TradeRES
New Markets Design & Models for
100% Renewable Power Systems

Pan-European case study – evaluating different types of Contracts for Difference

EERA-ESI TradeRES workshop

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Pan-European Case Study

1) Does the energy-only-market yield **sufficient returns** to incentivize investments in different fully renewable European energy system scenarios?

2) If **other instruments complementing the energy-only-market** are needed, how should they be designed?

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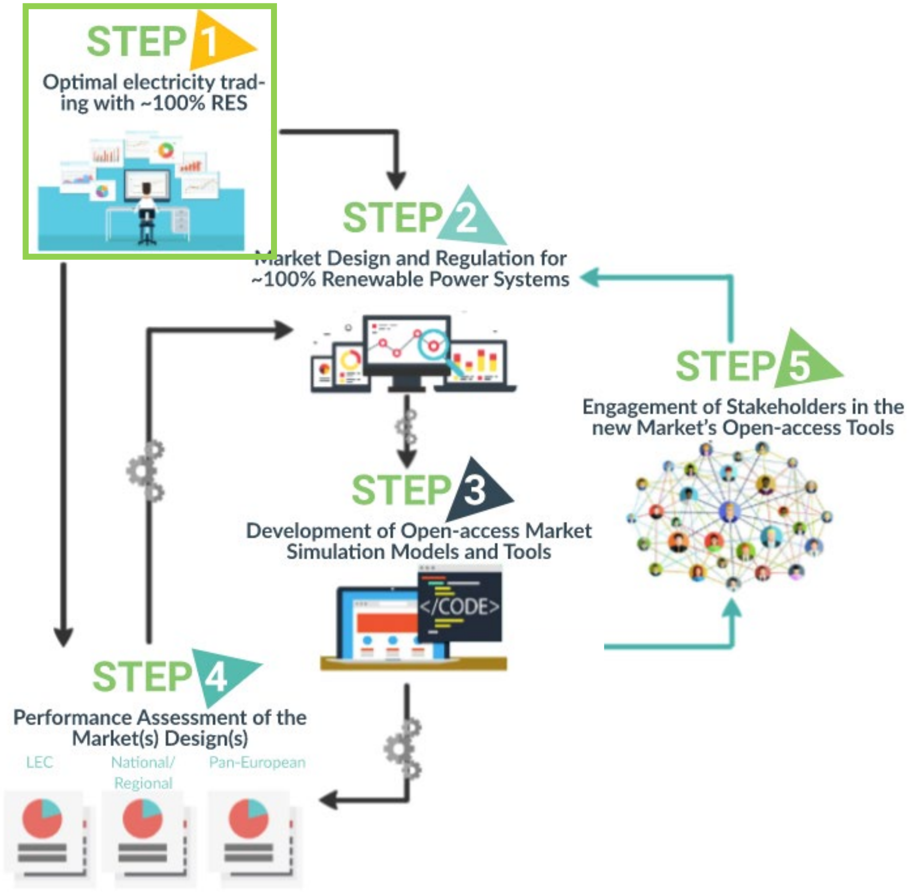
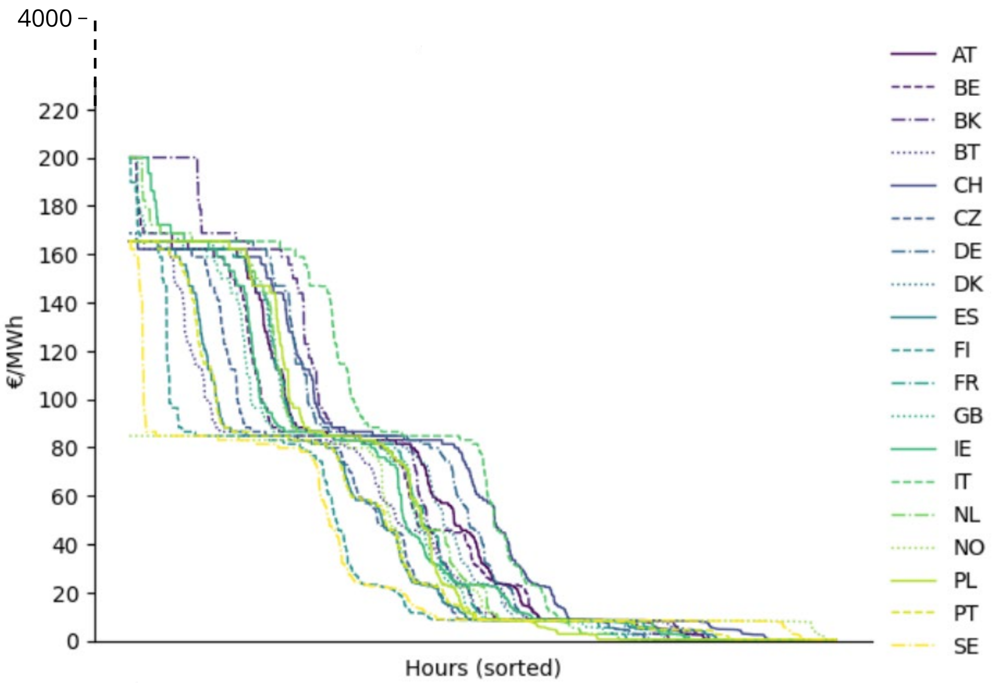
Different types of Contracts for Difference (CfDs) for wind onshore

