TradeRES

New Markets Design & Models for 100% Renewable Power Systems

The challenges of electricity markets for renewables. TradeRES ambition and goals.

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The facts

- In recent past, liberalized (marginal) **markets were very effective in reducing the costs of electricity** by adopting designs adapted to the technical and operational characteristics of the 20th century conventional dispatchable power plants, most fully dispatchable;

- **Electricity markets designed in the 80's are based on "certainty" and "commitment"** of actors, i.e. reliable sources and dispatchable power plants;

- **Energy Transition** towards decarbonization in the Power sector, is being made through **vRES - variable Renewable Energy Systems;**

The challenges

The **<u>main challenges for the participation of vRES in existing markets</u>** are:

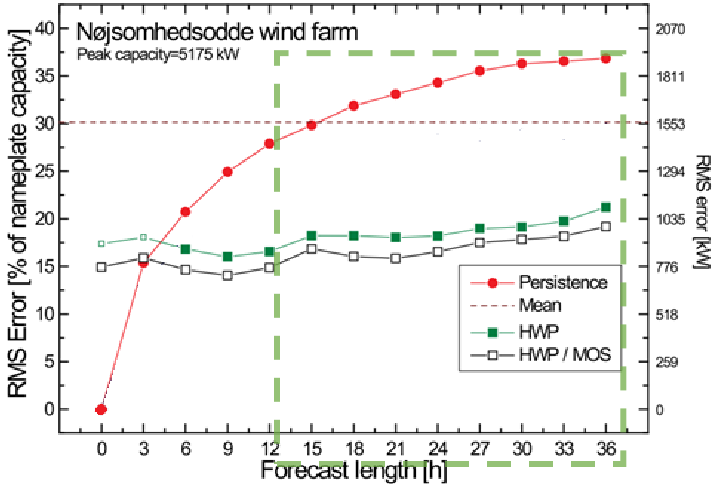
- **<u>they do not offer "*guarantee of (firm) power*"</u>**, i.e. one cannot ensure that, the next day (for a DAM designed market) a wind or PV solar plant will deliver a certain "XX" MW of power.
  - I.e. their production is forecastable (and forecasted!) but always with a non-negligible error (~7-15%);

- The time and spatial variability of resources, as well as the difficulties associated to forecasting them, introduces uncertainties in the vRES plants offers that have, as consequence a **<u>strong reduction of vRES market value</u>, since actual markets' design strongly penalizes their physical principles of operation;**

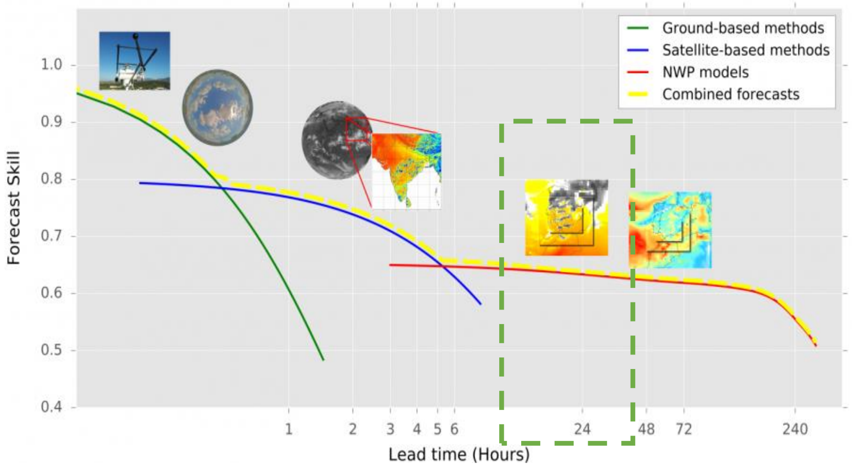
- Deviations with respect to offers are **strongly penalized in DAM** (day-ahead markets);
  - a consequence of that being **vRES participation in markets has such high risks**, they are hardly bankable…
  - …and the risk is being passed to governments through "market-bypass mechanisms" as CfDs.

The main challenge:
increasing the value of vRES in electricity markets

Wind power [1]



Solar power [2]



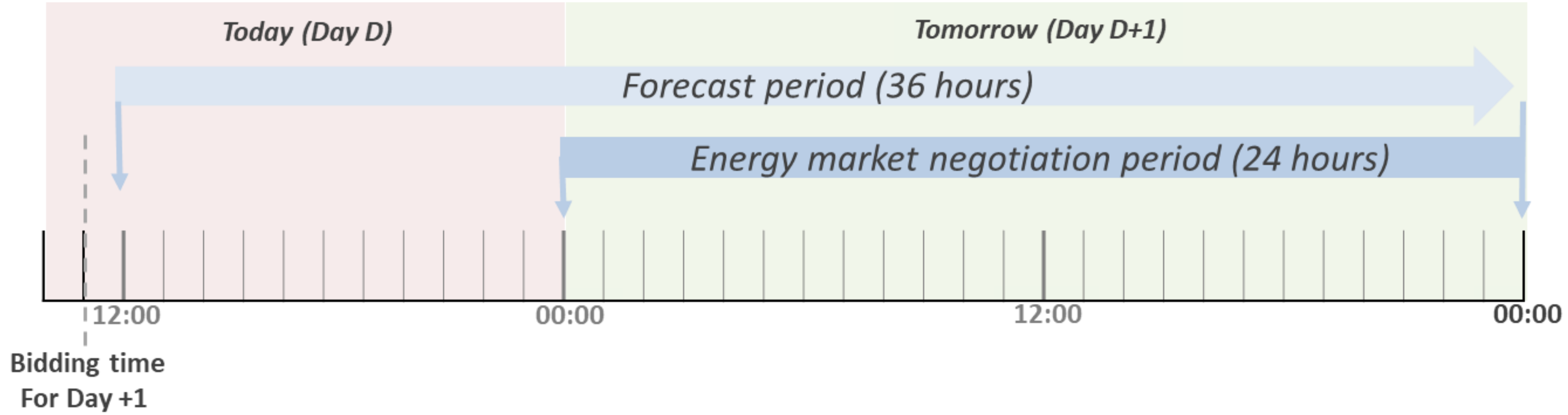
Despite the recent improvements observed in the power forecasts of renewable systems, **large errors are still observed**, especially for long time horizons (that involve a time lag up to 36h in some cases) **as currently still required by electricity markets**.

