Relative merits and design options for CfD and PPA

What can we learn form experience and analysis

Professor Karsten Neuhoff, TU Berlin and DIW Berlin

Brussels, 13th of May 2025

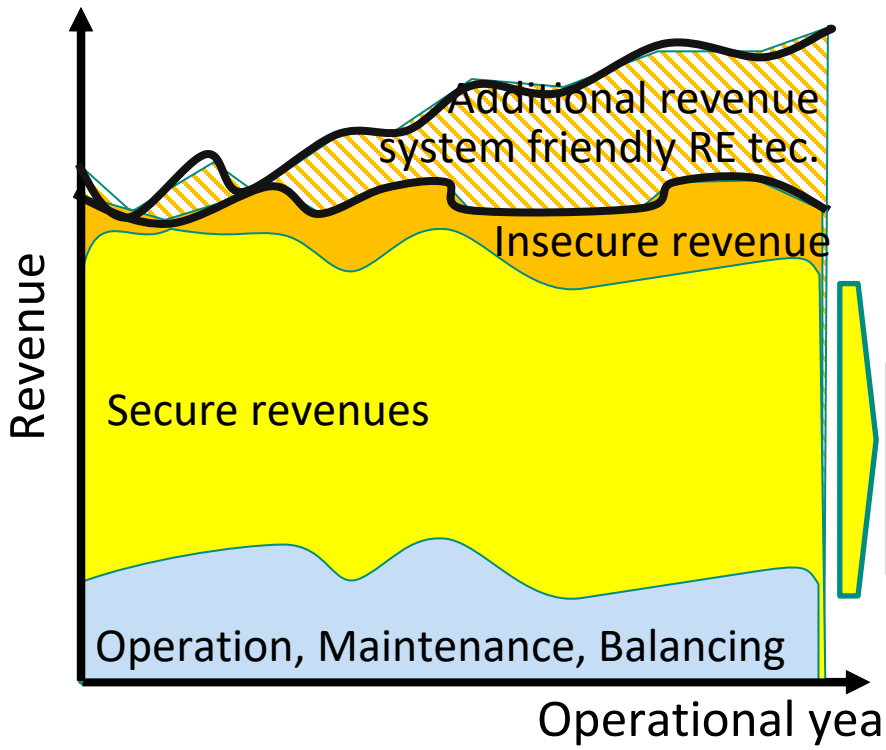
Overview

1. What to consider for CfD contract structure and tender?
2. How to realize synergies between CfDs and PPAs?
3. How to realize synergies with flexibility?

Three fundamental options for CfD design

Description	Efficient operation	Incentives for system friendly design and location	Financing costs
Production based • Excluding neg. price • Payment relative to e.g. monthly reference	Some distortions	Incentives from operation revenue propagate to investment, but weak due to discounting	Risks from (i) uncertain hours of negative prices (ii) difference to reference plant increases financing costs.
Capability based (e.g. Hybrid scheme, Italy) • For production • In negative price hours, capability	No distortion	Full incentives for system friendly design to be included in tender design.	Complete hedged minimizes financing costs. (use commercial hedge for annual variations)
Reference installation • Payment relative to revenues calculated for benchmark • Independent of production etc. of installation	No distortion	Incentives from operation revenue propagate to investment, but weak due to discounting	Basis risk from deviation of (i) production and (ii) local price profile relative to reference increases financing costs.

Incentive for system friendly design limited because uncertain future revenues are highly discounted



Secure revenue allow debt finance: **Low financing cost**

Insecure revenue only relevant for equity: **Financing cost for additional investments of system friendly turbines high**

Implied discounting of revenue:	1,7%	10%
Weight on revenue in years 11-30:	61%	35%

See also Nils May (2017) The impact of wind power support schemes on technology choices, Energy Economics, https://doi.org/10.1016/j.eneco.2017.05.017
Kröger, Neuhoff, Richstein (2022) Contracts for Difference Support the Expansion of Renewable Energy Sources while Reducing Electricity Price Risks, DIW Berlin Report

Options to incentivise system friendly design in tender for capabilty based CfD?

