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# ISGAN
# International Smart Grid Action Network
# ISGAN Academy Webinar

## **POSYTYF project:** Dynamic Virtual Power Plant to combine flexibilities of dispatchable and non-dispatchable RES

**18. 11. 2021,**
**Online Webinar**

# POSYTYF project: Definition and specification of Dynamic Virtual Power Plant (DVPP) scenarios

Description of the webinar

The speakers:

- Bogdan Marinescu, Professor, Ecole Centrale Nantes, Coordinator of POSYTYF project
- Oriol Gomis-Bellmunt, Professor, CITCEA-UPC
- Carlos Collados-Rodriguez, PhD student, CITCEA-UPC

Please, use the **Q&A tool** to pose questions, the speakers will answer at the end of the presentation.

The recording will be available through the **ISGAN YouTube channel.**

# Agenda

1. Overview of POSYTYF Project and the DVPP concept
2. WP1 description
3. Background and definitions
4. Scenario definition
5. Sizing of scenarios
6. Conclusions

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## ***POSYTYF Project:*** POwering SYstem flexibiliTY in the Future through RES

Call: LC-SC3-RES-16-2019- Development of solutions based on renewable sources that provide flexibility to the energy system
Duration: June 2020 – November 2023
Budget: 4,7 M€
Coordinator: Ecole Centrale Nantes, France

## ***Context:***

- System stability is the main bottleneck to the further integration of Renewable Energy Sources (RES) into the power system.
- Distributed RES, if aggregated and technically/economically optimized, have the potential to provide flexibility to the grid and contribute to system stability.
- Dispatchable RES can beneficially complement non-dispatchable RES for such optimization ; alternative to electrochemical storage

posytyf

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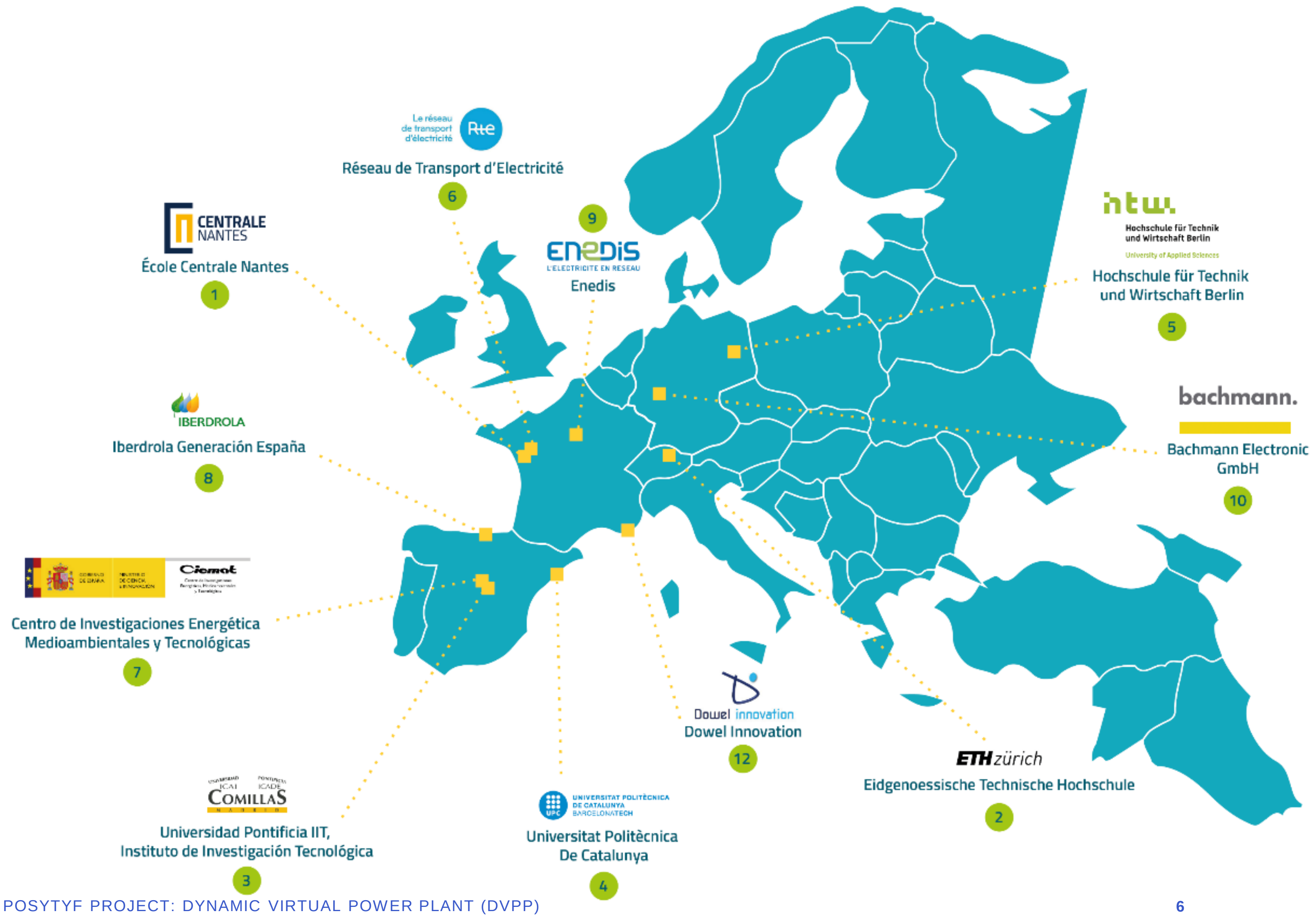
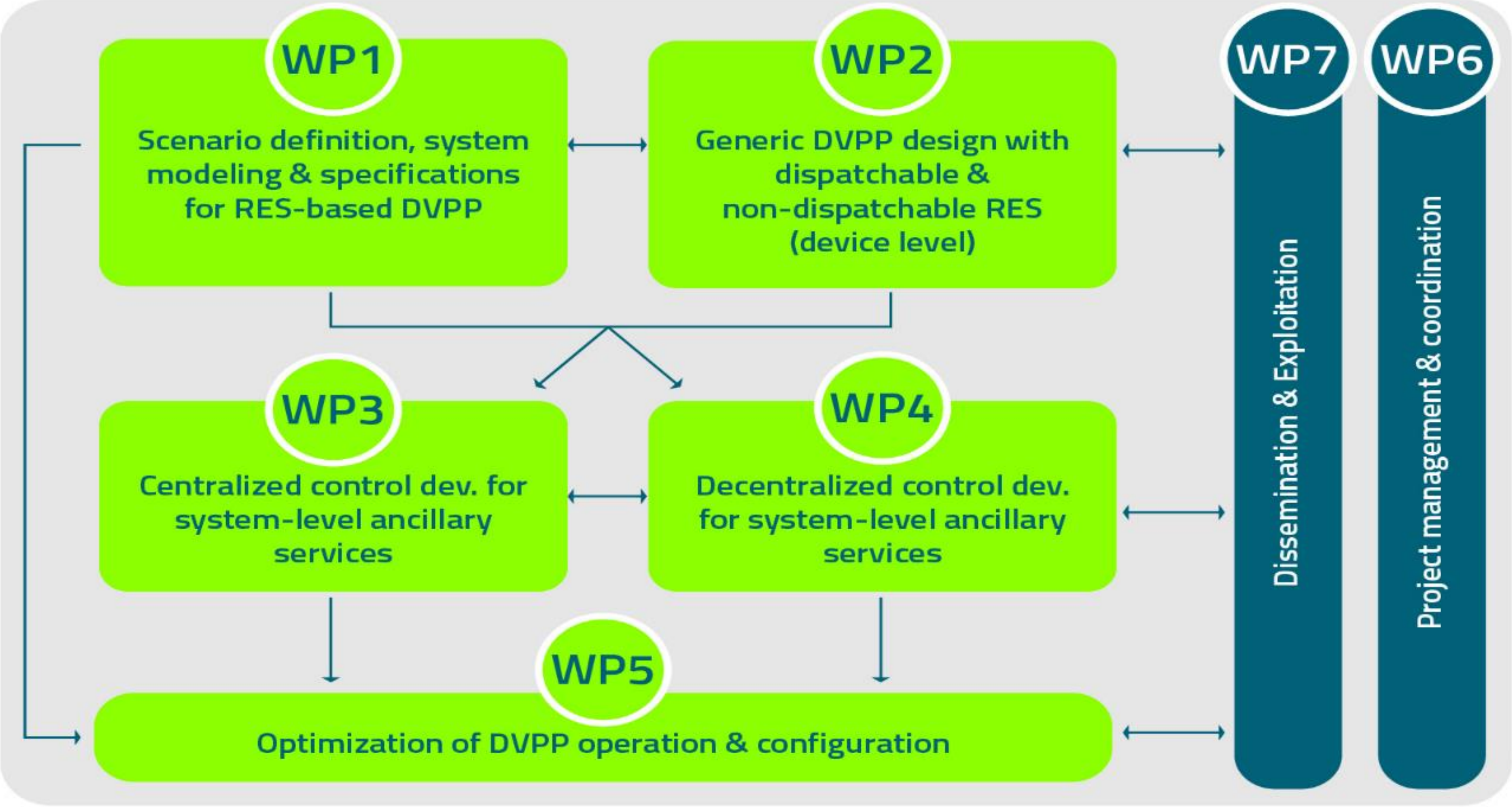
# Consortium