[1] *Figure from: G. Giebel, R. Brownsword, G. Kariniotakis, M. Denhard, and C. Draxl, "The State of the Art in Short-Term Prediction of Wind Power," ANEMOS project.*

[2]. *Solar power forecast skills according to time horizon and type of forecast approach. Figure extracted* from SOLARGIS, https://solargis.com/blog/best-practices/improving-accuracy-of-solar-power-forecasts

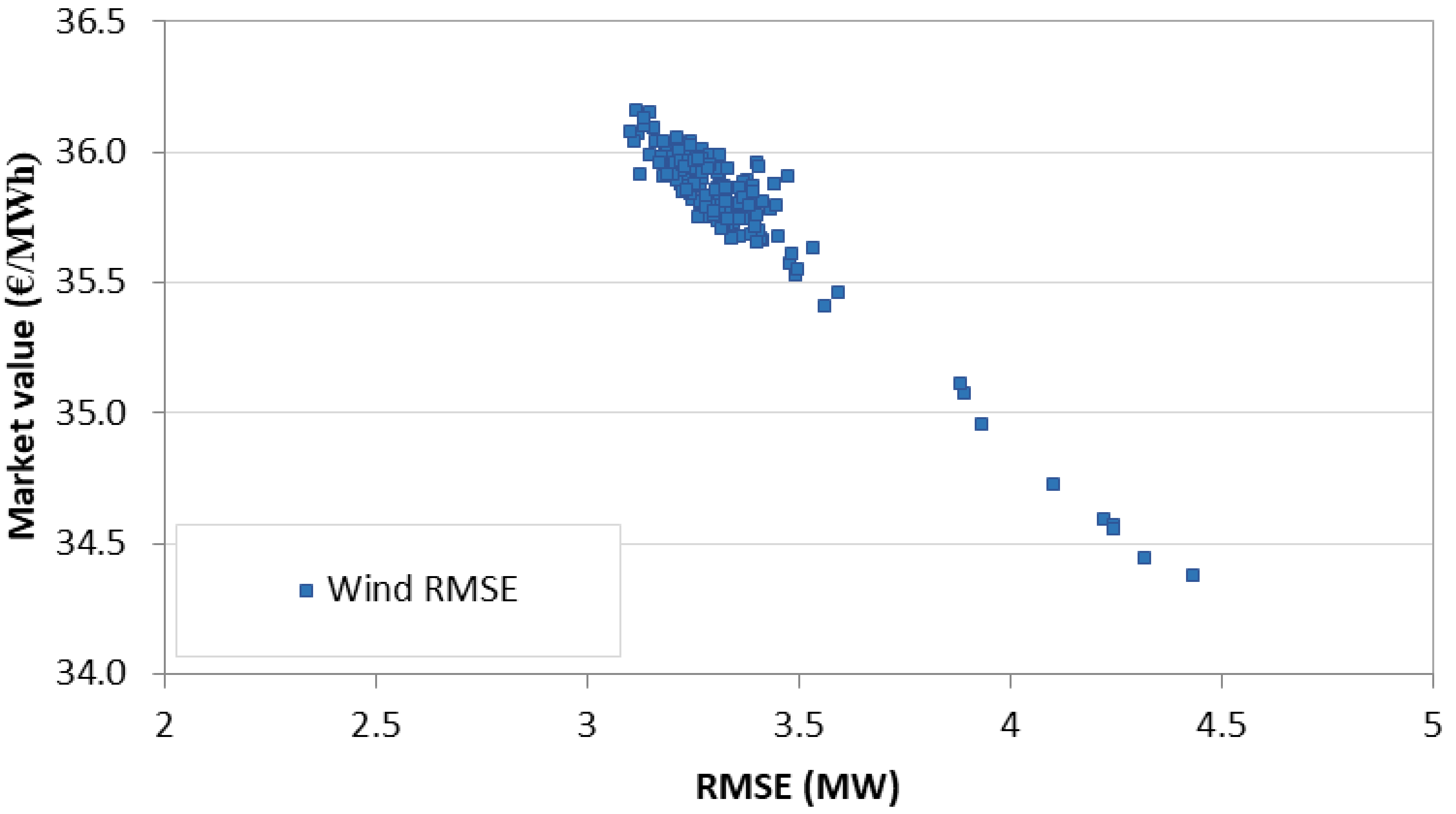
The main challenge: increasing the value of vRES in electricity markets

Current market designs compromise the profitability of vRES producers and prevent a full (and fair) integration of these technologies into electricity markets



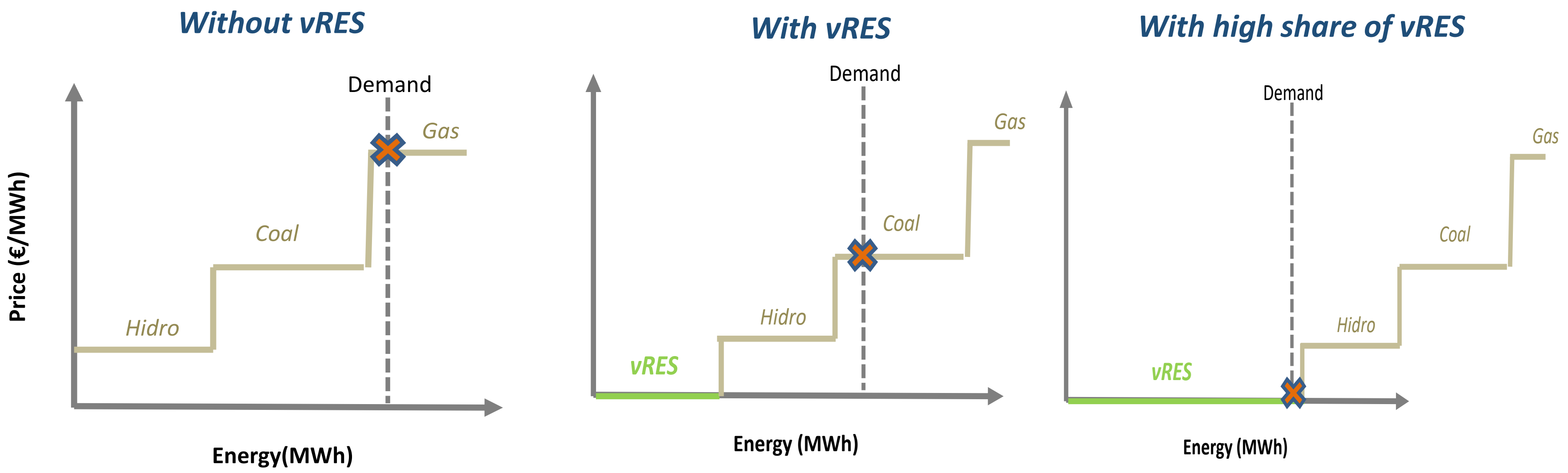
The main challenge: increasing the value of vRES in electricity markets

