TradeRES

New Markets Design & Models for 100% Renewable Power Systems

Evaluating different types of CfDs in a fully decarbonized European wholesale electricity market

IEEE‘s European Energy Markets Conference 2023

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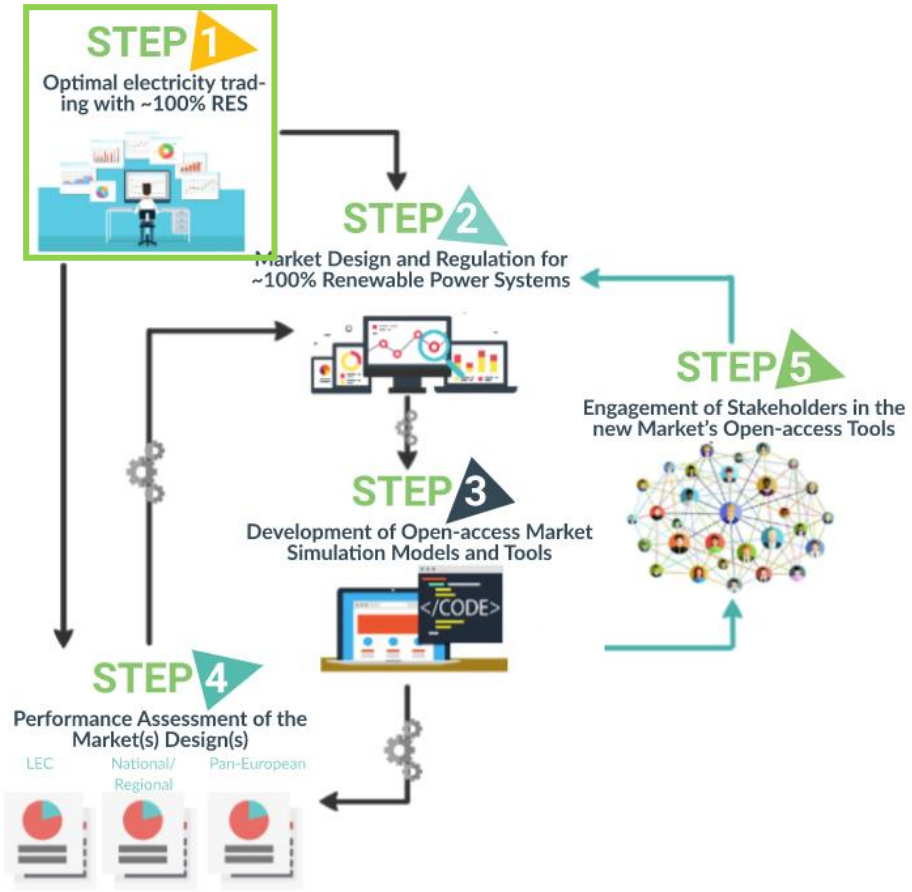
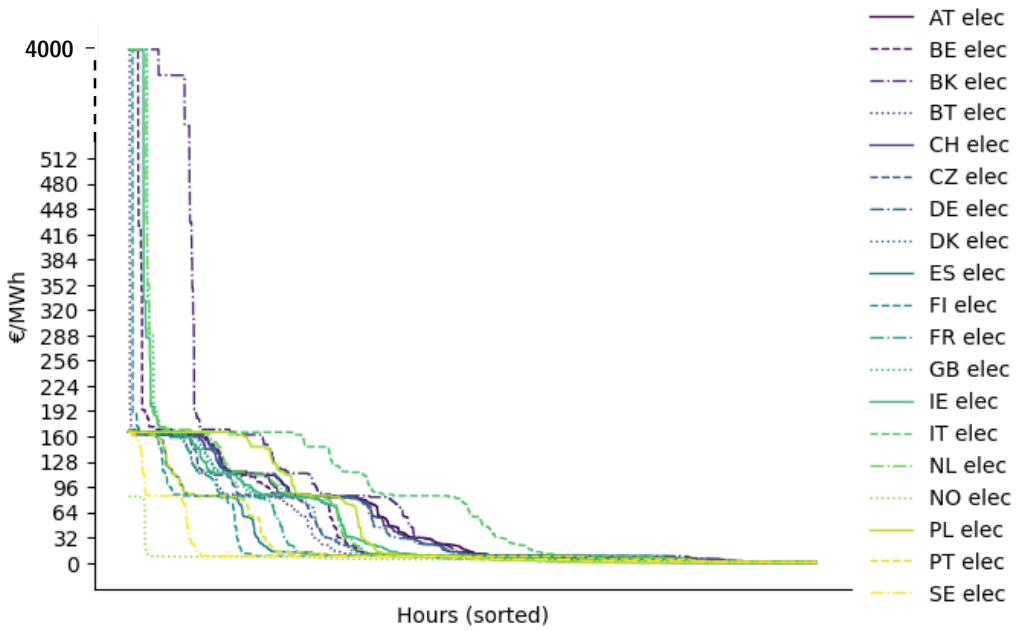
Different types of Contracts for Difference (CfDs) for wind onshore

