλώνουν την

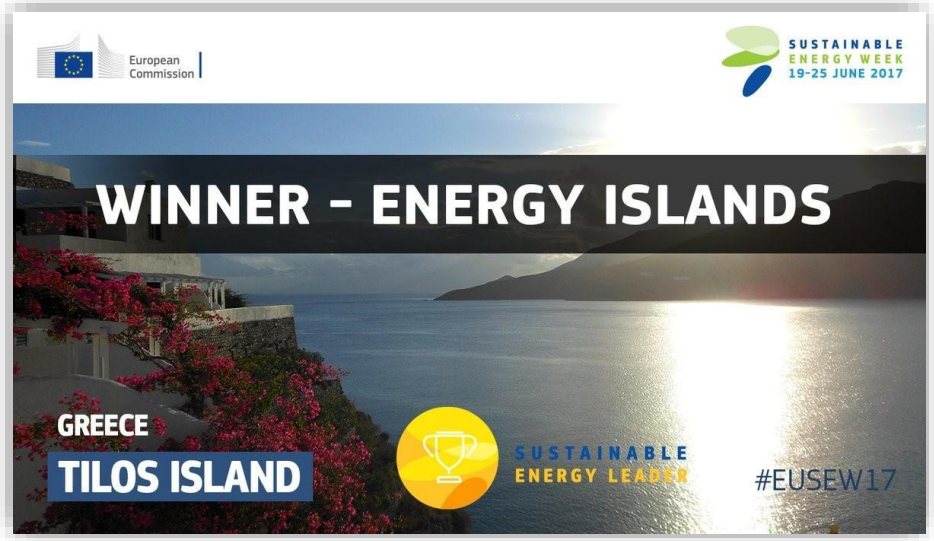
Ανεμιστήρας ☐ Τηλεόραση ☐
ψυγείο ☐ Λαμπτήρες φωτισμού ☐ Κουζίνα ☐
ς νερού ☐ Σίδερο ρούχων ☐ Πιστολάκι μαλλιών ☐

για την ενεργειακή τους κλάση;

οντικός ☐

PUBLICITY

bridge
HORIZON 2020



COP23 | FIJI
UN CLIMATE CHANGE CONFERENCE
BONN 2017-18

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Conclusions

MAIN CONCLUSIONS

- Profile testing demonstrated the **ability of the HPS to respond** and be effectively scheduled under **different operational conditions**
- Alternative profiles, e.g. load-following (+peak exports), could be offering **maximum exploitation of similar HPSs' potential** under a microgrid entity configuration
- Complementarity between **forecasting and energy storage** was demonstrated, which may lead to **optimized design and operation** for similar hybrid configurations
- DSM infrastructure developed, including also the local solar-based EV charging station, offers an **appreciable demand response potential**, especially in terms of **aggregation**
- A robust **power cut recovery mechanism** has been developed and proof-tested on the island, which allows the **alleviation of severe black-outs** with the strong support of the **local HPS** and coordination of the **High-Level EMC**
- **Local population and local authorities continuous Support of the Project**

Technology Innovation *for the* Local Scale
Optimum Integration *of* Battery Energy Storage

Thank you for Your Attention