TradeRES Approach



Fully decarbonized reference system

Price Duration Curves by node



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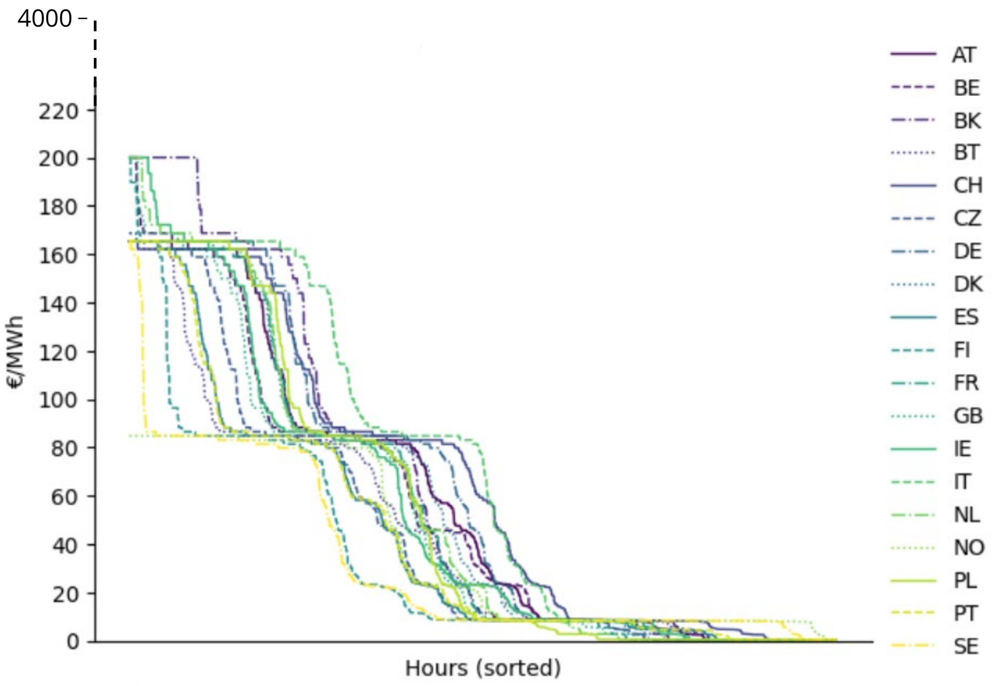
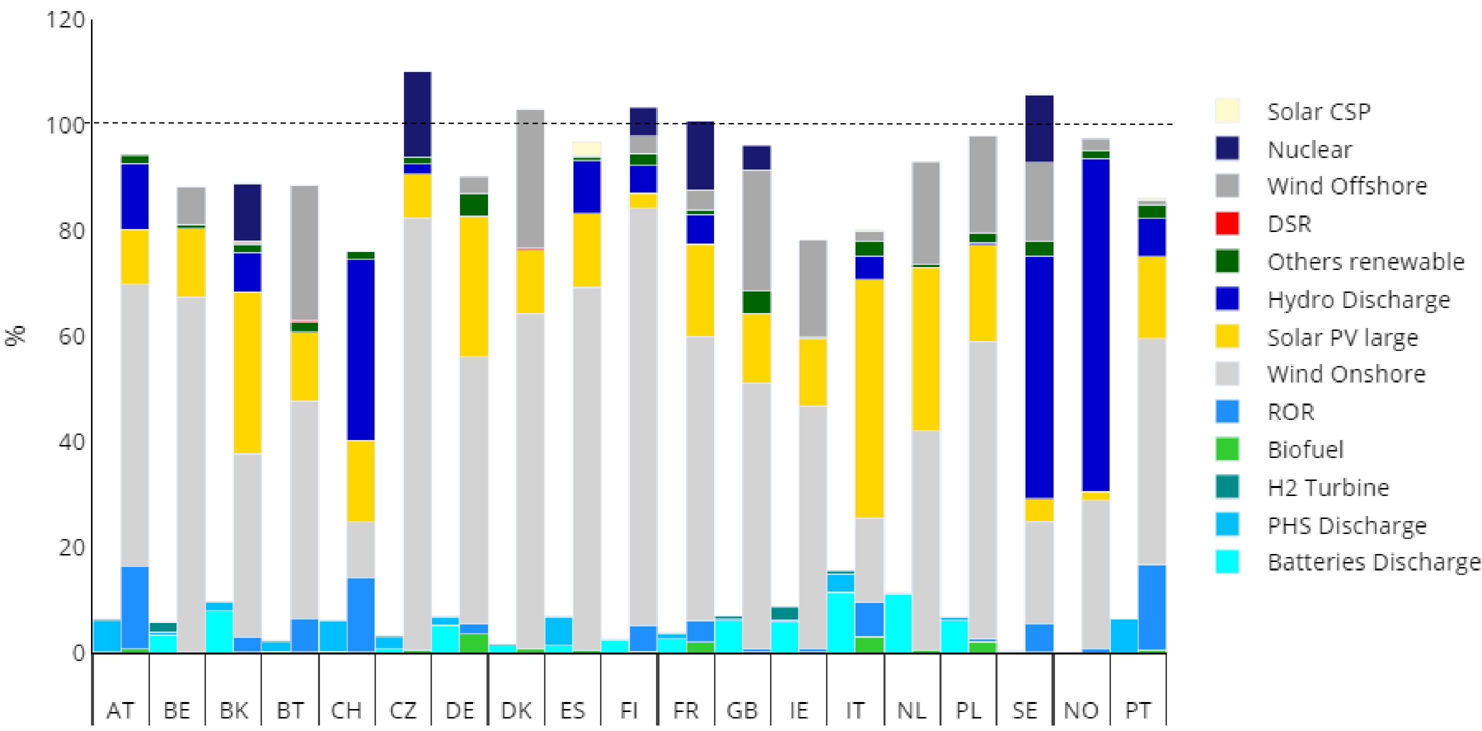
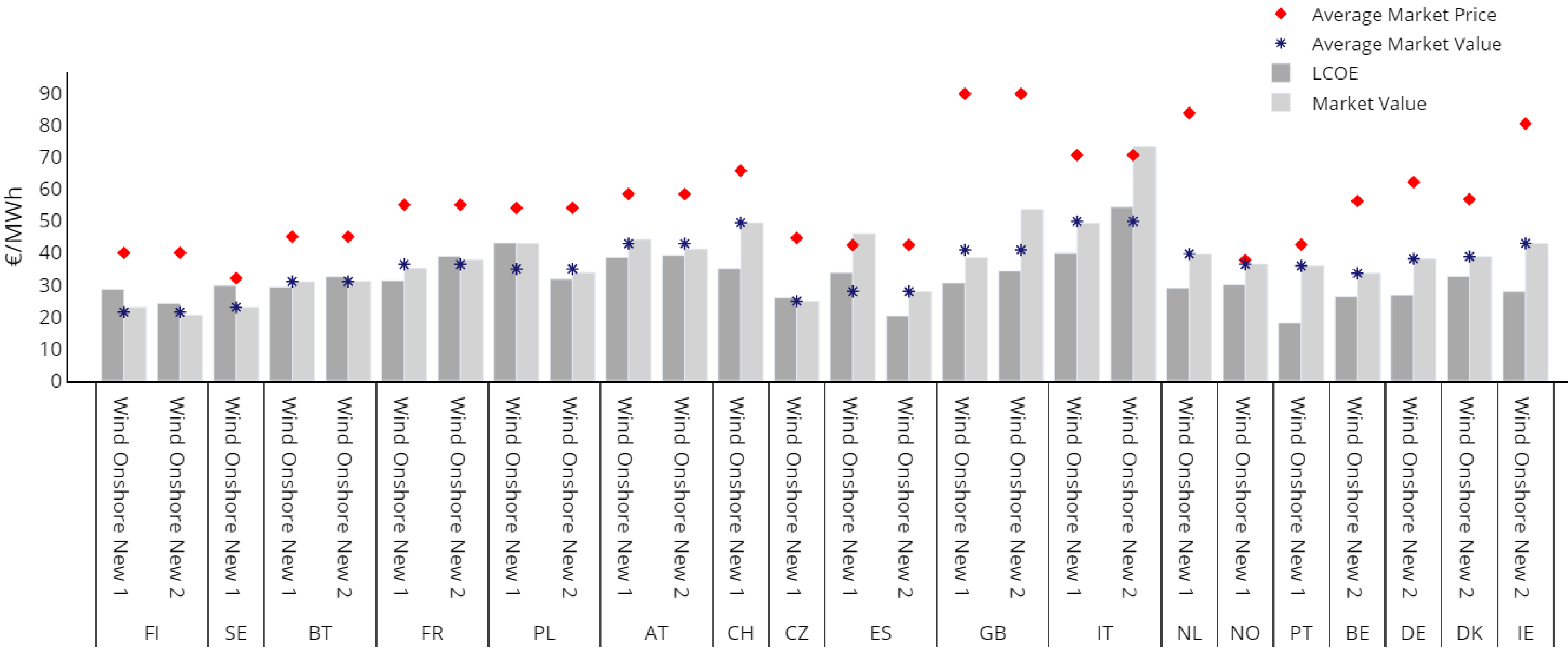