It is common, e.g. for wind plants trading in DAM, for penalties to (almost) equal profits…



Other market challenges: the effect of (very) low marginal cost of vRES…

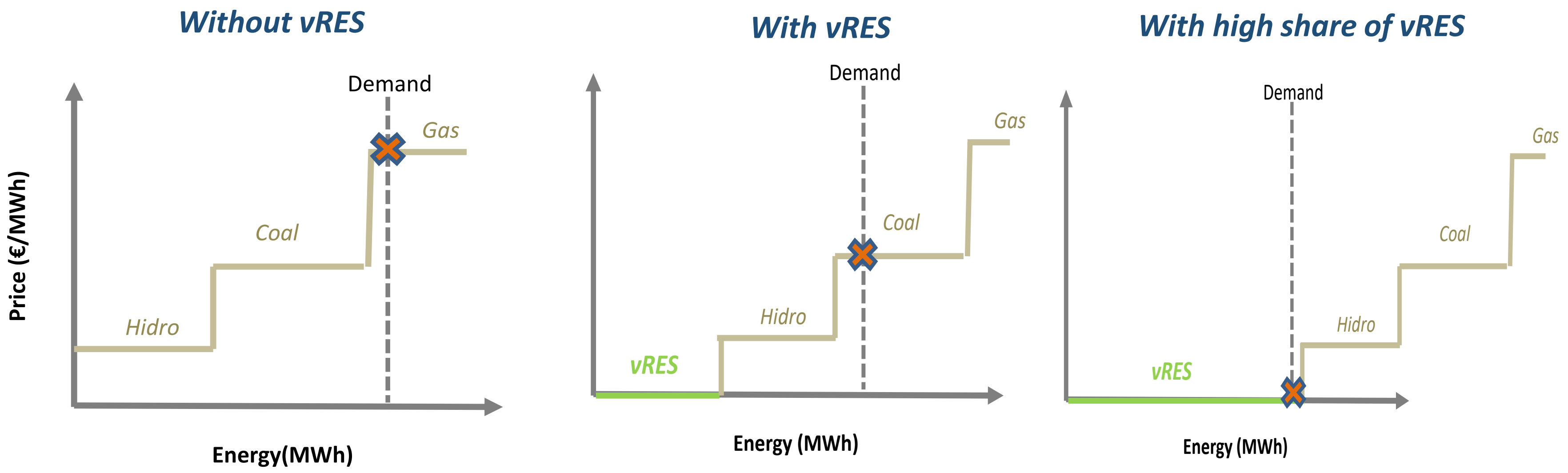
- New vRES dynamics, are already having to have a significant impact on the electricity energy markets.
- Markets design and products, defined when conventional technologies dominated, are based on marginal costs (cost necessary to produce one additional megawatt) in the formation of its hourly price.
- The merit order effect… can trigger the "self-cannibalization” effect.



To participate in the daily market, producers take into account their marginal costs and the expected production quantity, creating a stack of offers. Since vRES plants have very low marginal costs when compared to conventional technologies, there is a tendency for a decrease in the energy costs verified in wholesale markets with a large participation of VREs.

Other market challenges:
the effect of (very) low marginal cost of vRES…

"Self-cannibalization effect" **reduces the incentives to invest in new capacity deployment** needed to ensure a stable electricity supply as well as to accomplish the ambitious European renewable target, being an actual concern in power systems with high to very high variable renewable participation.



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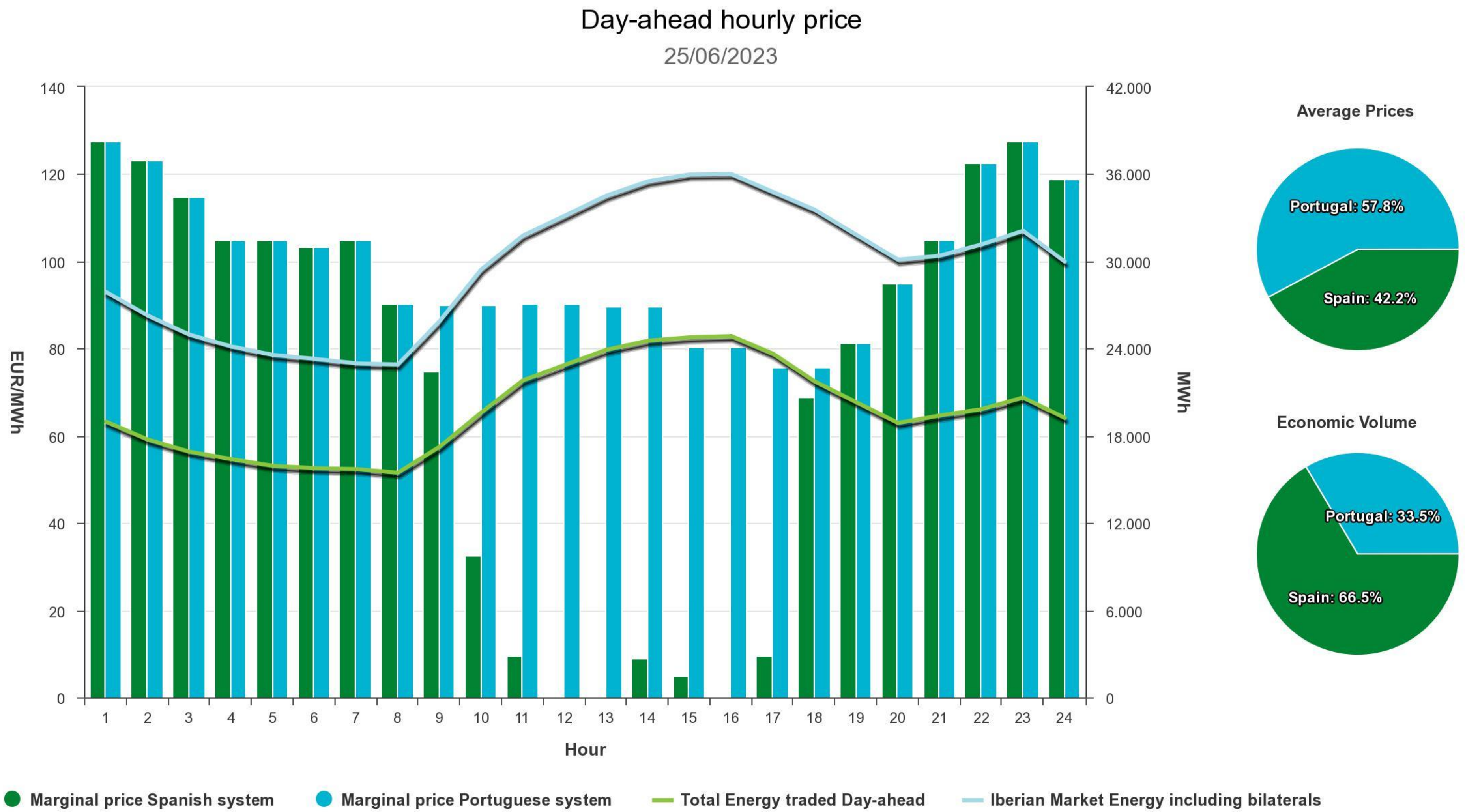
More facts: the future… is now.