TradeRES Approach

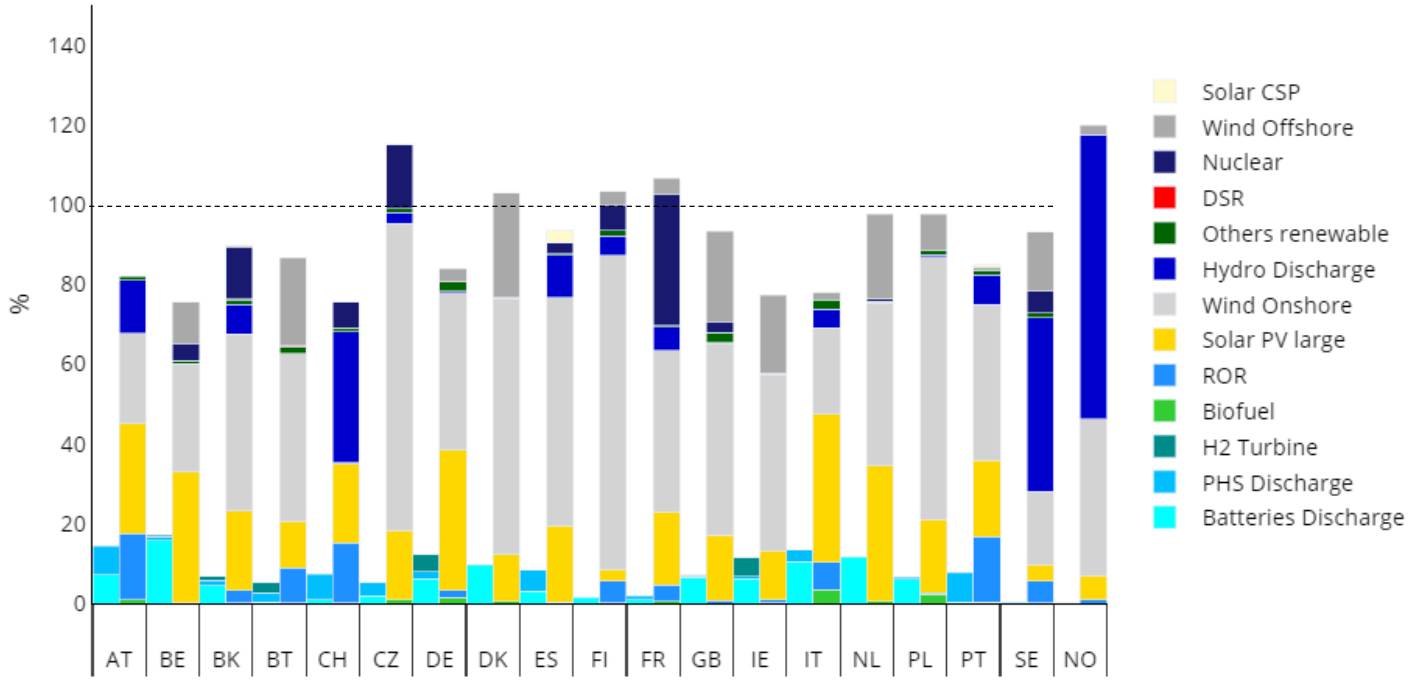


Reference System with ≥ 95% non-thermal renewables by constraint

Price Duration Curves



Electricity Generation Share by Type



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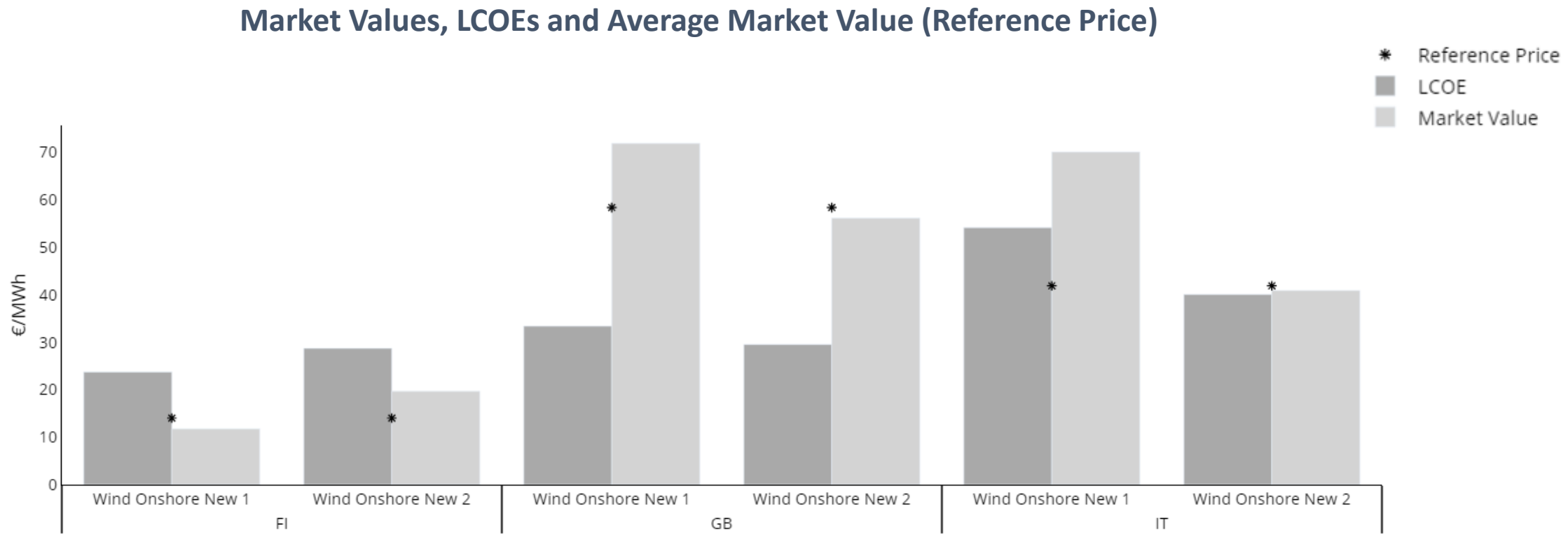

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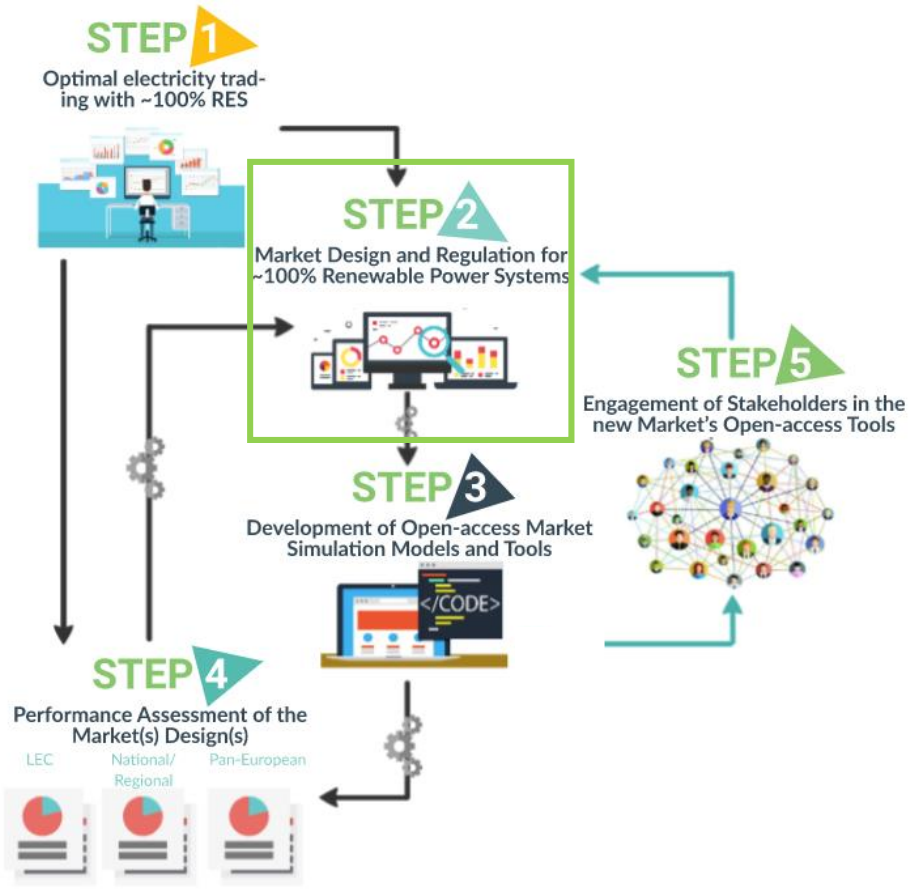

Contracts for Difference Definition and Elements

"CfDs are financial contracts that specify payments from a buyer to a seller if the **price** of an underlying is below the agreed-upon **strike price** and [in case of a two-way CfD] a reverse payment otherwise."

Reference: Schlecht, Hirth and Maurer (2022)

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Renewable electricity CfDs:

- seller: renewable energy producers
- buyer: government
- **strike price:** typically determined via an auction, competitive bid = ~ LCOE
- reference **price:** hourly/monthly/yearly day-ahead/intraday price?

Reference: Schlecht, Hirth and Maurer (2022)

Contracts for Difference Evaluation Criteria

1) Optimal design and siting (investment stage): investment in cheapest, but also system-friendly power plants

2) Optimal utilization (operational stage): always produce when price > actual short-term variable costs

3) Achieving a policy target: expansion of renewables by decreasing investment risks (and protecting consumers)

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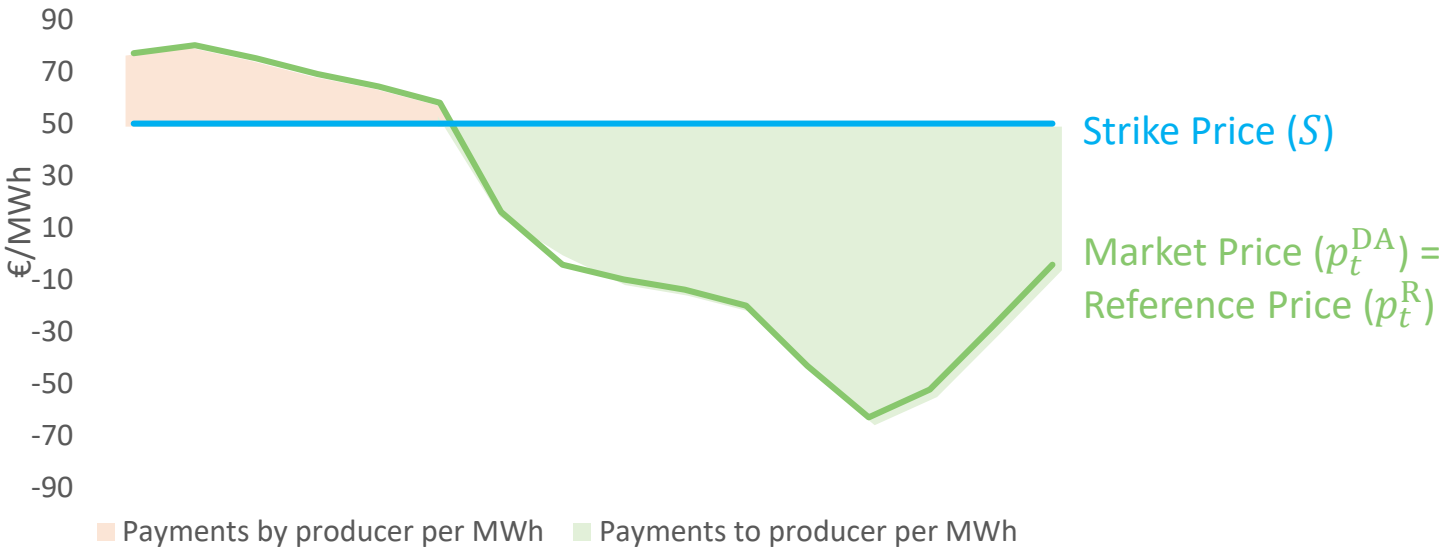
Simple 2-way Contract for Difference
Reference Price = Hourly day-ahead price