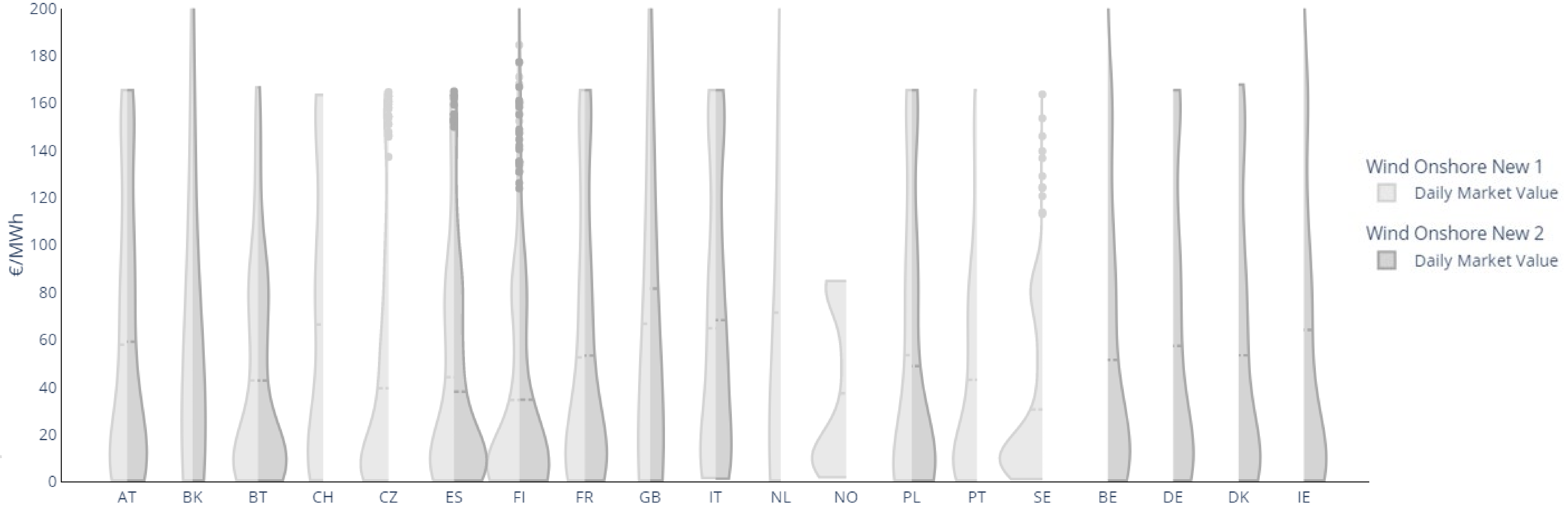
Electricity Generation Share by Type



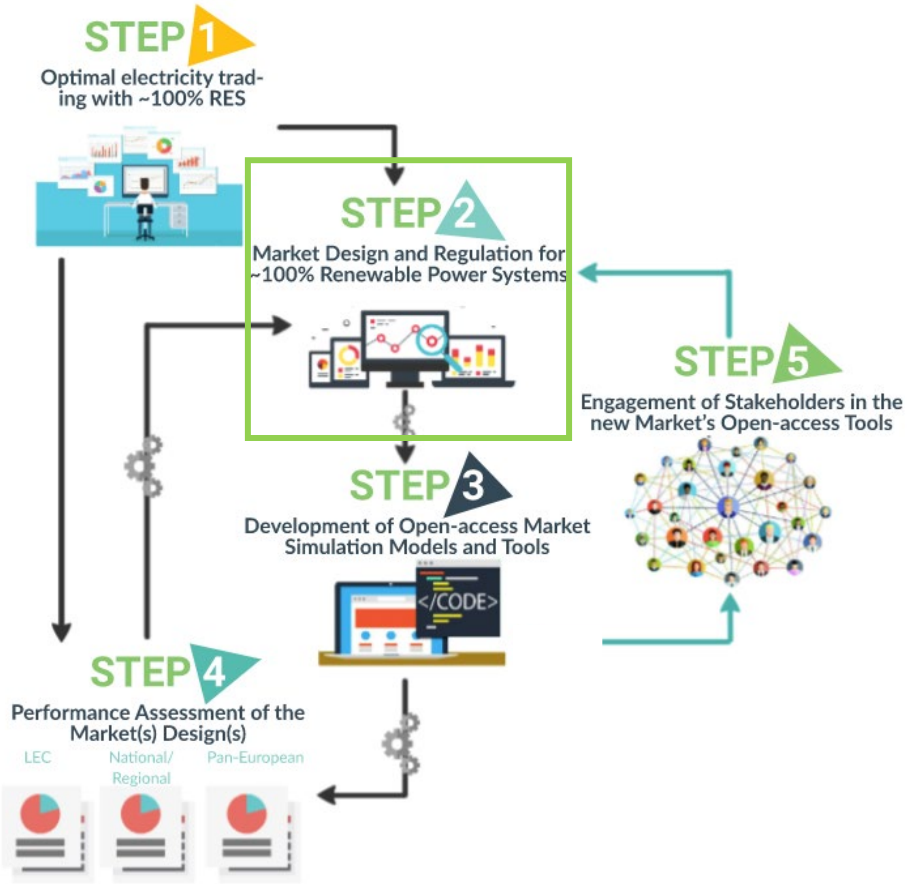
Profitability of wind power



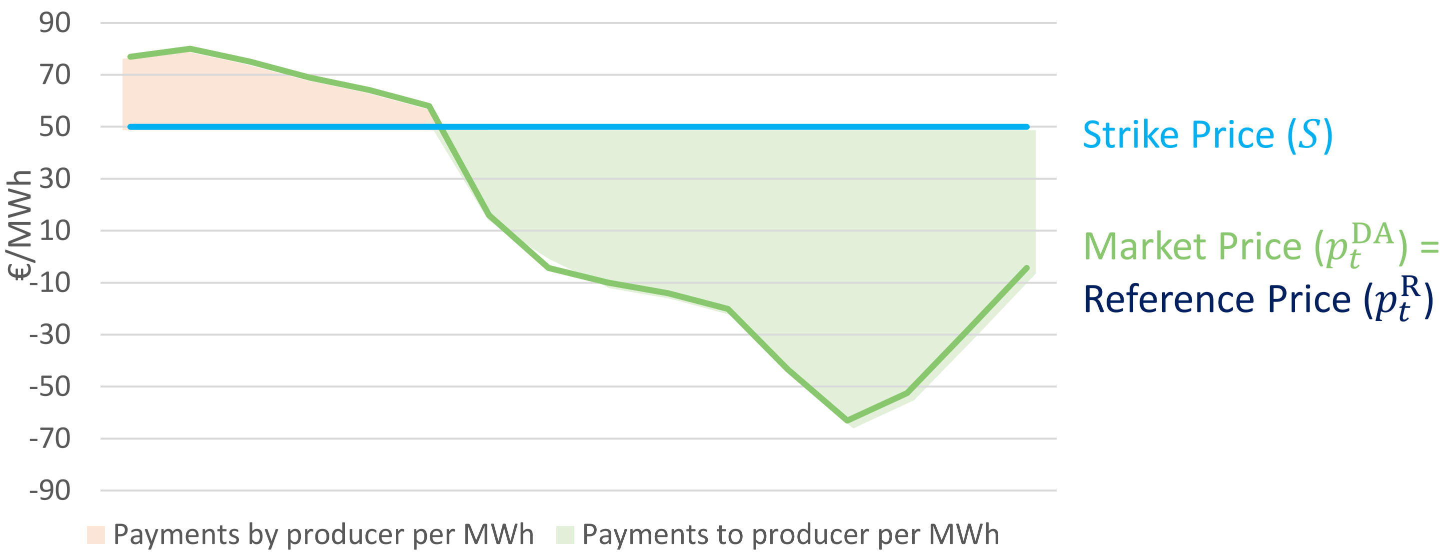
Risk profile of wind power



TradeRES Approach



Simple 2-way Contract for Difference
Reference Price = Hourly day-ahead price



Revenues with generation q_t:

$$\sum_{t}^{T}(p_t^{DA} + S - p_t^{R})q_t$$

Simple 2-way Contract for Difference
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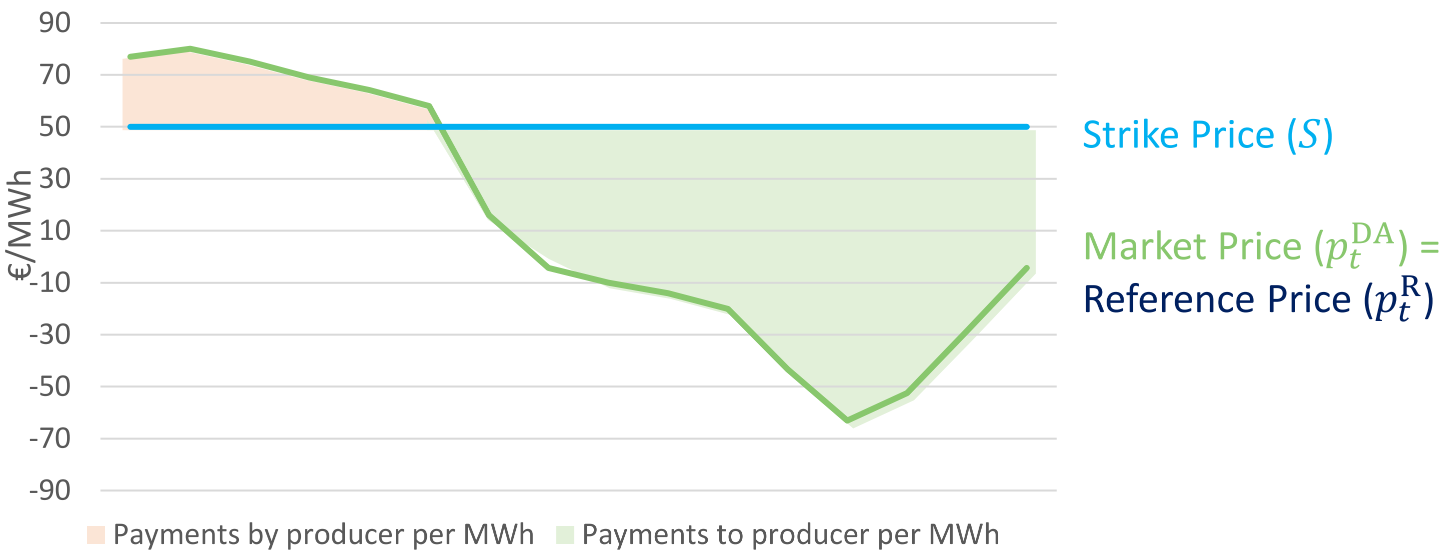
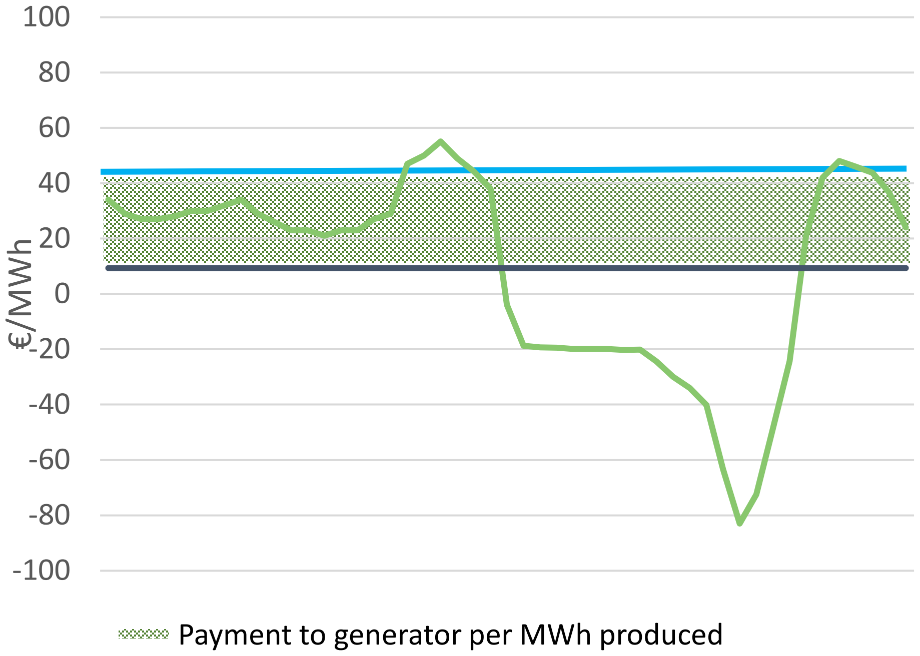


Revenues with generation q_t: $\sum_t^T (p_t^{DA} + S - p_t^R) q_t$

The simple 2-way CfD essentially constitutes a capacity premium at the level of $E(S - p_t^R) q_t$