Arithmetic average marginal prices:
- Spanish Electrical System: 72,27 EUR/MWh
- Portuguese Electrical System: 99,05 EUR/MWh

Total Iberian Market energy:
- 476.083,10 MWh

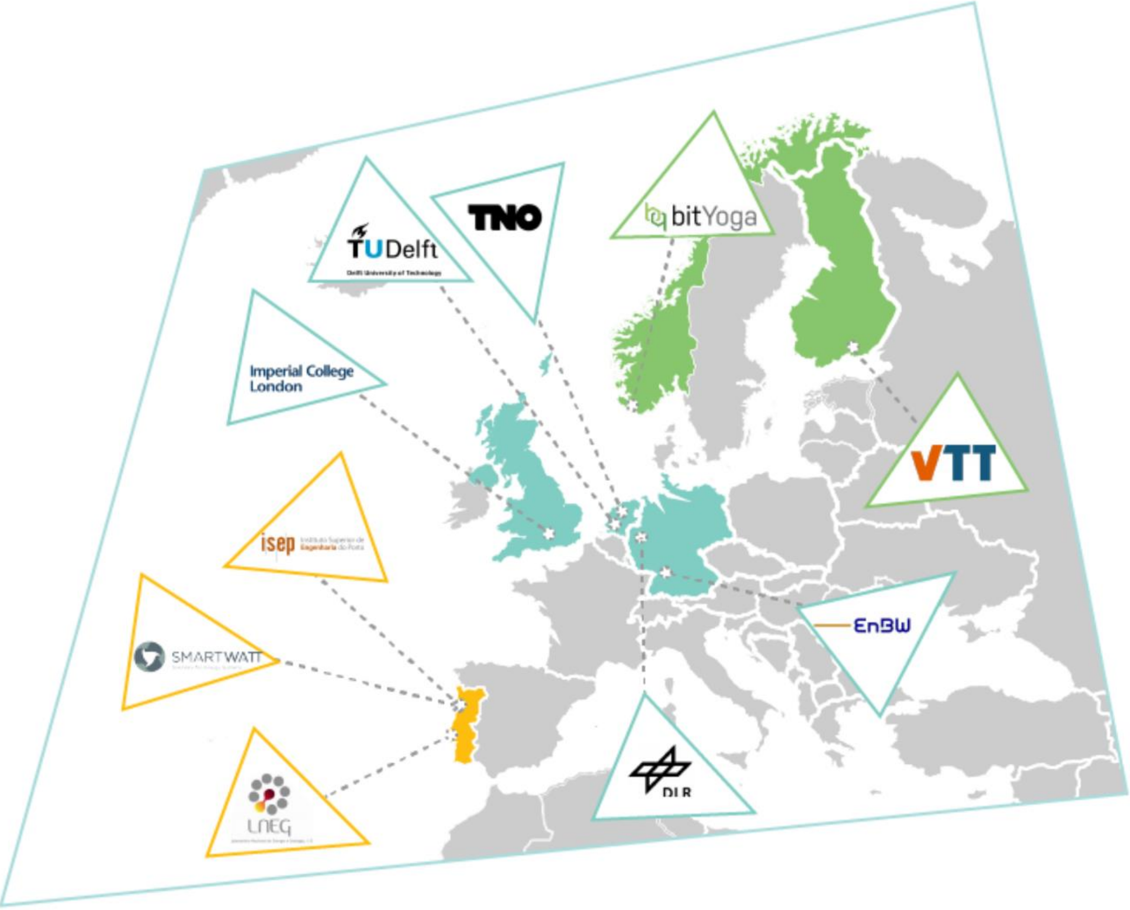
TradeRES objectives

TradeRES ground-breaking goals are to:

1. To develop **new electricity market designs for ~100% renewable power systems;**
2. To **model and simulate the new market** agents, procedures and mechanisms;
3. To develop **open-access tools for analyzing ~100% renewable** electricity markets;
4. To **engage key stakeholders** in the development, improvement and use of the new market simulation tools;

- **Identify actual barriers and deficiencies** of current pricing and energy market structures
- **Calculate cost, value, and price structure of electricity in a ~100% renewable** VRE-dominated electricity system for 2030 and beyond.
- **Conceive, design and model electricity markets** that correctly deal with **novel flexibility products** and options of the system.
- **Develop optimization and agent-based models beyond the state-of-the-art**, which are paramount to support the TradeRES project to reach the project objectives.