- Combined expertise on power systems, power electronics, automatic control and RES
- Industrial partners include (Transmission System Operators) TSO, (Distribution System Operators) DSO, RES generator, software vendor
- External advisors:
  - Prof. Costas Vournas, NTUA, Athens-Greece
  - WindEurope
  - ESTELA



# Organization



**WP1**
Scenario definition, system modeling & specifications for RES-based DVPP

**WP2**
Generic DVPP design with dispatchable & non-dispatchable RES (device level)

**WP3**
Centralized control dev. for system-level ancillary services

**WP4**
Decentralized control dev. for system-level ancillary services

**WP5**
Optimization of DVPP operation & configuration

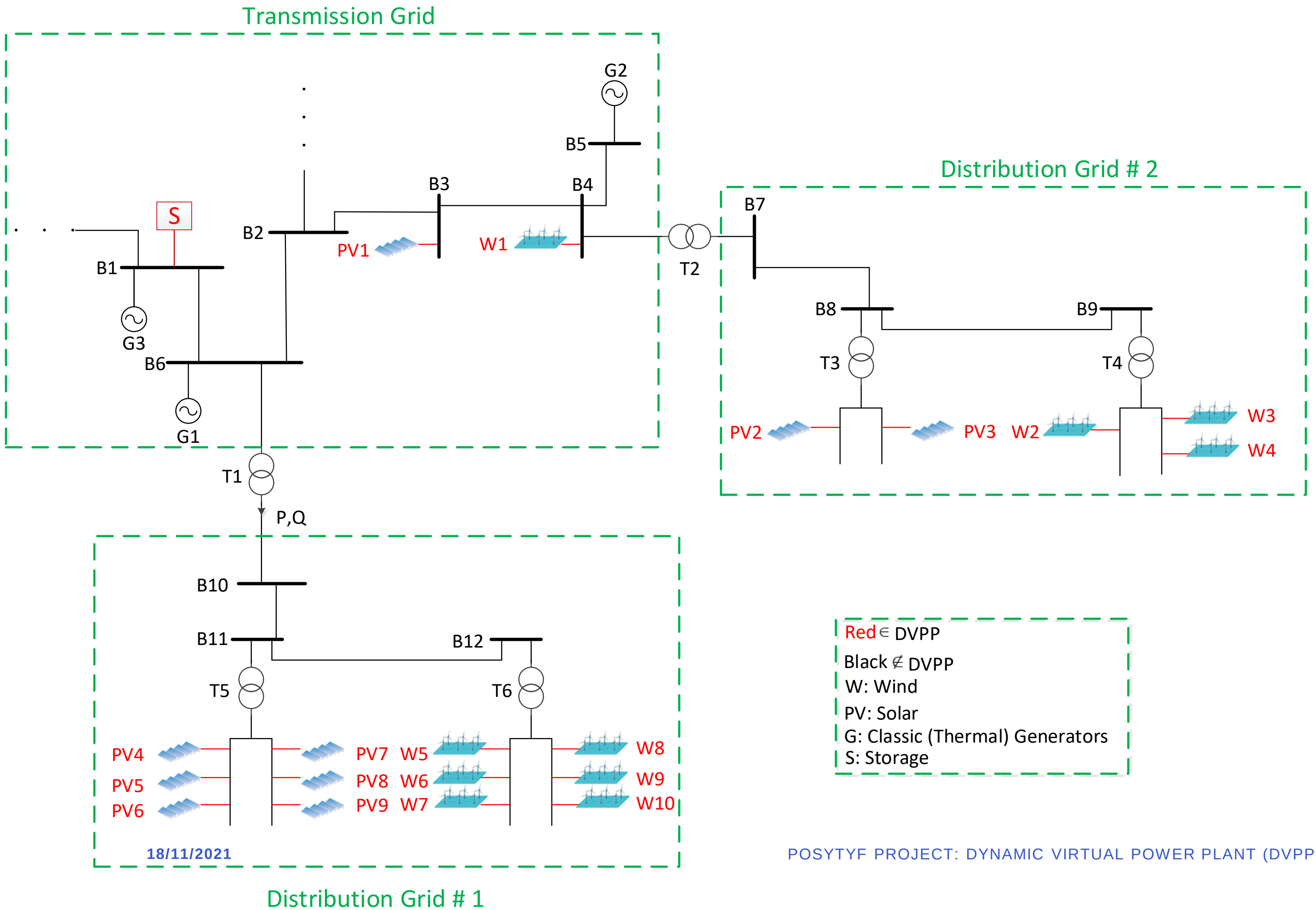
**WP7**
Dissemination & Exploitation

**WP6**
Project management & coordination

# Main scientific & technical issues

- Enable participation of distributed RES to ancillary services
- Manage specificities of decreasing global inertia of the system
- Deal with geographical spread of RES (also imbricated with non-participating entities)
  - Coordination/ centralization/ decentralization
  - Robustness/ disturbance rejection
  - Resilience (variable VPP perimeter)
- Aggregate RES at both transmission and distribution levels
- Address optimization (static & dynamic) at different levels: device / network/ economic standpoint

**DVPP concept/project goal:** Develop methodologies to increase the performance of an integrated portfolio of **dispatchable** and **non dispatchable** RES to operate together as a **Dynamic Virtual Power Plant (DVPP)**, capable of providing flexibility and ancillary services to the energy system.



Red ∈ DVPP
Black ∉ DVPP
W: Wind
PV: Solar
G: Classic (Thermal) Generators
S: Storage

***DVPP specificities:***

- Multiple grid connections
- Transmission & distribution grids
- Imbricated structure
  (participating & non participating generators)
- Dynamic interactions
  - Between DVPP RES generators
  - With the neighbor dynamic elements
- Resilience/plug&play capabilities
- Full participation to secondary regulations
- Actual & future scenarios
  - Intégration in actual operation schemes
  - 100% power electronics

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# WP1 - Tasks

WP1 – Scenario definition, system modelling and specifications for RES-based DVPP

- Task 1.1: Scenario definition
- Task 1.2: General system design
- Task 1.3: Specification definition for actual and future scenarios
- Task 1.4: Role assignment
- Task 1.5: Power system model development and model guidelines
- Task 1.6: Co-simulation

# WP1 - Objectives

### Task 1.1 Scenario definition

Defining scenarios based on the following criteria:

- System topology
  - Isolated
  - Synchronously connected (AC lines)
  - Non-synchronously connected (DC lines)
- One or several DVPPs 100% base on REN
  - Controllable and non-controllable renewables
- Scenarios with different penetrations of PE units
  - Limited penetration of renewables
  - Fully dominated by renewables and power electronics-based units
- Integration of transmission and distribution networks for some scenarios

### Task 1.2 General system design

Based on scenarios defined in T1.1:

- Quantify the size of the elements of the system
  - Installed capacity of power plants
  - Lines capacities
- Based on main economic and production data

