SMART RENEWABLE HUBS FOR FLEXIBLE GENERATION

SOLAR GRID STABILITY

GRIDSOL

Smart Renewable Hubs: Solar hybridisation to facilitate Renewable Energy integration

COBRA, IDIE, TECNALIA, CESI, HEDNO, NTUA

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INDEX

I. INTRODUCTION

II. SMART RENEWABLE HUB

III. CASE STUDY: CONTINENTAL EUROPE

IV. CASE STUDY: EUROPEAN ISLAND

V. CONCLUSIONS

APPROACH

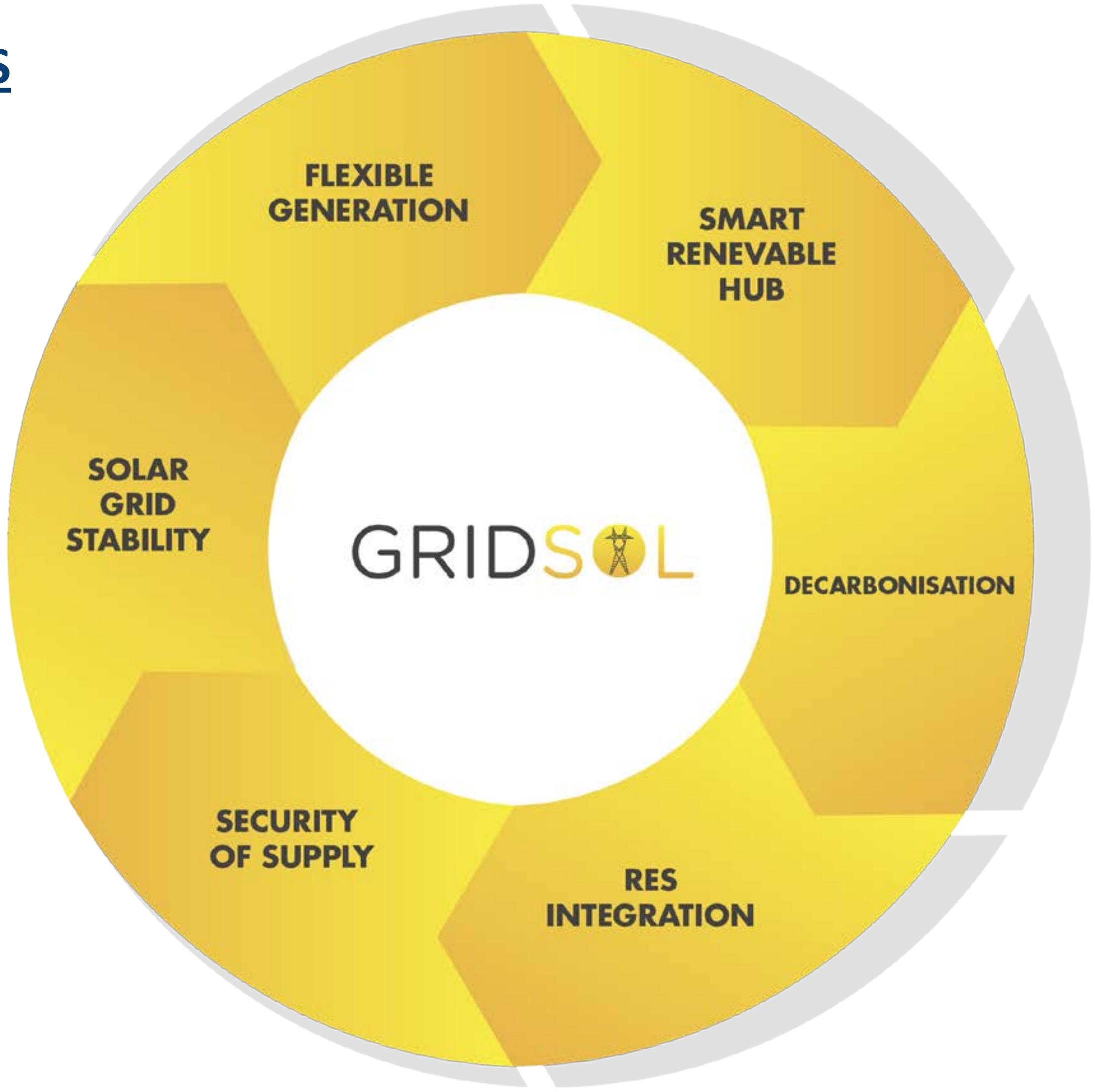
Smart Renewable Hubs for flexible generation:

Solar Grid Stability - GRIDSOL

GRIDSOL aims to provide secure, clean and efficient electricity by combining primary renewable energy sources and technology under an advanced control system. Video

- **Reduced investment**: Integrated operation of PV and CSP with HYSOL reduces the need for solar field area.
- **Dispatchability**: Battery and thermal **energy storage** provide with the ability of delaying the electric production. Having a **gas turbine acting in combined cycle** thanks to **HYSOL** improves this capacity, as the plant is able to produce power at any time.
- **High firmness**: Gas turbine, HYSOL and energy storage make possible to provide electricity output while fulfilling with the scheduled target.
- **High peak coverage**: Due to an optimized generation schedule.
- Ability to **follow a variable power target**: thanks to the dynamic output electricity manager (DOME).