The consortium

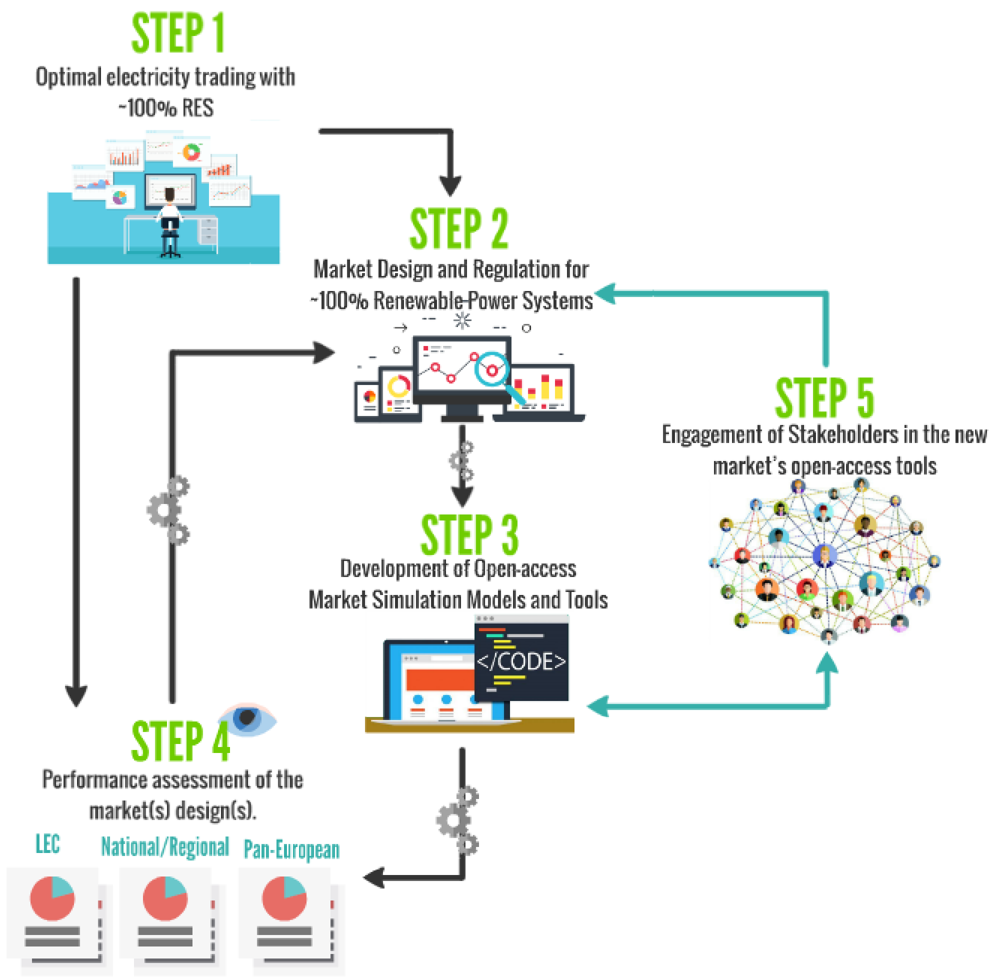


TRADERES – TOOLS FOR THE DESIGN AND MODELLING OF NEW MARKETS AND NEGOTIATION MECHANISMS FOR A ~100% RENEWABLE EUROPEAN POWER SYSTEM.

The TradeRES consortium includes seven renowned, specialized research groups from six European countries who are key players in their fields. This Pan-European consortium emerged from the EERA Joint Programme Energy Systems Integration (EERA-ESI) thus having ample experience in managing and collaborating in European projects, engaging with stakeholders as well as providing technical expertise and advice to policy makers. The consortium includes research laboratories and universities, one large electric utility, one energy optimisation company and a renewable forecaster and ensures the cooperation and collaboration between research institutes, energy industry and SMEs. The team has profound technical expertise to cover the modelling the electricity market for increasing the knowledge on how to design electricity markets with very high renewable energy participation.

Approach and Methodology

The approach has an iterative nature that consists of 5 steps:



STEP 1 - **Generation of reference power system**, **scenarios** and **input market data** (WP2)

STEP 2 - **Market Design** and Regulation for the ~100% Renewable Power Systems obtained in STEP 1 (WP3)

STEP 3 - Development of **Open-access Market Simulation Models and Tools** (to apply to markets designed in STEP 2 (WP4)

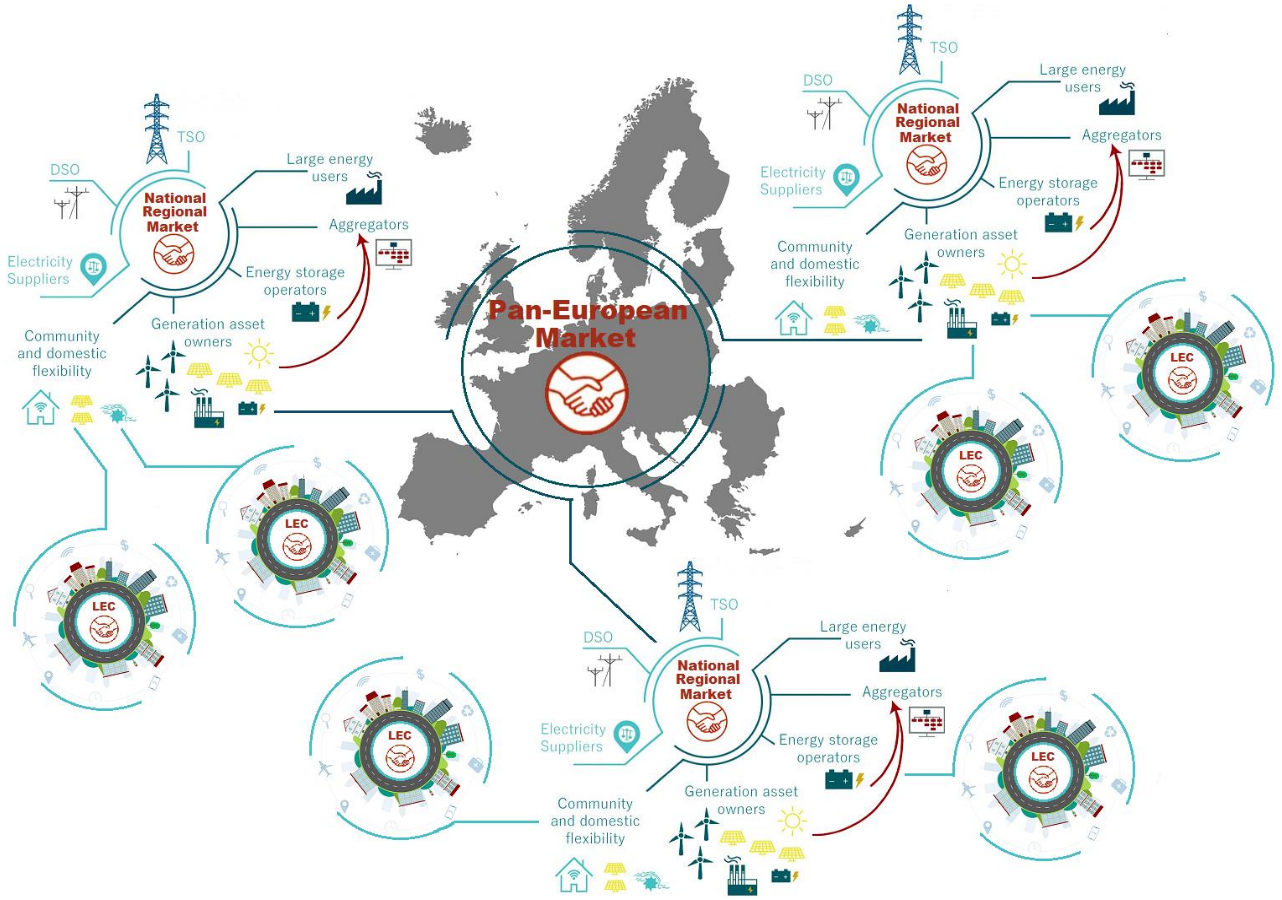
STEP 4 – **TEST the designs (and the models)** for different case studies (WP5)

STEP 5 – **Engage** (and collect reactions) from **stakeholders** (WP6)

(repeat until convergence!...)