- Adjustments for resources to capture resource rent (e.g. reference yield model)
  - No adjustment, full incentives but consumers pay large resource rents
  - Full adjustment, if site selection is based on pre-defined sites (Germany wind)
  - Partial adjustments to retain incentives for site and limit rents
- Mexican RE tender
  - Clearing includes calculated future market value for turbine at the location
  - Full incentives for location, Grid, system friendly design based on future needs
- Calculate and communicate simplified bonus/malus mark-ups used in clearing

See also;: Neuhoff, May, Richstein (2017) Incentives for the long-term integration of renewable energies, DIW Economic Bulletin (link)

No regret - using experience from commercial contracts

- Use a simple strike price, not a corridor
  - Corridors are difficult/impossible to evaluate in tender
  - less efficient for risk management
  - risks distortions in operation
  - to encourage market participants to sign instead long-term PPAs
- Include adjustments for construction cost inflation (index)
  - to reduce risks and resulting risk premia
  - to reduce scale of collateral required (enhances also competition)
  - to reduce risks for project delays
- Don’t grant land lease beyond contract duration
  - Value of public resource will capture highly discounted price
  - Distorts (and limits) competition based on capacity to value long-term land value

Further information: Zusammenfassung des Workshops: „Die Rolle von Differenzverträgen“ (CfDs) (link)

Overview

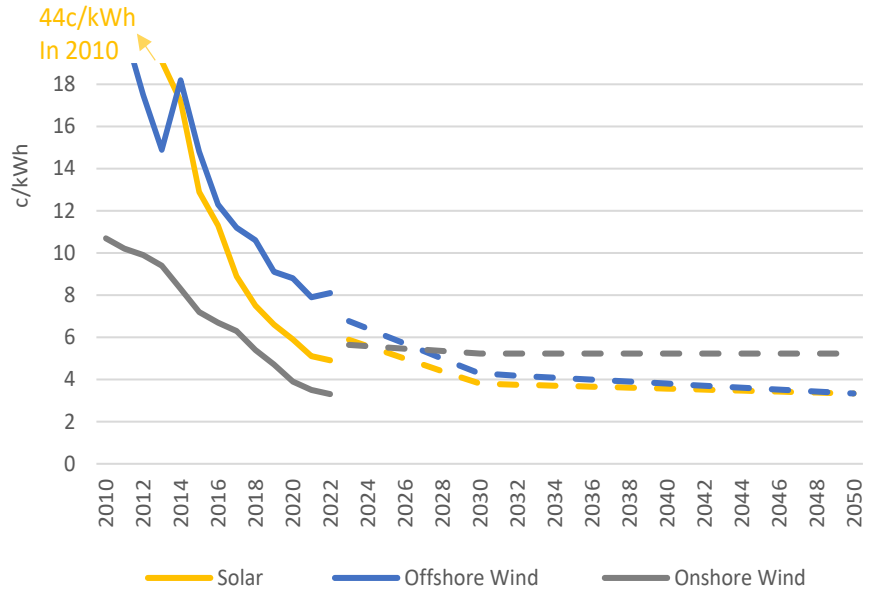
1. What to consider for CfD contract structure and tender?
2. How to realize synergies between CfDs and PPAs?
3. How to realize synergies with flexibility?

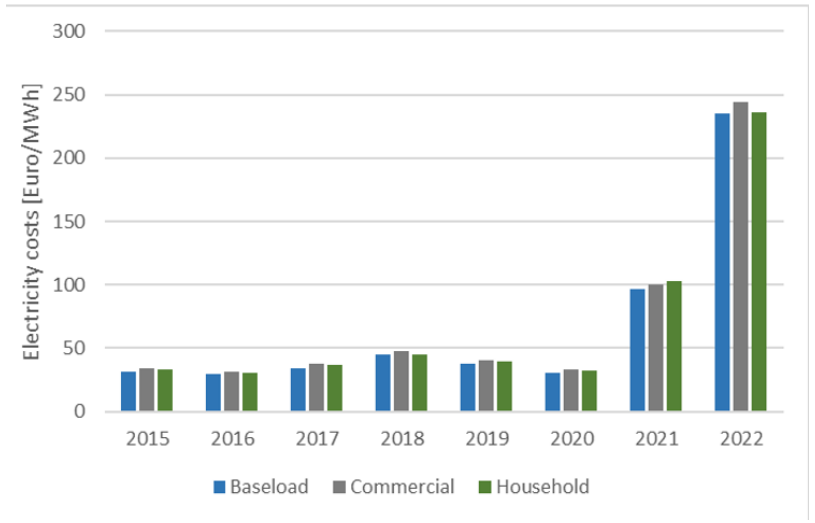
Objective of all long-term contracts:

Make wind and solar energy reliably affordable

Electricity generation costs are falling rapidly...