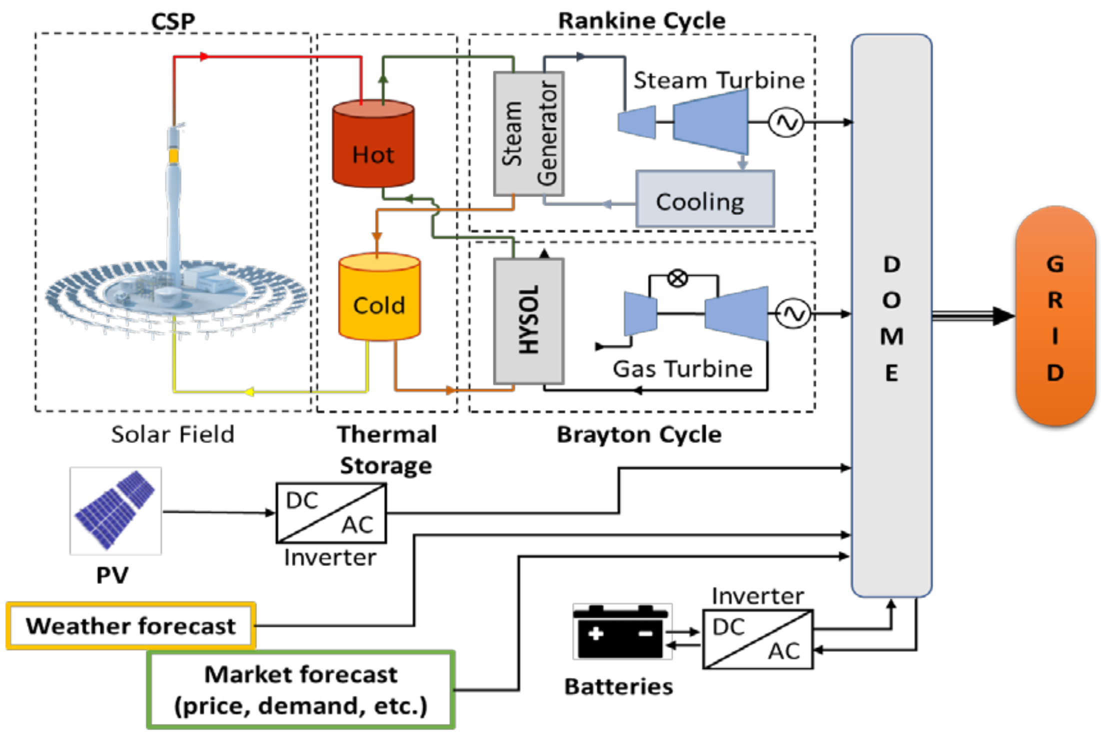
OBJECTIVES


FLEXIBLE GENERATION
SMART RENEVABLE HUB
DECARBONISATION
RES INTEGRATION
SECURITY OF SUPPLY
SOLAR GRID STABILITY
GRIDSOL

CONFIGURATION

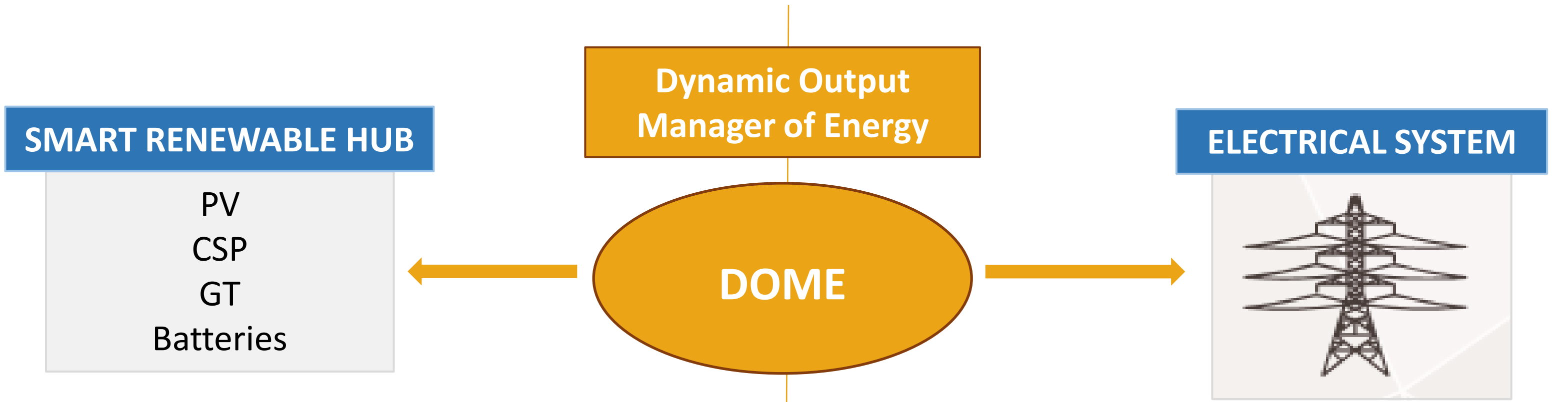
A **Smart Renewable Hub (SRH)** is a **flexible hybrid power plant** that **combines** a core of synchronous and non-synchronous **generators** (CSP, PV, GT or WIND) **with energy storage systems** (thermal and electrochemical).

GRIDSOL initial case is a kind of SRH based on **solar firm hybrid power plants**, and its solution is detailed as follows:



DYNAMIC OUTPUT MANAGER OF ENERGY (DOME)

- System operation: Flexible generation & Grid stability



➢ Flexible Generation

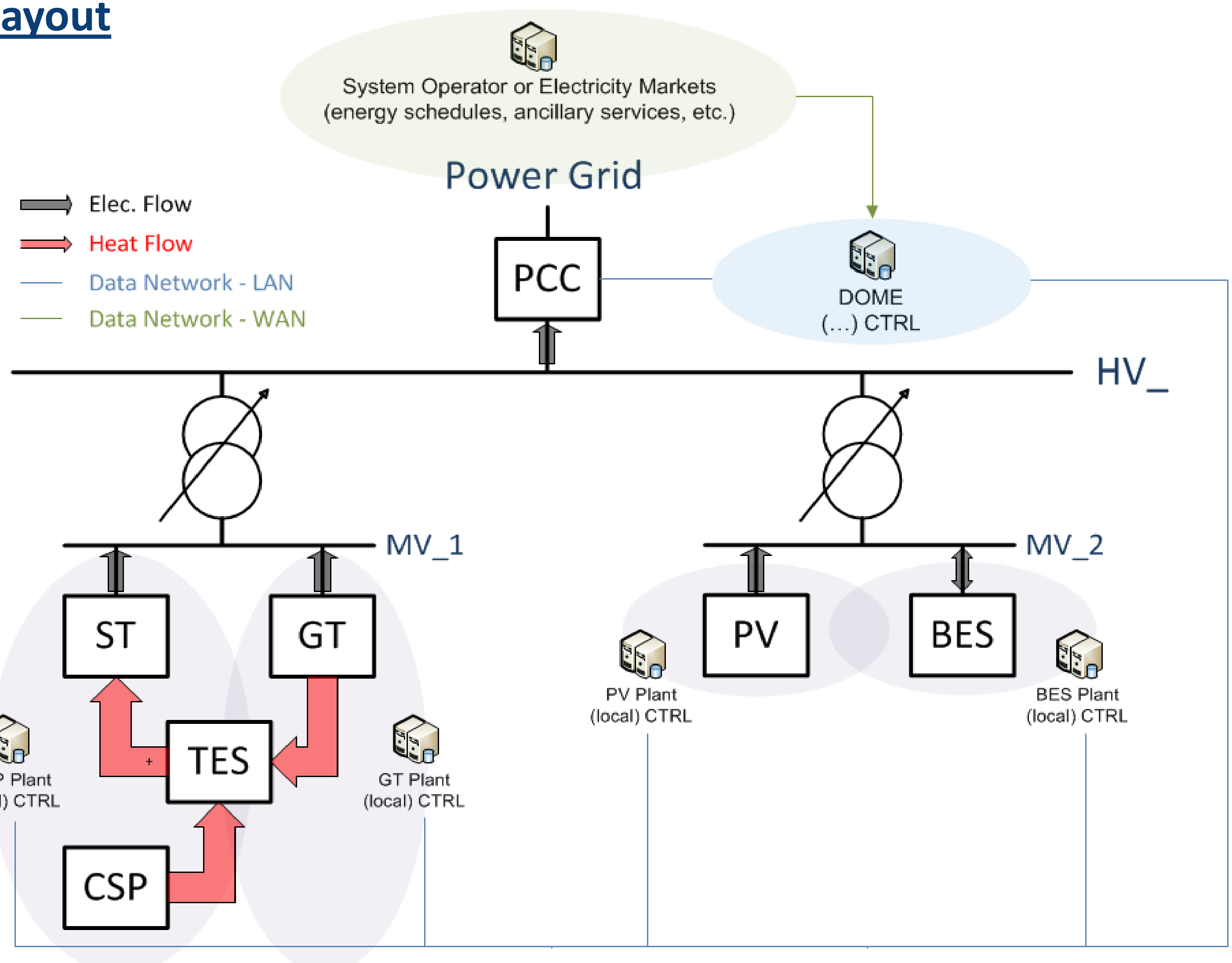
➢ Grid Stability

- Target:

  - **DOME** manages and controls the electricity produced to **meet TSOs requirements** in terms of quantity (power) and quality (voltage, frequency, reactive, etc.).

  - **DOME** considers market rules and grid requirements to **define the perfect generation mix** at each moment.

