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# STE Can Replace Coal, Nuclear and nearly Gas as Demonstrated in an Hourly Simulation over 4 Years in the Spanish Electricity Mix


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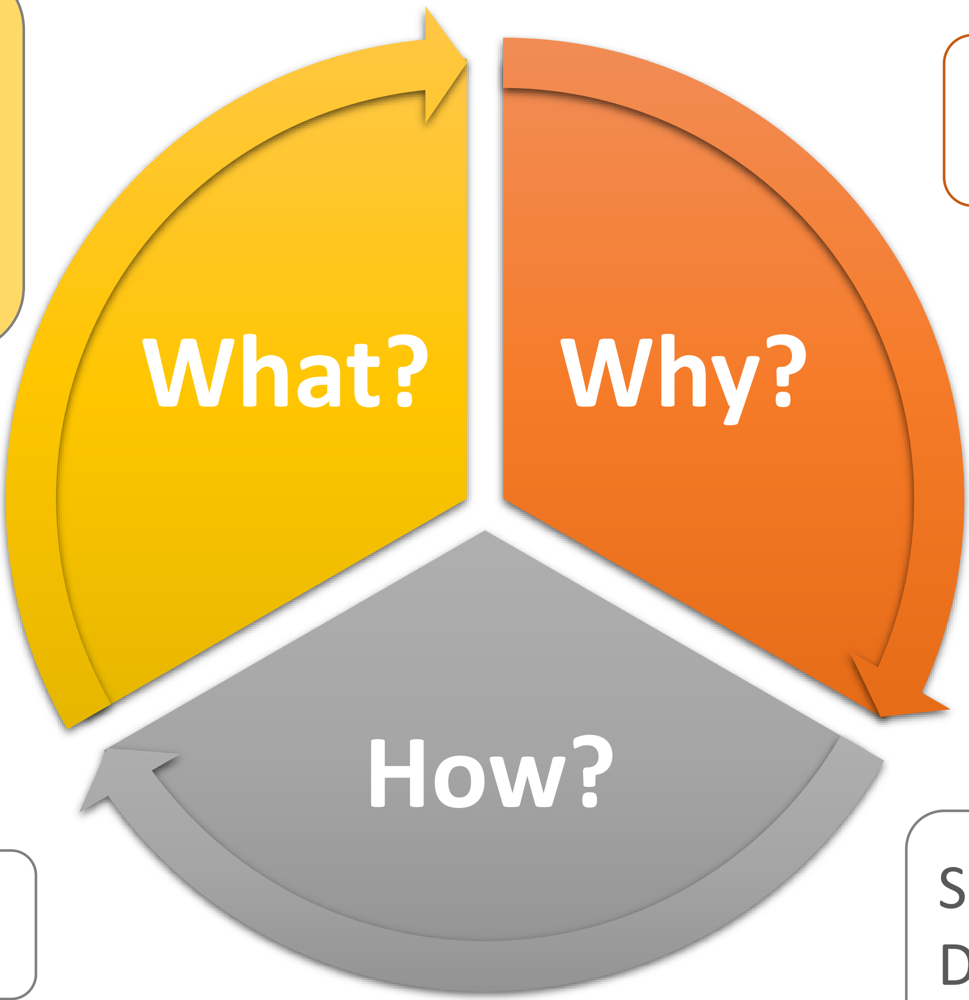
*Session 3-D: Policy & Marketing*

# Agenda

Demonstration that STE, smartly blended with other RES, can replace Coal, Nuclear and nearly Gas




Energy Political Context in Europe & Spain

Report Methodology

Spanish Electricity Mix Raw Data & Envisioned STE Role

# Political Context in Spain: Energy Transition towards being compliant with EU RES targets

Why?

Experts Committee Report:
*Recommendations for the decarbonization of the Spanish Energy Sector – (ExpCom)*

**STE / CSP: no ad. Capacity**

Motion of censure
Government Change

Integrated National Energy and Climate Plans

2030 EU RES TARGET = **30%** final energy consumption | 2030 EU RES TARGET = **32%** final energy cons.

**July 2017** — **April 2018** — **June 2018** — **December 2018**

Experts Committee Formation: 14 prestigious energy experts who were chosen by different political parties and unions

Base document to be followed in the Energy Transition Law

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*Demonstrate that STE/CSP shall be considered in the path towards the descarbonization of the electrical system in Spain*


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# Why hadn't been additional STE/CSP capacity considered by the Experts Committee?

Why?

Experts Committee Report *(ExpCom)*: *Recommendations for the decarbonization of the Spanish Energy Sector*

**STE / CSP: no ad. Capacity**

**Use of capacity expansion models**

MASTER SO
ENTSOE

**Optimization Criteria**

- Minimize generation costs
  - PV and Wind → chosen technologies

**Drawbacks:**

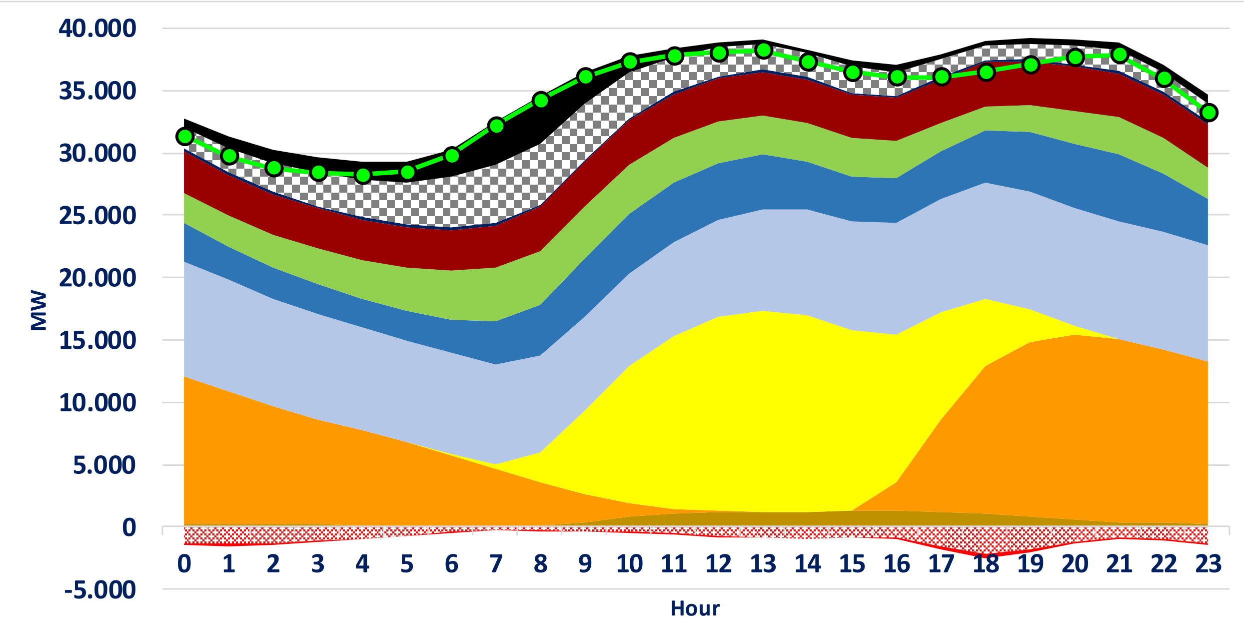
- Do not prioritize decarbonization
- End up with unfeasible generation fleet, both from technical and investor points of view
- Do not understand the dispatch flexibility of some renewables like STE or biomass
- The generation costs considered for STE plants were not updated

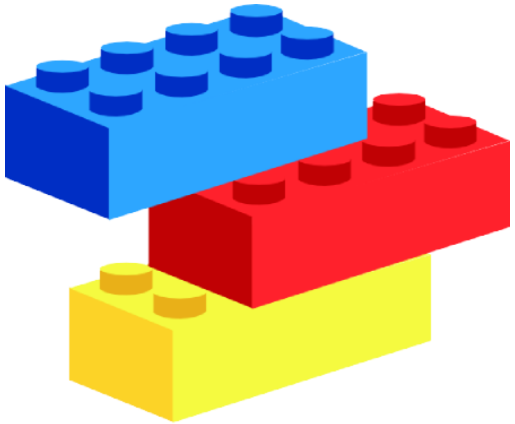
**We needed a different approach! Fast, robust and reliable allowing to show quantitatively STE / CSP value proposition**

# Fundamental principles: The distinct characteristics of the renewable generation technologies

How?