TradeRES "Markets"

TradeRES markets: case studies from Pan-European to National Markets and Local Energy Networks.



TradeRES

Scenarios, Models, Case Studies and MPIs- Market Performance Indicators

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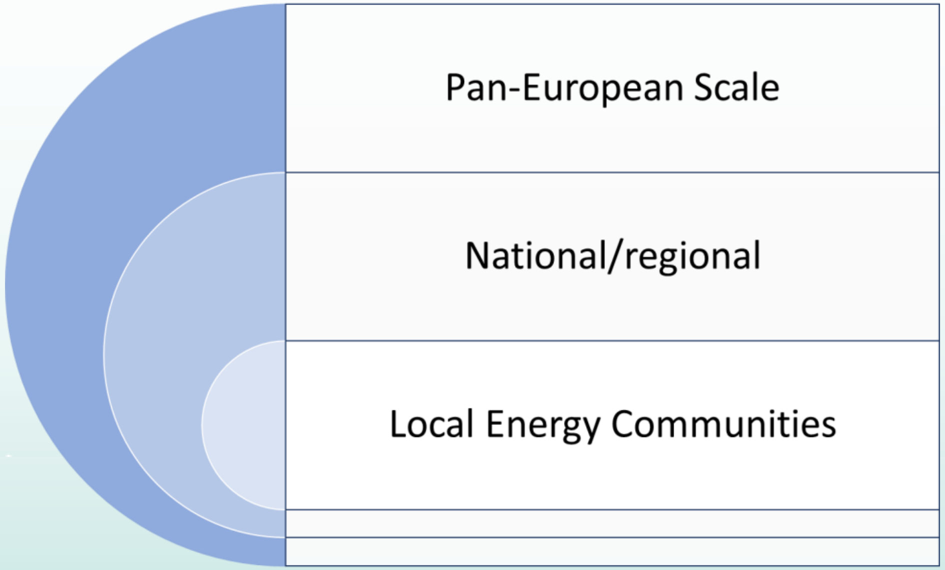
Consortium's models and tools

The TradeRES markets design: from Pan-European to National Markets and Local Energy Networks.

Type	Model	Scope	Spatial Resol.	Spatial Horizon	Time Resol.	Time Horizon	Grid Constraints
Optimization	COMPETES (TNO)	Invest and dispatch, minimize power system costs, account for constraints of generation & transmission	One node per country	EU28+	hourly	flexible	yes
Optimization	Backbone (VTT)	Value of flexibilities, other energy sectors	Flexible	Northern Europe	typically hourly	flexible	yes
Game-Theory	Multi-period equilibrium programming model (IMPC)	Strategic pricing of independent players, identification of system conditions	Transmission grid nodes	Individual countries	hourly	flexible	yes
Agent-based Simulation	Emlappy (TUDelft)	Policy instruments, power plant investments	One node	Europe	annually	decades	yes
Agent-based Simulation	AMIRIS (DLR)	Effects of regulatory frameworks, operation and investment of power plants, actor differentiation	one node	Germany	hourly	flexible	no
Agent-based Simulation	MASCEM (ISEP)	Different types of auctions, negotiation types and offers	flexible	Europe	hourly	flexible	yes
Agent-based Simulation	RESTrade (LNEG)	Balancing markets	one node per market	Iberian market	Hourly to 15 min.	flexible	no

New models developed within TradeRES

TradeRES Case Studies



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TradeRES' Scenarios

Demand side flexibility ↑

High level of sector coupling and demand-side flexibility	**S2 flexible**	**S4 radical**
Moderate level of sector coupling and demand-side flexibility	**S1 conservative**	**S3 variable**
	~85% wind + solar + hydro	>95% wind + solar + hydro

S0 base
~65% wind + solar + hydro
No sector coupling

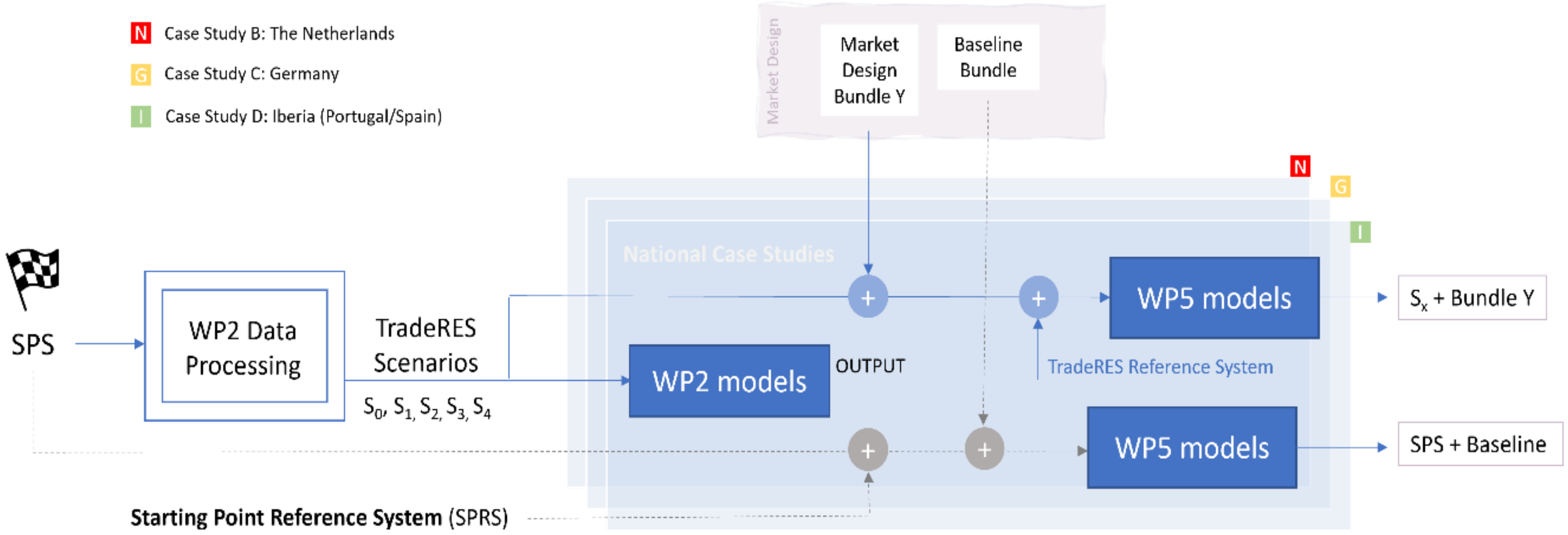
Non-thermal supply capacity →

Timeline for the scenarios.
2019 is the Starting Point Scenario (SPS).