... but costs exploded during the crisis.





If the market is only geared to the short term, then...:

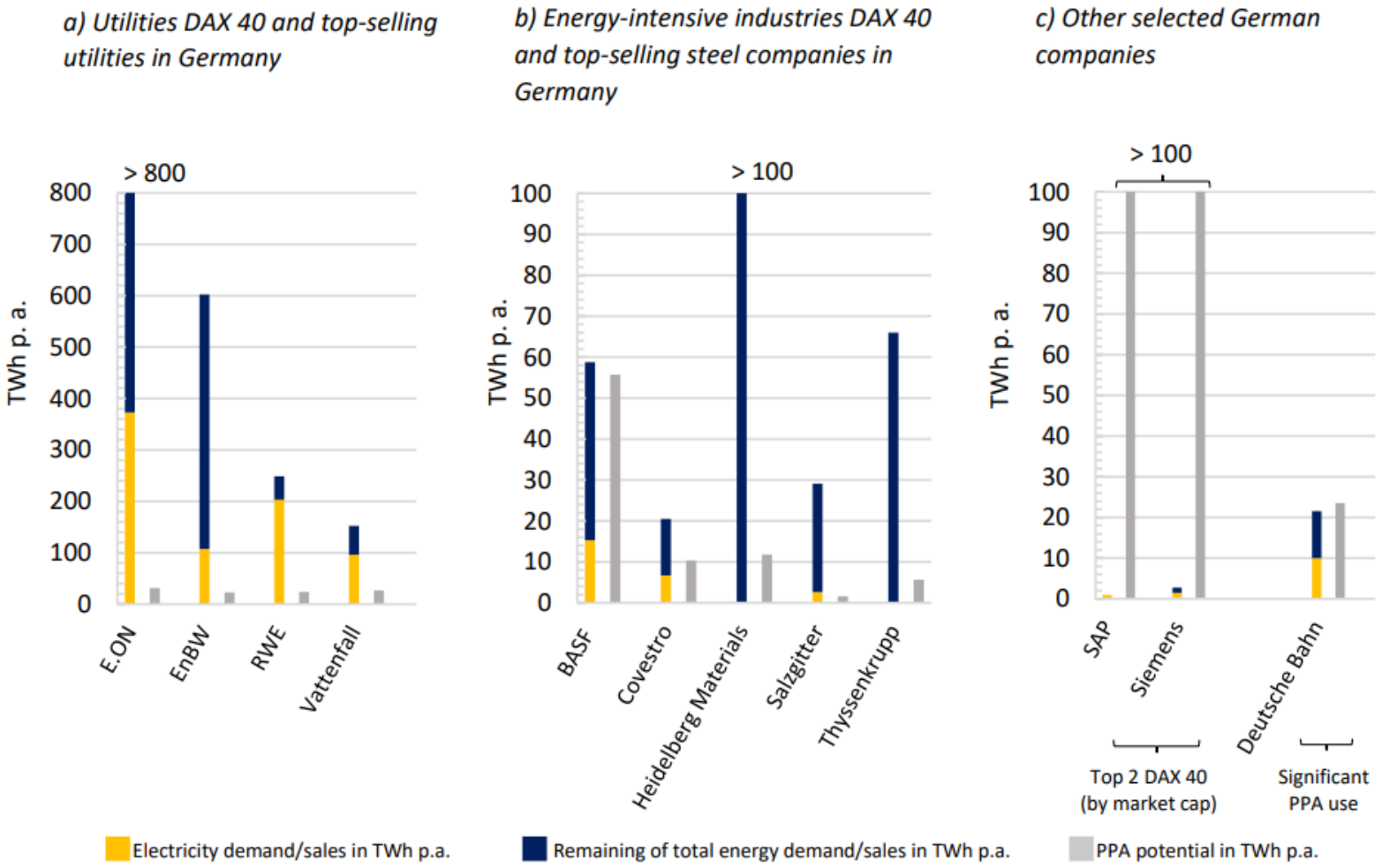
- ... the volatility of the marginal price leads to fluctuating electricity costs
- ... inframarginal and scarcity rents increase electricity costs

Until 2022: international average based on IRENA (2023). From 2023: European average based on the World Energy Outlook Projections (IEA, 2023). The values in the years between the projections are interpolated linearly. In 2022 prices, exchange rate €/$ = 0.95.