DOME Layout


System Operator or Electricity Markets
(energy schedules, ancillary services, etc.)
Power Grid
Elec. Flow
Heat Flow
Data Network - LAN
Data Network - WAN
PCC
DOME
(…) CTRL
HV_
MV_1
MV_2
ST
GT
TES
CSP
PV
BES
CSP Plant
(local) CTRL
GT Plant
(local) CTRL
PV Plant
(local) CTRL
BES Plant
(local) CTRL

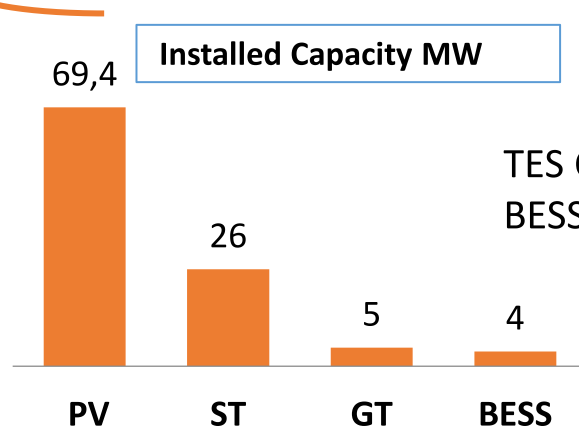
CASE STUDY: CONTINENTAL EUROPE

PUGLIA, ITALY

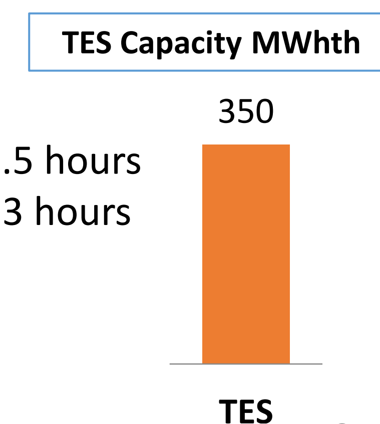
For the first simulation of GRIDSOL behaviour in the Day-Ahead electricity market the Italian region of “PUGLIA” has been selected

GRIDSOL Configuration	
PV Power [MW]	69.4
BESS Nominal Power [MW]	4.0
BESS Autonomy [hours]	3.0
Gas Turbine Nominal Power [MW]	5.0
Steam Turbine Nominal Power [MW]	26.0
TES Autonomy [hours]	5.5
Solar Multiple	1.87
GRIDSOL Nominal Power [MW]	104.4
TES Storage Capacity [MWhth]	350.1
Gas Turbine Nominal Efficiency [%]	33.7%
Steam Turbine Nominal Efficiency [%]	40.0%

1. High solar irradiance
2. High RES penetration
3. Need of dispatchable generation in future decarbonization scenario



TES Capacity: 5.5 hours
BESS Capacity: 3 hours



MARKET SIMULATOR

PROMEDGRID is the market simulator for the day-ahead energy market benefits assessment of new generation and network reinforcements at European level.

Optimal coordinated hydrothermal scheduling of the modelled electric system generation set, over a period of one year, with an hourly detail.

Deterministic model based on technical and economic characteristics of the power system.

Equivalent Network Model

Thermal Generation set

Hydro Generation set

Fuel Prices

Hourly load of each network/market zone

Imports/exports

Incentivized Power Plants

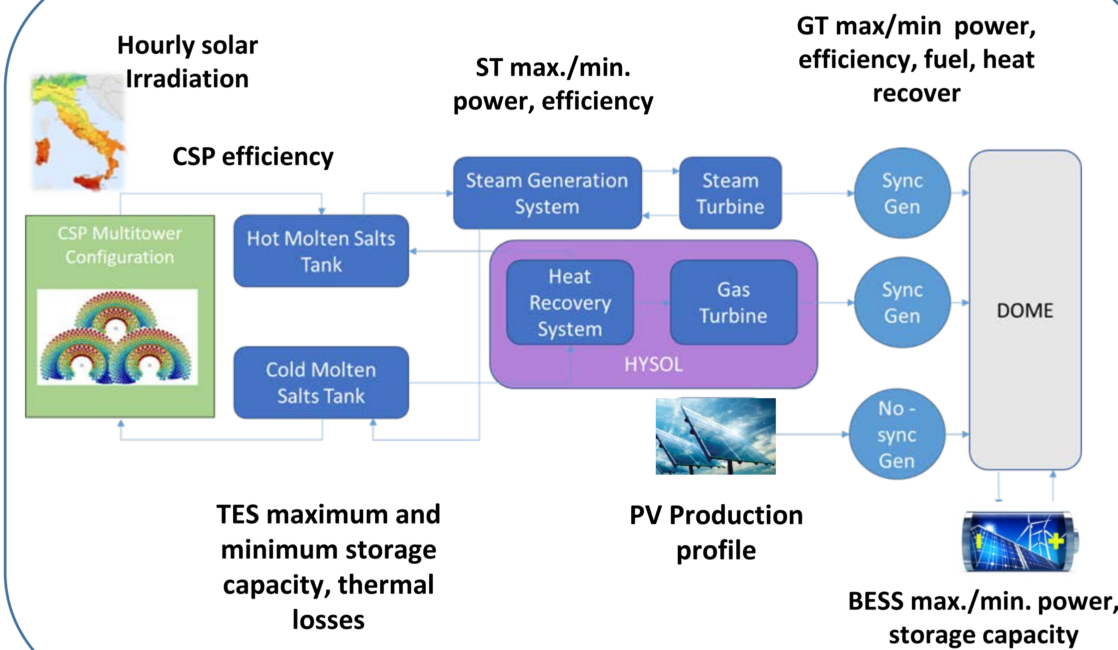
MARKET SIMULATOR PROMEDGRID

MAIN OUTPUTS

- Hourly electricity price forecasting
- Evaluation of revenues, costs, returns, market shares for generators
- Evaluation of the impact of an assumed system/market scenario on the electricity price
- Evaluation of the active power flows between system zones: congestion, marginal price/cost, congestion rents

GRIDSOL MODEL IN PROMEDGRID

Needed Input shared among WPs



Model

- ✓ The Optimization of GRIDSOL Production is carried out on the basis of the expected hourly price profile by PROMEDGRID.
- ✓ The optimization is aimed at maximizing the overall GRIDSOL profit.
- ✓ One synchronous generation always considered in operation (**CONSTRAINT**)
- ✓ Flexible production thanks to the Thermal and Battery storage system.

Independent Variables

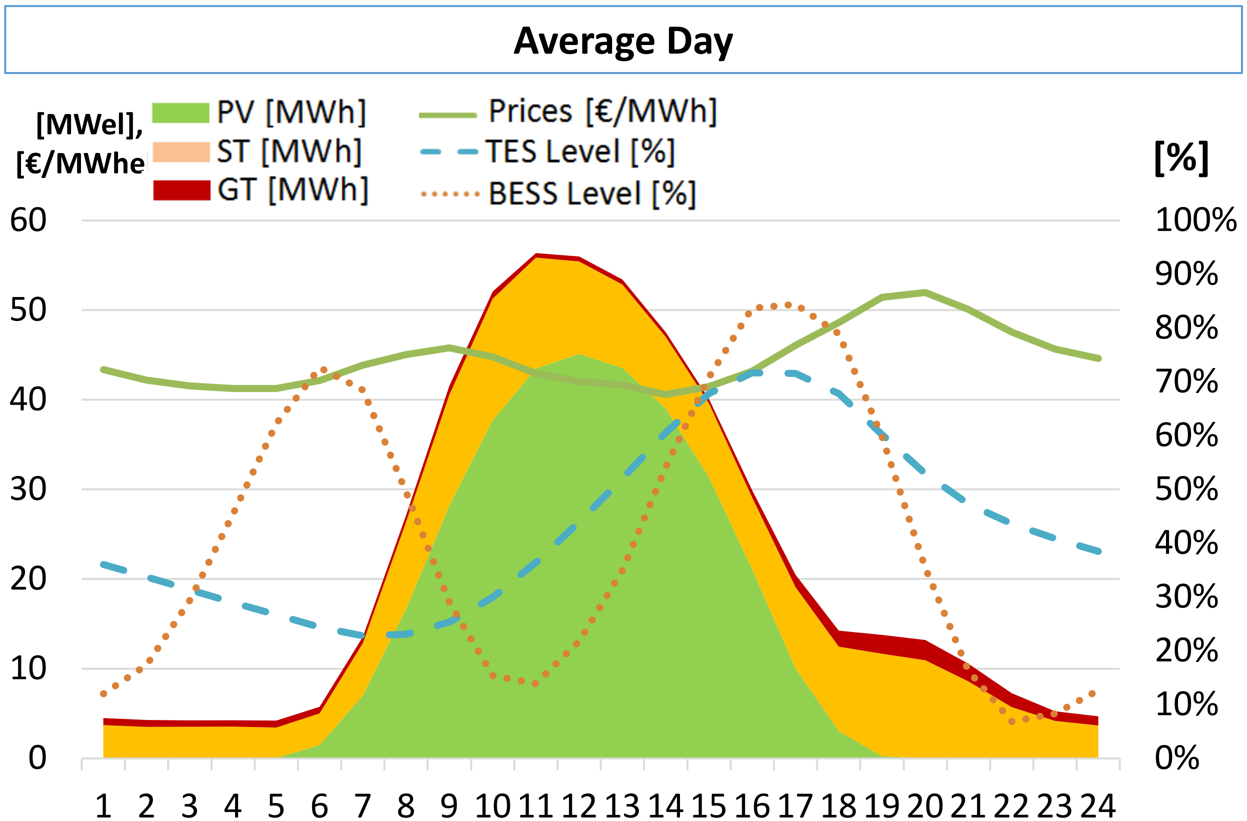
- ✓ *Gas Turbine production [MWh]*
- ✓ *Steam Turbine production [MWh]*
- ✓ *BESS Energy output [MWh]*