- ❑ **Satisfying the demand at any time is about putting together the appropriate generation units**
- ❑ The goal of planning is
  - To achieve a carbon free generation system
  - To ensure quality of supply and grid stability
  - At an affordable cost (not minimum)



- ✓ **Wind and Sun will be the pillars of electricity** generation in the future
  Big hydro and biomass will also contribute with dispatch capabilities
- ✓ But **Wind Parks and PV plants deliver only when the resource is available** and they have seasonal and hourly constraints.
- ✓ The **right generation pieces** should be put together **to satisfy the demand in the optimum way**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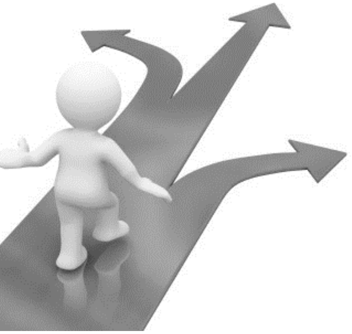
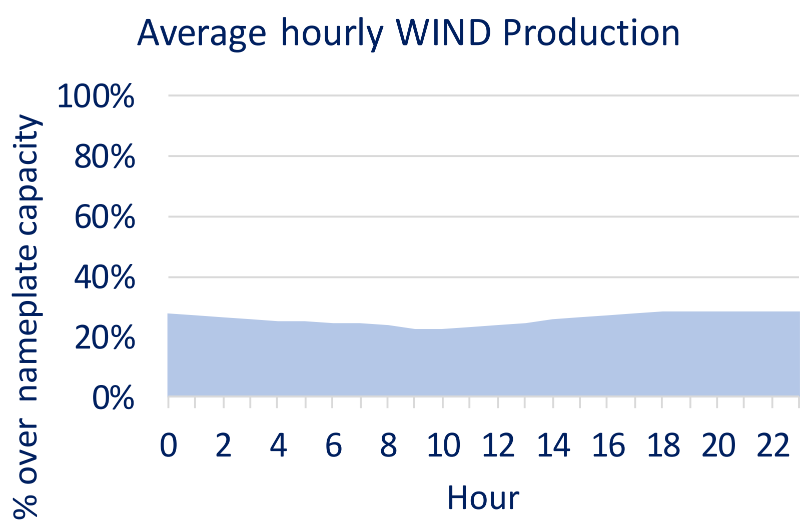
# Envisioned STE role: understanding which dispatch profile better suits in the future electrical system

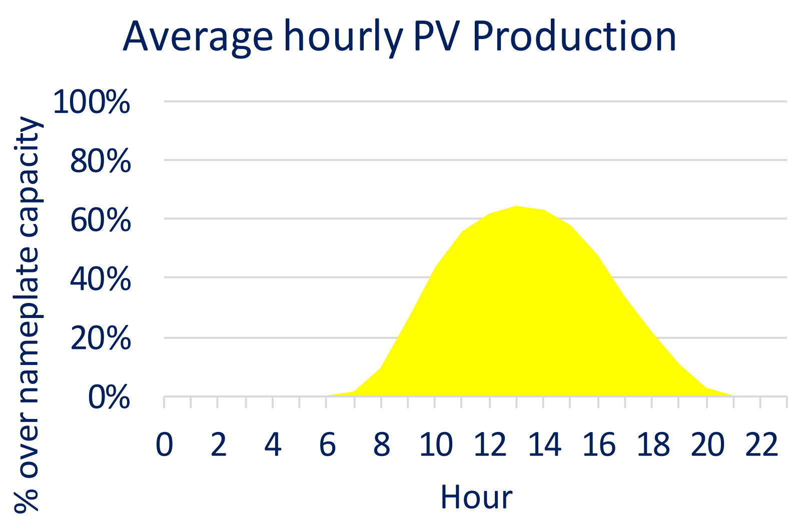
How?



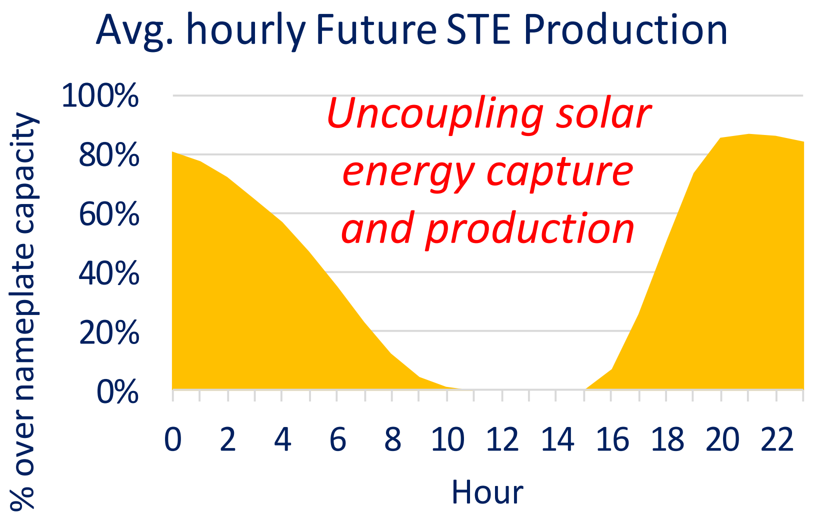
1. Build up a database with actual hourly data of the Spanish electrical system broken down by energy source along 4 years (2014-2017) → Matrix 35.064 hours x 12 columns (demand, existing solar thermal, solar photovoltaic, wind, hydropower, pumping, biomass & biogas, cogeneration, non-renewable waste, import, export, combined cycles). (Source: REE, Spanish TSO)

2. Hourly Analysis of Variable RES dispatch profile over this period




We need something else…




Envisioned STE Role for future plants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# Methodology: Building up 4 potential hourly scenarios for 2030

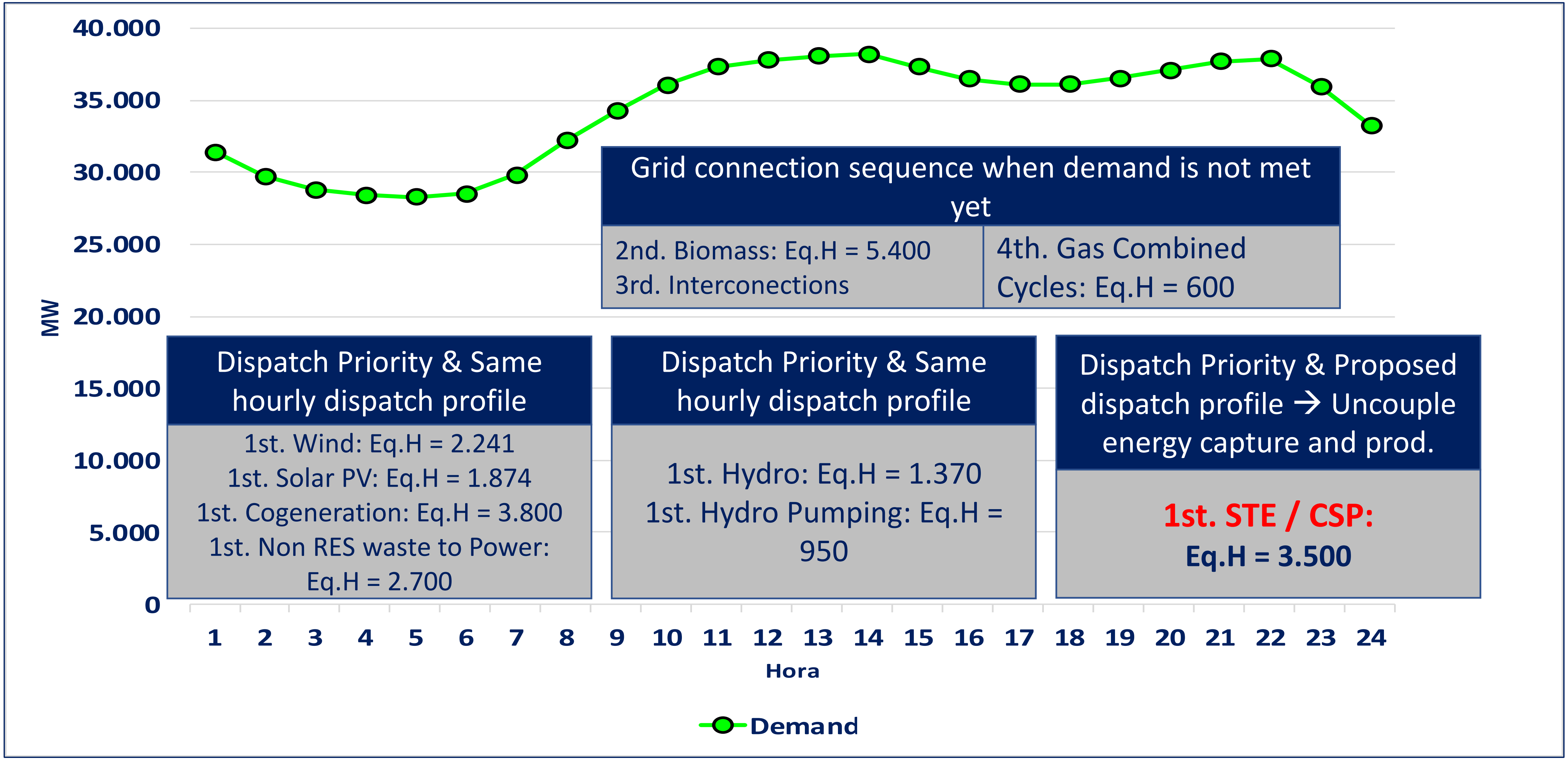
How?