What can guide the prioritisation of Cfd versus PPA?

	Cfd	PPA
Scale of contract volume		
Financing costs		
Hedge consumer prices		
Risks for public budgets		
Regional resource differentiation		
Local engagement		
Scale at local site		

Challenge for private long-term contracts (1): Lack of capacity to sign necessary contracts



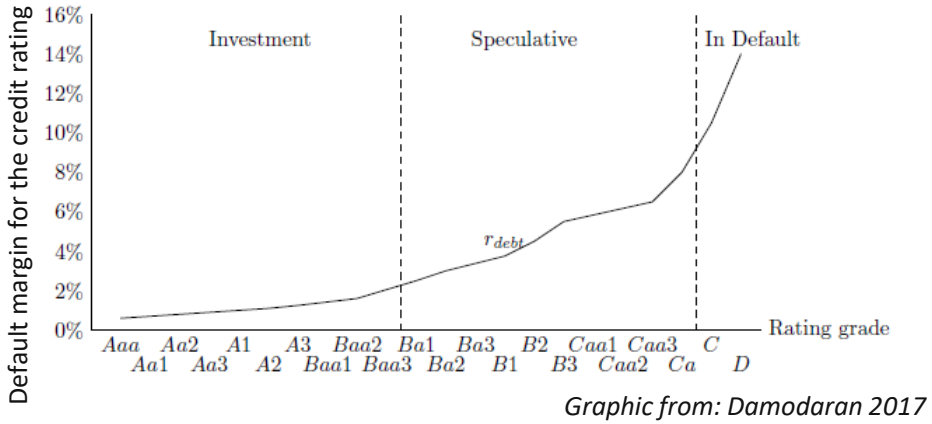
Guarantees for individual projects do not solve this problem.

Source: Karsten Neuhoff, Fernanda Ballesteros, Mats Kröger, Jörn Richstein (2023): Contracting Matters: securing producers and consumers with a renewable energy pool. (Link), Energy Journal (2025) https://doi.org/10.1177/01956574251325486

DIW BERLIN

Challenge for private long-term contracts (2): Financing costs higher for private than for public contracts

1. The counterparty risk for project developers increases with private long-term contracts (PPAs): electricity generation costs around 10% higher
2. Higher financing costs on the demand side mean a 20% increase in the electricity generation costs for wind and solar energy.



Graphic from: Damodaran 2017

3. Overall effect of increased financing costs and risks on the balance sheet
   - 29% (DIW, 2018 / May, 2021)
   - 28% (Aurora Energy Research, 2018)
   - 25% (Enertrag, 2019)

Public guarantees only cover the counterparty risk (10%)

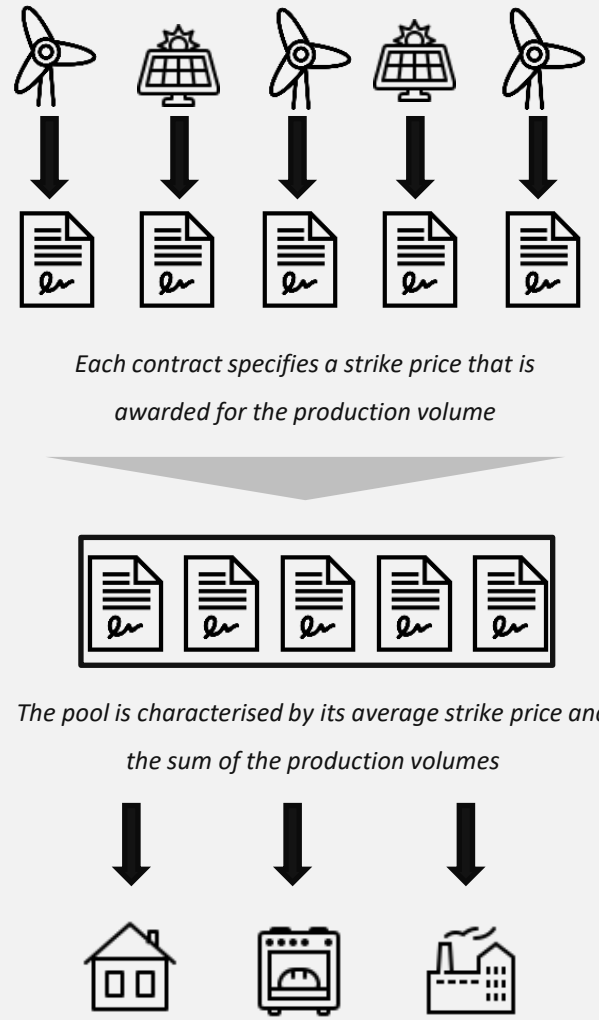
Source: Nils May, Karsten Neuhoff (2021): Financing power: Impacts of energy policies in changing regulatory environments. (Link) & Karsten Neuhoff, Nils May, Jörn Richstein (2022): Financing renewable energy in the age of falling technology costs. (link)