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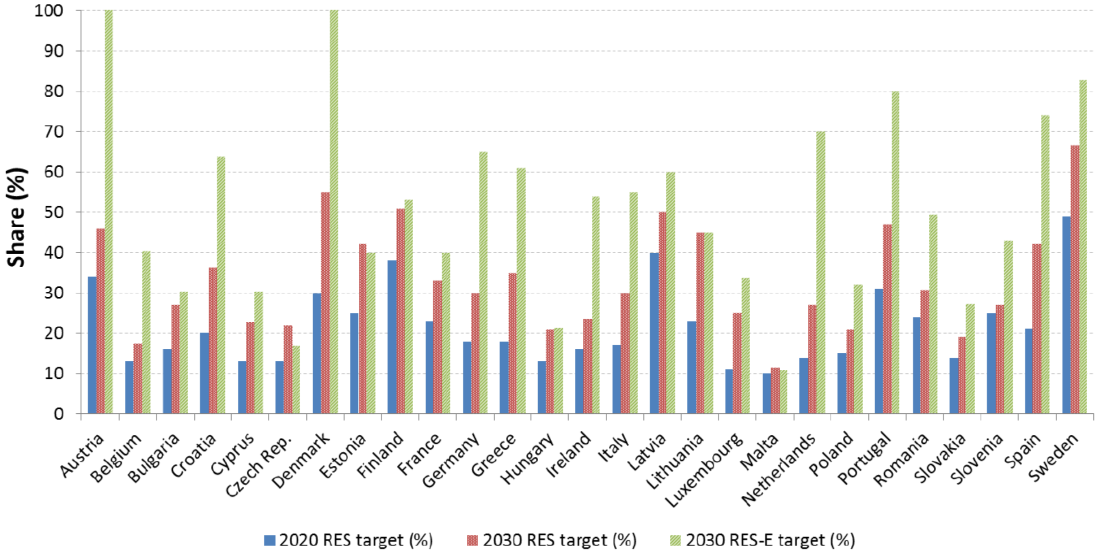
# Background and definitions

**European environmental policies**

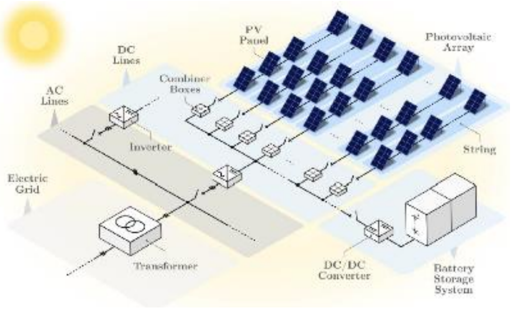
- Horizon 2030:
  - Target for Renewable Energy Sources (RES) at the EU for 2030 of at least 32%
  - Target for final electricity consumption for France (40%) and Germany (65%)
  - Spain 42% of RES share on energy end use
- Horizon 2050: RES share at least 55% in gross final energy consumption

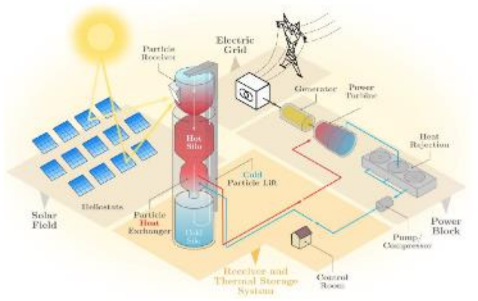


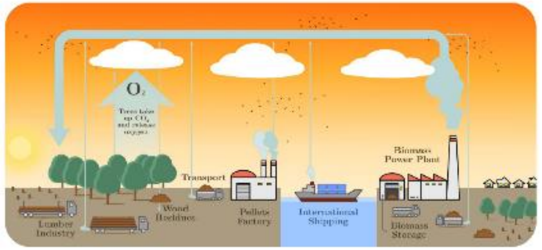
# Generation technologies in a DVPP

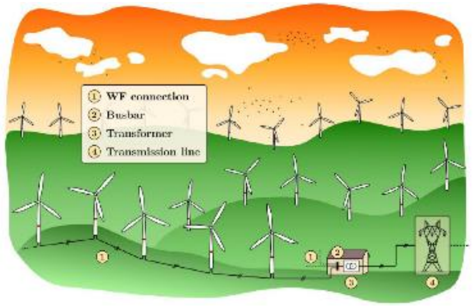
**Main generation technologies that could be part of a DVPP (only renewables):**

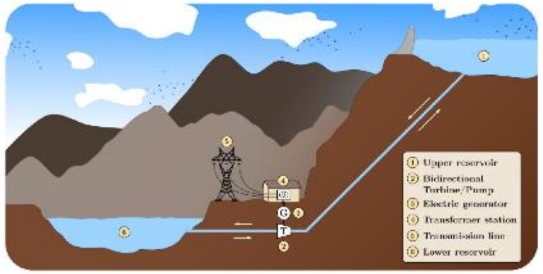
- Solar energy:
  - Photovoltaic
  - Solar thermal
- Wind energy
  - Onshore wind
  - Offshore wind
- Hydropower
- Biomass
- Geothermal
- Non-electrochemical storage
  - Pumped-storage hydropower











# Generation technologies in a DVPP

**Key definitions for analysis and comparison of different technologies**

Technical characteristics:

- Controllability
- Dispatchability
- Response time
- Inherent storage time

Economic characteristics and emissions:

- Levelized cost of electricity (LCOE)
- Capital expenditure (CAPEX)
- Operational expenditure (OPEX)
- Fuel cost
- CO2 Emissions

# Generation technologies in a DVPP

**Key definitions for analysis and comparison of different technologies**

Controllability: capability to store and control the power exchange with the network.

Level definitions:

1. Non-storage capability. The resource defines the power injection to the grid. It can be only curtailed.
2. Limited storage of the converted energy. Example: thermal energy can be stored in solar thermal power plants.
3. Storage of primary energy - Low capacity
4. Storage of primary energy - Medium capacity
5. Storage of primary energy - High capacity

| Technology | Controllability |
|---|---|
| PV | 1 |
| Solar termal | 2 |
| Wind | 1 |
| Hydro | 3 |
| Biomass | 4 |
| Coal | 5 |
| Combined cycle | 5 |
| Nuclear | 5 |
| Pumping hydro | 3 |
| Geothermal | 5 |

# Generation technologies in a DVPP

## Key definitions for analysis and comparison of different technologies

Dispatchability: capability of an electricity generation technology to provide power based on the operation set-point

### Level definitions:

1. The primary energy availability permanently constraints the power output capability.
2. The power can exceed the available resource temporarily (short time-seconds)
3. The power output depends on resource but can be increased by means of a secondary (inherent storage) energy source.
4. No constrains for the output power.
5. Possibility of power reversal

| Technology | Controllability | Dispatchability |
|---|---|---|
| PV | **1** | **1** |
| Solar thermal | 2 | 3 |
| Wind | **1** | 2 |
| Hydro | 3 | 4 |
| Biomass | 4 | 4 |
| Coal | **5** | 4 |
| Combined cycle | **5** | 4 |
| Nuclear | **5** | 4 |
| Pumping hydro | 3 | **5** |
| Geothermal | **5** | 4 |

# Generation technologies in a DVPP

## Key definitions for analysis and comparison of different technologies

| Technology | Controllability | Dispatchability | Response time | Fuel cost | $CO_2$ emissions |
|---|---|---|---|---|---|
| PV | **1** | **1** | **100 ms - 5 s** | **0** | **Very low** |
| Solar thermal | 2 | 3 | 15 min – 4 h | **0** | **Very low** |
| Wind | **1** | 2 | **0.5 ms - 1 s** | **0** | **Very low** |
| Hydro | 3 | 4 | 2 - 5 min | **0** | **Very low** |
| Biomass | 4 | 4 | 10 min – 6 h | **High** | Medium |
| Coal | **5** | 4 | 80 min - 8 h | **High** | **High** |
| Combined cycle | **5** | 4 | 5 min – 3 h | **High** | Medium |
| Nuclear | **5** | 4 | **~24 h** | Low | **Very low** |
| Pumping hydro | 3 | **5** | 2 - 5 min | **0** | **Very low** |
| Geothermal | **5** | 4 | 30 s – 2 min | **0** | **Very low** |

# Generation technologies in a DVPP

## Summary of technical characteristics

| Technology | Response time | Inherent storage time | Controllability | Dispatchability |
|---|---|---|---|---|
| PV | 100 ms – 5 s | 0 | 1 | 1 |
| Solar thermal | 15 min – 4 h | 0 – 24 h | 2 | 3 |
| Wind | 0.5 ms – 1 s | 0 | 1 | 2 |

## Summary of costs and emissions

| Technology | LCOE [$/kWh] | CAPEX [$/kW] | OPEX [$/kW] | Fuel cost | $CO_2$ em. [$g_{eq}$/kWh] |
|---|---|---|---|---|---|
| PV | 0.029 – 0.042 | 1313 | 15.25 | 0 | 18 - 180 |
| Solar termal | 0.126 – 0.156 | 7221 | 85.4 | 0 | 9 - 63 |
| Wind | 0.026 – 0.054 | 1265 | 26.34 | 0 | 8 - 40 |