Revenues with generation q_t:

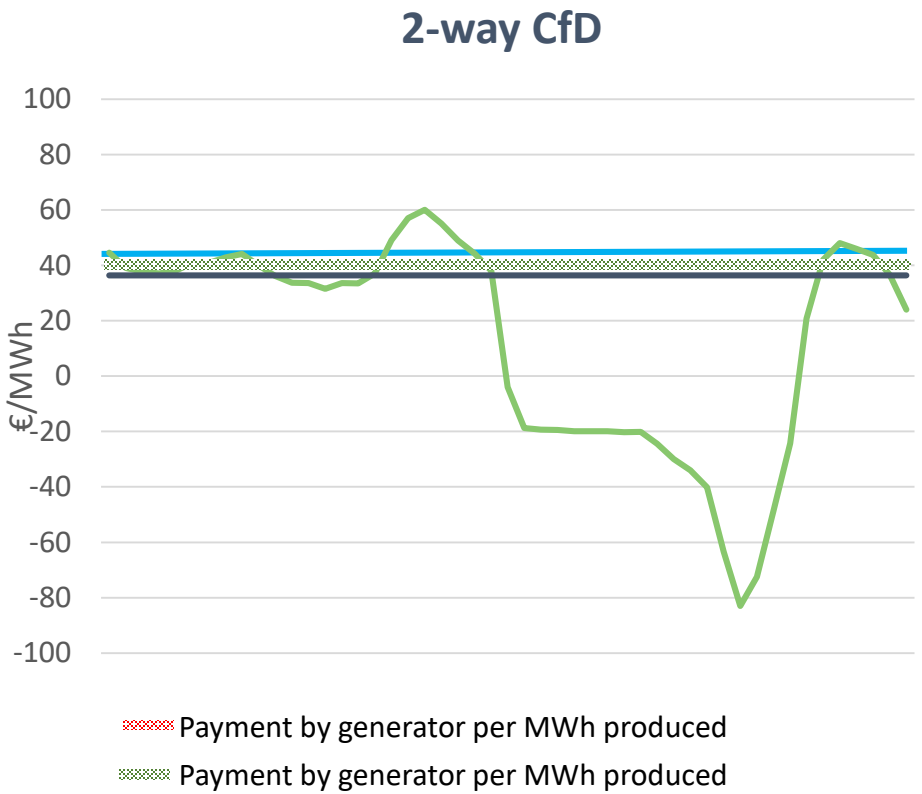
$$\sum_t^T (p_t^{DA} + S - p_t^R) q_t$$

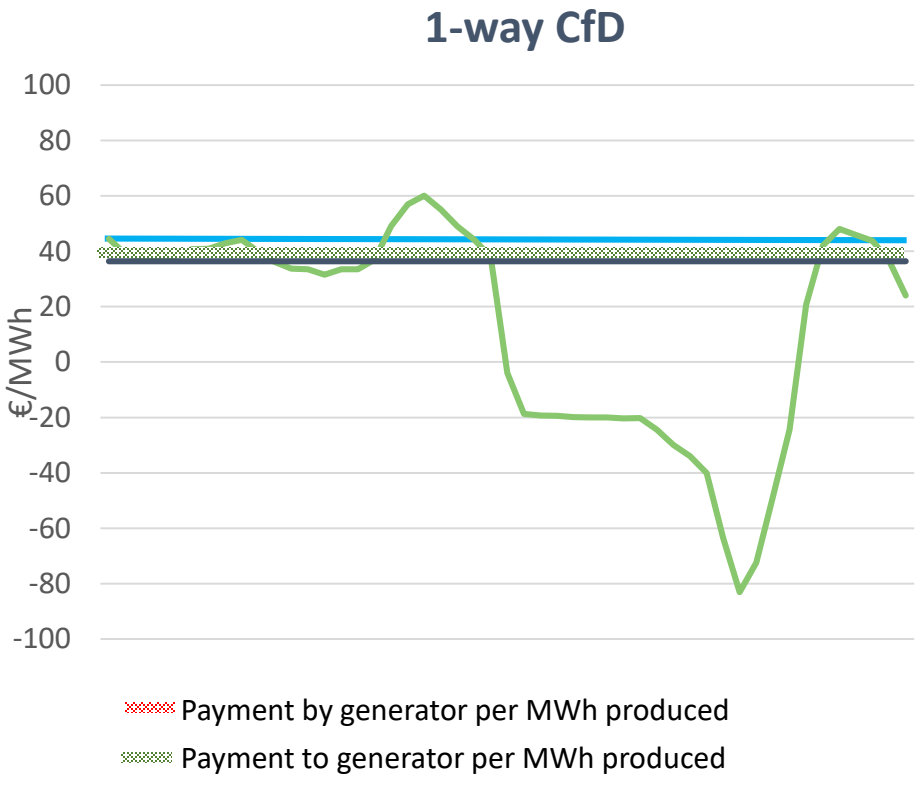
Evaluation:

1) Optimal design and siting **X**
   - price signals are eliminated

2) Optimal utilization **O**
   - always dispatch in day-ahead market

Sophisticated Contract for Difference – Case 1
Reference Price = Reference Market Value





Strike Price (S)

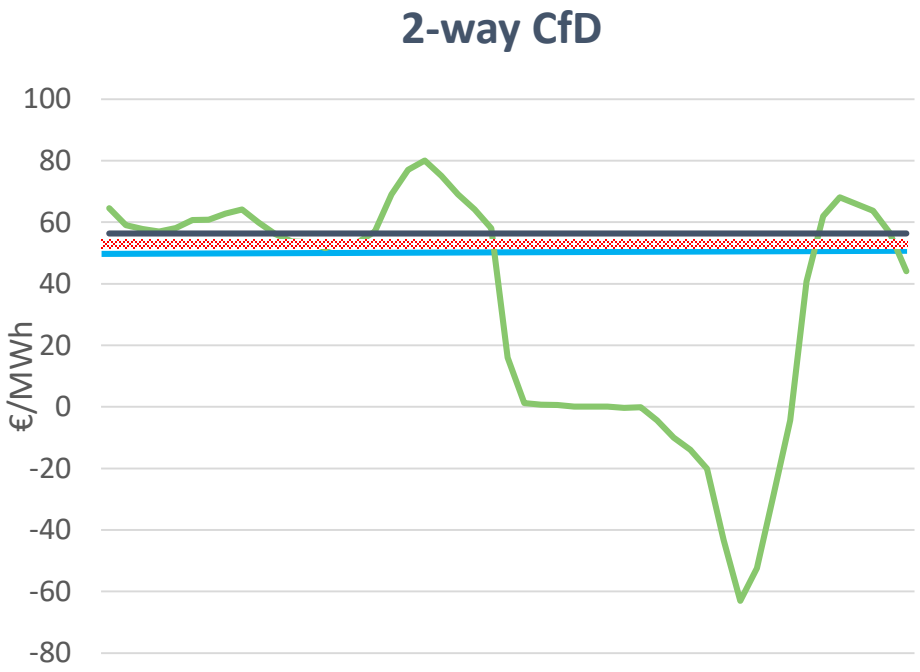
Reference Price ($\bar{p}$)