Elimination of market failures due to lack of private contracts: Publicly guaranteed pool for contracts for difference

Wind and solar projects take part in the tender for long-term contracts (as frequently practice)

All long-term contracts are bundled in a pool (as common in risk management)

The electricity consumers (or wholesalers) receive shares in the pool (policy decision)



Source: Karsten Neuhoff, Fernanda Ballesteros, Mats Kröger, Jörn Richstein (2023): Contracting Matters: securing producers and consumers with a renewable energy pool. (Link), Energy Journal (2025) https://doi.org/10.1177/01956574251325486

Characteristics of a CfD pool

Tenders for long-term contracts for RE projects

- Enabling differentiation of resources to reduce costs for consumers
- May include comprehensive incentives for system-friendly technologies#

Public guarantee for the pool, 5-year exit option for consumers

- Provides legal certainty: participants are not disadvantaged
- Avoidance of a 30% surcharge on financing costs for long-term private contracts
- Securing financing, higher probability of project realization -> securing the project pipeline, industrial value chain

Who is granted access to pool?

- Policy choice for prioritization, if over-subscripted pro-rata
- Not auctioning (counter to affordable energy objective)
- Pass green attribute to users of pool (to avoid distortions compared to PPA)

Source: Karsten Neuhoff, Fernanda Ballesteros, Mats Kröger, Jörn Richstein (2023): Contracting Matters: securing producers and consumers with a renewable energy pool. (Link), Energy Journal (2025) https://doi.org/10.1177/01956574251325486

Why governments usually do not provide long-term risk guarantees, and should avoid guaranteeing PPAs?

- **Inertia in political processes** can result in huge accumulated risk
  - EU only revised opposition to long-term contracting after Putin screwed our economy in short-term trading)*
  - Imagine member states were to build up huge PPA guarantee position over years …
- **Optionality of guarantees** offers opportunities for gaming
  - Markt participants can sign multiple parallel contracts (unobserved)
  - thus (i) get pay-out if price develops in one direction (ii) allow entity go bankrupt in other

➔ Avoid long-term public guarantees for PPAs

➔ Guarantee CfD Pool only if it is **public** (i) with simple contract structures (ii) without optionality (if contracts are terminated, future ups **and** downs remain in pool)

* Neuhoff, K. and von Hirschhausen, C., (2005), Long-term vs. short-term contracts: A European perspective on natural gas, Cambridge EPRG Working Paper; 05/05.

Relative merits of CfD and PPA

	Cfd	PPA
Scale of contract volume	**No constraint**	Limited to <<20% of demand
Financing costs	**30% lower**	-
Hedge consumer bills	**Attractive with CfD Pool**	Complex for smaller actors
Risks for public budgets	**Public CfD pool guarantee largely a regulatory guarantee**	PPA guarantee schemes may be gamed and thus costly
Financing costs	**30% lower**	-
Regional resource differentiation	**Possible to partially capture for consumers**	Resource rents remain with sites/developer
Engagement of local industry	To the extent part of CfD Pool	**Direct local involvement**
Scale at local site	Grid capacity + firm local load	**For local use possible beyond transmission grid capacity**