Full data in Deliverable 1.1: https://posytyf-h2020.eu/english-version/deliverables-1

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# Scenario definition

Defining preliminary scenarios based on the following criteria:

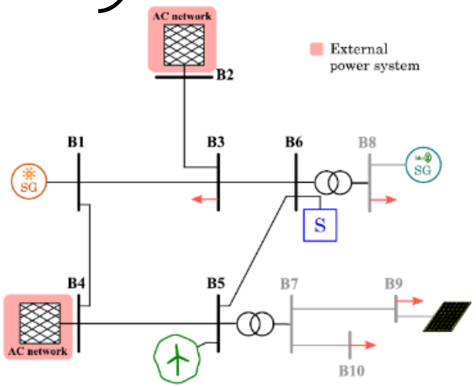
- Three grid configurations:
  - Isolated
  - AC interconnected
  - DC interconnected
- Distribution grid: yes/no
- Presence of conventional generation: yes/no
- Non-chemical storage: yes/no

## 24 preliminary scenarios

| Type | Distribution | Conv. thermal synchronous generation | Storage | **Scenario** |
|---|---|---|---|---|
| Type I: isolated | YES | YES | YES | **1** |
| | | | NO | **2** |
| | | NO | YES | **3** |
| | | | NO | **4** |
| | NO | YES | YES | **5** |
| | | | NO | **6** |
| | | NO | YES | **7** |
| | | | NO | **8** |
| Type II: AC interconnected | YES | YES | YES | **9** |
| | | | NO | **10** |
| | | NO | YES | **11** |
| | | | NO | **12** |
| | NO | YES | YES | **13** |
| | | | NO | **14** |
| | | NO | YES | **15** |
| | | | NO | **16** |
| Type III: DC interconnected | YES | YES | YES | **17** |
| | | | NO | **18** |
| | | NO | YES | **19** |
| | | | NO | **10** |
| | NO | YES | YES | **21** |
| | | | NO | **22** |
| | | NO | YES | **23** |
| | | | NO | **24** |

### Example: scenario 11

- AC interconnected
- Distribution
- No conventional generation
- Storage



# Scenario definition

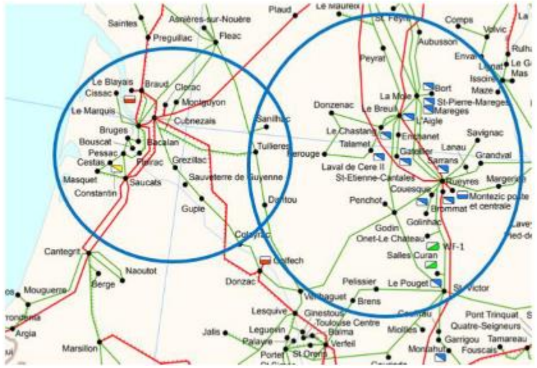
Identify real locations where the DVPP scenarios can be inspired on:

- Based on types I, II and III
- Locations restricted to Europe
- Relevant amount of renewable resources (currently or potentially)

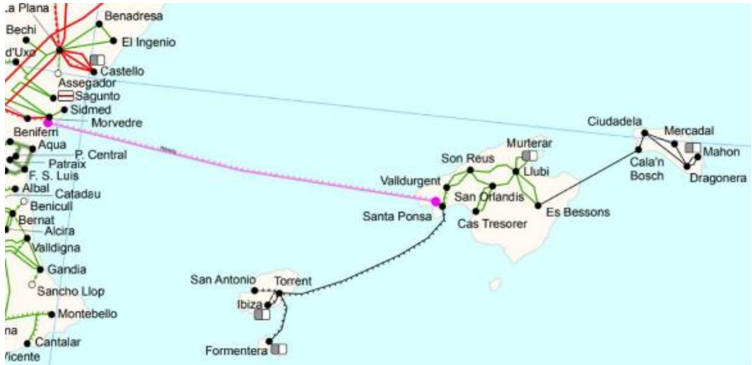
Examples:

Isolated
Gran Canaria (Spain)

AC interconnected
Central-west France



DC interconnected
Balearic islands (Spain)



# Scenario definition

**Selection of realistic scenarios:**

Type I: isolated

- Small islands, simpler than continental scenarios
- Low number of buses (in this case, 7)
- Single voltage level

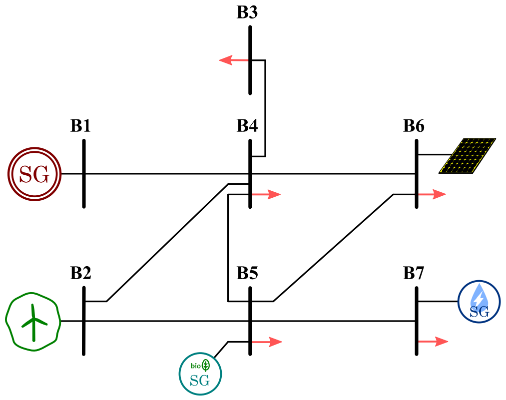
Type II: AC interconnected

- Most systems are AC interconnected systems
- Typically bigger and more meshed
- Higher number of buses (in this case, 13)
- Different voltage levels (transmission and distribution)

Type III: DC interconnected

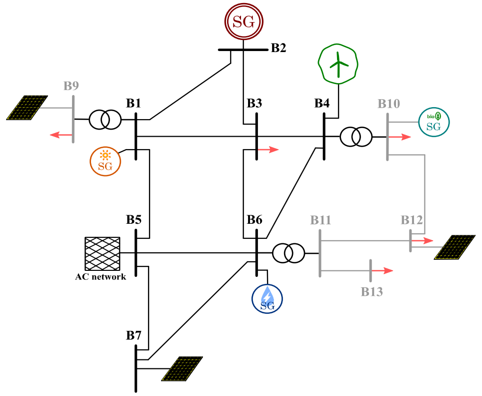
- They typically correspond to bigger islands
- Grid layout considered is slightly more complex than Type I
- Higher number of buses as compared to Type I (in this case, 11)
- Also, different voltage levels are also considered in this case