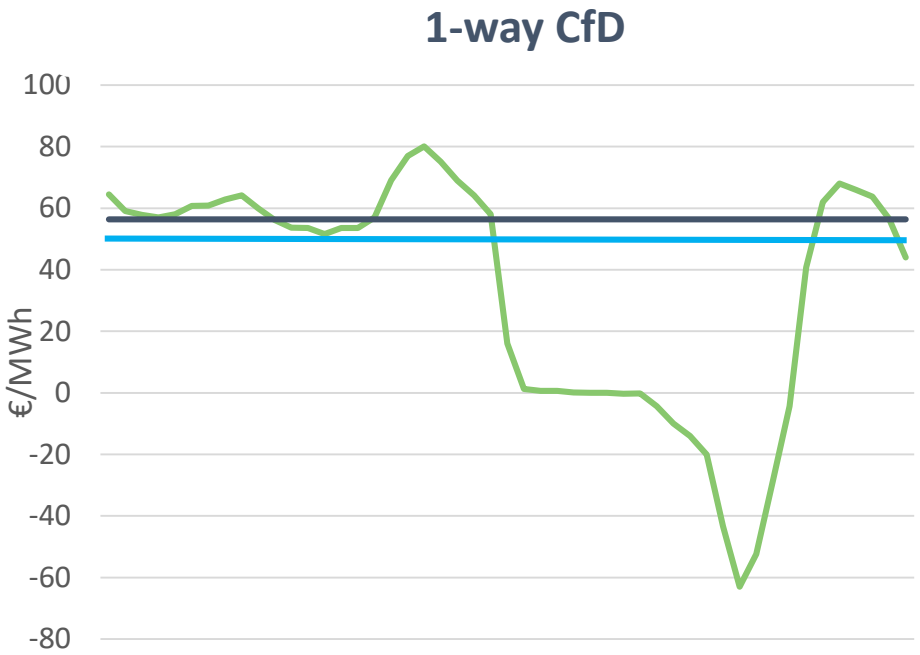
Market Price (p_t)

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 – Case 2
Reference Price = Reference Market Value





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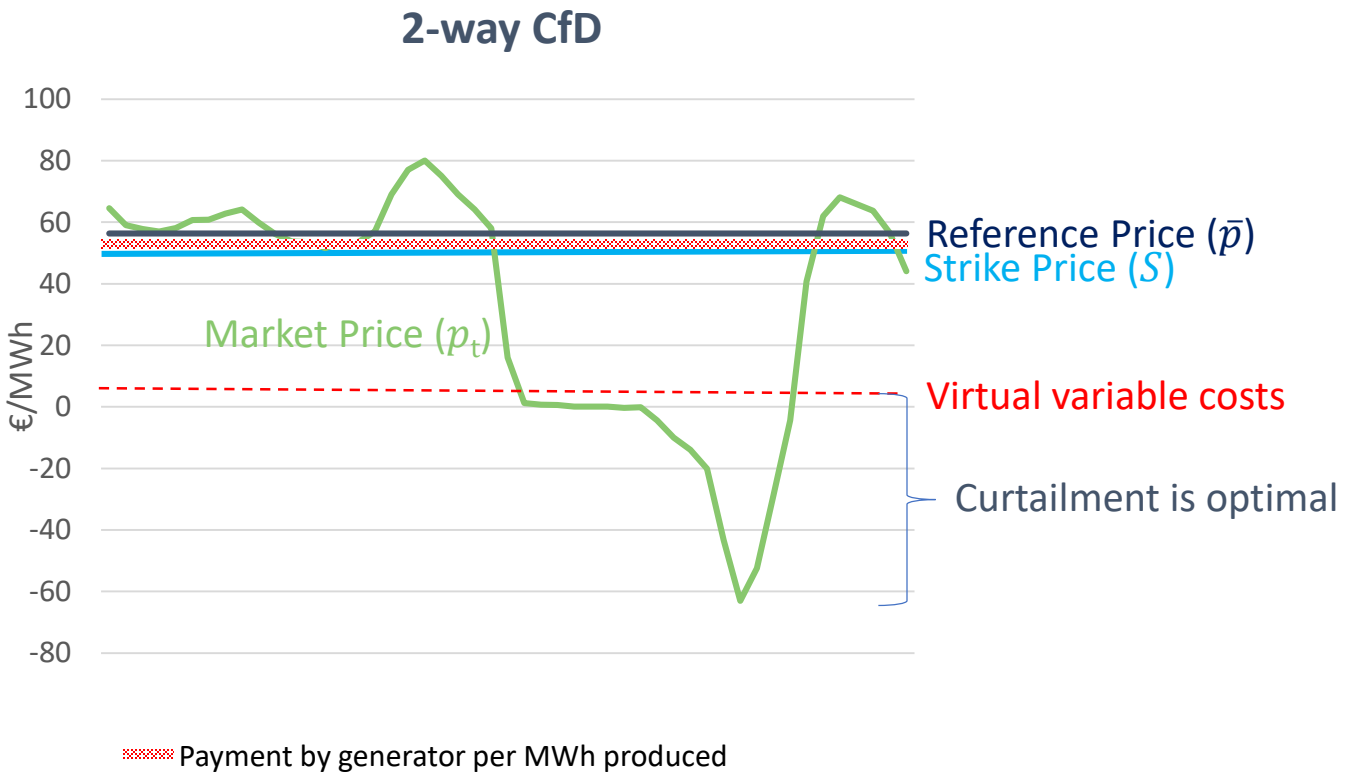
Sophisticated 2-way Contract for Difference
Reference Price = Reference Market Value



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

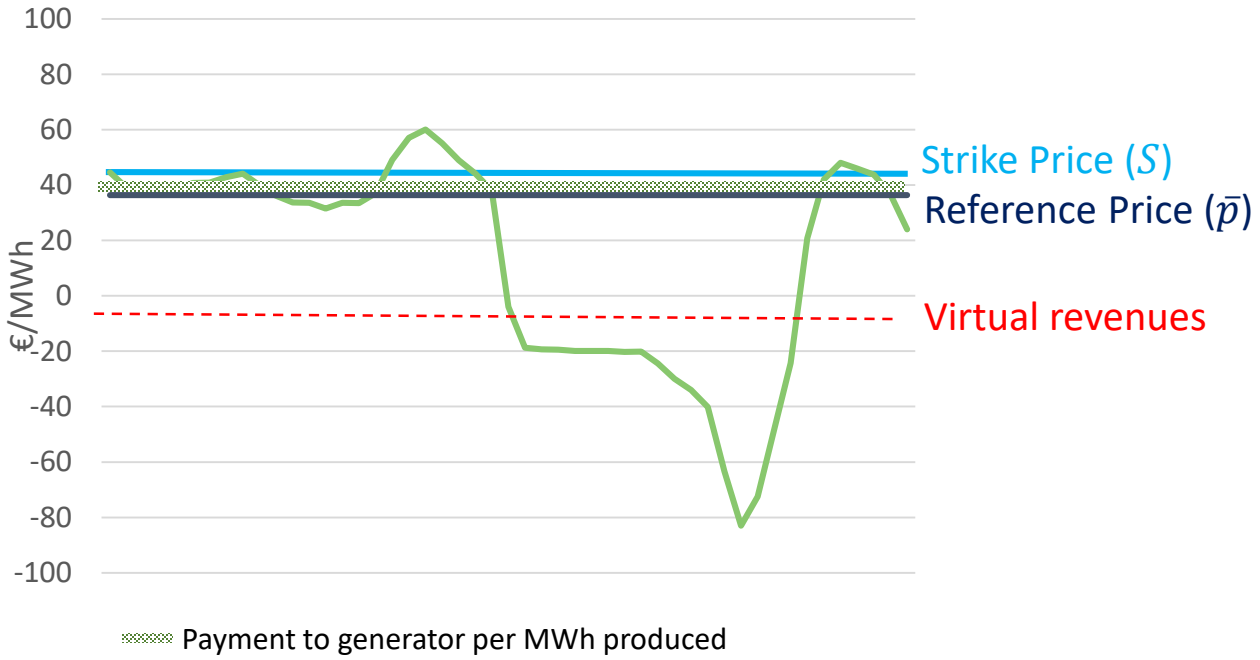
Evaluation:

1) Optimal design and siting **√**
   - Payments are decoupled from own market revenues and therefore, exposed to market price signals

2) Optimal utilization **X**
   - Market actors form expectations of reference price
   - Anticipated payments constitute virtual marginal costs

Sophisticated 1-way Contract for Difference
Reference Price = Reference Market Value

1-way CfD



Revenues with generation q_t:

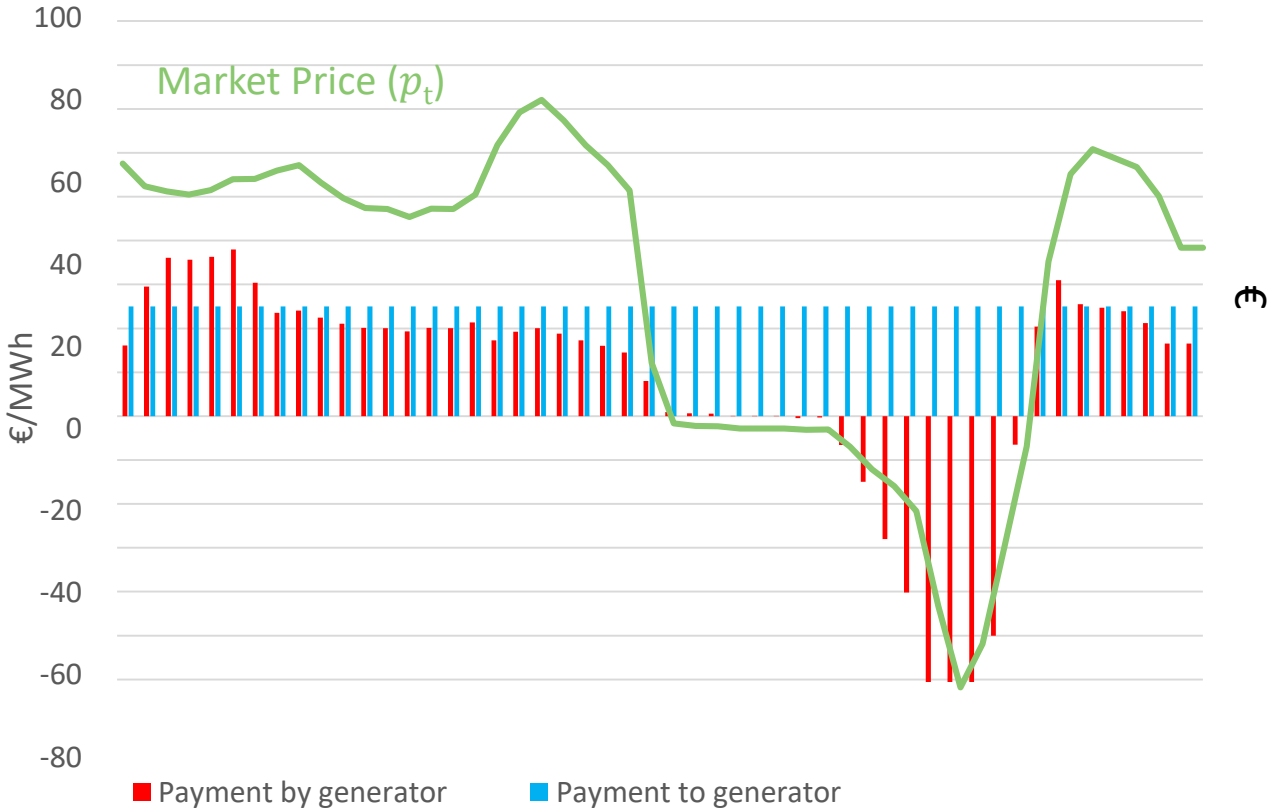
$$\sum_{t}^{T}(p_t q_t - (\min\{0, \bar{p} - S\})q_t)$$

Evaluation:

1) Optimal design and siting **v**
   - Payments are decoupled from own market revenues

2) Optimal utilization **O**
   - Dispatch up to negative market prices

Financial Contract for Difference
Payments = Reference Revenues
Strike Price = fixed hourly payment



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

Reference: Schlecht, Hirth and Maurer (2022)

Evaluation:

1) Optimal design and siting ✓
   - Payments are decoupled from own market revenues

2) Optimal utilization ✓
   - Full price exposure without any virtual costs because payment does not depend on volume

Conclusions and hypotheses on outcomes of different types of CfDs

- Sophisticated CfDs lead to efficient investment decisions, yet distort dispatch
  - 2way CfD: increase in curtailment, decrease in storage activity, higher market prices
  - 1way CfD: decrease in curtailment, increase in storage activity, negative market prices

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  - investments distorted towards technology with highest number of full load hours

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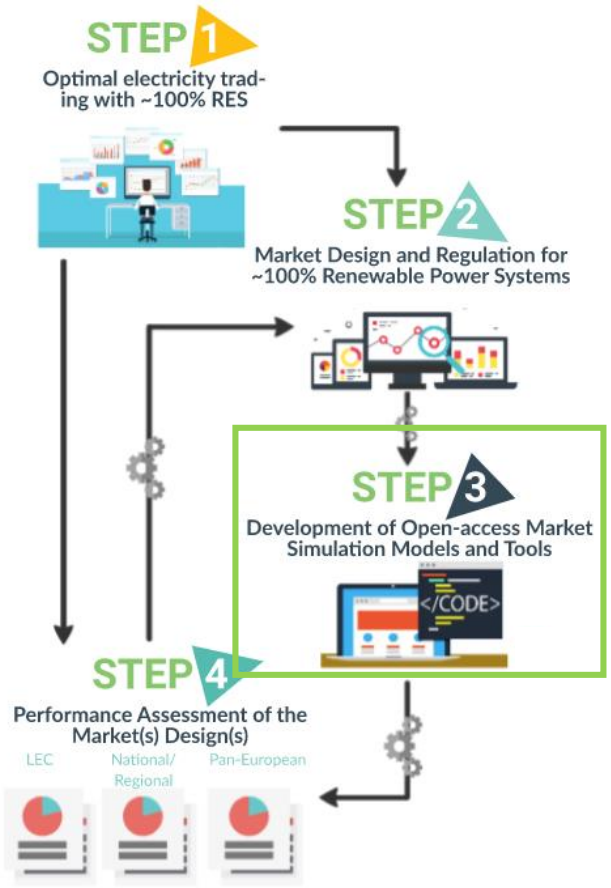
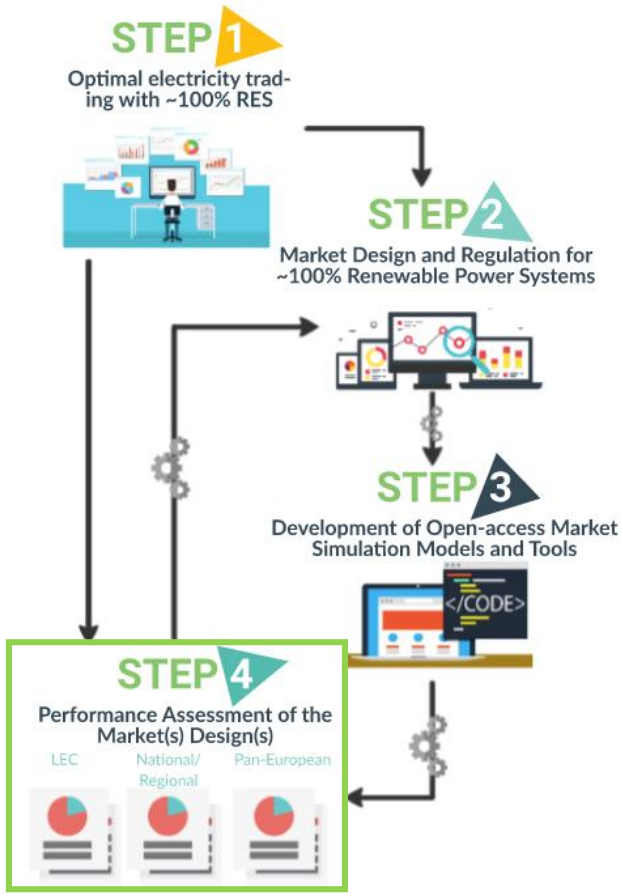
- Neither dispatch nor investment decision is distorted under financial CfDs
  - Does it come closest to the reference scenario?