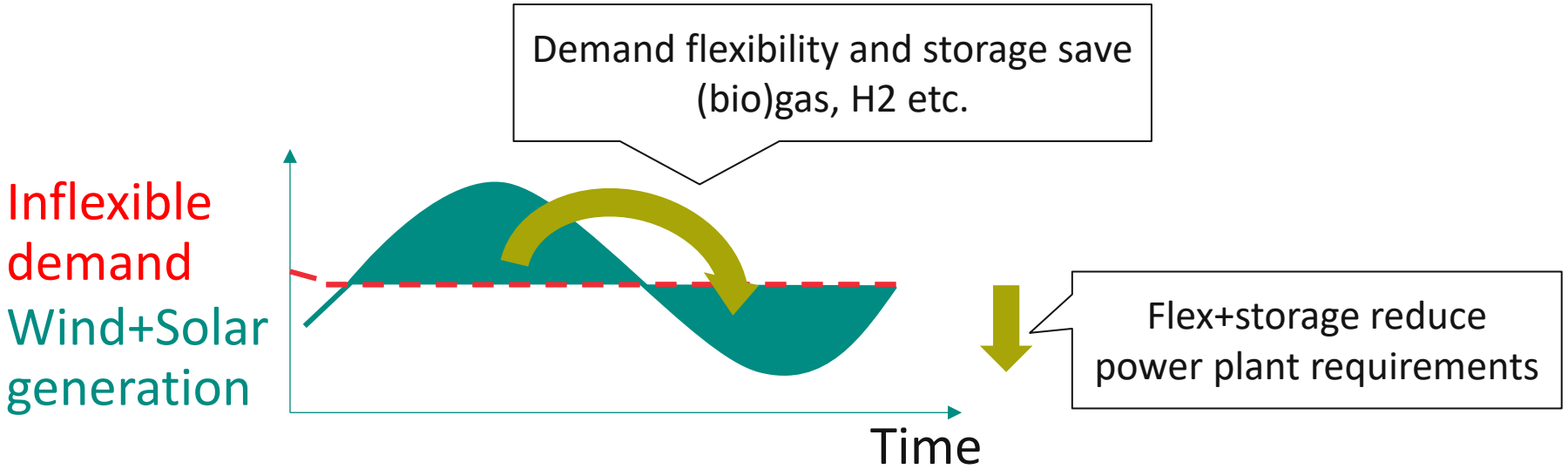
Options to combine PPA and CfD within a project?

- **Optionality:** PPA with CfD as fall back option
  - Return of the risk of windfall profits & bail out costs for governments
- **Temporal profile:** PPA for first years followed by CfD to cover the rest
  - Complex contracting (in contrast to experience with pre-defined share)
  - Higher costs for consumers in initial years (PPA priced at market value)
  - How to ensure system friendly design matching long-term needs?
- **Banding:** PPA for fraction of output and CfD to cover the rest
  - Adverse selection, difficult to compare strike price of different CfD profiles
  - If base band for CfD, peaks for PPA – who underwrites PPAs?? (If peak for CfD, how to pass it on?)
- **Share of output:** Bidder specifies how production is shared between CfD and PPA (equal for all times)
  - Established practice (e.g. German projects can nominate monthly share covered by premium)
  - Can increase project realization risks of PPAs fail – may therefore require higher collateral for tender
  - Share must not be clearing criteria to avoid distorting of CfD clearing price, competition …

Overview

1. What to consider for CfD contract structure and tender?
2. How to realize synergies between CfDs and PPAs?
3. How to realize synergies with flexibility?

Flexibility reduces costs in hours with less wind/solar



Sector-coupling offers great & cost-effective flexibility potential

- Transport: Time-flexible charging of electric cars
- Buildings and neighbourhoods: Heat storage for heat pumps
- Industry: Climate-neutral basic material production (storing intermediate products), process heat
- Supplemented by batteries (especially in the distribution grid)

Portfolio of storage technologies minimises costs

[1] https://www.wittlich.de/de/aktuelles/wittlich/2023/oktober/eco-stor-plant-eines-der-groessten-batteriespeicherwerkes-europas-in-der-kreisstadt-wittlich-stadtteil-wengerohr/; Image: ECO STOR GmbH; Investment costs: Elalfy, Dina A., et.al. (2024), Danish Energy Agency (2024)

[2] MVV Energie AG: Annual Report 2012/13, investment costs (Arnold, Karin (2019)); assumptions for the conversion of kWh_{th} into kWh_{el} via heat pump COP = 2 (AgoraEnergiewende(2023)), storage efficiency = 0.9 (Arnold, Karin (2019))

Lithium-ion battery Wittlich[1] :