Output

- ✓ Expected energy production of each part of GRIDSOL
- ✓ expected profitability (revenues and cost estimation)
- ✓ reduction of CO_2 emissions and fuel savings due to GRIDSOL project

RESULTS

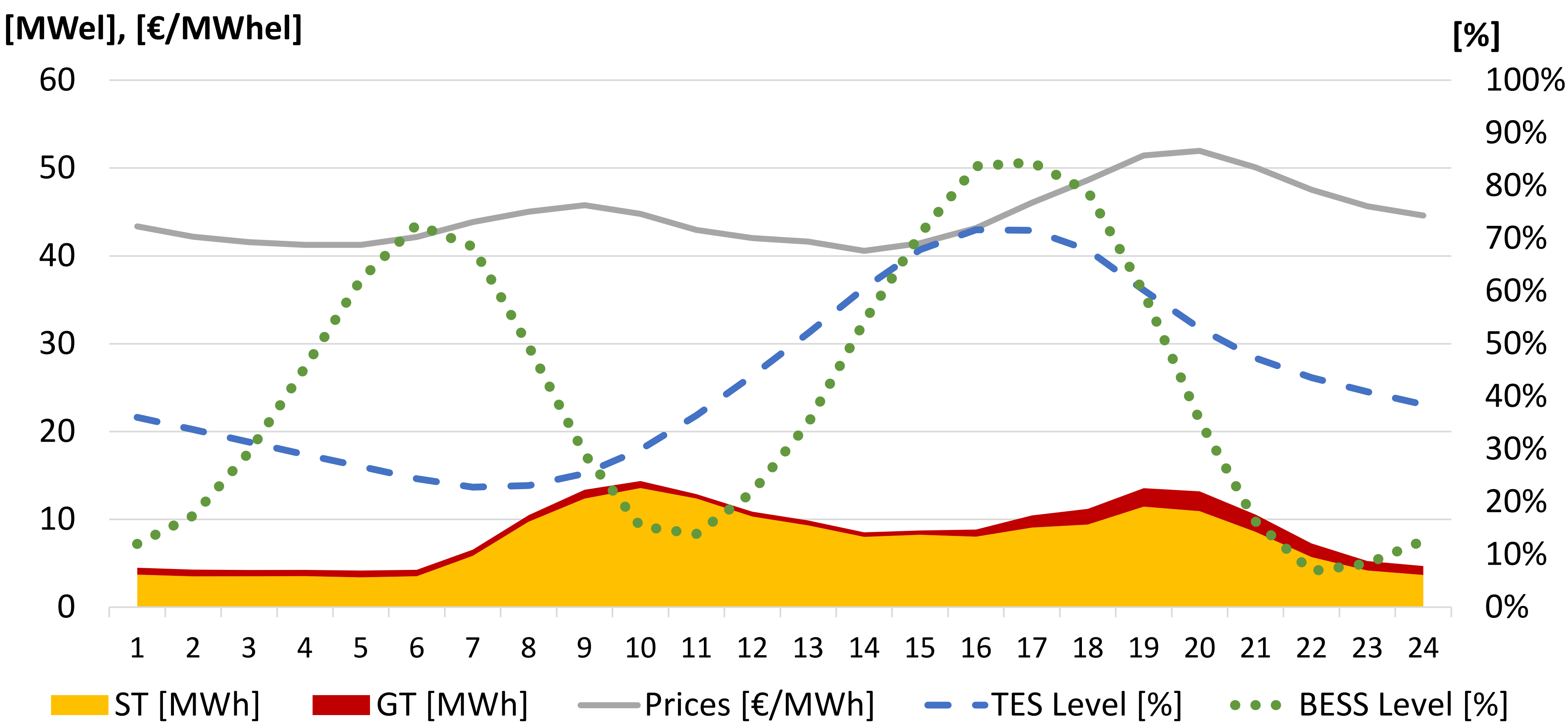
- GRIDSOL Pilot Simulation in the **2020 Expected Progress Scenario** (ENTSO-E TYNDP 2016)
- The **market zone of South Italy** is characterized by an expected **flat price** profile with average value equal to **46 €/MWh**
- GRIDSOL does not exploit its full potential due to low differences from peak to lower prices



- ST and GT concentrated in the hours with higher prices
- Baseload Generation profile thanks also to the constraint

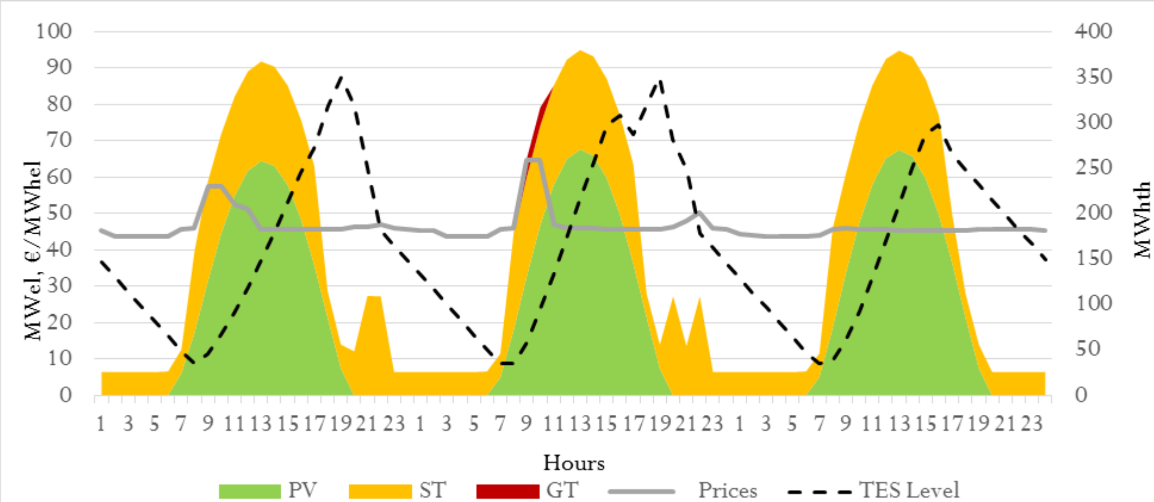
RESULTS: Focus on the GT, ST and BESS performance