TradeRES Approach



Session II

TradeRES Approach



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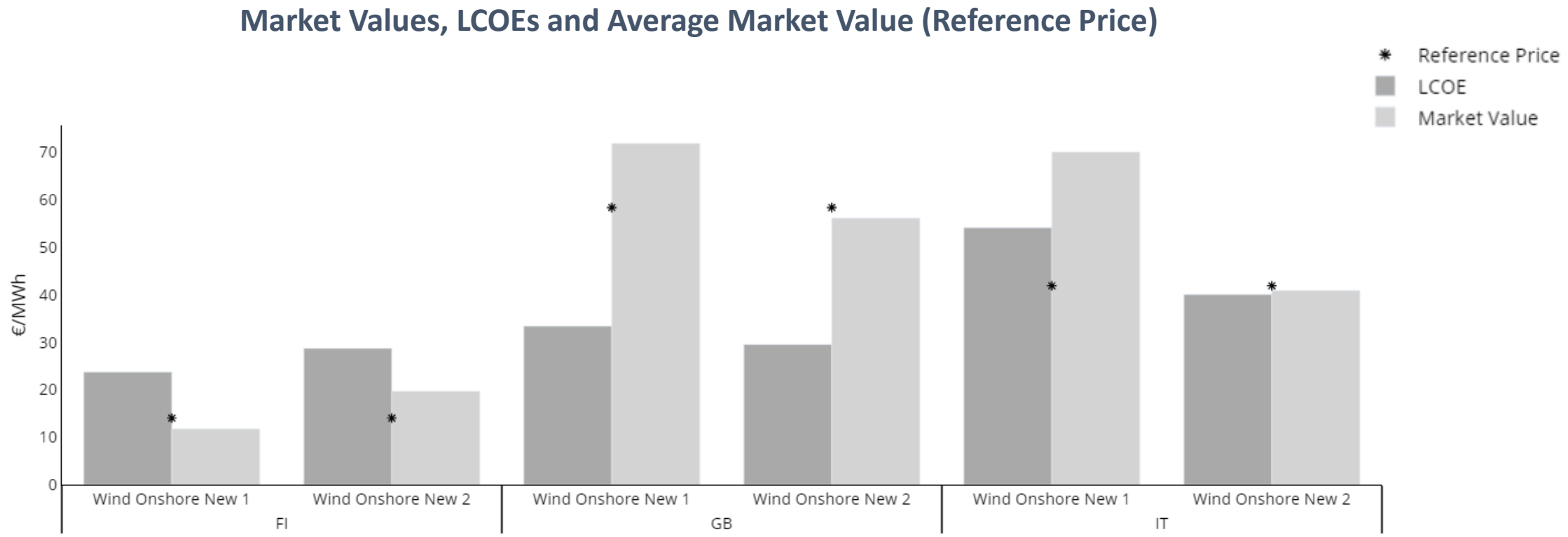
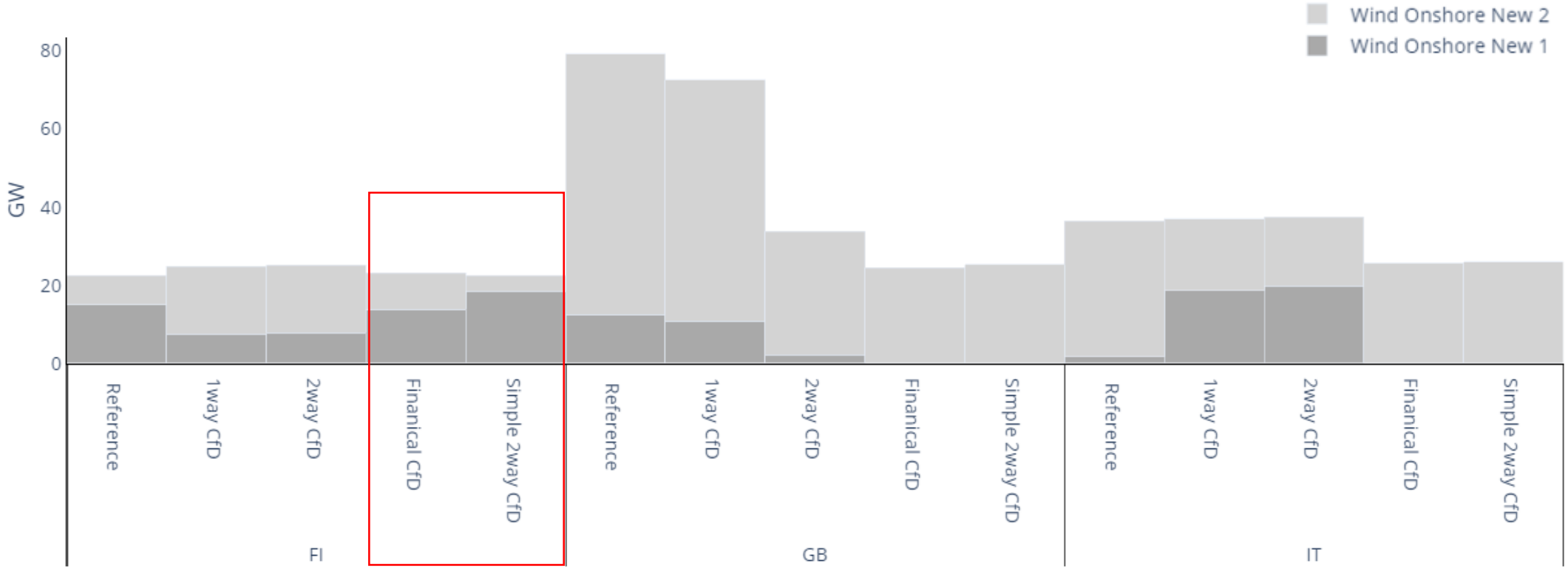