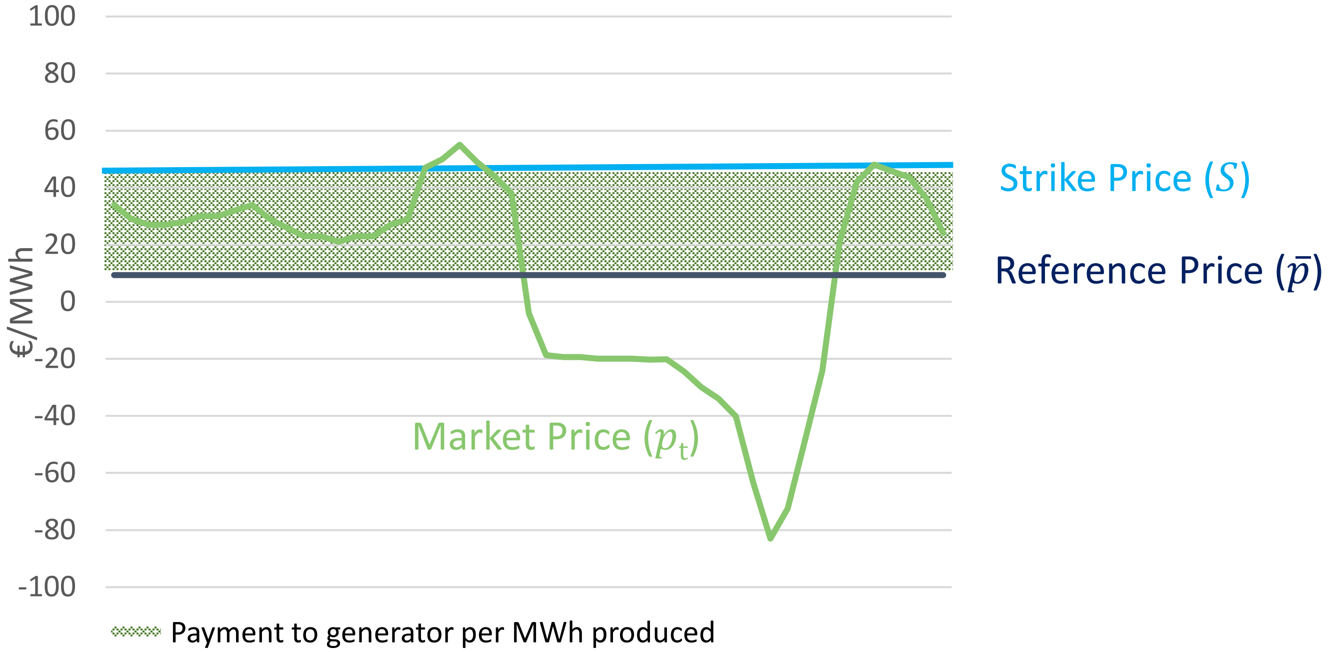
Sophisticated Contract for Difference – Case 1
Reference Price = Average price/market value

2-way CfD



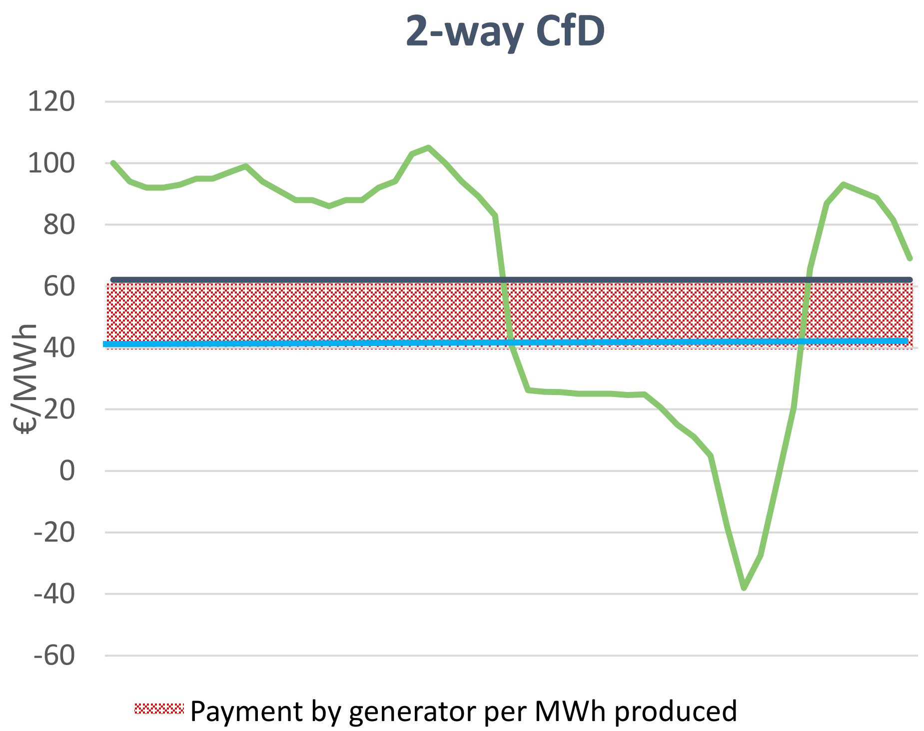
Revenues with generation q_t: $\sum_{t}^{T} (p_t q_t - (\bar{p} - S) q_t)$

1-way CfD

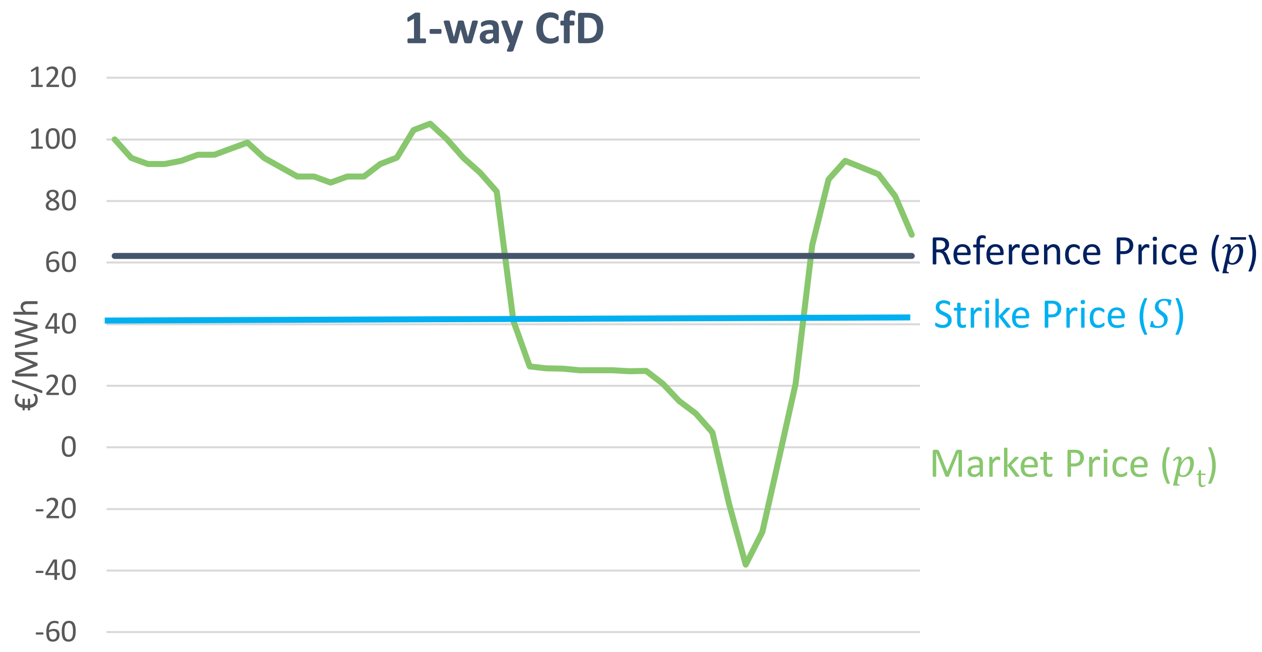


Revenues with generation q_t: $\sum_{t}^{T} (p_t q_t - (\min\{0, \bar{p} - S\}) q_t)$

Sophisticated Contract for Difference – Case 2
Reference Price = Average price/market value