Average Day



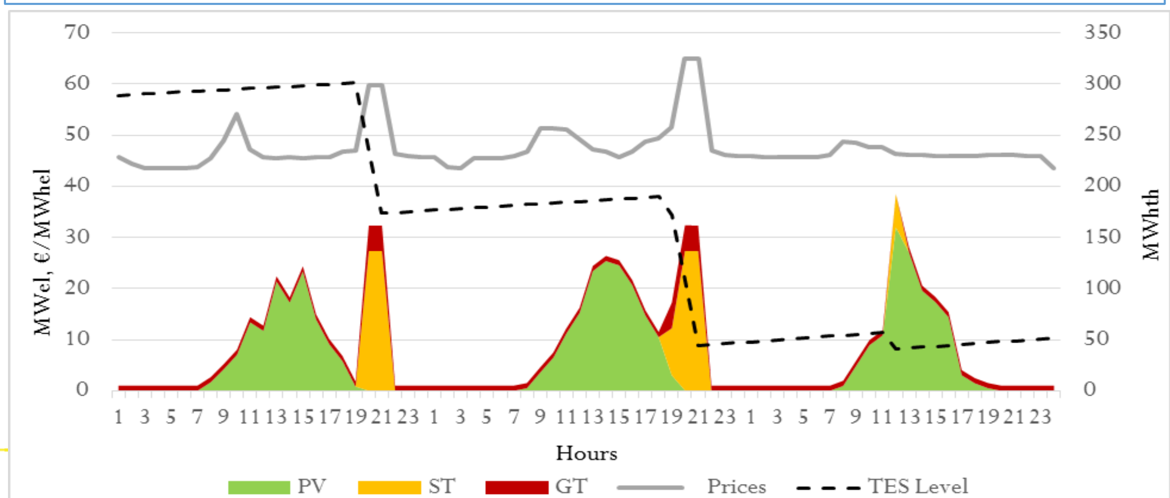
RESULTS: SUNNY DAYS VS. CLOUDY DAYS PERFORMANCE

Three Days Performance of GRIDSOL in Sunny Days



- Max injection of heat from CSP
- ST produce H24 optimizing its production in function of the solar irradiance and the price profile
- GT produce in peak price hours

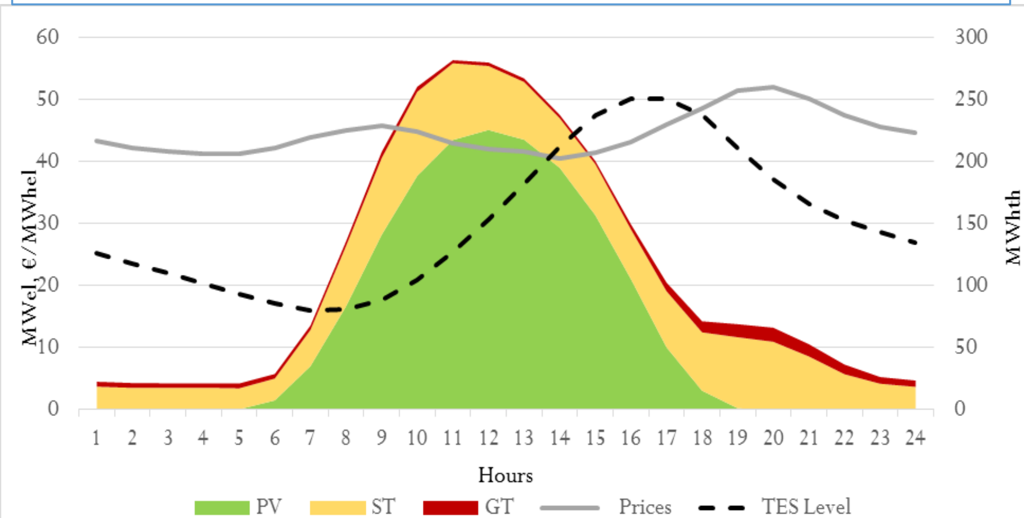
Three Days Performance of GRIDSOL in not Sunny Days



- ST concentrate its production in the price peak hours
- GT produces at its technical minimum to respect the constraint

RESULTS: CONSTRAINT EFFECT ON DAY-AHEAD MARKET

Average Day with the Constraint

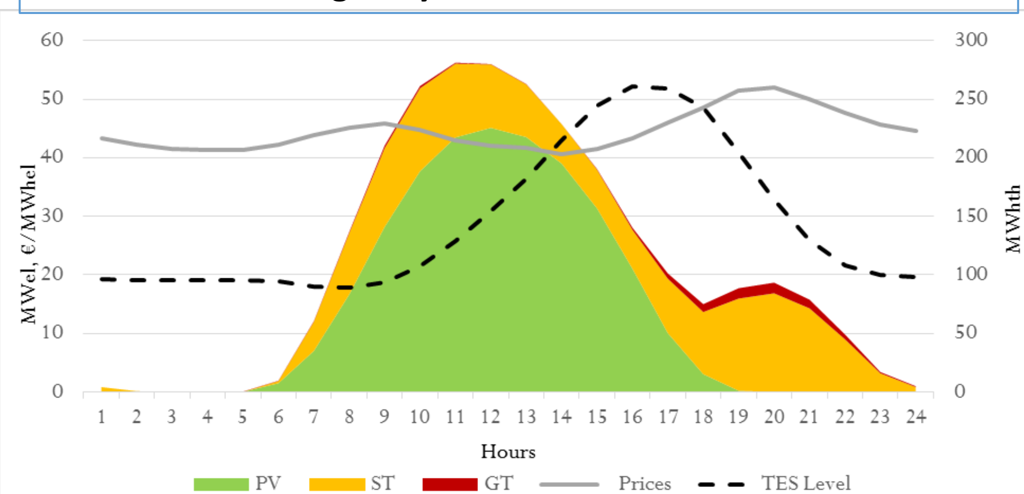


	Annual Production [GWh]	Average Selling Price (€/MWh)	Operation Hours
Average Market Price		45.8	
Steam Turbine	66.2	47.1	5 700
Gas Turbine	8.9	52.1	3 700
PV	119.5	44.0	
TOTAL	**194.6**		

Gross Margin [k€]: 8.2 M€

Renewable Energy Content [%] = 93.7%

Average Day without the Constraint



	Annual Production [GWh]	Average Selling Price (€/MWh)	Operation Hours
Average Market Price		45.8	
Steam Turbine	64.3	49.0	2 700
Gas Turbine	3.8	62.0	800
PV	119.5	44.0	
TOTAL	**187.6**		

Gross Margin [k€]: 8.4 M€

Renewable Energy Content [%]= 97.2%

CASE STUDY: CONTINENTAL EUROPE

GRIDSOL

DAY-AHEAD MARKET RESULTS

- **Flexible and continuous generation** thanks to the DOME
- **Flat price profile does not valorize properly this flexible generation**
- The **economic results** of this preliminary configuration **are not sufficient to cover the high investment costs of some technologies** (BESS and CSP)

ANCILLARY SERVICES

(Under study)

- **Forcing the operation of at least one synchronous generator** (ST or GT) **can increase the possibility to provide ancillary services** but increases the costs in the day-ahead market

	Active constraint	No constraint
Upward Reserve	50% of time with upward reserve >10 MW	Very low upward reserve (15% time >10MVA)
Downward Reserve	no particular differences (40-50% time: >10MVA)	

OPEN ISSUES

- The pilot simulations allowed to identify the **main items that impact the GRIDSOL performances**:
  - **Gas Turbine Size and Efficiency**
  - **The constraint of one synchronous generator always ON**
  - **Investment costs of CSP and BESS**
  - **Price profile**
- The goal of an **high flexibility of renewable generation is achievable under favourable external conditions** including a proper regulatory framework