- Storage: 600 MWh_{el}
- Investment: € 250 million
- About 400 €/kWh
- Size: 6 ha

District heating Mannheim[2]

- Storage: 1500 MWh_{th} ≙ approx. 650 MWh_{el}
- Investment: € 27 million
- About 40 €/kWh
- 40 m diameter,
- 36 m height

Economics differ for storage of wind and PV

PV

- Shorter storage (hours) suffices to meet daily cycles
- Grid savings by spreading feed-in highly valuable (1/3 full load hours of wind)

➔ **Investment in battery storage valuable, co-located with PV plants**

Wind

- Longer storage (days) valuable to match variations of wind output

➔ **Investment in cost efficient storage options at demand side (heat, process heat, intermediary products, using hybrid energy supply)**

- **Operation** of all storage according to system needs (e.g. local pricing)

How to unlock flexibility co-located with PV generation?

Option 1: Separate tender criteria

E.g. 5% of scoring if 100 MW flexibility (Estonian tender)

How to define it to meet system needs (beyond illustration of technical feasiblity)

- How to define how much energy should be stored? In Estonia available for 1 hour
- What capacity for charging battery?

Can it support broader storage options?

- Technology neutrality? DSR allowed, but how to do DSR on site
- How to also unlock cheap options with larger potential?
- Competition? Market participants use bundling to reduce (i) participation (ii) comparability -> why should governments do this?

How to unlock flexibility co-located with PV generation?

Option 2: Contract for difference for solar plus storage

- Replicates experience in market – new large PV projects combine PV and battery
  - Thus reduce grid needs and benefit from higher prices in other hours of the day
  - Offer consumers a contract that better hedges their consumption pattern
- Proposal
  - Define over which period PV + battery is expected to spread output
    - Option 2a: Fixed pre-defined e.g. 8am- 8pm (for initial tenders)
    - Option 2b: Average over many of PV+battery installations (perhaps future tenders)
  - All feed-in from PV+battery system is remunerated based on difference between strike price and average local price over this period (Production basaed CfD)
- Benefit:
  - Hedges PV+Battery against price risks, operation price rsponsive without distortions
  - As part of CfD Pool valuable to consumers as it meets their hedging needs

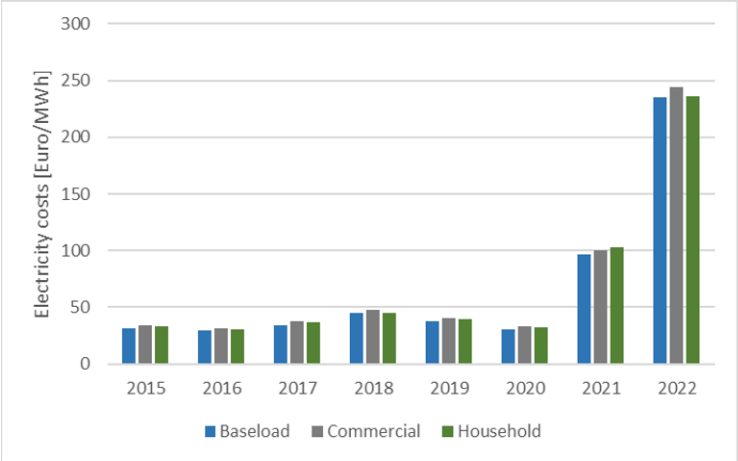
How to unlock flexibility investment at the demand side? (storage for heat, cooling, intermediary products, or hybrid systems)

- Efficient spot markets are important
- Avoiding distortions from structures of grid charges is important
- But is it sufficient to unlock demand side flexibility / will this suffice to encourage consumer to invest in flexibility?
  - Currently electricity costs are hedged with base and peak contracts
  - Efficient operation of flexibility technology creates additional revenue (or save energy costs) – but these are uncertain
  - Industry usually does not invest to realize uncertain revenues outside of core business