1. Isolated

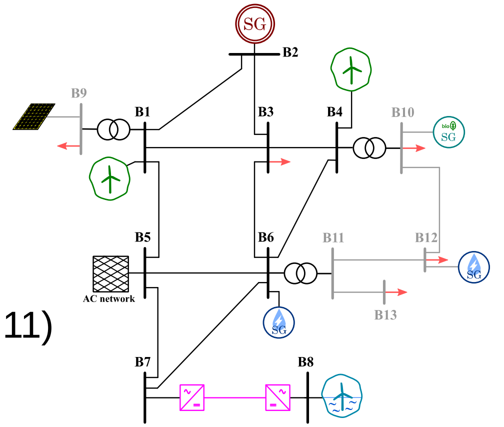


2. AC interconnected

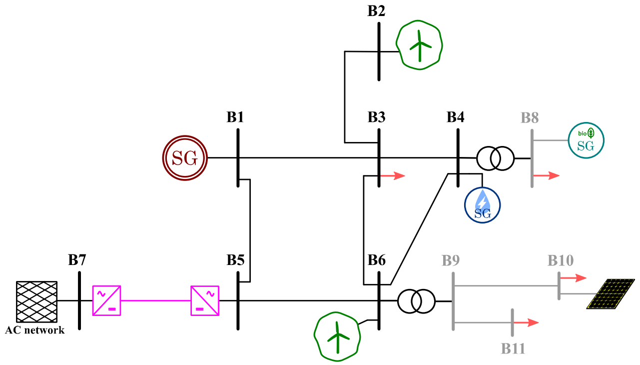
Southern Europe



3. AC interconnected
Northern Europe



4. DC interconnected



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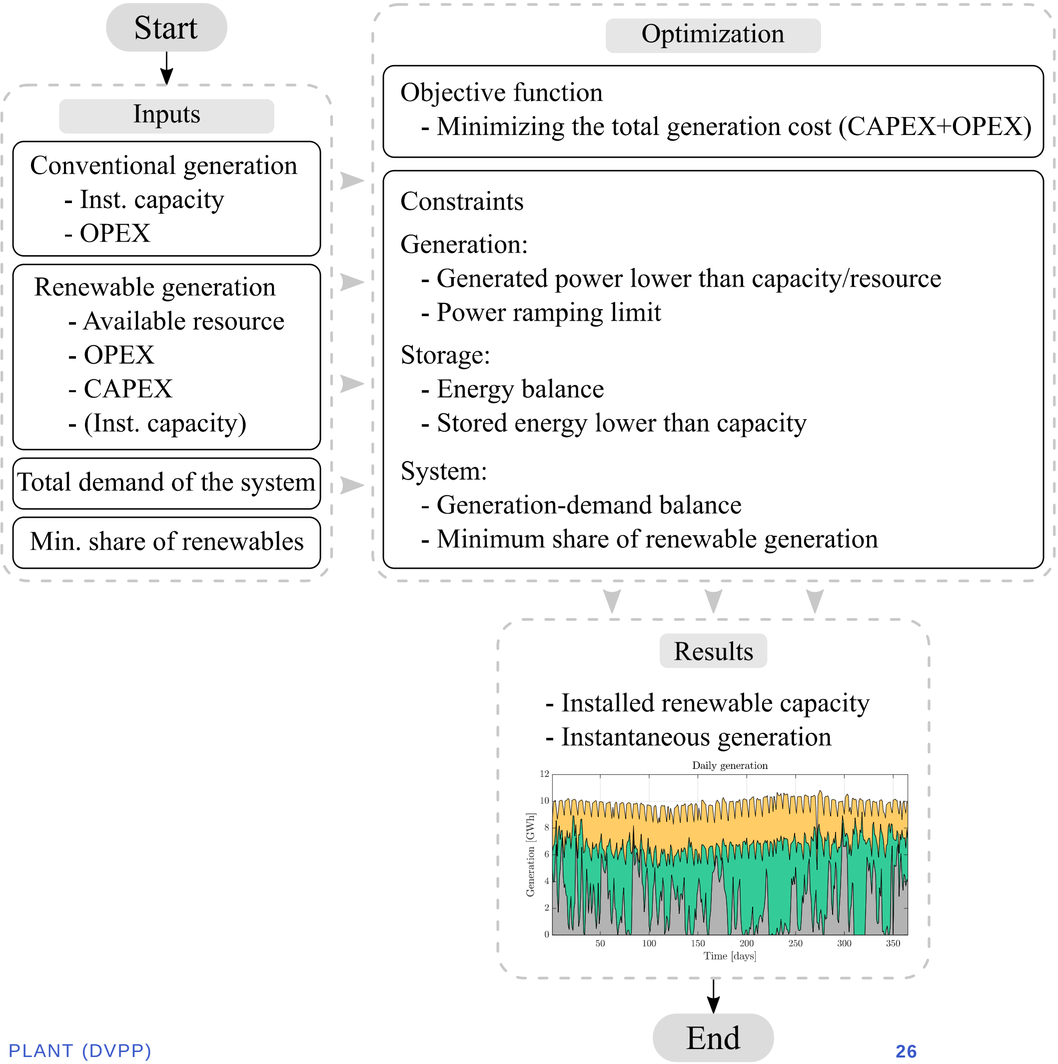
# Sizing of scenarios

Methodology based on an optimization of the generation costs

- Conventional generation is assumed to be installed
- Grid constraints have not been considered
- Outputs:
  - RES installed capacity (grouped by technology)
  - Instantaneous generation for every technology



Start

Inputs

Conventional generation
- Inst. capacity
- OPEX

Renewable generation
- Available resource
- OPEX
- CAPEX
- (Inst. capacity)

Total demand of the system

Min. share of renewables

Optimization

Objective function
- Minimizing the total generation cost (CAPEX+OPEX)

Constraints

Generation:
- Generated power lower than capacity/resource
- Power ramping limit

Storage:
- Energy balance
- Stored energy lower than capacity

System:
- Generation-demand balance
- Minimum share of renewable generation

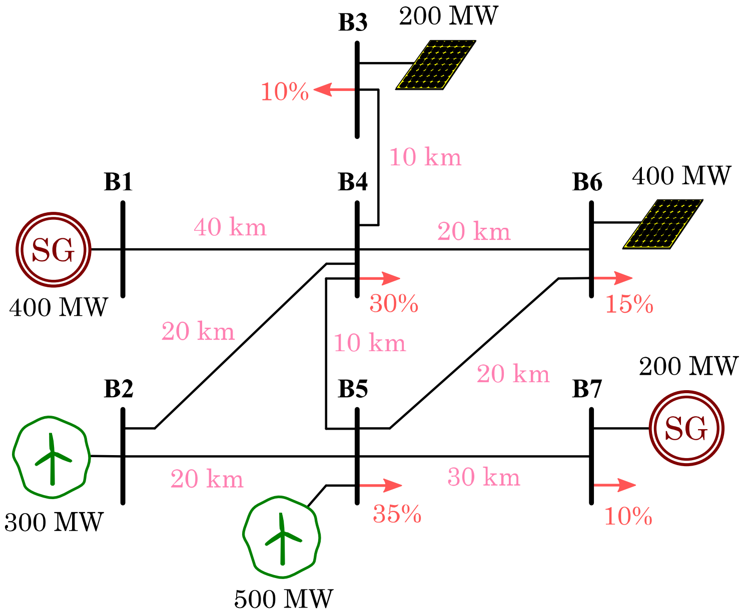
Results
- Installed renewable capacity
- Instantaneous generation

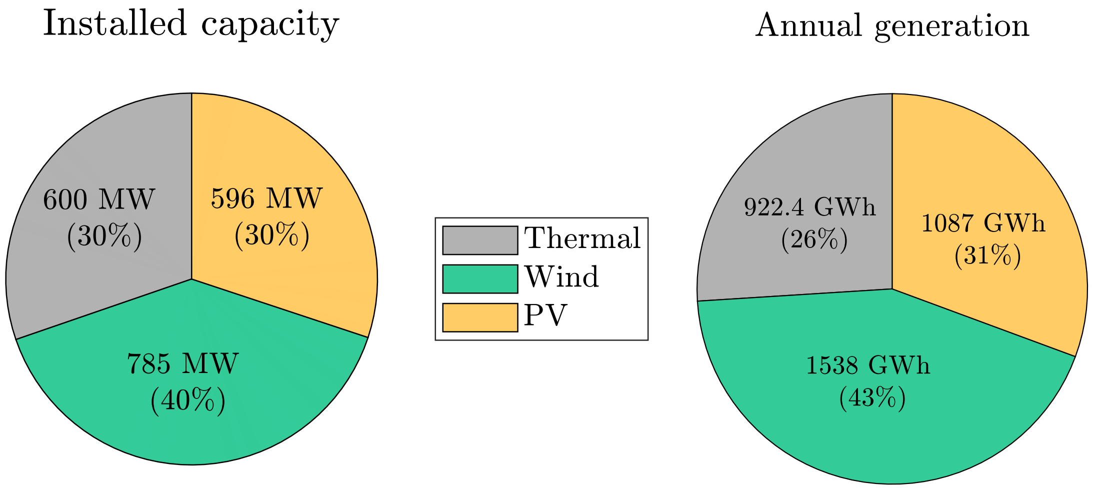
End

# Sizing of scenarios

**Scenario 1: Type I – Isolated without storage**

- Demand and wind and solar resource data: Tenerife 2019
  - Maximum demand: 552 MW
- Min. share of renewables: 74% (Spain's goal for 2030)