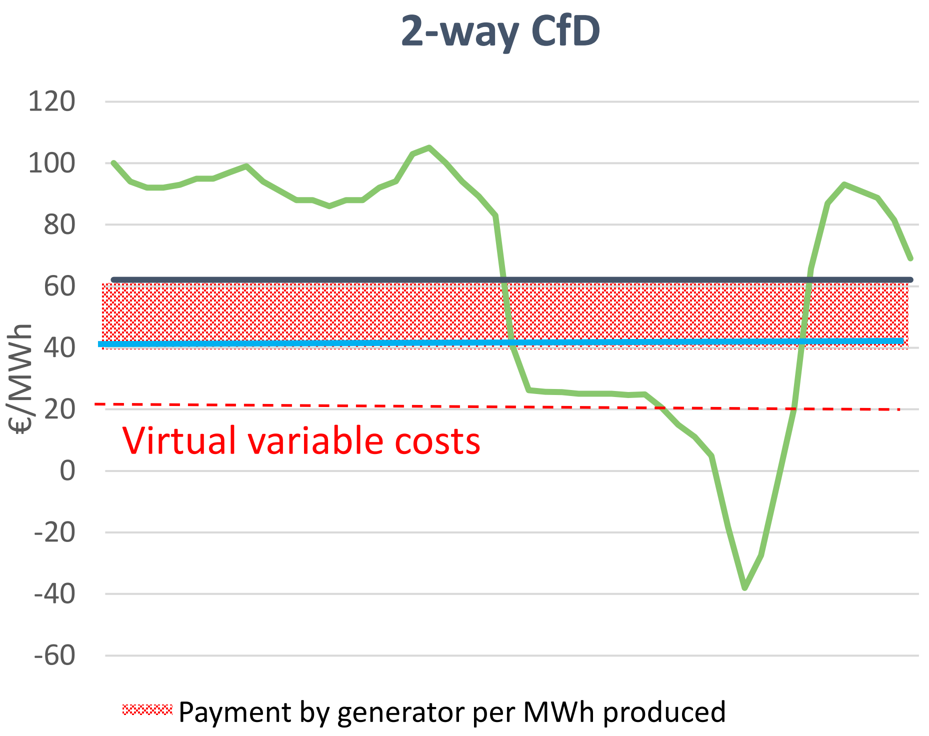


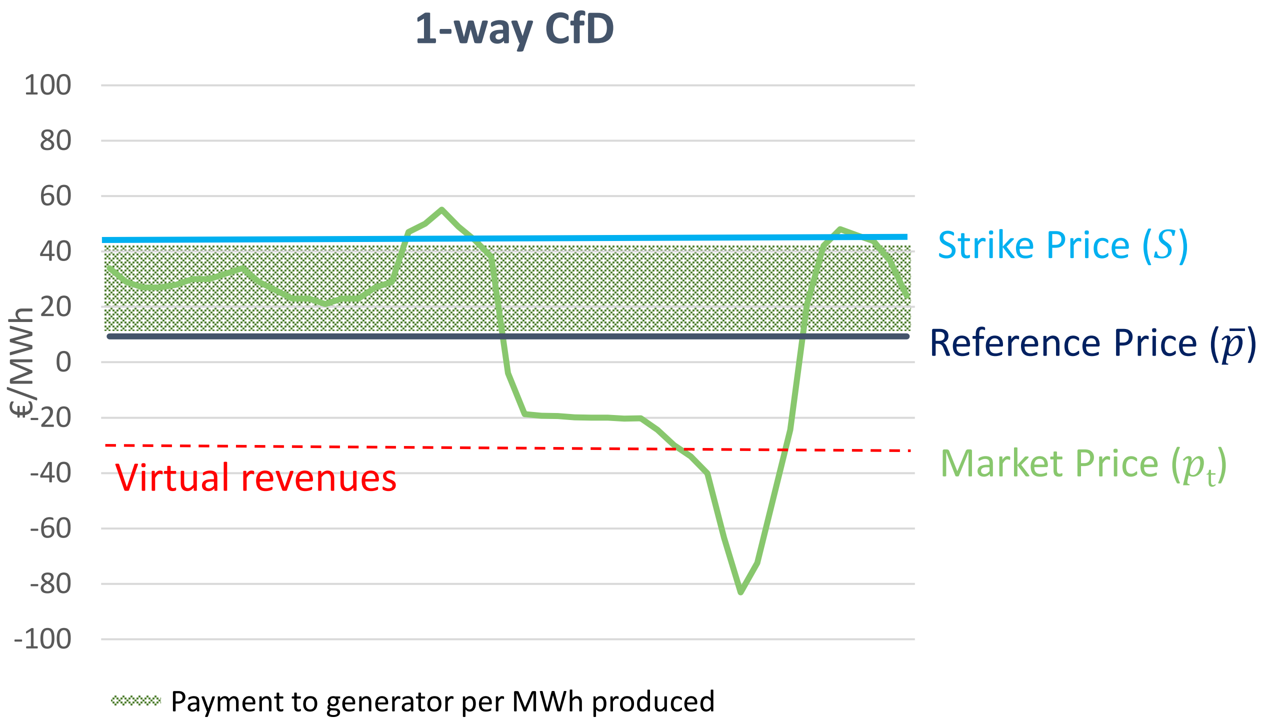
Revenues with generation q_t: $\sum_{t}^{T}(p_t q_t - (\bar{p} - S)q_t)$



Revenues with generation q_t: $\sum_{t}^{T}(p_t q_t - (\min\{0, \bar{p} - S\})q_t)$

Sophisticated Contract for Difference Reference Price = Average price/market value

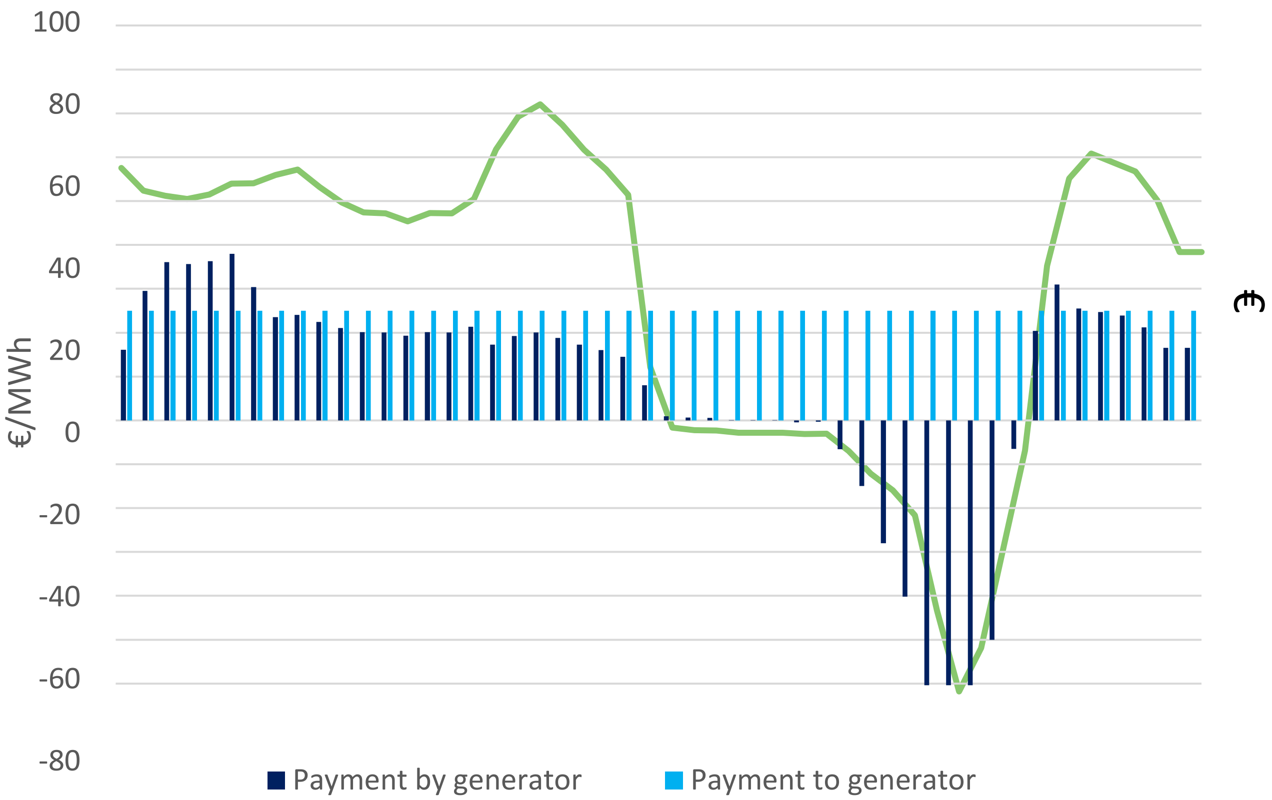




From an ex ante perspective the anticipated payments from sophisticated CfDs constitute virtual variable costs/revenues

Financial Contract for Difference
Payments independent of power produced

Market Price (p_t)