| INPUTS | ASSUMPTIONS | OUTCOME |
|---|---|---|
| Generation data of all technologies in previous years<br><br>Takes into account **actual meteorological conditions in Spain along 4 years.** Sun, wind and water potential is hourly shown in this matrix<br><br>Matrix 35.064 x 12 = 420.768 hourly data of 2014, 2015, 2016, 2017 | **Proposed fleet in 2030**<br>• Same Total RES installed capacity than Exp.Com Report<br><br>**Demand forecast by 2030**<br>• Same 2030 Spanish expected demand than Exp.Com Report<br>• Same demand profile for 2030 than the actual ones for the analyzed period<br><br>**Future STE plants dispatch profile**<br>• Similar to DEWA Project | What if 2030 is like either 2014 (2030'14), 2015 (2030'15), 2016(2030'16) or 2017(2030'17) regarding renewable resources, or the average of them (2030'M)?<br><br>✓ How much backup is required?<br>✓ Which is the generation cost?<br>✓ Which is the electrical system emissions level?<br><br>Matrix 35.064 x 13 = 455.832 hourly data of 2030'14,15,16,17 |

# Methodology: Proposed sequence for meeting demand needs.

**TSO should maximize the reduction of $CO_2$ emissions**

How?



# Methodology: STE/CSP & PV Complementarity.

## Avoiding overlapping with PV at full capacity

How?

STE/CSP 3.500 Eq.H dispatch profile

STE

| Month/Hour | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | Total Monthly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7% | 4% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 9% | 13% | 14% | 14% | 13% | 11% | 9% | 100% |
| 2 | 7% | 5% | 3% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 8% | 12% | 13% | 13% | 12% | 11% | 9% | 100% |
| 3 | 8% | 8% | 7% | 6% | 5% | 3% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 5% | 8% | 9% | 10% | 9% | 9% | 9% | 100% |
| 4 | 8% | 8% | 7% | 7% | 6% | 5% | 4% | 3% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 4% | 7% | 9% | 9% | 9% | 9% | 100% |
| 5 | 8% | 8% | 8% | 7% | 7% | 6% | 5% | 3% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 4% | 6% | 8% | 8% | 8% | 8% | 100% |
| 6 | 7% | 7% | 6% | 6% | 6% | 6% | 5% | 5% | 4% | 3% | 2% | 1% | 0% | 0% | 0% | 0% | 1% | 3% | 5% | 6% | 7% | 7% | 7% | 7% | 100% |
| 7 | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 6% | 5% | 4% | 2% | 1% | 0% | 0% | 0% | 0% | 1% | 3% | 5% | 6% | 6% | 6% | 6% | 6% | 100% |
| 8 | 7% | 7% | 7% | 6% | 6% | 6% | 5% | 5% | 4% | 3% | 1% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 5% | 6% | 7% | 7% | 7% | 7% | 100% |
| 9 | 8% | 7% | 7% | 6% | 6% | 5% | 4% | 3% | 2% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 4% | 6% | 8% | 8% | 8% | 8% | 8% | 100% |
| 10 | 8% | 7% | 6% | 4% | 3% | 1% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 6% | 10% | 11% | 11% | 11% | 10% | 9% | 100% |
| 11 | 7% | 5% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 10% | 13% | 13% | 13% | 12% | 11% | 9% | 100% |
| 12 | 4% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 12% | 15% | 15% | 15% | 14% | 11% | 8% | 100% |

PV 1.800 Eq.H dispatch profile

PV

| Month/Hour | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | Total Monthly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 10% | 14% | 16% | 16% | 15% | 13% | 8% | 3% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| 2 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 6% | 10% | 13% | 14% | 15% | 14% | 12% | 9% | 5% | 1% | 0% | 0% | 0% | 0% | 0% | 100% |
| 3 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 7% | 10% | 12% | 13% | 13% | 13% | 11% | 9% | 6% | 3% | 0% | 0% | 0% | 0% | 0% | 100% |
| 4 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 5% | 8% | 10% | 12% | 12% | 12% | 12% | 10% | 8% | 6% | 3% | 0% | 0% | 0% | 0% | 100% |
| 5 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 6% | 8% | 10% | 11% | 11% | 11% | 11% | 10% | 8% | 6% | 3% | 1% | 0% | 0% | 0% | 100% |
| 6 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 6% | 8% | 10% | 11% | 11% | 11% | 11% | 10% | 8% | 6% | 4% | 2% | 0% | 0% | 0% | 100% |
| 7 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 5% | 8% | 9% | 11% | 11% | 11% | 11% | 10% | 8% | 7% | 4% | 2% | 0% | 0% | 0% | 100% |
| 8 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 5% | 8% | 10% | 11% | 12% | 12% | 11% | 10% | 9% | 6% | 3% | 1% | 0% | 0% | 0% | 100% |
| 9 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 5% | 8% | 11% | 12% | 13% | 13% | 12% | 11% | 8% | 5% | 2% | 0% | 0% | 0% | 0% | 100% |
| 10 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 4% | 9% | 12% | 13% | 14% | 14% | 13% | 10% | 7% | 3% | 0% | 0% | 0% | 0% | 0% | 100% |
| 11 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 7% | 12% | 14% | 16% | 15% | 14% | 11% | 7% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| 12 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 11% | 15% | 17% | 17% | 16% | 12% | 7% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

# What do we claim/demonstrate?
# Another mix of electricity generation is possible (and desirable)

What?

The natural complementarity of renewables in Spain (Wind / Sun and Water) together with the smartly use of STE / CSP would allow a 2030 scenario*:

- ✓ **Without coal power plants**
- ✓ **Without nuclear power plants**
- ✓ **With less support of combined cycles than in the report of the Experts Committee Report (ExpCom)**
- ✓ **With 85.6% of renewable generation with very few curtailments (82% less than the discharges foreseen by the ExpCom)**
- ✓ **With very reduced emissions (half that provided by the Exp.Com)**
- ✓ **Achieving a 34% penetration of renewable energy in the final energy demand**
- ✓ **Fulfilling EU objectives**
- ✓ **And less than 5 c€ / kWh generation cost**

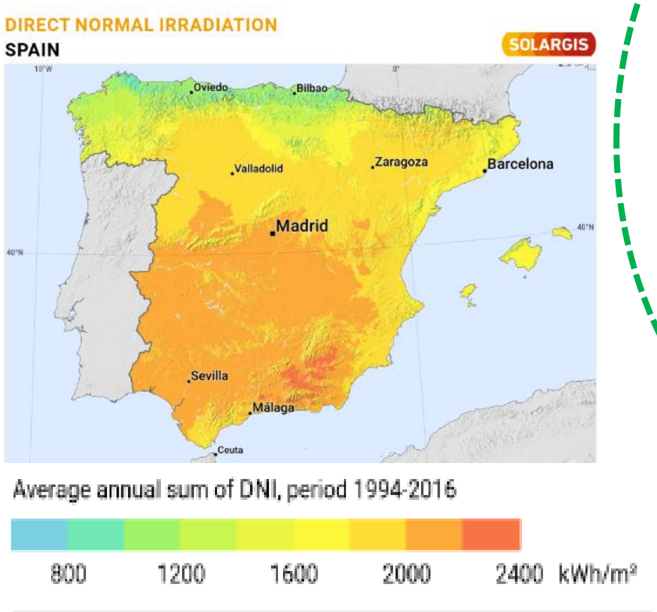
This is a **true Energy Transition** with enormous additional benefits for the economy of the country

*Note: The results of this report do not correspond to theoretical simulations, but to the projection made from of generation time data in real years of the mix considered