S1 to S4 Scenarios differ on two parameters:

1) **Demand side flexibility**, and
2) **Non-thermal supply capacity**

Case studies & input scenarios



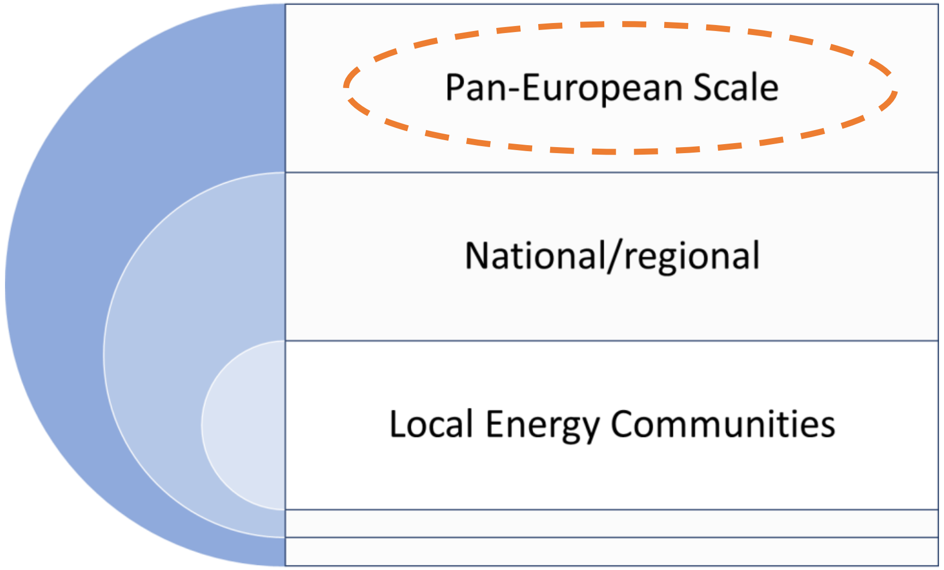
- ***Starting Point Scenario (SPS)*** corresponds to year 2019
- ***TradeRES Reference System (TRS)*** is the Reference System created by the optimization models for $S_0 - S_4$
- ***Starting Point Reference System (SPRS)*** is the Reference System that uses data and conditions of 2019
- ***Market Design Bundle*** refers to a combination of market design options that are being studied.

MPIs: the quantification of market performance

MPI #1	
Name (and acronym)	Share of renewable energy sources (RES) in the national demand.
Detailed description	This MPI indicates the level of integration of RES, including wind, solar, biomass, biogas, concentrated solar power, hydro power plants, others in the power system under analysis. Important to understand the position of the different energy mix scenarios analysed in the TradeRES project in the pathway for a near 100% RES power system.
Measuring the MPI/Unit	%
Mathematical formulation	$RES_{share} = \frac{\sum_{k=1}^{K}\sum_{t=1}^{T} RES\_Generation_{k,t}}{\sum_{t=1}^{T} Demand_t}$ where $RES\_Generation_{\square}$ is the generation from the *k-th* RES asset/technology at *t-th* time step. $Demand_t$ is the total electricity demand.
Target and optimal value (when applicable)	100%
Case studies	National/regional case studies; pan-European case study.

- A list of **MPIs – Market Performance Indicators** was established according to the project objectives.
- **MPI results** are being **used**:
  - i) to **provide recommendations for market design in a ~100% renewable power system**, and
  - ii) in the **stakeholders' engagement and dissemination activities** (WP 6 and 7, respectively).

❑ Pan-European wholesale electricity: Case Study E

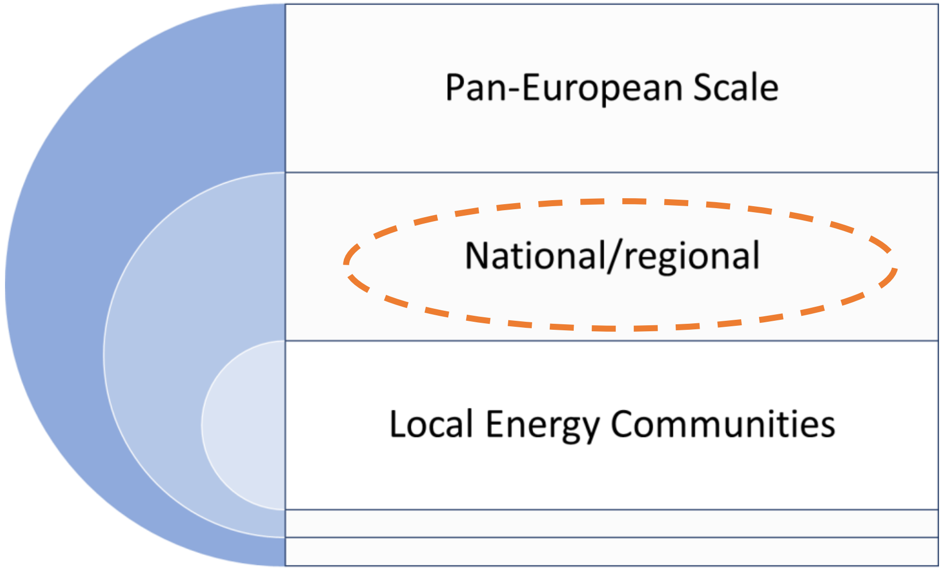


- As foreseen in the European Clean Energy Plans.

- Very large scale requires some simplifications since:
  i) intraday markets, some countries use auctions and other continuous trading.
  ii) European balancing markets use several different methodologies for procuring energy.

- One main issue for a **full harmonization of the European day-ahead markets is the implicit allocation of the cross-border capacity** (e.g., by EUPHEMIA) → we propose to include a **dynamic line rating** approach **to calculate the cross-border ampacity** (transmission capacity) for pre-identified constrained connections, using VREs generation forecasting.