GRIDSOL

CRETE (GREECE)

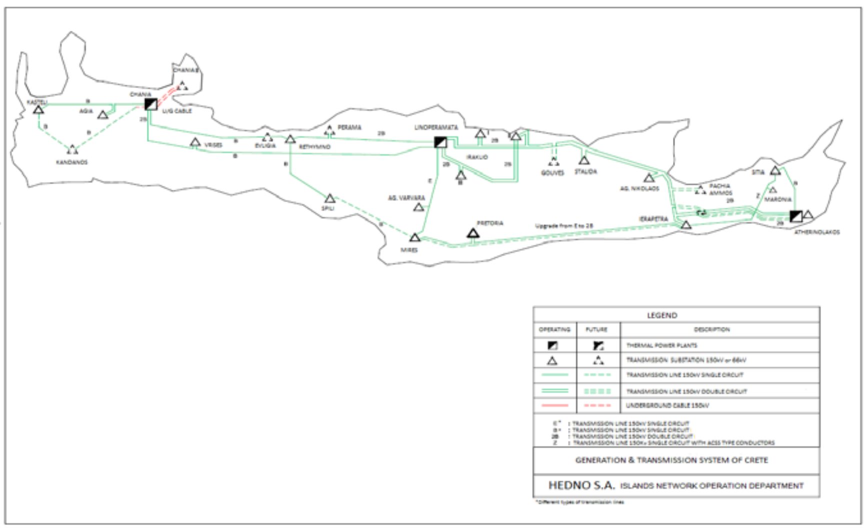
Size: 8,303 km^2

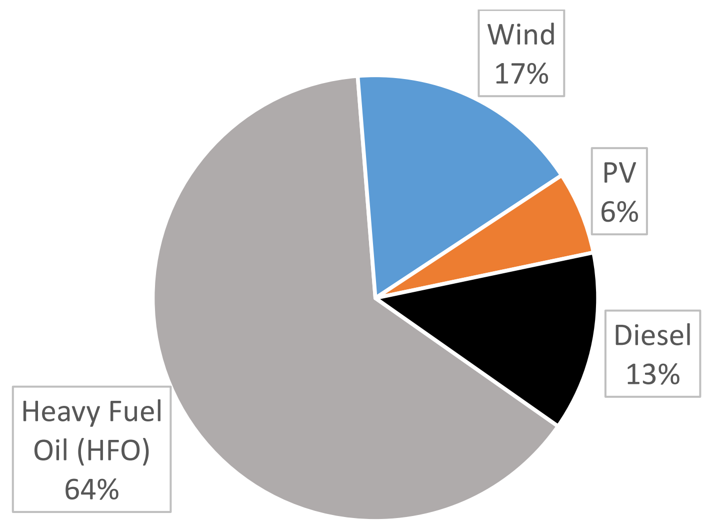
Population: 623,065 inhabitants

Peak demand 2016: 616 MW

Average Load Demand 2016: 331 MW

Installed Thermal Capacity (MW)	Installed RES Capacity (MW)				Total Installed Power (MW)
	Wind	PV	Hydro	Total	
820.02	200.29	95.54	0.30	296.13	1116.15

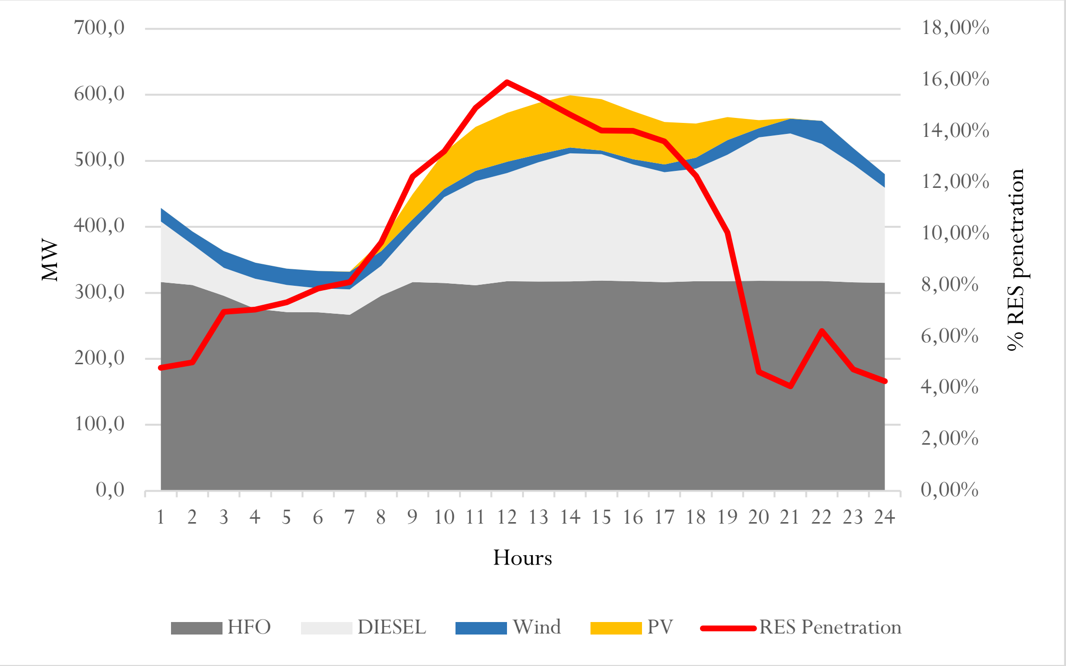




Electricity Production Share per Origin (2015)

DAY OF HIGHEST DEMAND

- Days of highest demand are **warm days of summer**, usually with **very low wind**.
- **Wind parks** are **unable to cover** the excess demand.
- **Expensive diesel** -consuming units operate **increasing the cost** of the system.
- **RES penetration** is **very low**.



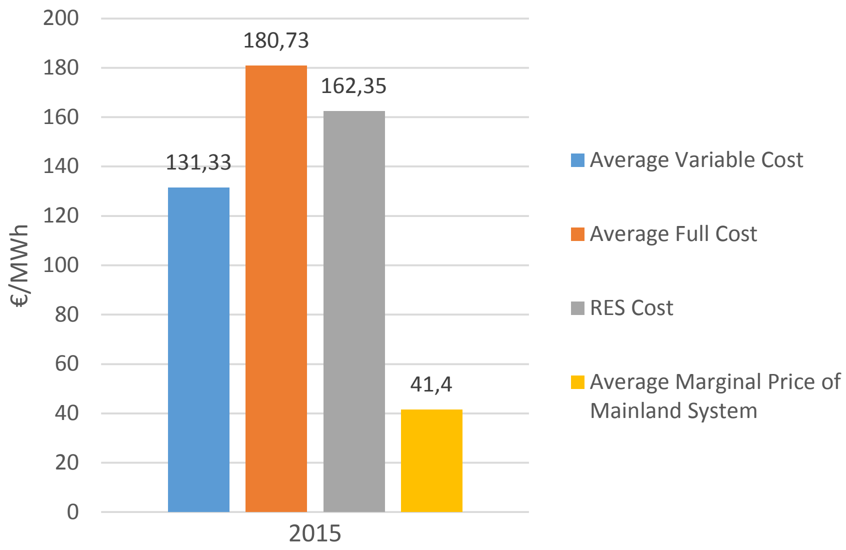
Hourly production per fuel type and hourly RES penetration during the day with the highest load demand (31/07/2015) on Crete

GRIDSOL could be **a solution** for days like this **lowering the cost, increasing RES penetration**, while **ensuring grid stability**.