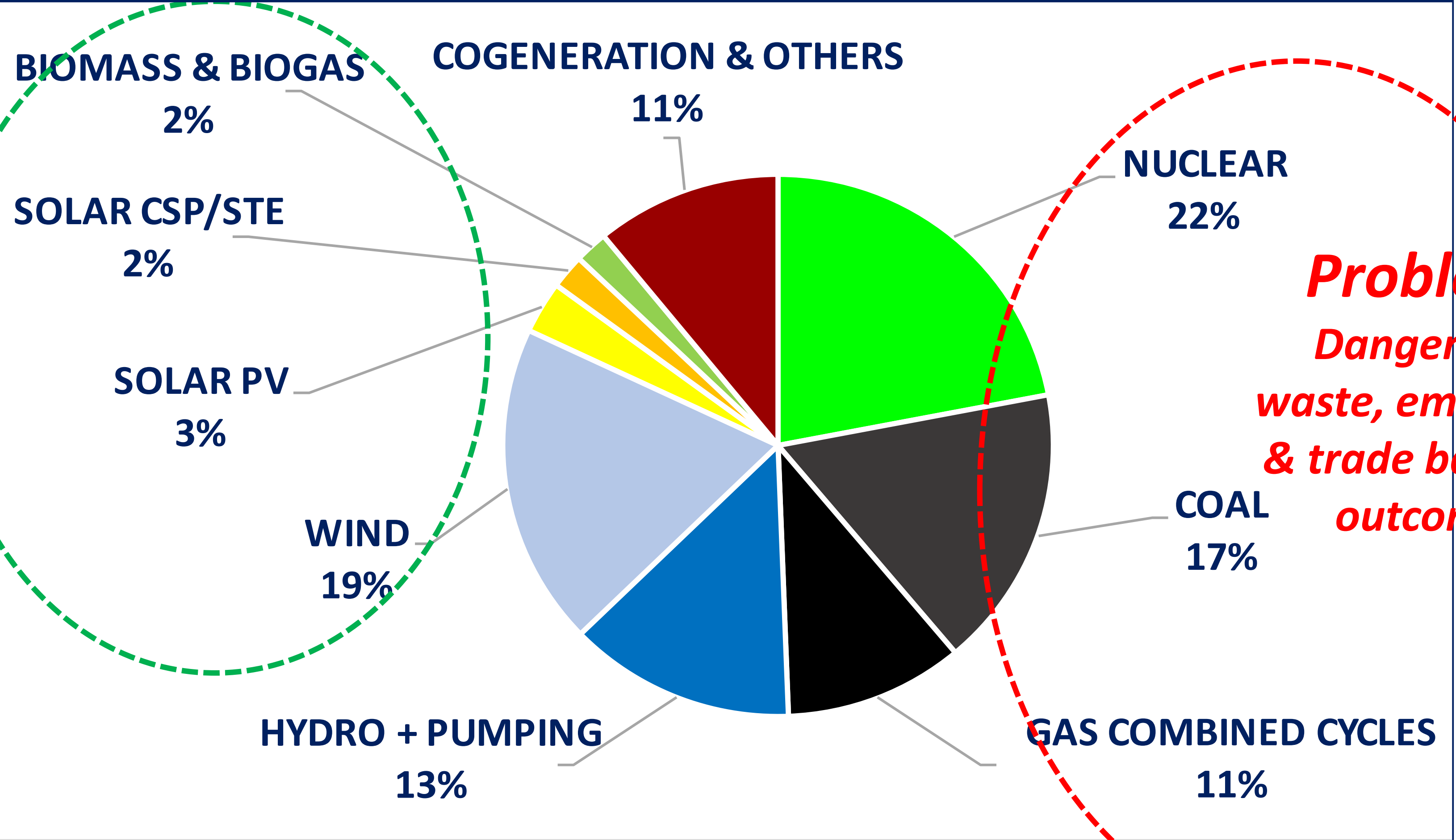
# What does it need to be changed in the electricity mix?
# Where do we come from?

What?

**SOLution**




Generation Mix by energy source in Spain, average of the period [2014 – 2017]




***Problem***

***Dangerous waste, emissions & trade balance outcome***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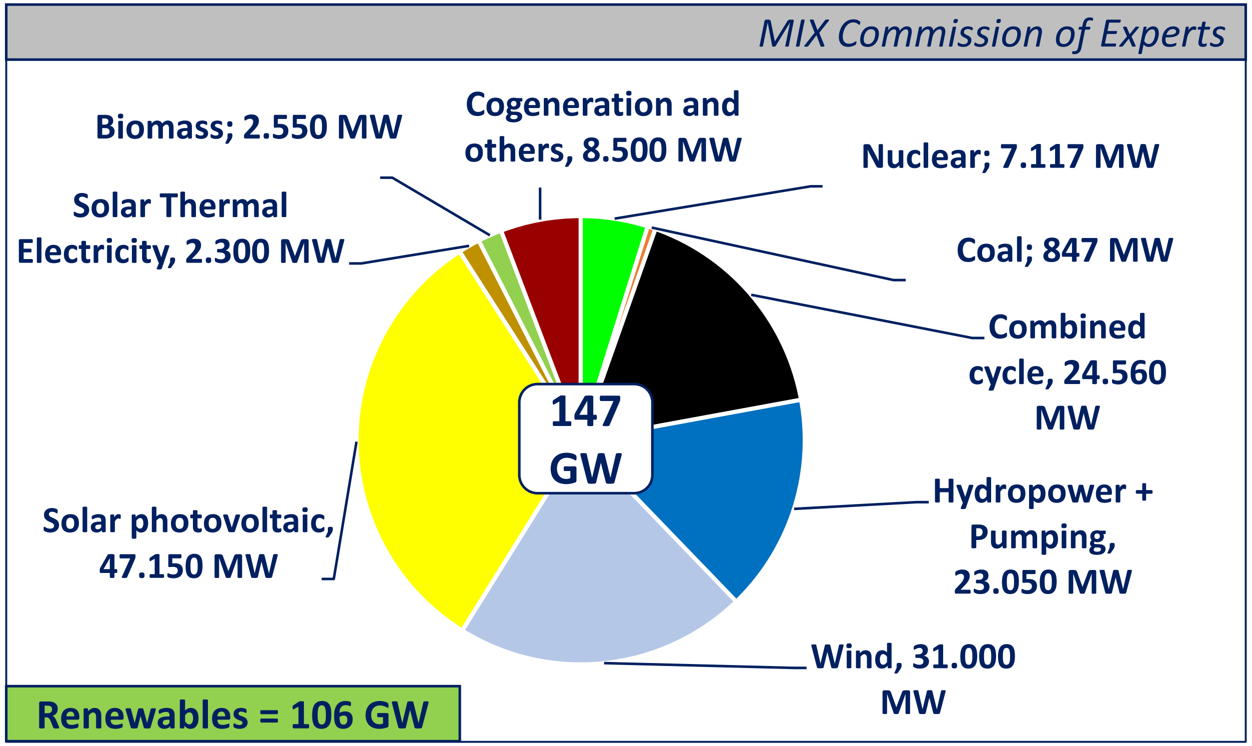
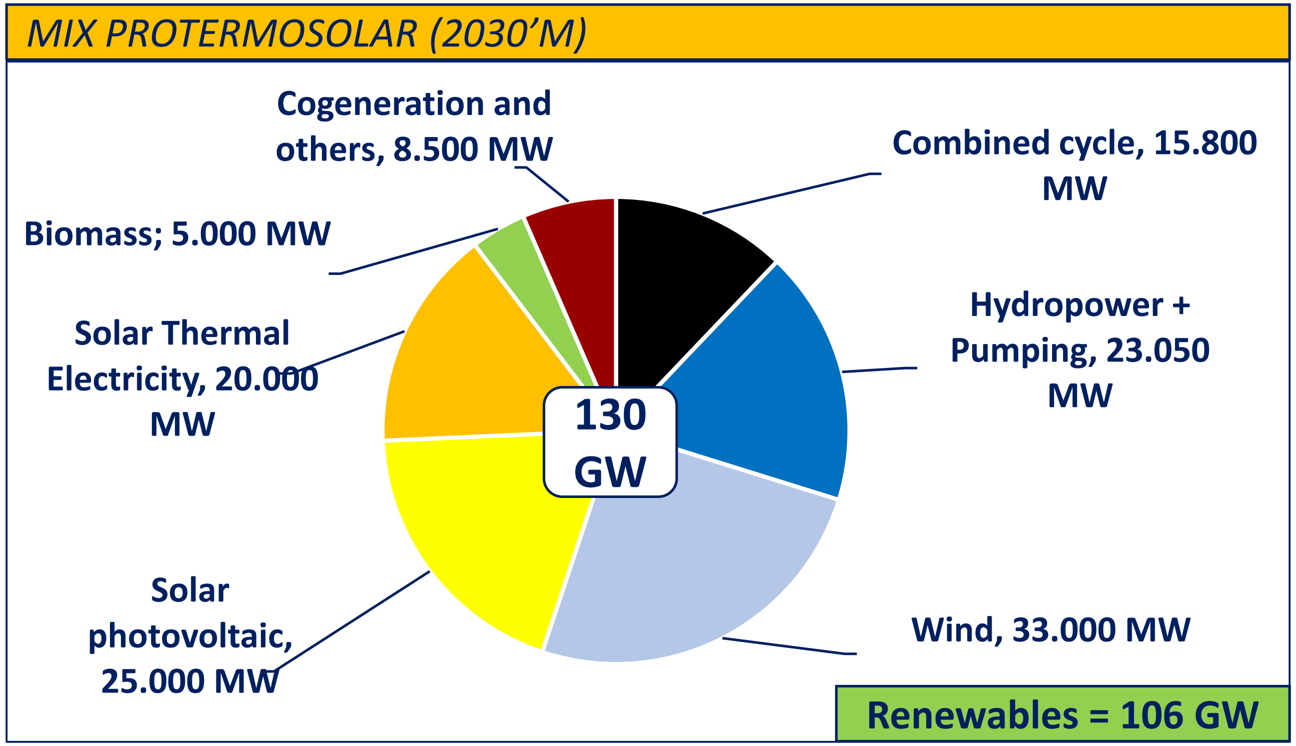
# What are the differences (Installed Capacity) between suggested solutions of the electricity mix? Exp.Com vs Protermosolar

What?