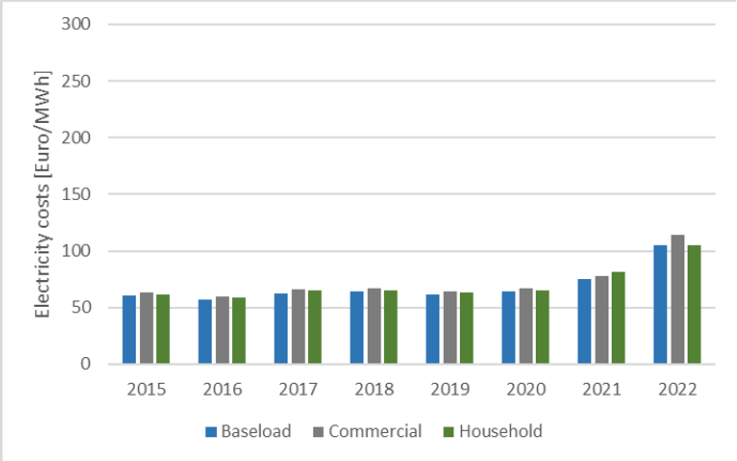
What reforms imply consumers reduce risk by investing in storage?

Cfd pool completely stabilizes electricity costs - only in combination with flexibility. This encourages consumers to invest in flexibility to reduce their risk

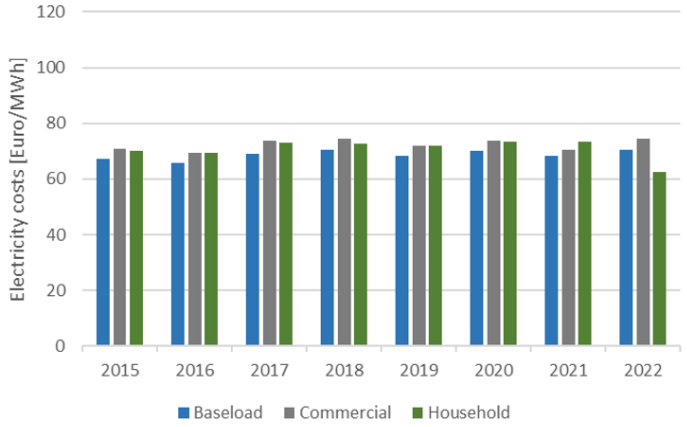
(i) Spot price



(ii) Spot price + 100% CfD pool



(iii) Spot price + 100% CfD pool + 4h battery storage/day



Source: Karsten Neuhoff, Fernanda Ballesteros, Mats Kröger, Jörn Richstein (2023): Contracting Matters: securing producers and consumers with a renewable energy pool. (Link), Energy Journal (2025) https://doi.org/10.1177/01956574251325486

DIW BERLIN

Catalyzing demand-side flexibility – with CfD Pool

- Ensure investors in transformation projects are exposed to RE profile so they have full incentive to invest in flexibility at the time of investment
- Expose electricity intensive users to RE profile – as they have large benefits (and low transaction costs) to realize flexibility (viable for many hours)

➔ **Grant priority access to these two user groups to CfD Pool to catalyze transformation** (investments in demand side flexibility & catalyze contract structures suitable for flexibility)

Building on state aid decision for Carbon contracts for difference, that ensure (initially partial) exposure of transformation projects to RE profile.

Hedging investors and consumers against local price risks with CfD (Pool)

Status quo:

- Market participants are promised de-facto unlimited network capacity
- Is a bad cheque - if more is used than is available, the grid operator must buy it back (redispatch)
- Redispatch costs in 2023 were € 4 bn c.a. € 10 /MWh extra grid fee

Local marketplaces

- Creates local price differences – and worries about local price risks for RE and industry
- Auction design ensures grid used to transport energy from low to high price markets
- This results in public congestion revenues, that must be used to hedge local price risks

CfD Pool efficient vehicle can hedge local price risks

- It will comprise actors most sensitive to local price risks (investors in RE, demand side flex)
- It comprises contract that should be referenced to local price to hedge price risk
- Therefore (part) of congestion revenue should be granted to CfD pool

Conclusion

- **Capability based CfD for wind projects**
  - Capability based CfD (like Italy) combined with system friendly incentives in tender
  - Hedges with CfD Pool consumers …
  - … and support thus investment in demand side flexibility to match demand to RE profile
  - Index for construction costs, no free access to seabed beyond contract duration
- **Output based CfD for solar projects that may include on site battery**
  - Output based CfD: difference strike price to average price during expected PV+battery feed
  - Incentivises investment in PV+battery & provides valuable hedge for consumer in CfD pool
- **Common design elements**
  - Bidder can freely announce at tender share of production not covered by CfD (e.g. for PPA with local off-taker)
  - One strike price (no corridor), reference is local price (to hedge local price risks)