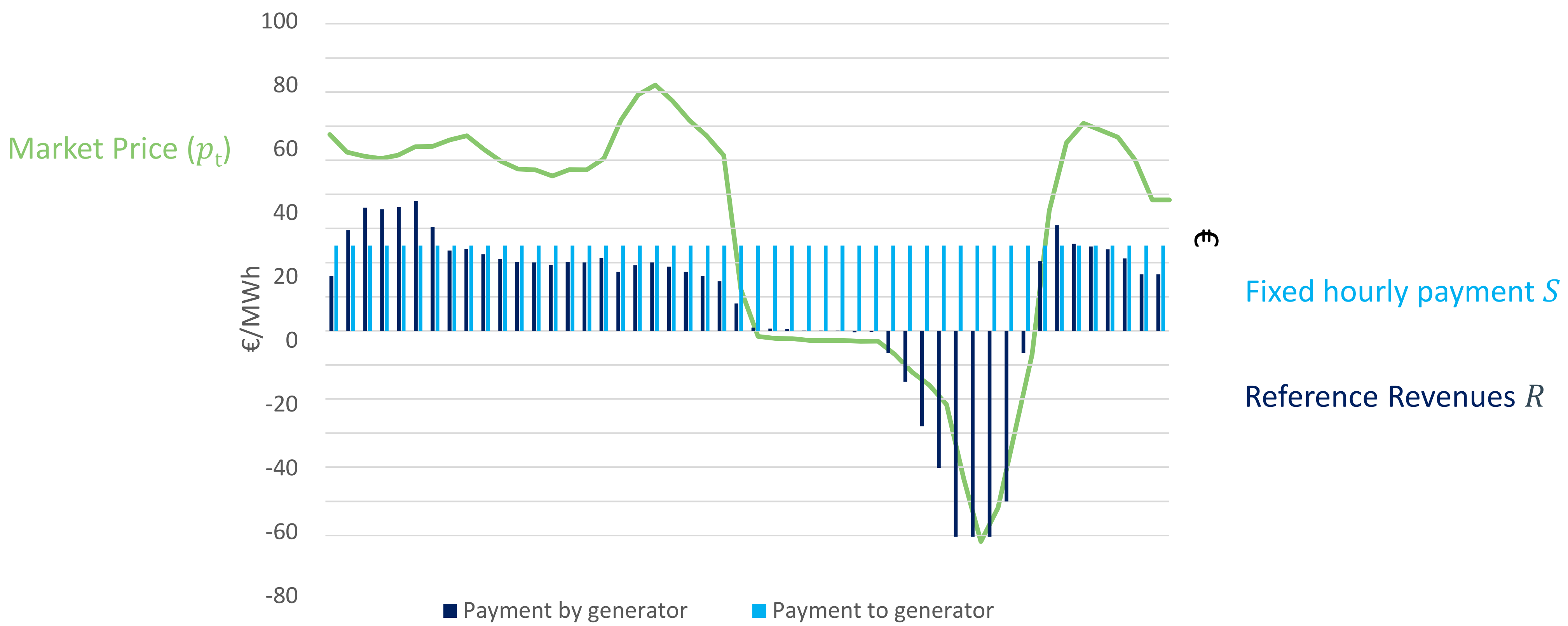
Fixed hourly payment S

Reference Revenues R

Revenues with generation q_t: $\sum_{t}^{T}(p_t q_t) + S - R$

Reference: Schlecht, Hirth and Maurer (2022)

Financial Contract for Difference
Payments independent of power produced



From an ex ante perspective the financial CfD constitutes a capacity premium at the level of $S - R$

Reference: Schlecht, Hirth and Maurer (2022)

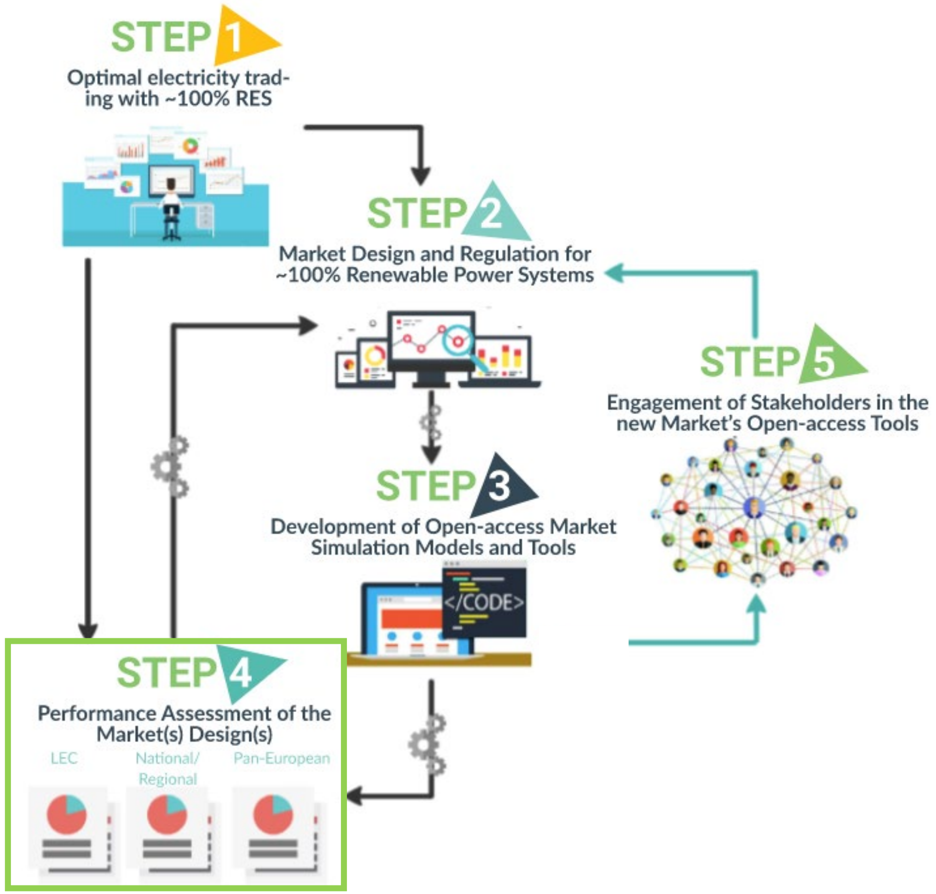
Theoretical conclusions on different types of CfDs

- Simple 2way CfD eliminates price signals and therefore, causes inefficient investment

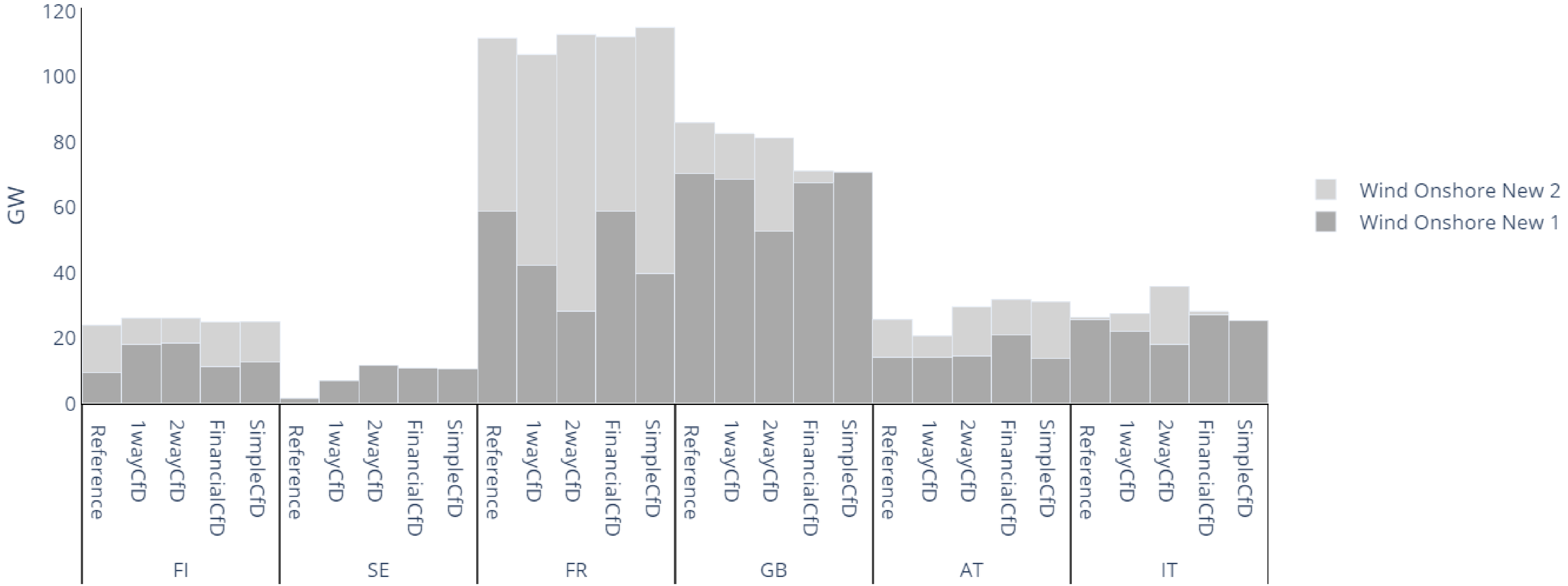
- Sophisticated CfDs expose renewables to price signals and therefore, incentivize investments in system-friendly power plants, yet they cause dispatch distortions