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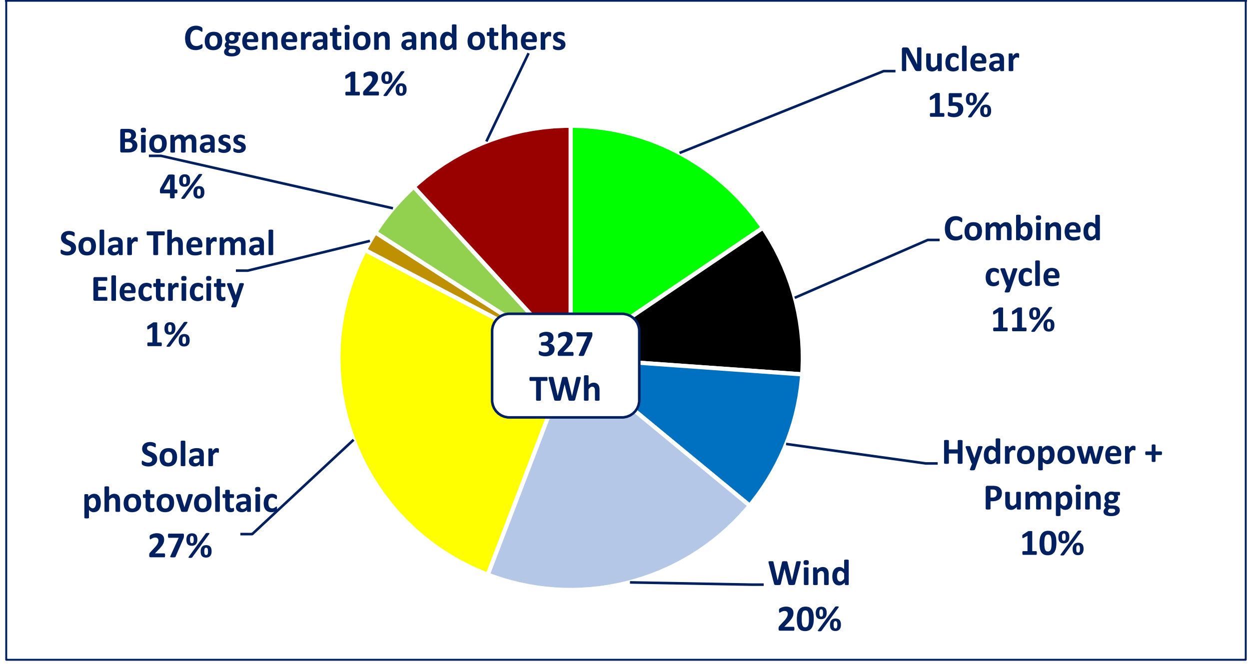
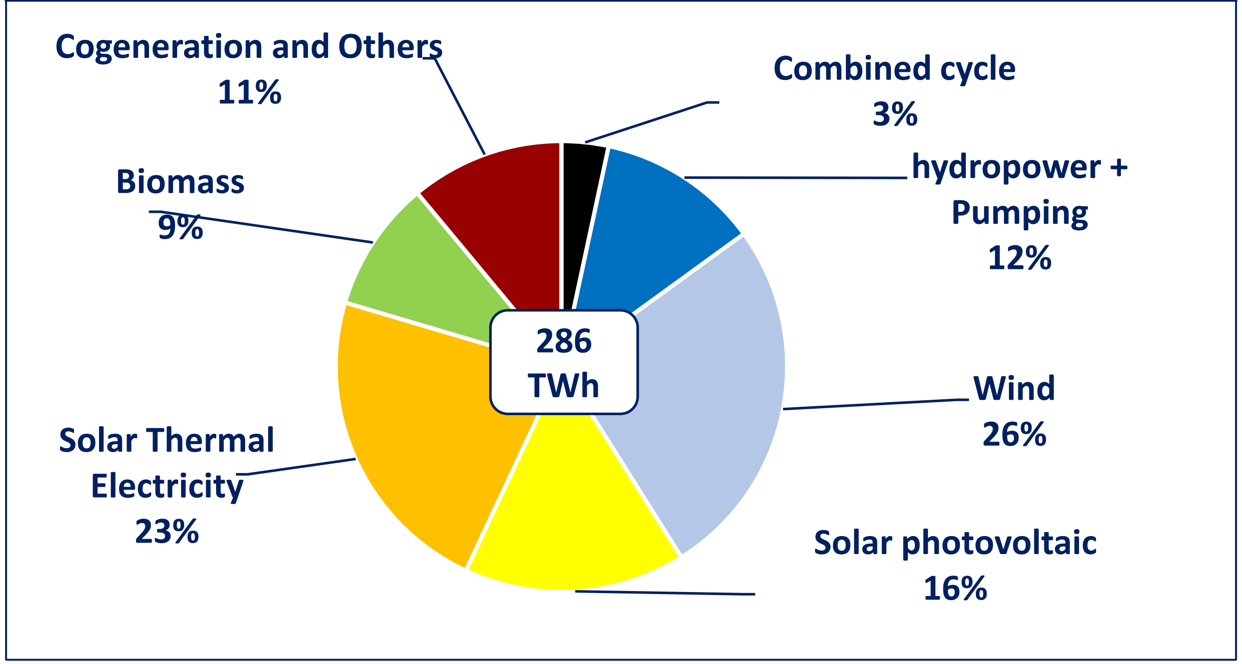
# What are the differences (Generation) between suggested solutions of the electricity mix? Exp.Com vs Protermosolar

What?

*MIX Commission of Experts*




*MIX PROTERMOSOLAR (2030'M)*

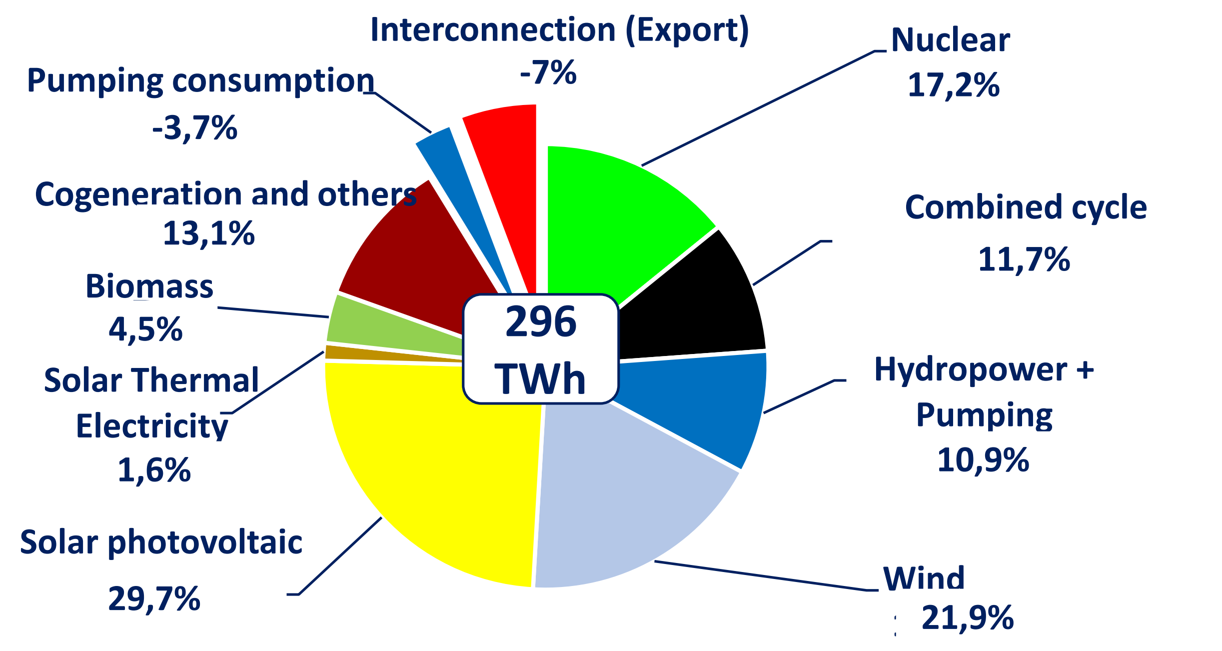



- ✓ 85.6% of electricity generation is renewable sources compared to 62.1% of the ExpCom
- ✓ Gas Combined cycles would only contribute 3.4% to the generation mix
- ✓ Carbon and nuclear would phase out of the generation system