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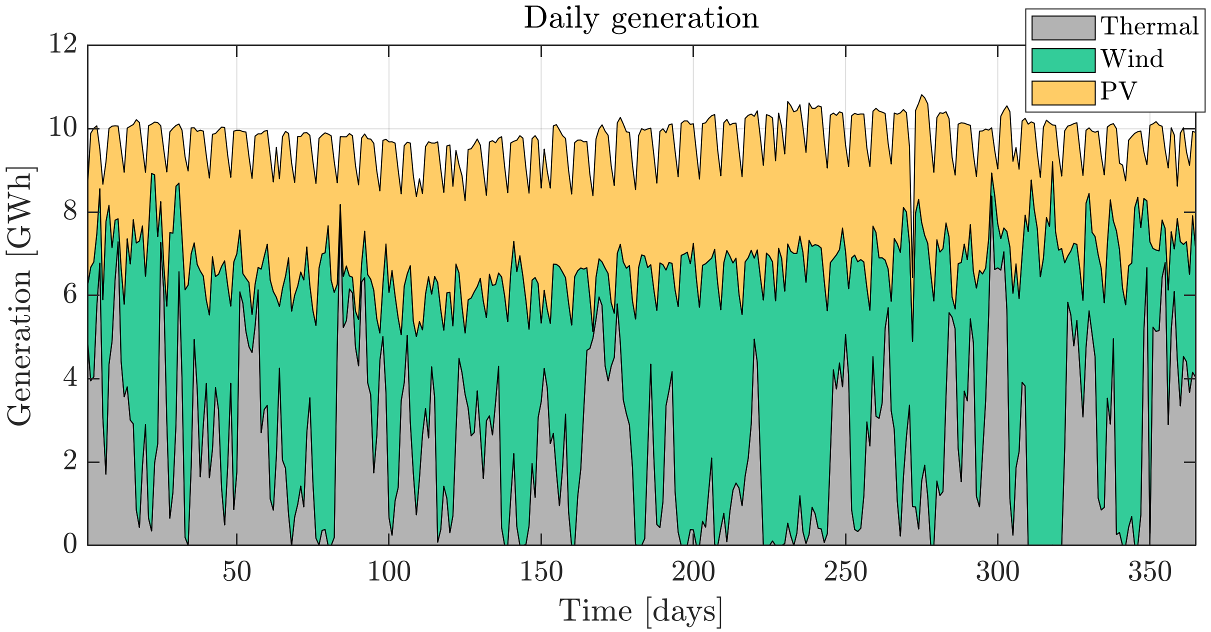
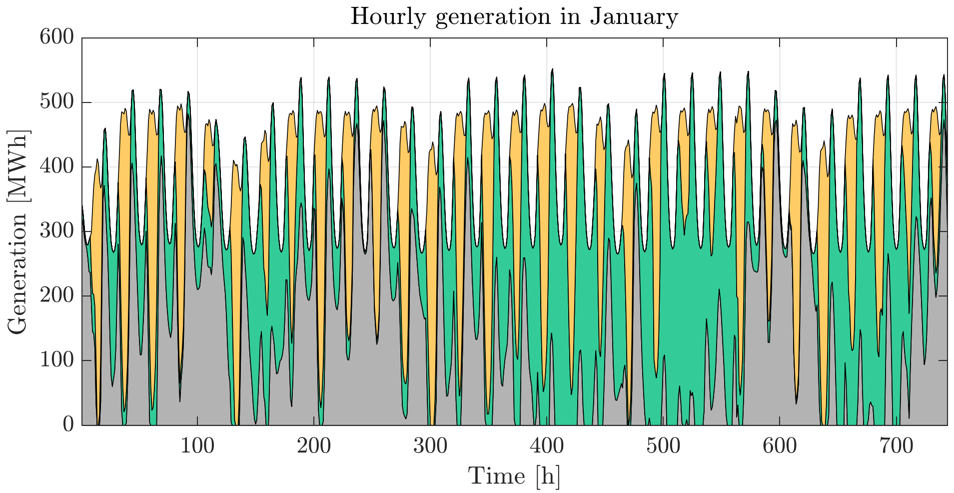
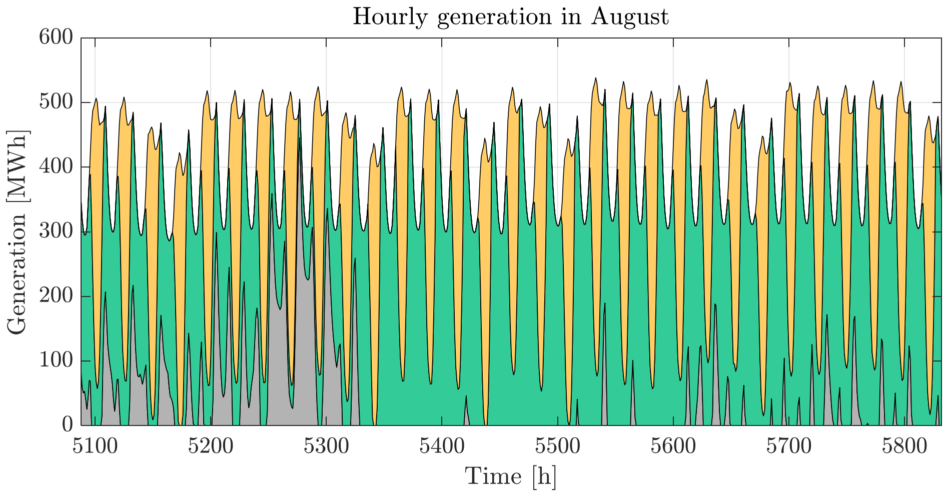


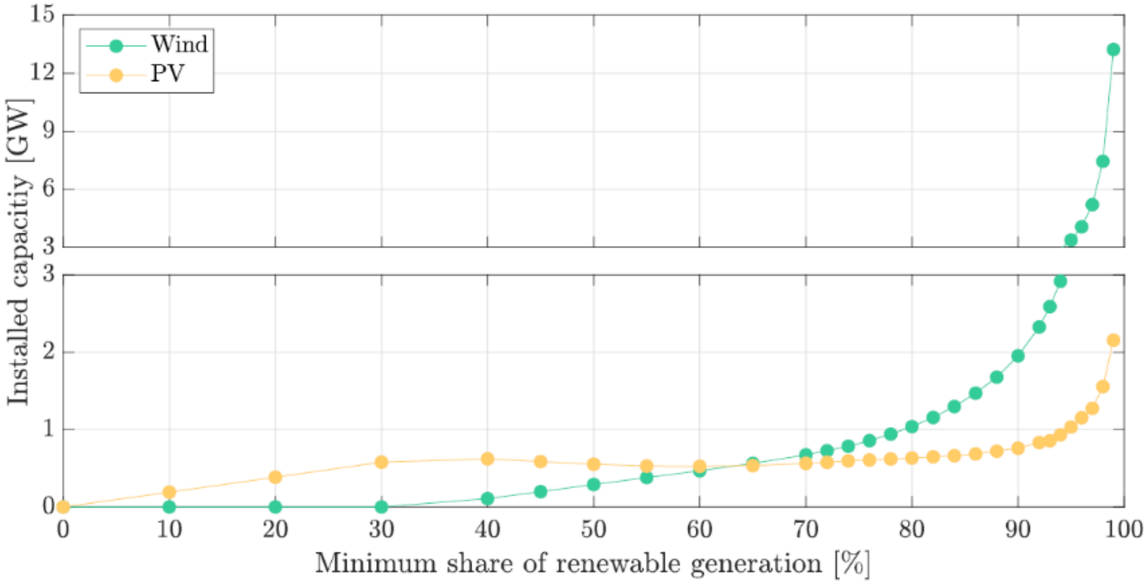




# Sizing of scenarios

**Scenario 1: Type I – Isolated without storage**

- Maximum demand: 552 MW
- Variation of the minimum share of RES (α)
  - Evolution of the wind and PV installed capacity
    - Exponential curve
    - The installed capacity for α > 90% is excessively high



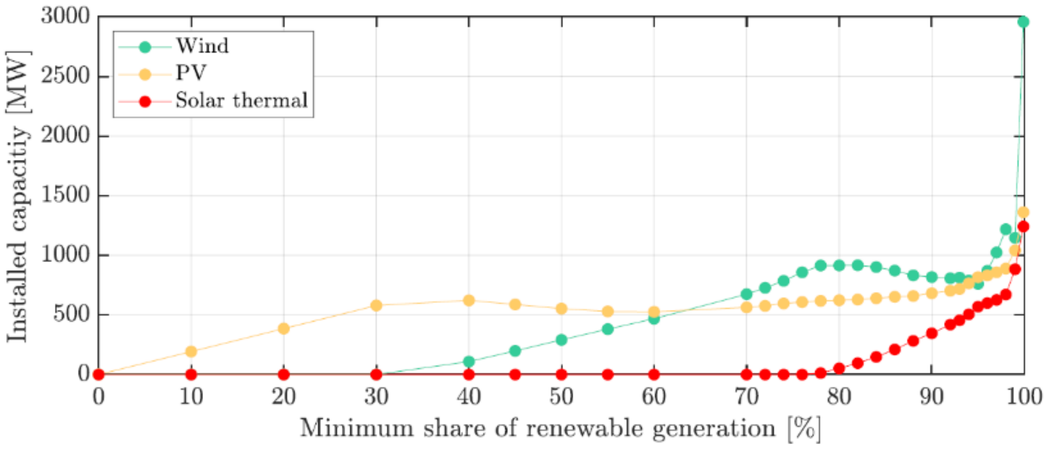
Additional flexibility for the system is needed to avoid the cost increase