- Financial CfDs expose renewables to price signals without distorting dispatch

TradeRES Approach



Preliminary Results: Investments



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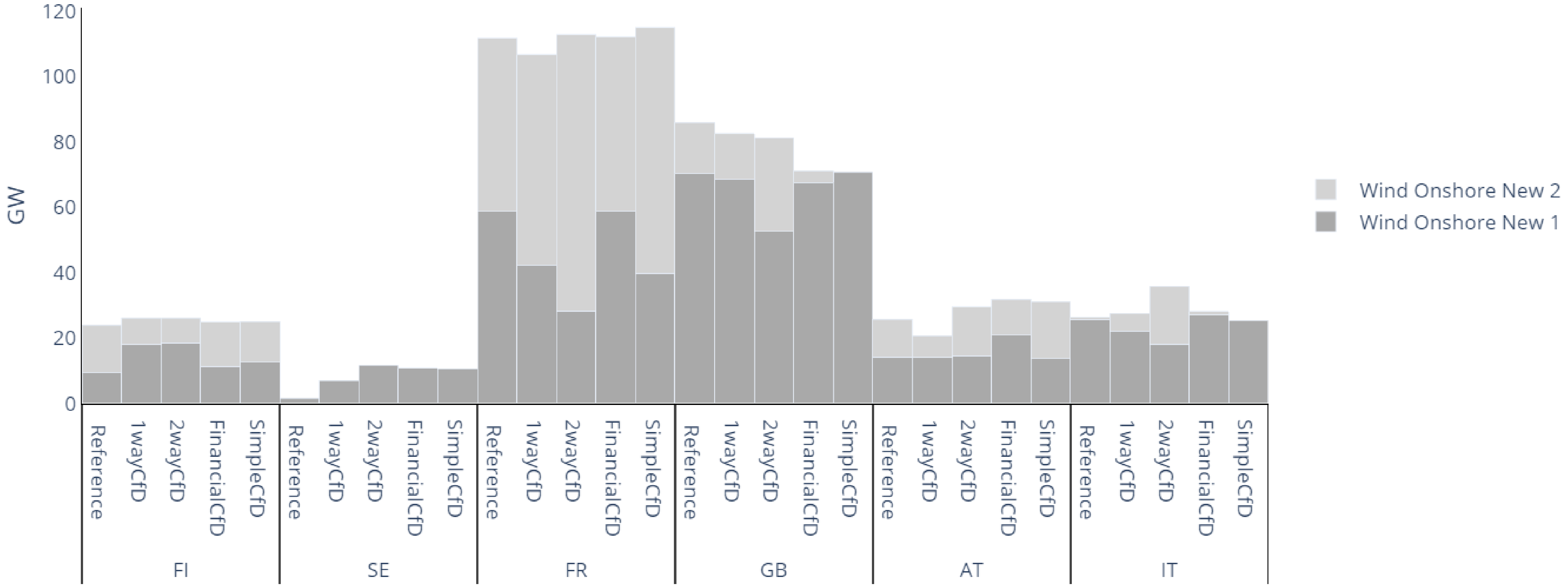
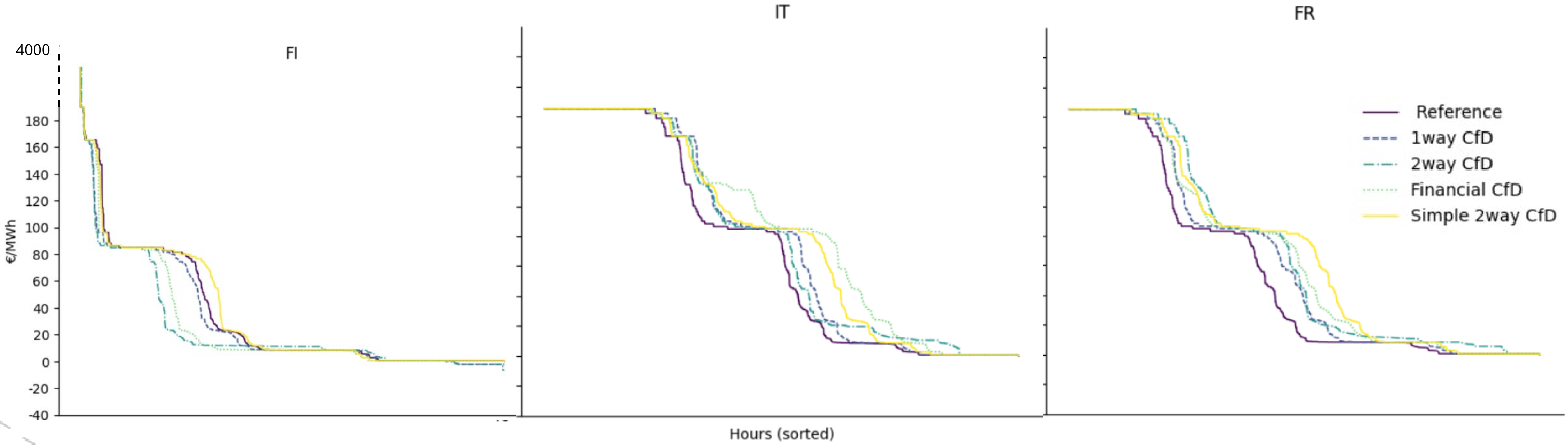


Mix of profiles: Financial CfD comes closest to reference in most countries
Level of investment: payments can lead to overshooting or missing expansion goal

Preliminary Results: Resulting Price Duration Curves



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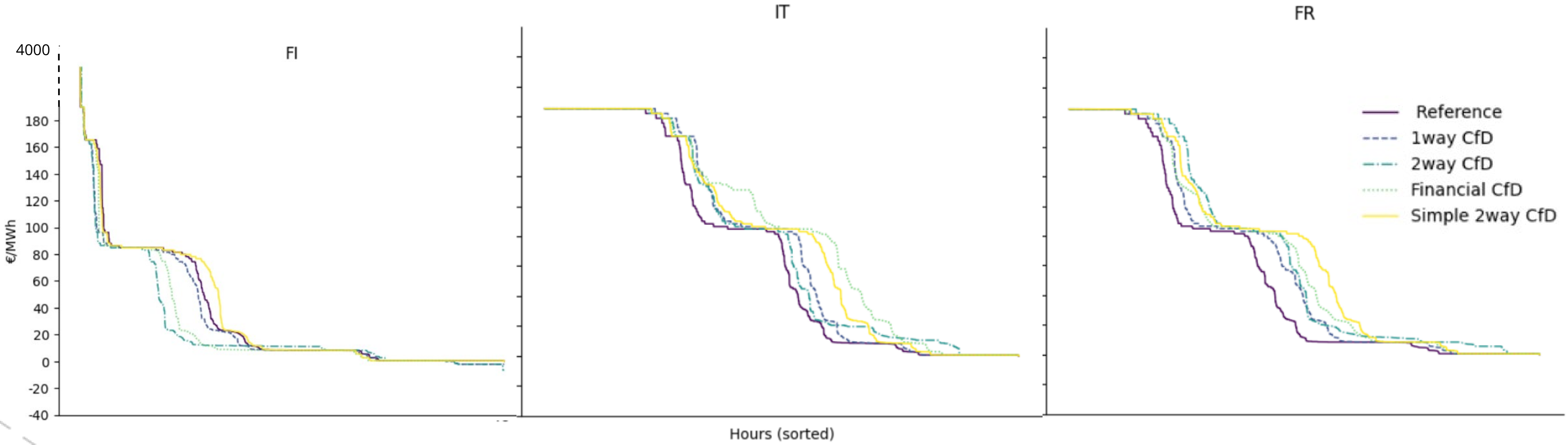

Wholesale prices are affected by both distorted investment and dispatch caused by the CfDs

Conclusion, Limitations and Outlook

Preliminary Conclusion:

- Design of CfDs impacts investment in type of wind power plant, financial CfD comes closest to reference scenario
- Dispatch is impacted by both distorted investment and virtual variables costs/revenues, resulting in shifts in price duration curves

Limitations and Outlook:

- More analyses:
    - Consumer perspective: system costs and subsidy payments
    - Investor perspective: ex-post profitability and risk analysis
- Ex ante vs. ex post payments -> more iterations
- Assumption: all power plants are remunerated within the auction -> limit „payments“ to a certain capacity?
- TradeRES will cover more market designs

EnBW

RUB EE Chair of Energy Systems & Energy Economics

TradeRES

New Markets Design & Models for 100% Renewable Power Systems

Thanks ☺

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www.traderes.eu

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Data

Model

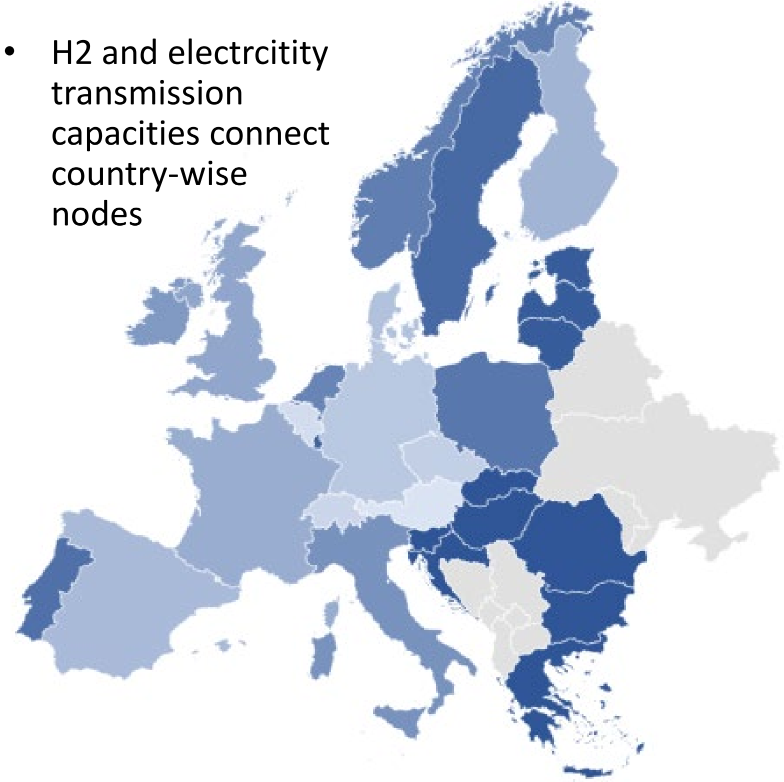
- Flexible open-source energy system modelling framework **Backbone**
- Cost-minimizing **capacity expansion planning** and subsequent **unit commitment**
- Minimum share of variable renewables as **constraint**
- Interpretation of **marginal system costs as electricity prices**