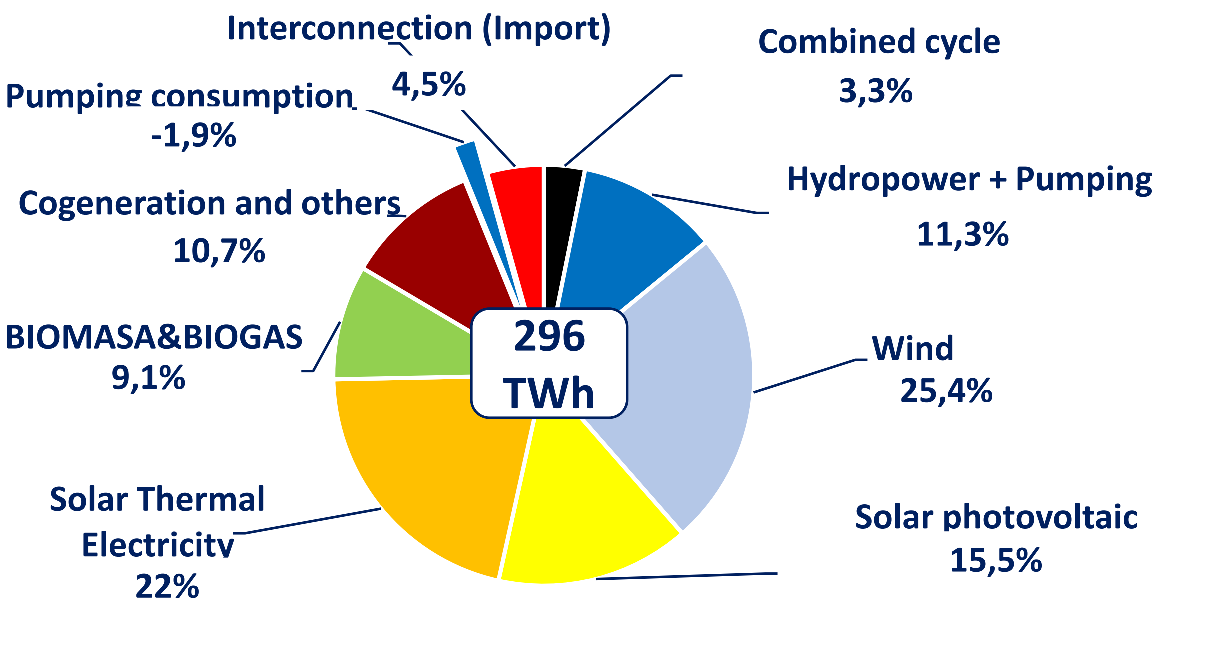
# What are the differences (Demand) between suggested solutions of the electricity mix? Exp.Com vs Protermosolar

What?

*MIX Commission of Experts*



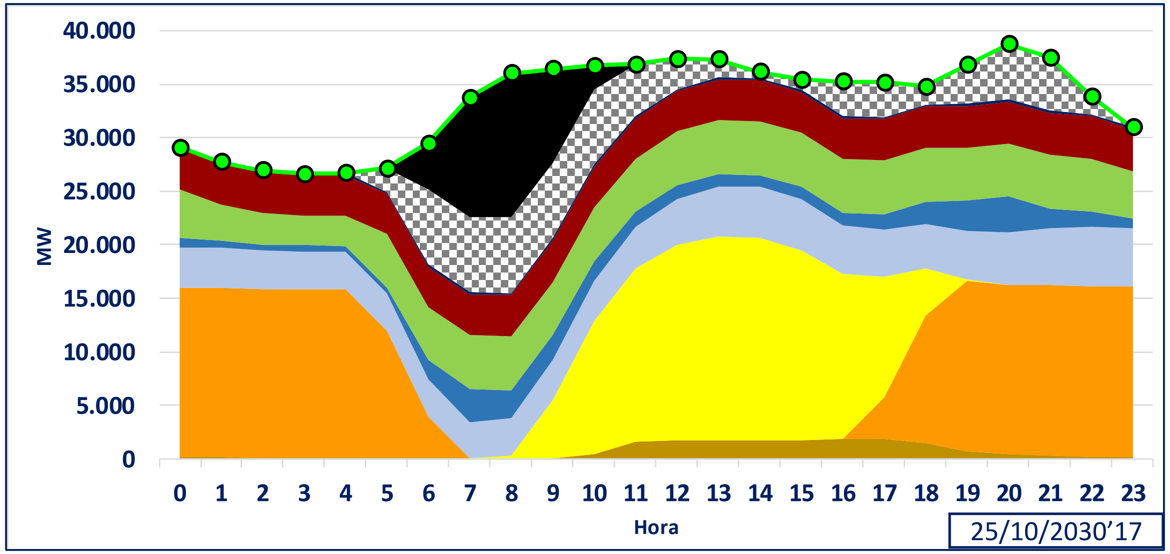

*MIX PROTERMOSOLAR (2030'M)*

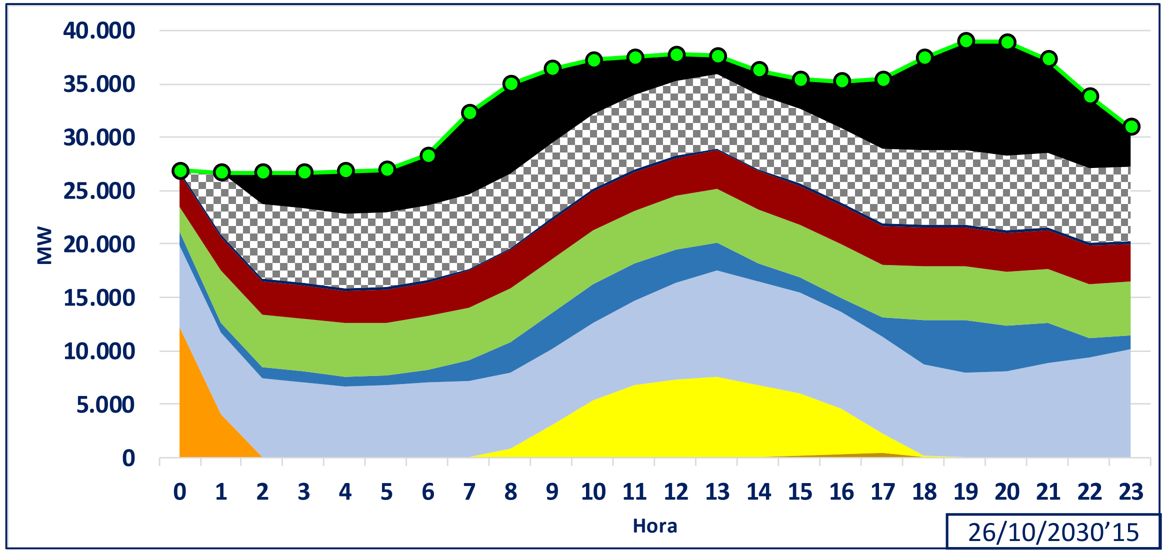



- In the mix proposed by Protermosolar the demand coverage for renewable sources is 83%, compared to 69% of the ExpCom
- Both generation mix correspond to a demand of 296 TWh. (The hydraulicity of the mix of Protermosolar (hydraulic + pumping) shown in this graph takes into account the average of the last 4 years = 33.5 TWh, a value very close to the 32 TWh of the scenario of average hydraulicity taken into account in the base case by the ExpCom
- The saturation of interconnection considered for 2030 in the scenario proposed by Protermosolar is 7 GW, both import and export, which can be considered as more conservative compared to the sum of capacity with France, Portugal and Morocco taken by ExpCom

# What is behind these pie charts? → Daily analysis of cumulative production figures of 1.460 days. **AUTUMN** example of sunny and non-sunny specific days

What?