CASE STUDY: EUROPEAN ISLAND

GRIDSOL

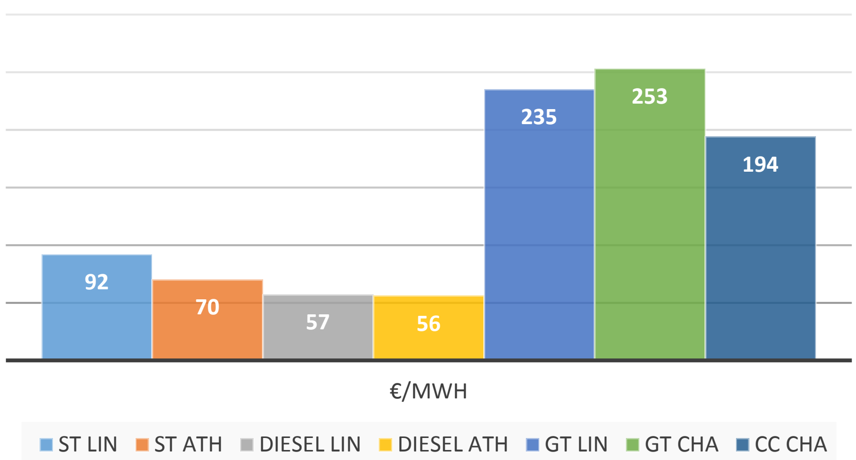
GENERATION COST



Crete Power Generation Costs vs. Mainland

- **Higher cost** compared to mainland.

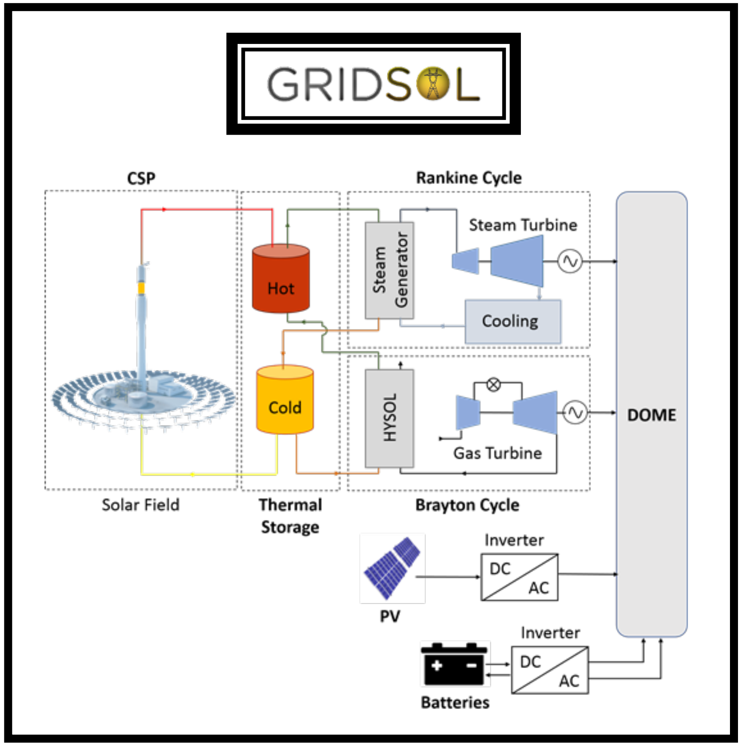
- **Expensive units** operate during **peak demand** periods or to secure **grid stability**.



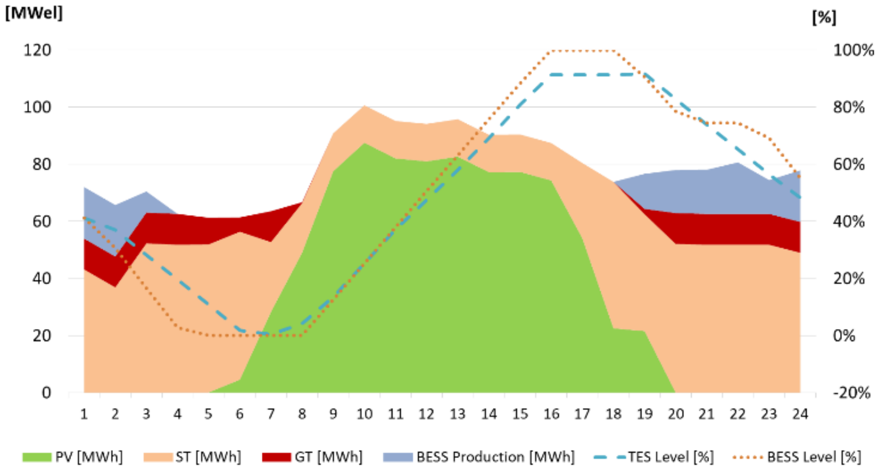
Fuel Cost per Type of Unit for 2016

OPERATIONAL RULES

How does it operate internally?



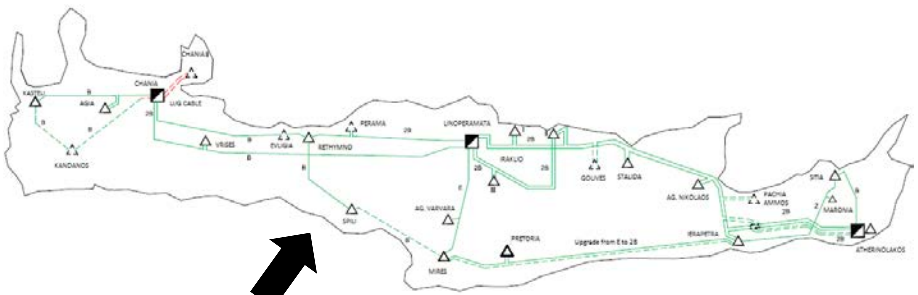
Configuration under test	
PV Power (MW)	111
Batteries Nominal Power (MW)	54
Batteries Autonomy (hours)	4.20
Gas Turbine Power (MW)	12
Steam Turbine Power (MW)	50
TES Storage Time (hours)	11.30
GRIDSOL Nominal Power (MW)	227
Renewable Energy Content (%)	81



Daily average GRIDSOL behavior in Crete. Source IDIE

CASE STUDY: EUROPEAN ISLAND

How does it operate <u>in the grid</u>?