Preliminary Results: Investment in Wind Onshore



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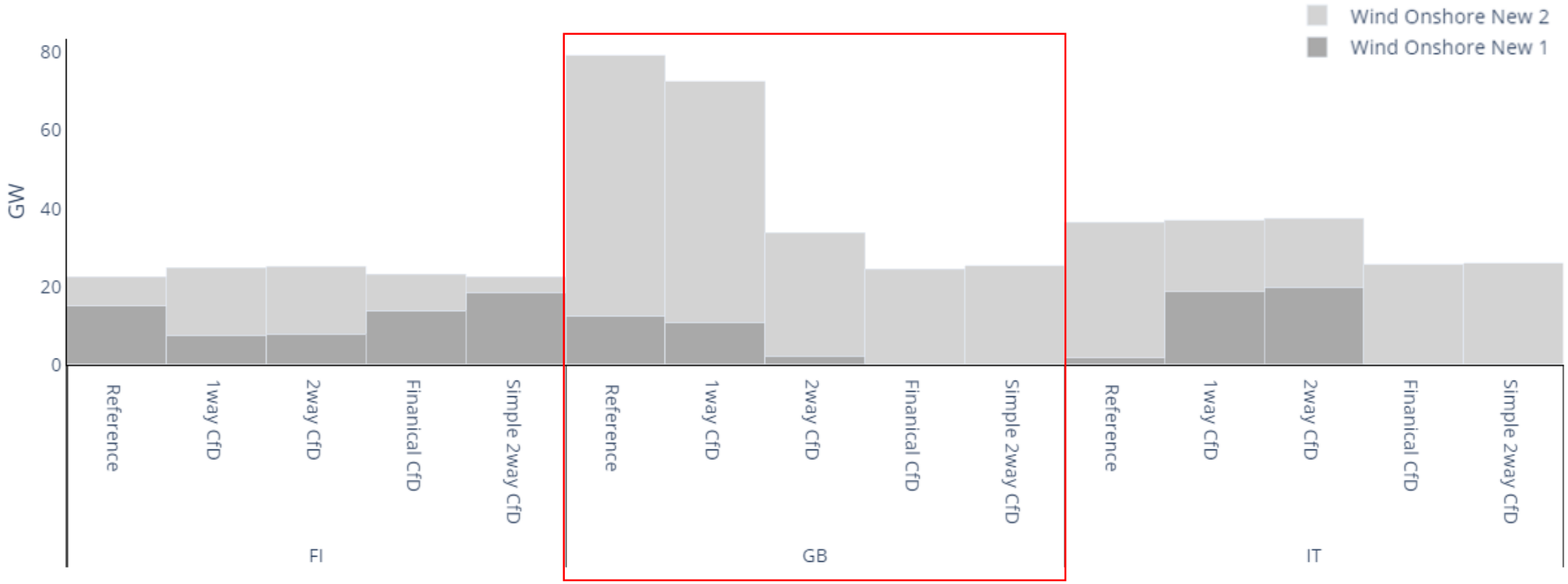
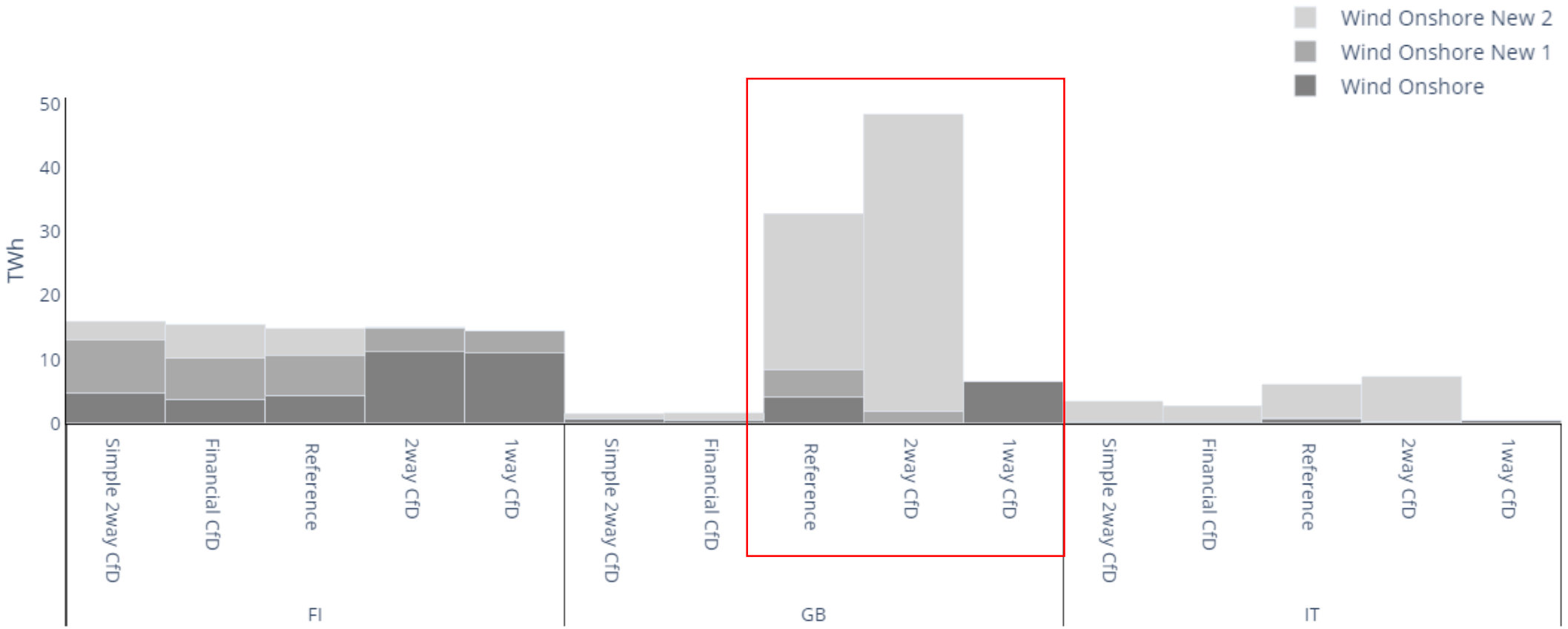