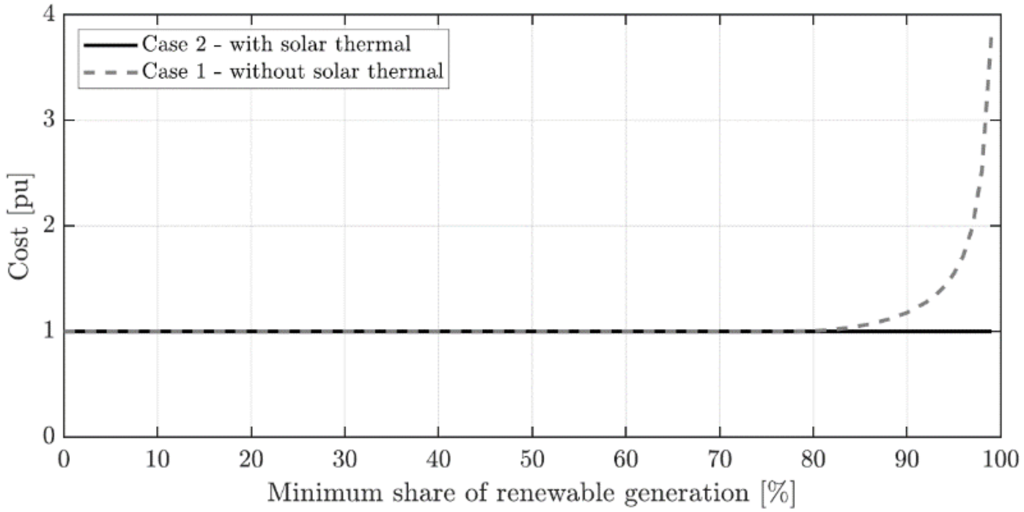
# Sizing of scenarios

**Scenario 2: Type I – Isolated with storage**

- Maximum demand: 552 MW
- Introduction of solar thermal power plant
  - Inherent storage (8 h), which provides some flexibility
- Variation of the minimum share of RES (α)
  - Solar thermal is only optimal for high values of α (>80%)
  - The solar thermal storage help to reduce the RES installed capacity

The storage of the solar thermal power plant can lead to a reduction of the generation costs for high penetration of RES

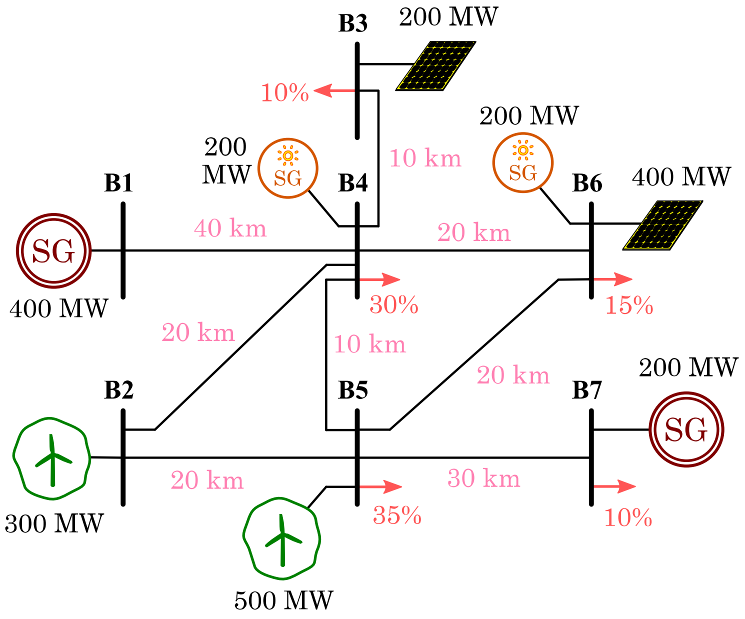


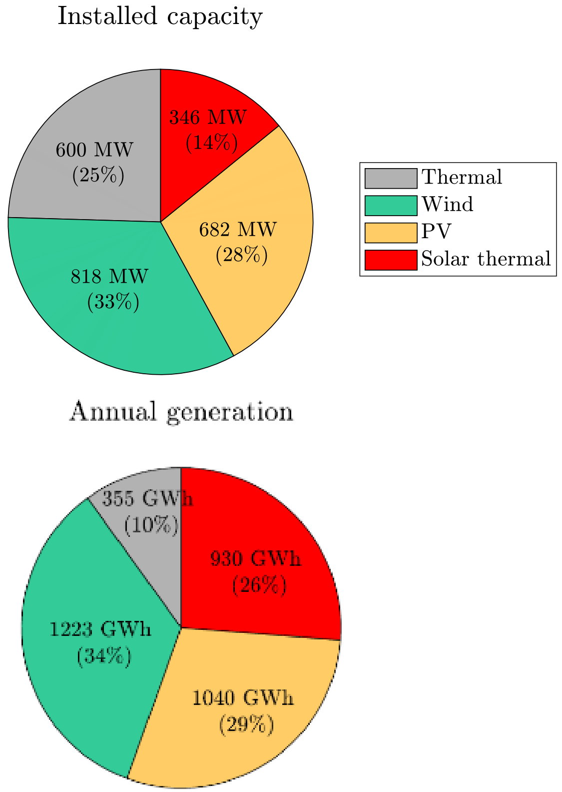


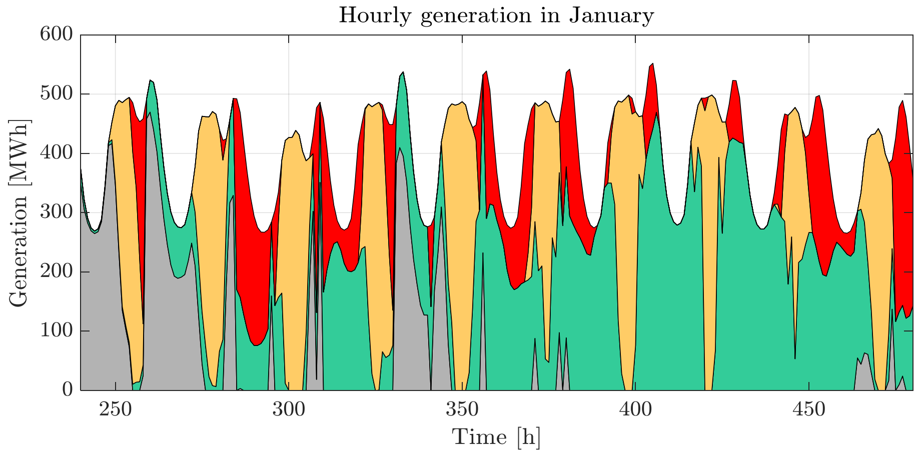
# Sizing of scenarios

### Scenario 2: Type I – Isolated with storage

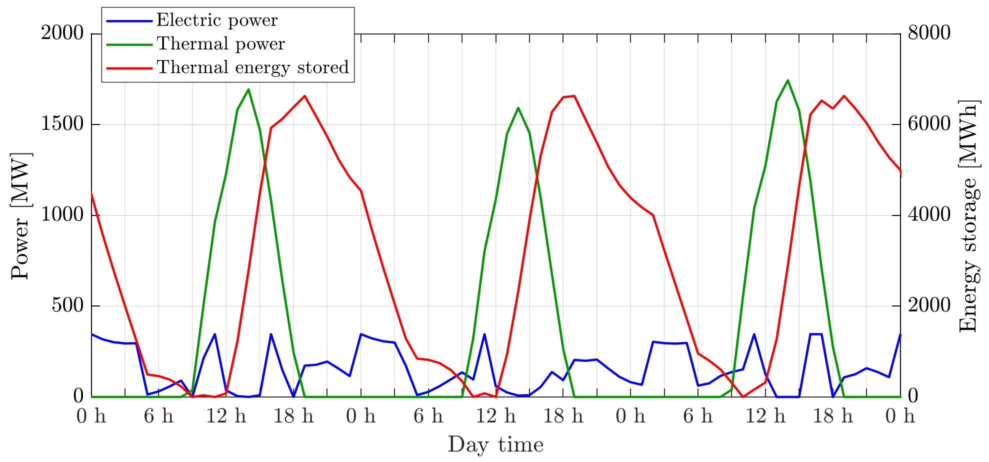
- Demand and wind and solar resource data: Tenerife 2019
  - Maximum demand: 552 MW
- Min. share of renewables: 90%