- On a sunny autumn day, the solar thermal works until late into the following night, although the decrease of solar thermal generation coincides with the absence of the photovoltaic, which implies that the combined cycles are required to cover the demand from 5 to 10 in the morning.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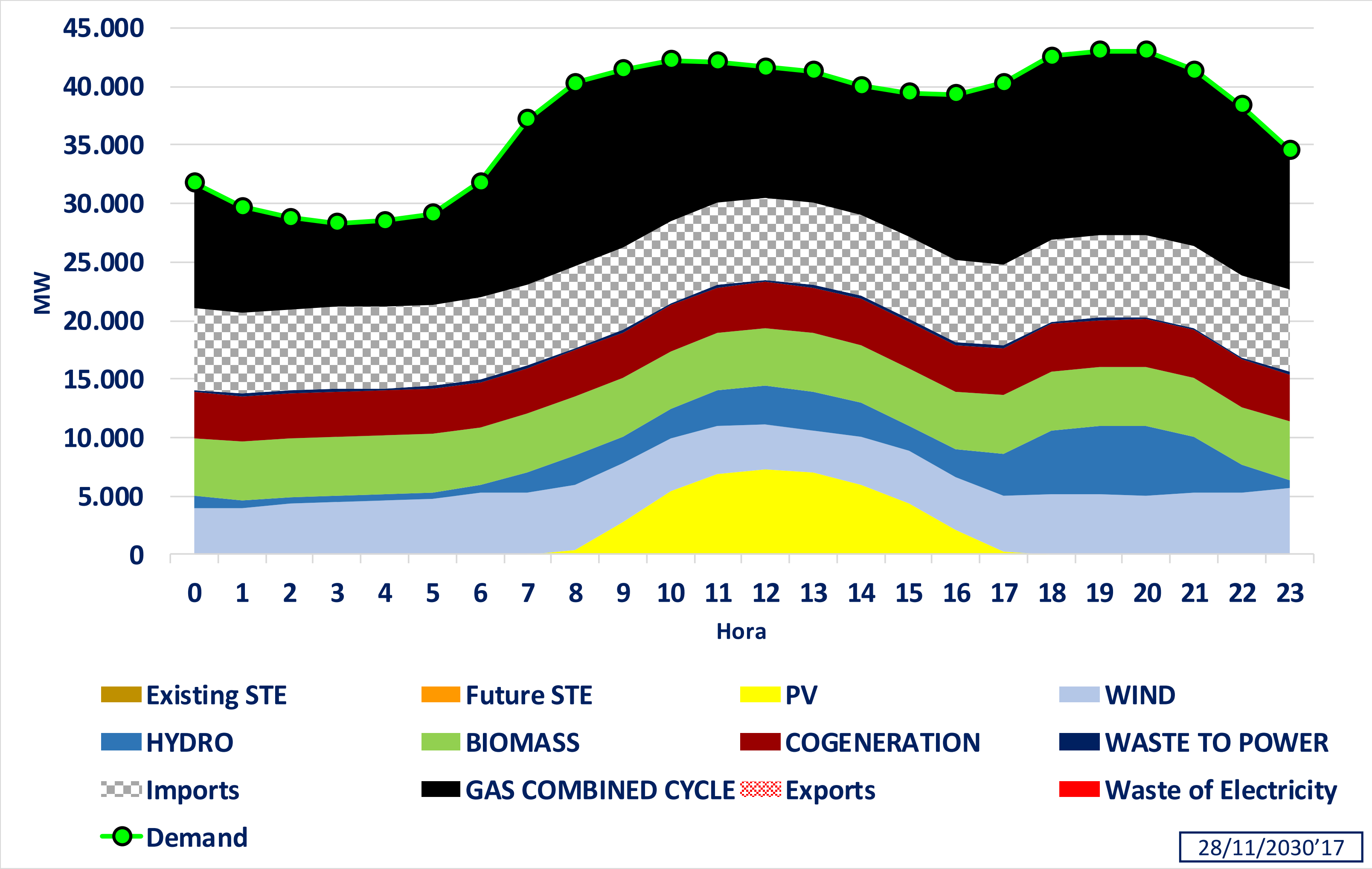
# What if there isn't wind, sun and water at the same time?
# System response on the worst day of the 4 years

What?

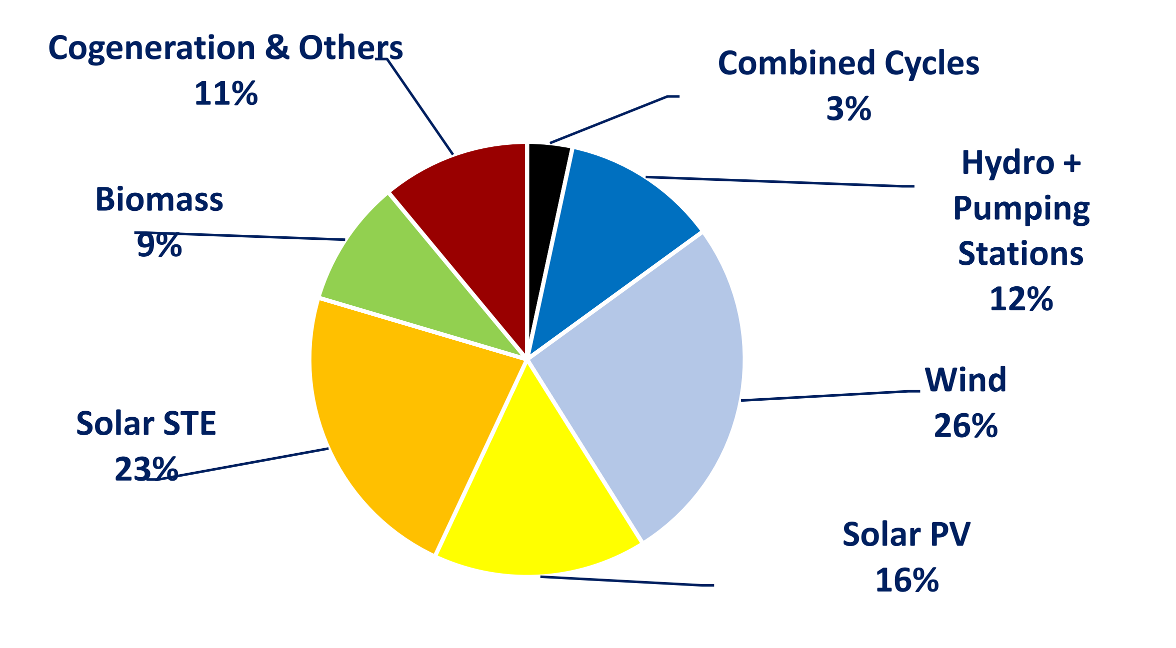
The most unfavourable day of the 4 years analysed is the equivalent of November 28, 2017 projected into 2030.
The solar resource was very low, so much that the solar thermal plants could not have collected any energy during the day, when photovoltaic hardly generated and there was little wind, the hydraulic resource being also very scarce. For these reasons biomass operates at full load all the day, imports saturating interconnections and combined cycles work all day.




# What about generation costs?

What?