Demand prediction

Thermal producers
Availability of units

+

Dispatchable RES producers
Energy Offers or Hourly Generation Schedules

+

Operator
Technical minima & RES penetration margins

Non dispatchable RES production forecasting

=

Dispatch Schedule

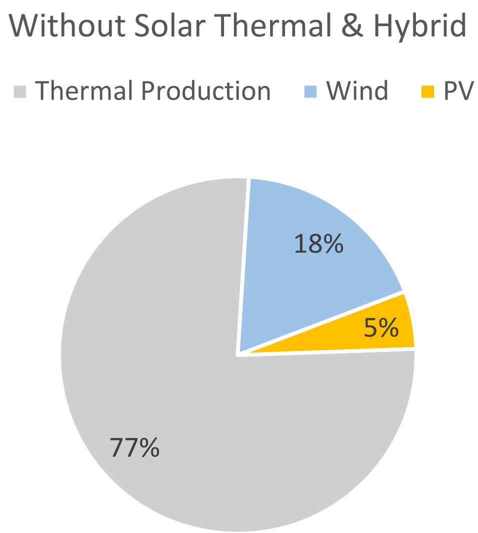
PRELIMINARY SYSTEM TEST

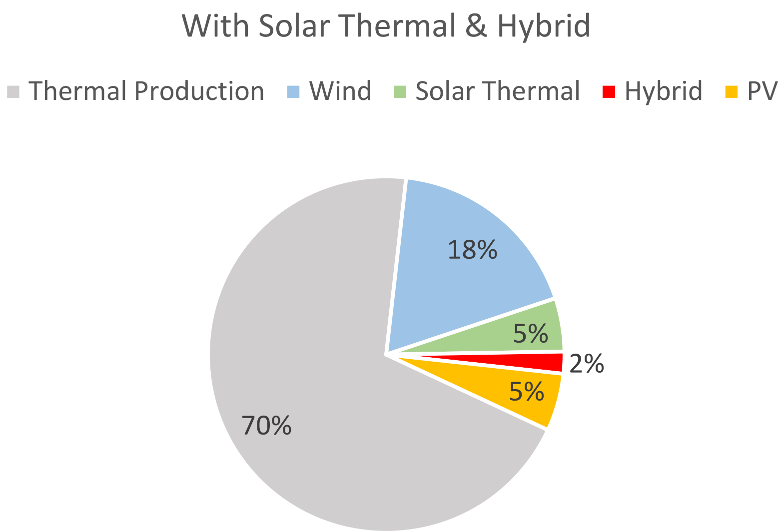
The Application

These results are obtained with the **Energy Planning Application**.
In this application the user has the ability to input the appropriate data and parameters according to which a **unit integration algorithm** runs for the hourly participation in the energy balance of **Crete's isolated power system**.

The Results

Annual results for **Crete**'s power system **with** and **without** an addition of **a 50 MW Solar Thermal station and a 50 MW Hybrid station** (60 MW PV & 50 MW BESS).





PRELIMINARY SYSTEM RESULTS

	Crete's Power system with 50 MW Solar Thermal & 50 MW Hybrid Station	Crete's Power System
Thermal production (MWh)	2,037,291	2,233,112
RES Penetration (%)	30.14	23.43
CO2 emissions (tn)	1,460,057	1,638,846
Solar Thermal production (MWh)	141,545	-
Hybrid production (MWh)	57,986	-
Wind production curtailed (%)	6.40	5.65
Thermal units operating time (h)	89,037	98,446

With **the addition of the Solar Thermal & Hybrid station**:

Thermal production

↓ 8.77%

Co_2 emissions

↓ 10.91%

RES penetration

↑ ~7%

Thermal units operating time

↓ 9.56%

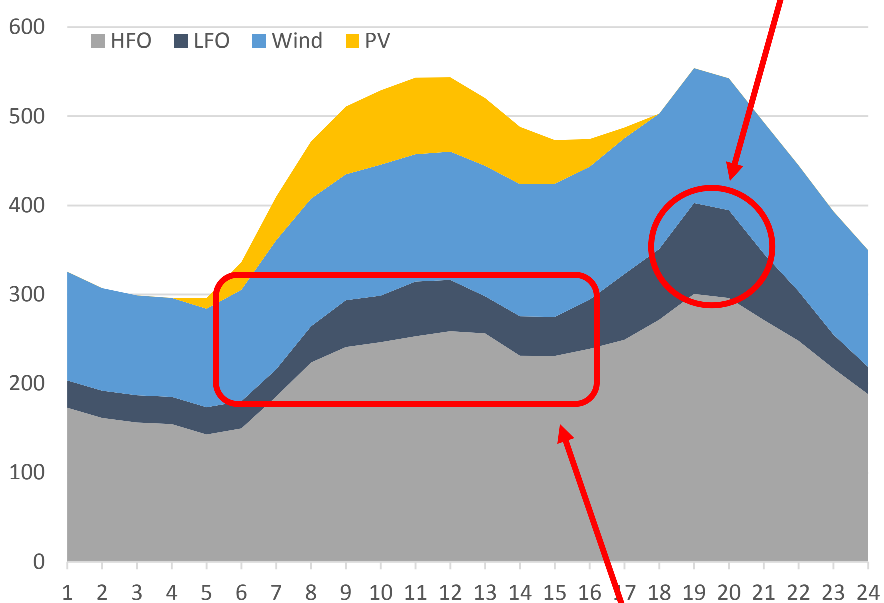
Combined Solar Thermal & Hybrid production

199,531 MWh

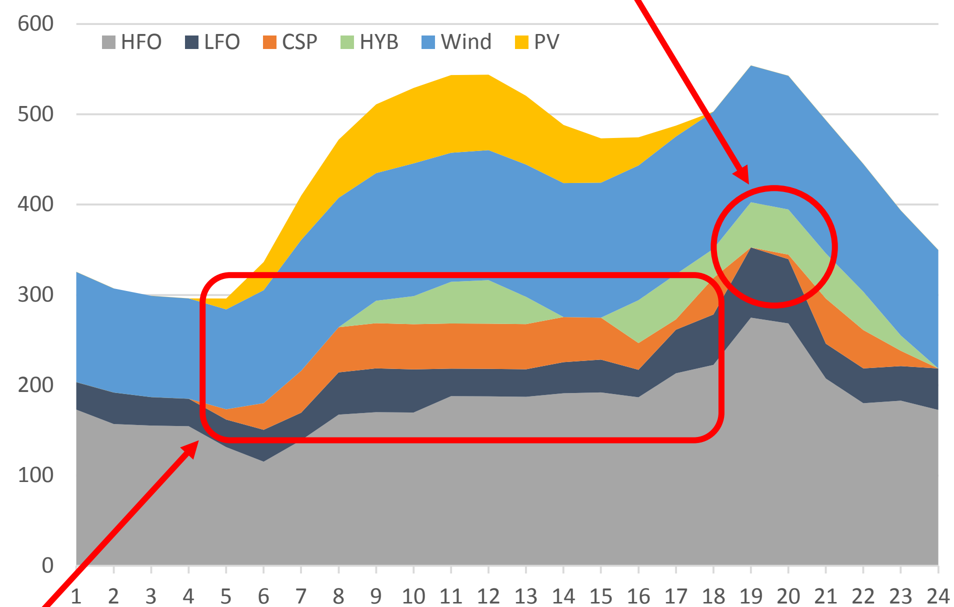
GRIDSOL

RESULTS : Crete's Power System daily operation

Expensive Unit replaced by Hybrid station during night peak demand



Daily operation of Crete's Power System



Daily operation of Crete's Power System with 50 MW CSP and 50 MW Hybrid Stations

Thermal Production Replaced by Solar Thermal & Hybrid stations during the day

CONCLUSIONS

GRIDSOL

- **Smart Renewable Hubs**, as a novel concept, **do not have a proper regulatory framework** approved for its development yet over the whole European Union (EU). Then, it is required to settle the ground (new market rules and mechanisms) in several countries **to promote the installation of these flexible hybrid plants**.
- In **Continental Europe**, forecasted **low prices** for coming years **do not promote fully-flexible hybrid plants**. Current rules and mechanisms of EU Wholesale Electricity Market are not good to integrate flexible renewable hybrid plants such as GRIDSOL. In following stages of the project, incomes via ancillary services will be assessed to have a whole picture of the EU electricity market.
- The **necessity of flexibility** (energy storage) **to integrate RES will increase** in coming years as a result of a progressive shut-down of conventional power plants. Then, a more reasonable electricity price signal trough a capacity or flexibility market and a greater CO2 price are needed to achieve EU decarbonisation goals.
- For **European islands**, it is identified a **first niche market** where hybrid power plants have a real added-value to provide due to **higher electricity generation costs** and the greater necessity of firmness to secure electricity supply. Thus, EU island rules and mechanisms are better also due to Power Purchase Agreements (PPAs).
- In this context, **GRIDSOL represents a major drive to integrate renewable energy sources thanks to flexible generation and grid stability**. Along the project execution, GRIDSOL will assess different SRH configurations taking into account market rules and grid requirements to deliver the most cost-effective solution at each location.

GRIDSOL

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THANK YOU FOR YOUR ATTENTION

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