Power Plants

- **VRE:** Solar PV, Solar CSP, Wind onshore and offshore, Run of river hydro (weather year 2019)
  - 2 wind profiles
- **Thermal:** Biofuel, waste, nuclear and hydrogen CCGT
- **Storage:** Pumped hydro and reservoir hydro, batteries and hydrogen storage with electrolysers
- Industrial **load shedding** units
- Maximum price = **4000€**
- Exogeneous and unlimited endogeneous capacities for all technologies except hydro power
- Fixed fuel prices

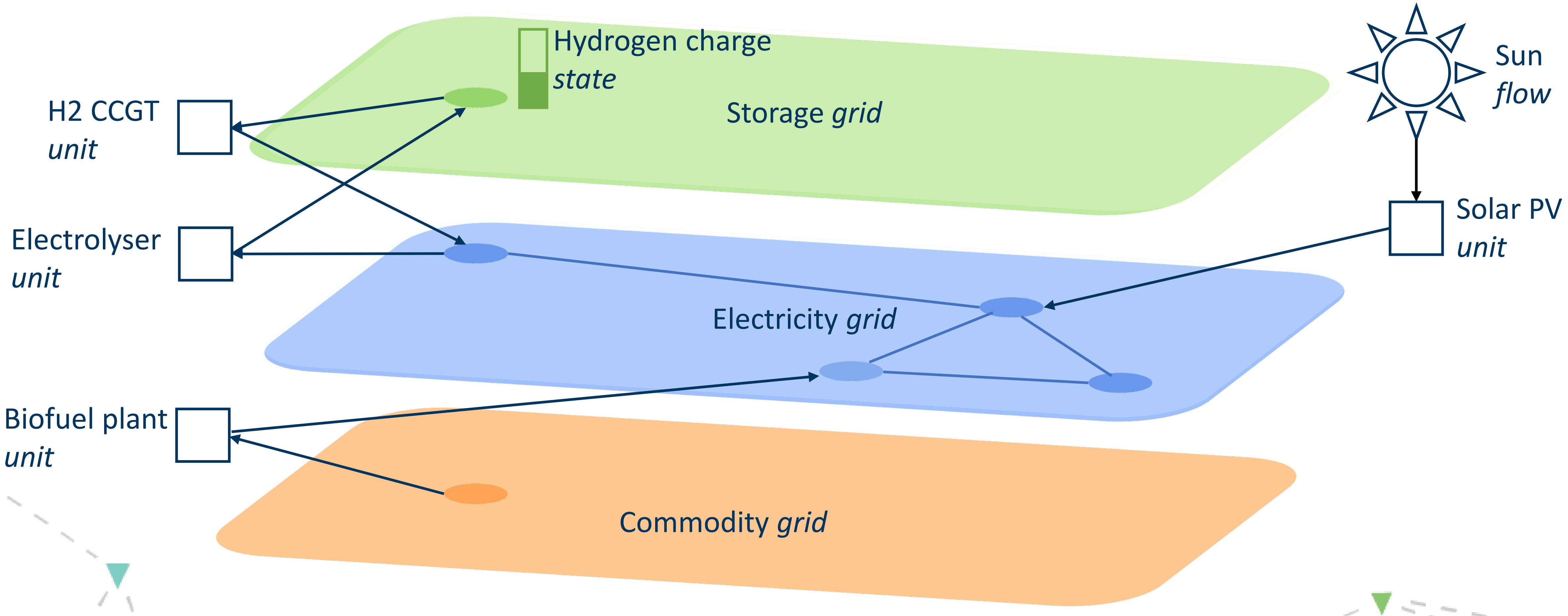
Geographical Scope

- H2 and electrcitity transmission capacities connect country-wise nodes



Data: TradeRES Public Deliverable D2.1, Entso-E ERAA 2022, Entso-E TYNDP 2022, Renewables Ninja, RUB EE‘s Pypsa-to-BB, Denish Energy Agency, Gils et al. (2014)
Literature: Helistö et al. (2019), Böttger et al. (2022), Gillich & Hufendiek (2022), Finke et al. (2023)

Optimization model: Backbone



Reference: Helistö et al. (2019), https://gitlab.vtt.fi/backbone/backbone

Implementation of sophisticated CfDs in our model

Idea: add ex ante anticipated virtual variable costs/revenues as variable costs in the model

Reference System →

LCOE per technology and country = Strike Price (S)

Average yearly market value per technology = Reference Price ($\bar{p}$)

Variable costs $= \min\{0, \bar{p} - S\}$ → 1-way-CfD

No VRE constraint

Variable costs $= \bar{p} - S$ → 2-way-CfD

Literature: Frey et al. (2020), Gillich & Hufendiek (2022)

Implementation of simple 2-sided CfD and financial CfD

Idea: substract ex ante anticipated payments from investment costs in the model (capacity premium)

Reference System

LCOE per technology and country = Strike Price (S)

Generation = gen

own revenues

reference revenues = average revenues per technology and country

InvCosts = InvCosts – (S x **gen** - own revenues)

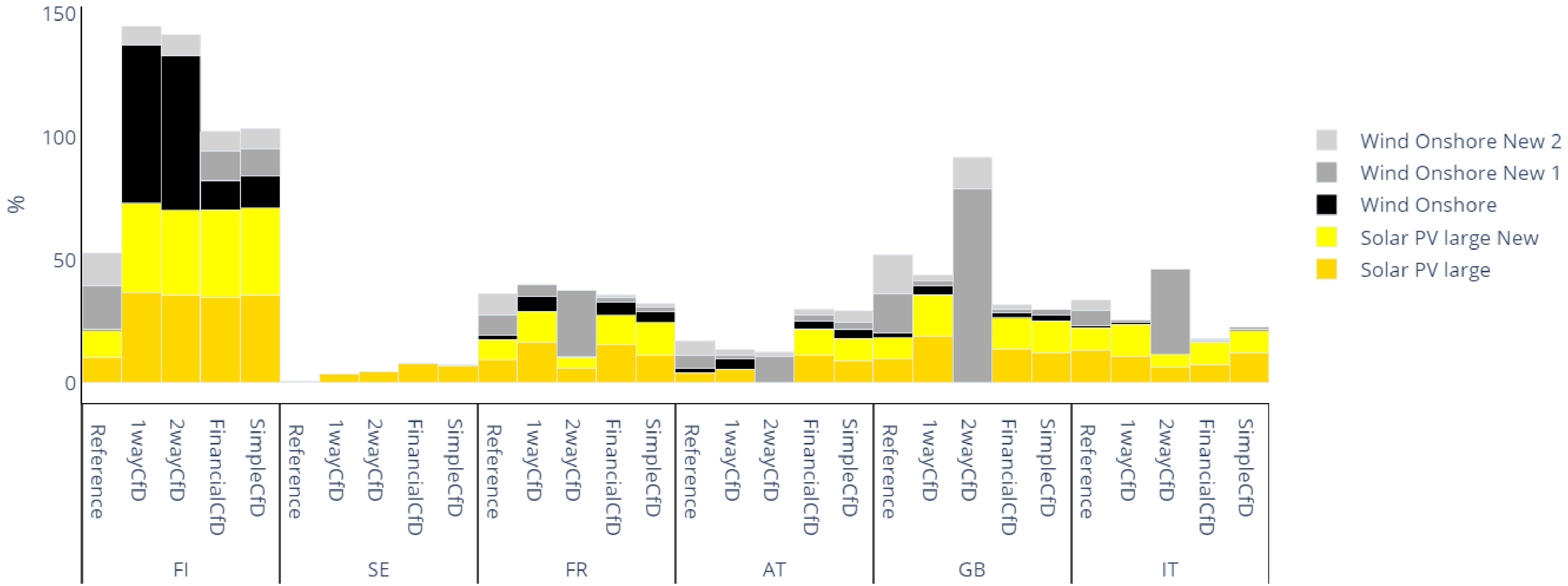
Simple CfD

No VRE constraint

InvCosts = InvCosts – (S x **gen** - reference revenues)

Financial CfD

Preliminary Results: Curtailment



Preliminary Results: Storage activity