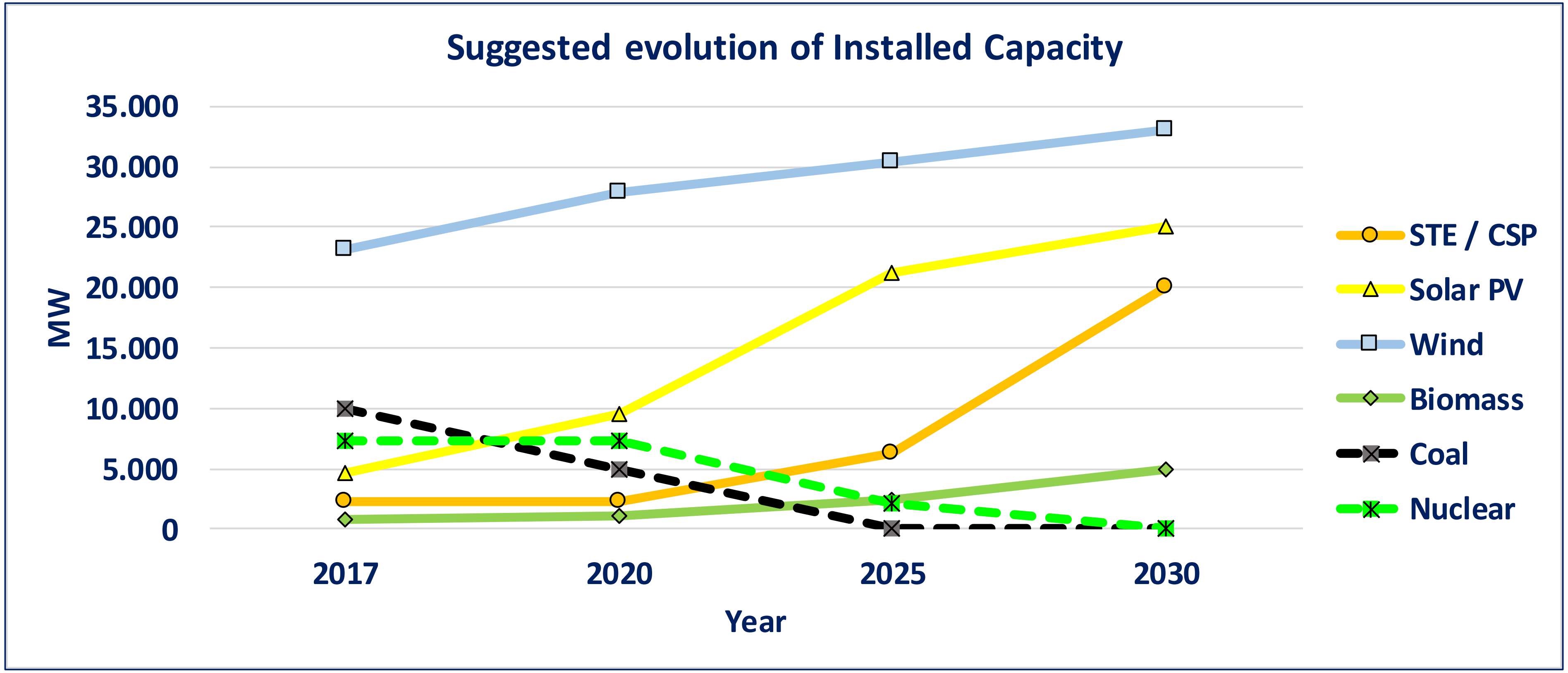
*MIX PROTERMOSOLAR - Generation*




| Energy Source | Generation Cost in 2030 (€/MWh) |
|---|---|
| Gas Combined Cycle(50€/ton $CO_2$ - ExpCom Value) | 73,83 |
| Hydro | 20 |
| Pumping Stations | 25 |
| Wind | 40 |
| Solar PV | 35 |
| Solar STE | 55 |
| Biomass | 60 |
| Cogeneration & Others | 70 |
| Waste to Power | 80 |
| Imports | 60 |
| Exports | 40 |
| TOTAL Generation Costs | 48,8 |

# What does it need to happen to before 2030?
# Different Technology needs at different timing

What?




2017 – 2020: Already awarded auctions (PV, Wind & Biomass) + PPAs
2020 – 2025: Linear increase for Wind, High penetration of PV, Small penetration of STE/CSP & Biomass
2025 – 2030: Variable RES capacity will be close to market limits. High penetration of STE/CSP & Biomass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# What does it need to happen to before 2030?
# Specific Technology auctions and a foreseeable RES planning

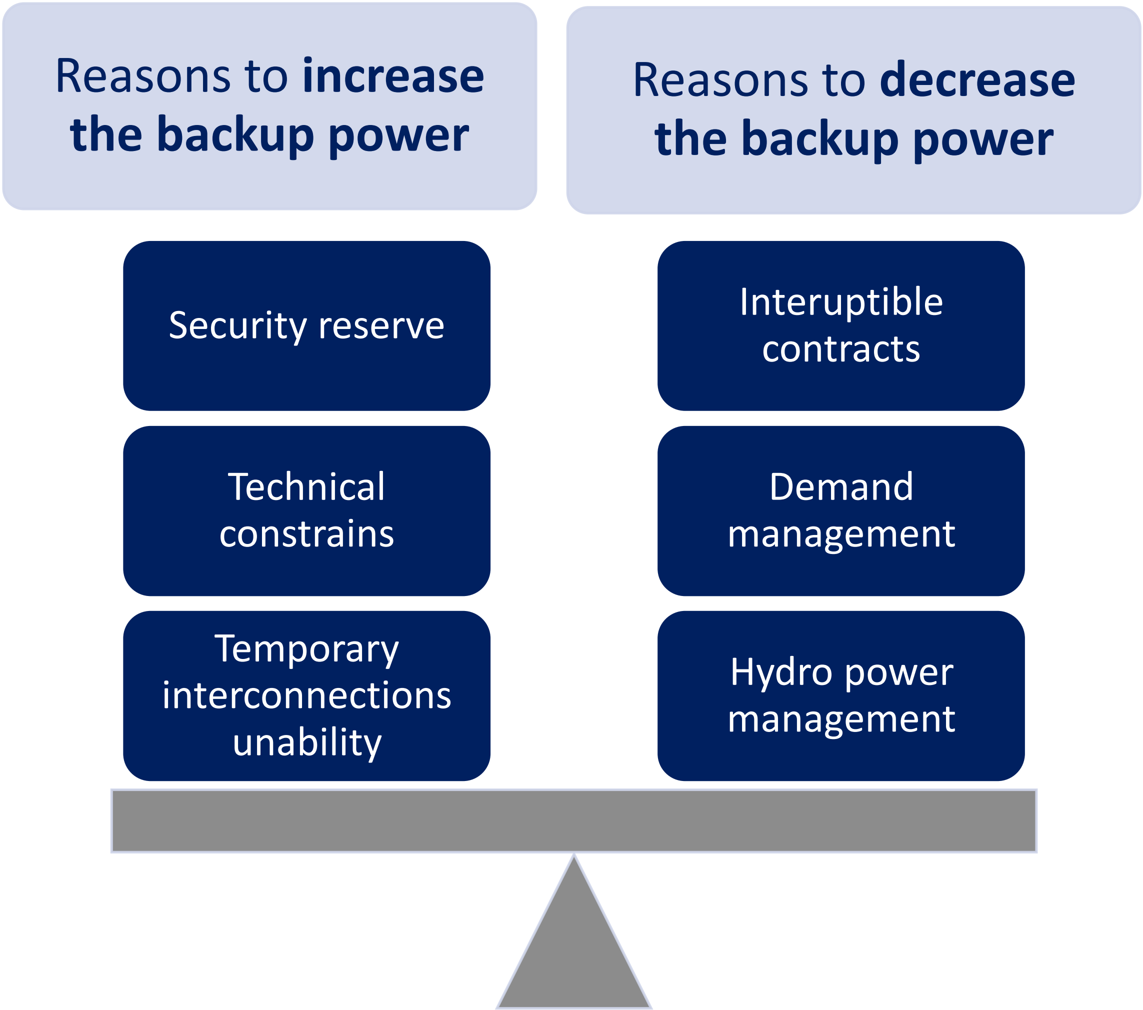
What?

| | STE / CSP | | Solar PV | | Wind | | Biomass | |
|---|---|---|---|---|---|---|---|---|
| | €/MWh | New Inst. Capacity (MW) | €/MWh | New Inst. Capacity (MW) | €/MWh | New Inst. Capacity (MW) | €/MWh | New Inst. Capacity (MW) |
| **2021** | 75 | 500 | 40 | 2.700 | 45 | 514 | 95 | 200 |
| **2022** | 72 | 500 | 38 | 2.700 | 43 | 514 | 85 | 200 |
| **2023** | 70 | 500 | 37 | 2.700 | 42 | 514 | 75 | 200 |
| **2024** | 67 | 1.000 | 35 | 2.000 | 41 | 514 | 70 | 300 |
| **2025** | 63 | 1.500 | 32 | 1.500 | 40 | 514 | 65 | 400 |
| **2026** | 59 | 2.000 | 31 | 1.000 | 39 | 514 | 60 | 500 |
| **2027** | 54 | 2.925 | 30 | 701 | 39 | 514 | 55 | 536 |
| **2028** | 51 | 2.925 | 29 | 701 | 38 | 514 | 50 | 536 |
| **2029** | 48 | 2.925 | 28 | 701 | 37 | 514 | 50 | 536 |
| **2030** | 47 | 2.925 | 27 | 701 | 36 | 514 | 48 | 536 |
| **Weighted average by Technology in 2025** | **67** | | **37** | | **42** | | **75** | |
| **Weighted average by Technology in 2030** | **55** | | **35** | | **40** | | **60** | |

# What have & haven't we considered in this study regarding grid technical features?; Do we need more back-up?

What?

- ✓ **Minimum requested synchronous generation** in the electricity systems is 5.500MW
- ✓ **Ramps** have been **checked** to be within the technical feasible range for:
    - ✓ Gas Combined cycles
    - ✓ Biomass
- ✓ **Interconnections** operating at full load capacity are lower than Exp.Com Report
- × The main limitation of this study is that it has been taken into consideration **Spain a unique node**
- × It has not been analyzed whether there could be or not new **network needs linked to the future location of the new electricity mix**. STE plants would be erected in the mid-south of Spain, whereas dismantled coal power plants are mainly located in the north-west of Spain.



# Conclusions



- **Actual meteorological complementarity of wind, water and sun shall be deeply analyzed at country level when planning future electricity mix.** Least cost expansion models may have been designed for non-dominated RES electricity mix

- The outcomes of this study shows that **Spain could close the polluting and risky coal and nuclear power plants while sharply reducing the need of gas** combined cycles back-up **by 2030**

- A smart **combination of dispatchable and non-dispatchable shows how PV and STE shall work together, avoiding overlapping** at full capacity. This combination would lead to an unbeatable electricity cost

- Although the study refers to the Spanish case, the conclusions may apply to all Sunbelt countries. **High RES penetration is feasible when appropriate complementarity of natural resources is given**

# *THANKS FOR YOUR ATTENTION*

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*Session 3-D: Policy & Marketing*