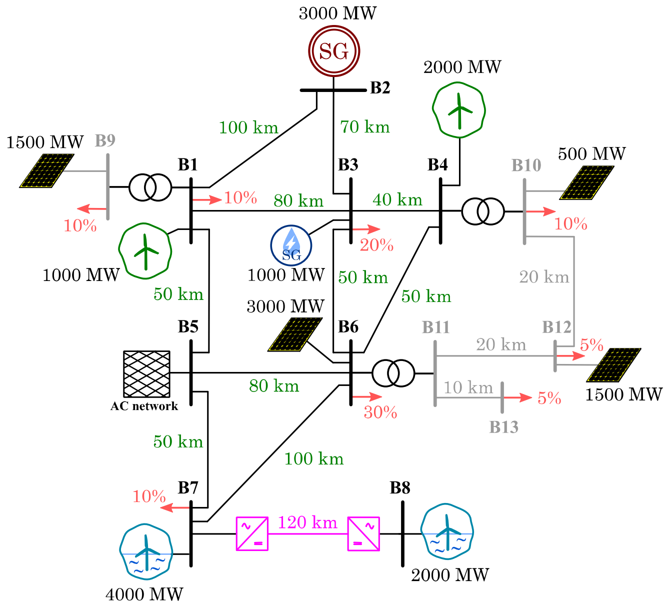
Performance of the solar thermal power plant

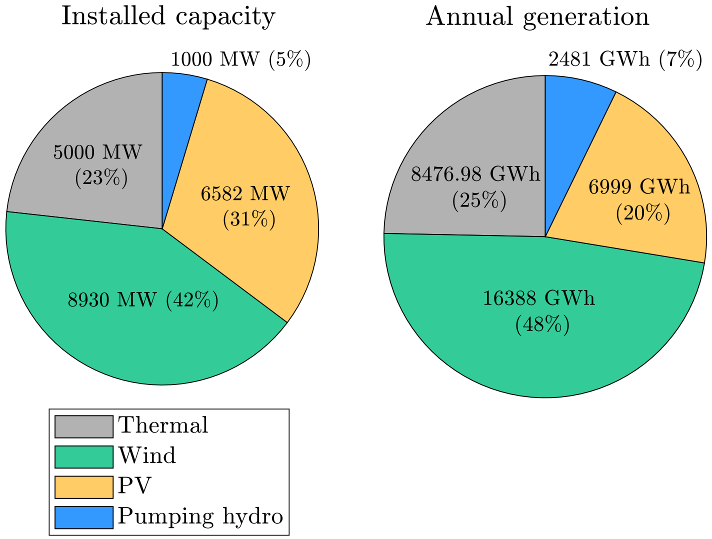


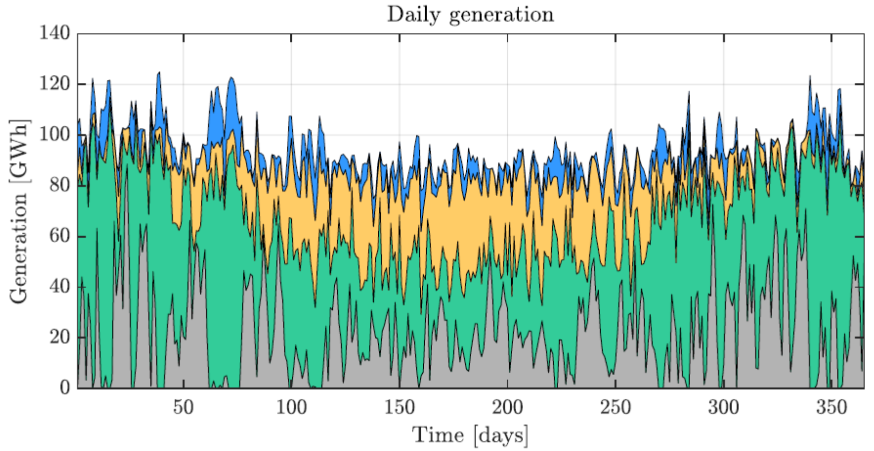
# Sizing of scenarios

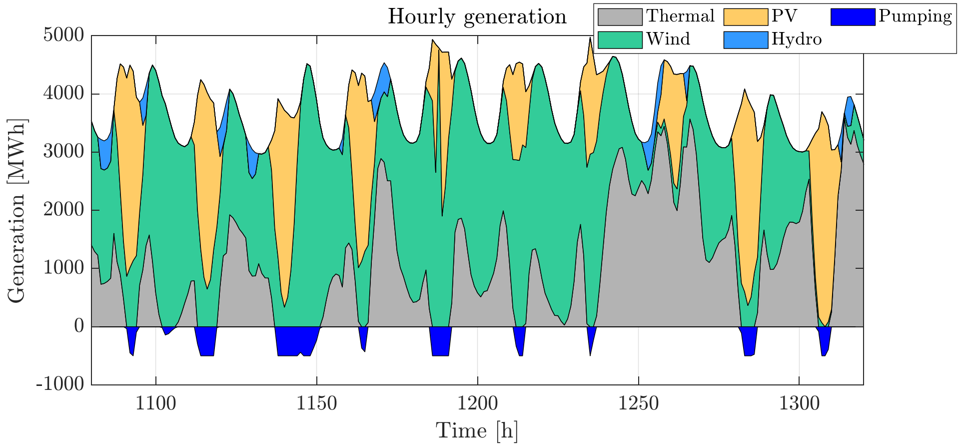
### Scenario 3: Type II – AC interconnected – Northern Europe

- Demand and wind and solar resource data: Netherlands 2019
  - Maximum demand: 5000 MW (scaled)
- Min. share of renewables: 74%
- Case 3:









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# Conclusions

In this Deliverable D1.1 of POSYTYF project:

- Realistic scenarios for the analysis of virtual power plants are provided
  - Inspired in real data of consumption and resources
  - Non-real systems
  - Based on a cost optimization methodology
- Different renewable energy technologies have been considered to meet specific requirements up to 100% of renewables

Solar PV and wind:

- Can provide the renewable backbone
- but they lack the flexibility needed to achieve a very high penetration

Solar thermal and pumped hydro:

- Can become important to cover the last range of integration
- Storage provides flexibility
- Too expensive for low penetration

# For more information….

www.posytyf-h2020.eu

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POSYTYF position paper: https://arxiv.org/abs/2108.00153

*Dynamic Virtual Power Plant: A New Concept for Grid Integration of Renewable Energy Sources*

**… and more webinars in 2022!**

# Webinar Q&A – POSYTYF project: Definition and specification of Dynamic Virtual Power Plant (DVPP) scenarios

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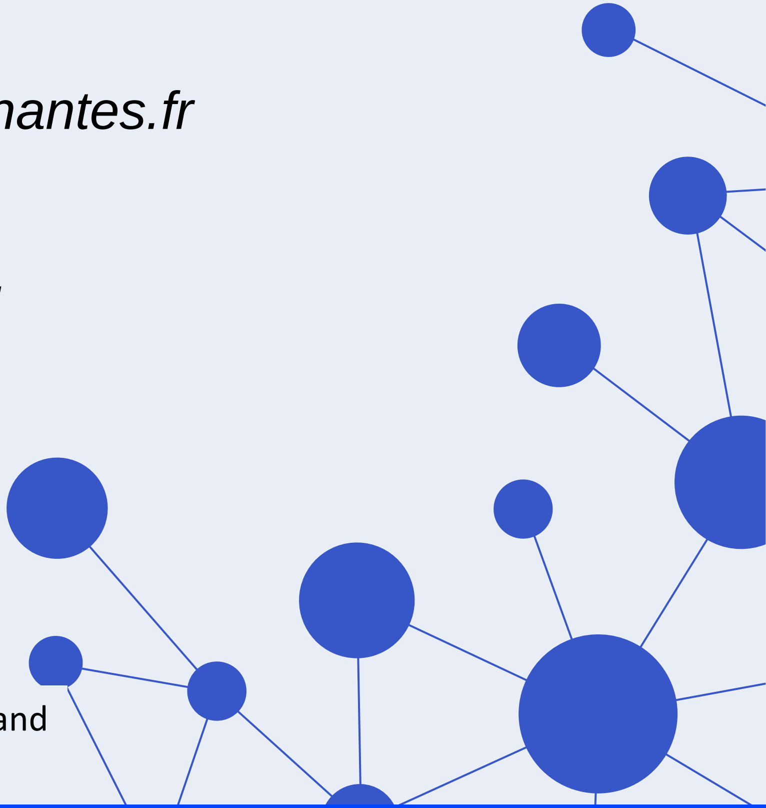

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