❑ National and Regional Markets: Case studies B - D



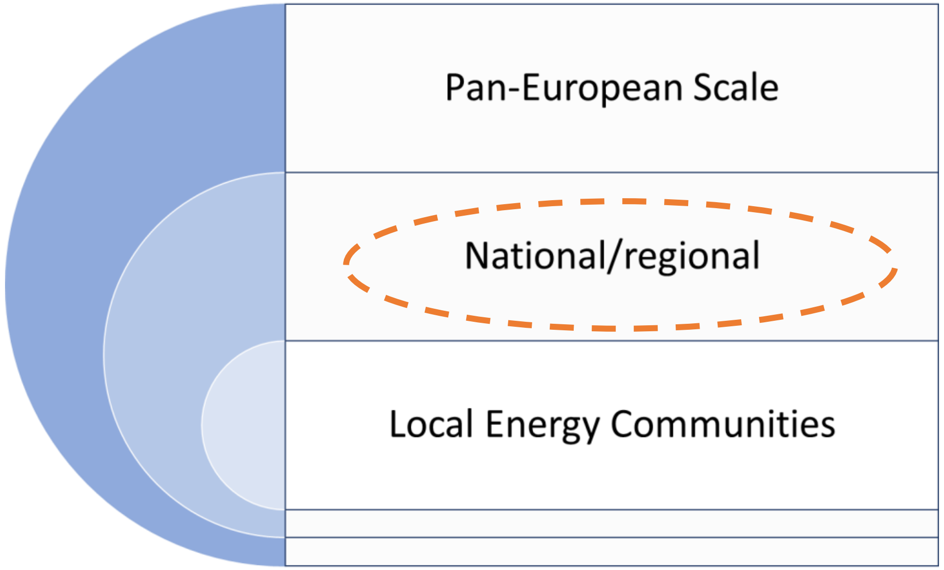
- **3 case studies (Netherlands, Germany,** and **Iberia)** will be considered and the performance of the new market designs (and products) under different markets features will be assessed;

- The **results compared/validated** in two steps with:

  i) a **reference (optimal) energy mix/capacity obtained from WP2**, with design from WP3 and tools from WP4, excluding economic effects, and;

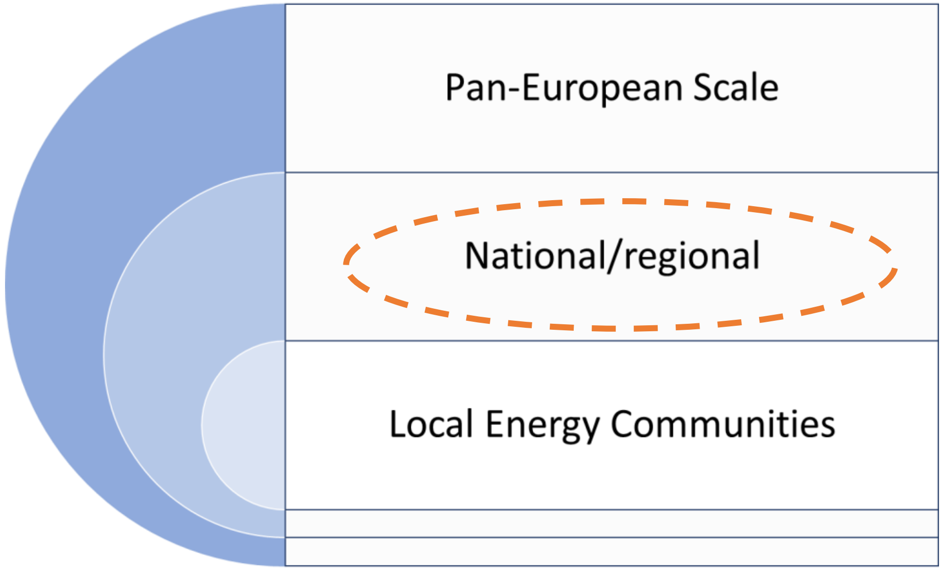
  ii) a "**baseline market scenario",** corresponding to the WP2 reference data applied to <u>market designs and models existing nowadays</u>.

❑ National and Regional Markets: The Netherlands - Case study B



- The Netherlands is part of the EPEX SPOT market (together with seven other countries);
- The large-scale potential of wind offshore in the North Sea puts The Netherlands in a privileged position to accommodate large shares of VRE and distribute energy to its neighbors;
- The performance assessment of a new market design (WP3) for Netherlands will be addressed using TradeRES novel tools (WP4) and COMPETES for the baseline scenario.

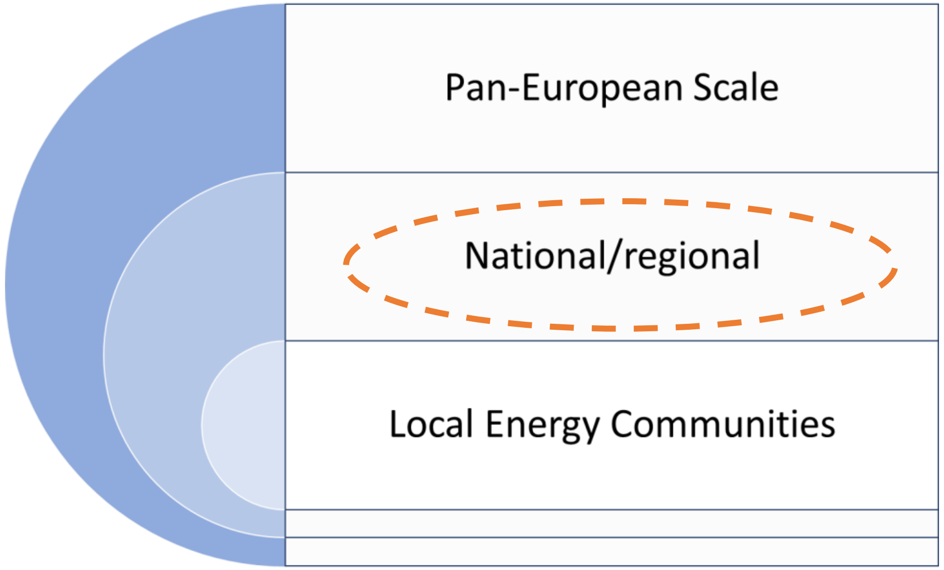
❑ National and Regional Markets: Germany - Case study C



- Germany is the country with the highest share of variable renewables within Europe. Therefore, the assessment of the new in TradeRES developed electricity market designs here is of utmost importance;

- DLR will run this case study with the model AMIRIS and compare the new TradeRES market designs with the baseline market scenario.

❑ National and Regional Markets: MIBEL Portugal/Spain - Case study D



- The Iberian market is one of the markets with the highest liquidity in intraday markets, share of bilateral trades and penetration of VREs;
- It is also the European market with the highest costs at all trading horizons, especially in the ancillary services of the system, thus constitutes an ideal case study to test the performance of the TradeRES novel market designs and products;
- ISEP (and LNEG) conduct this case study using this task common methodology and the models MASCEM and RESTrade for all scenarios.

TradeRES

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Questions/Comments?

More information at https://traderes.eu/

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