Preliminary Results: Curtailment



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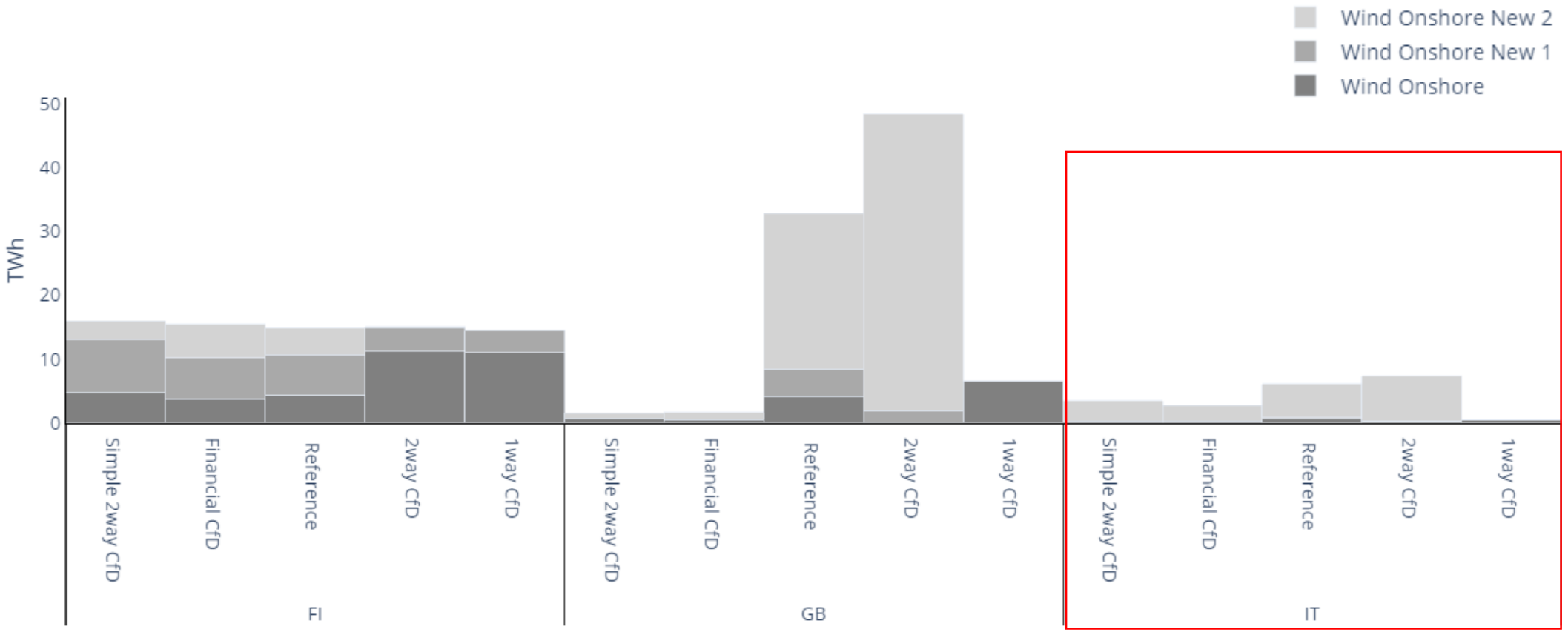
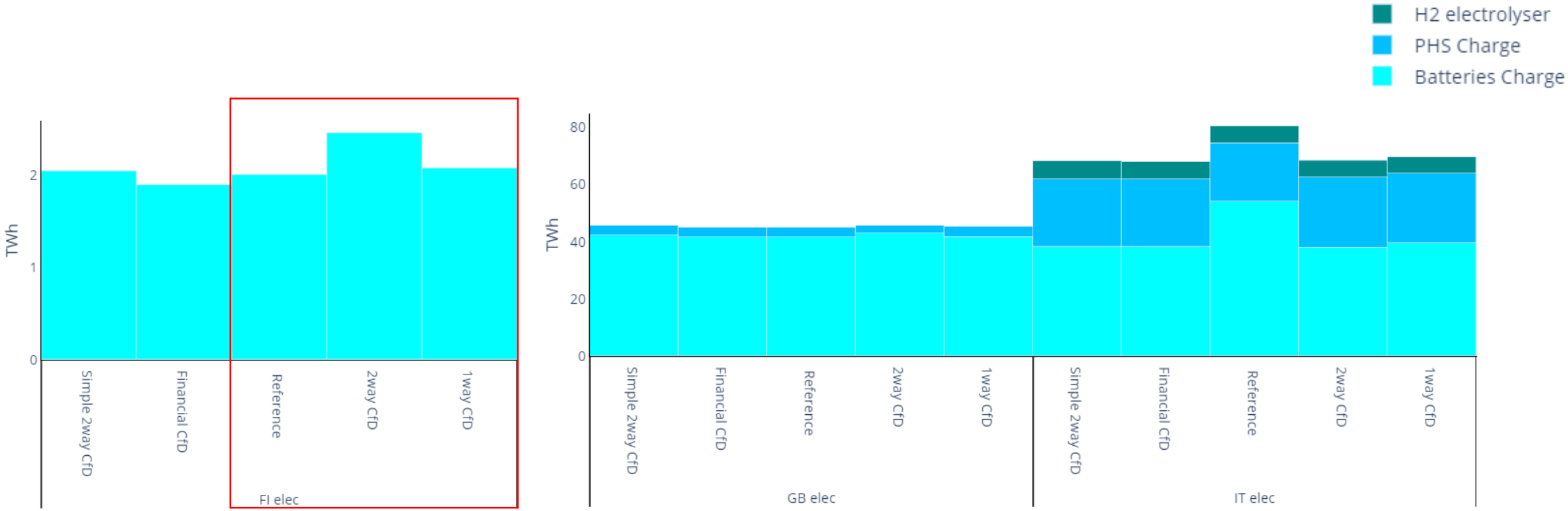
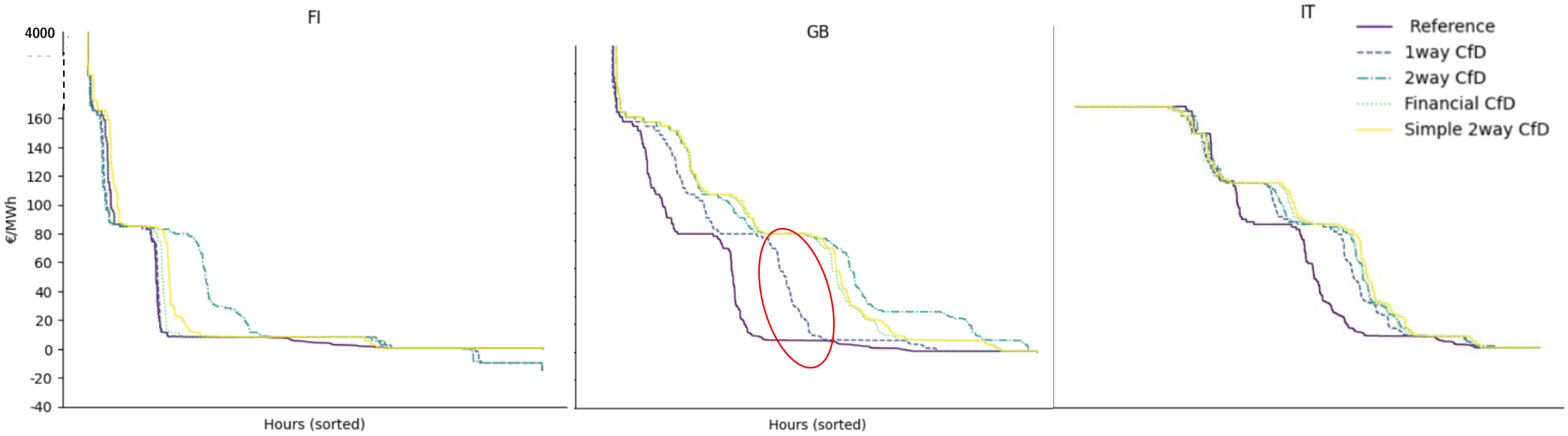


Preliminary Results: Storage activity



Preliminary Results: Price Duration Curves



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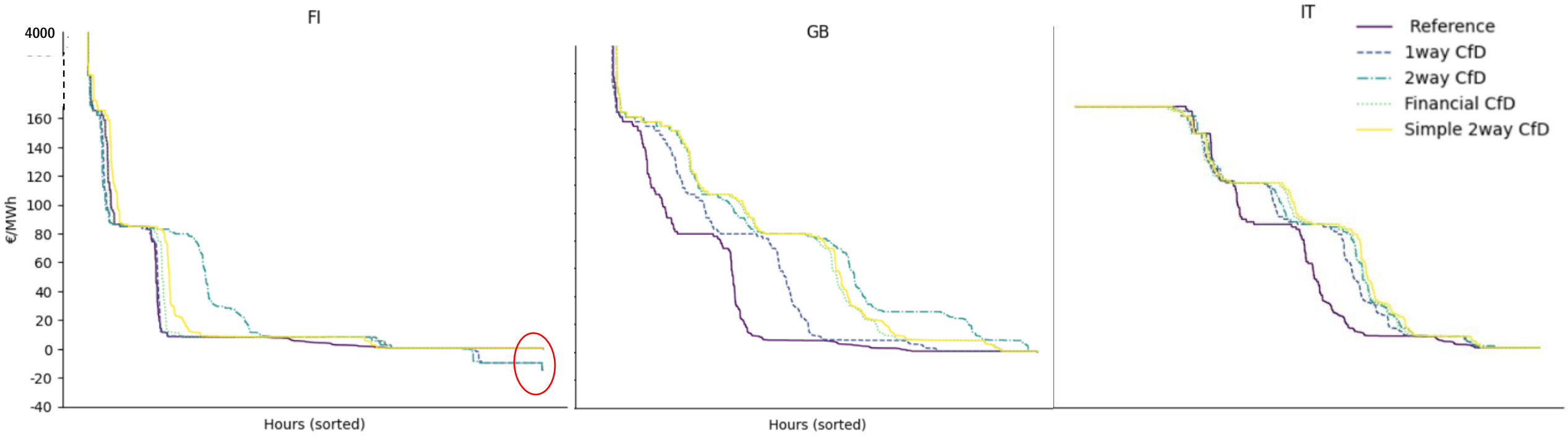

Conclusion and Outlook

Conclusion:

- Simple 2way CfDs can increase investments in power plants with high full load hours
- Anticipated CfD payments can harm investments in renewables
- Virtual marginal costs can impact storage activity, curtailment and market prices

Limitations:

- Mix of impact on investment and dispatch (seperation?)
- More iterations to account for more „clever“ market actors
- Assumption: all power plants are remunerated within the auction
- TradeRES: will cover more market designs and include demand flexibility from other sectors

EnBW

RUB Chair of Energy Systems & Energy Economics

TradeRES

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Thanks ☺

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www.traderes.eu

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3. Method
Energy System Model

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)
- **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

Geographical Scope

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)