Market Design and Risk Allocation for Renewables: CfDs and Beyond

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AGENDA FOR TODAY

- Framing and objectives
- Markets, Risk and Investment
- Contracts-for-Difference
- CfD Design: From instruments to Policy Tool
- Beyond CfDs & outlook

Framing and objectives

The energy world is changing…

SYSTEM MEGATRENDS

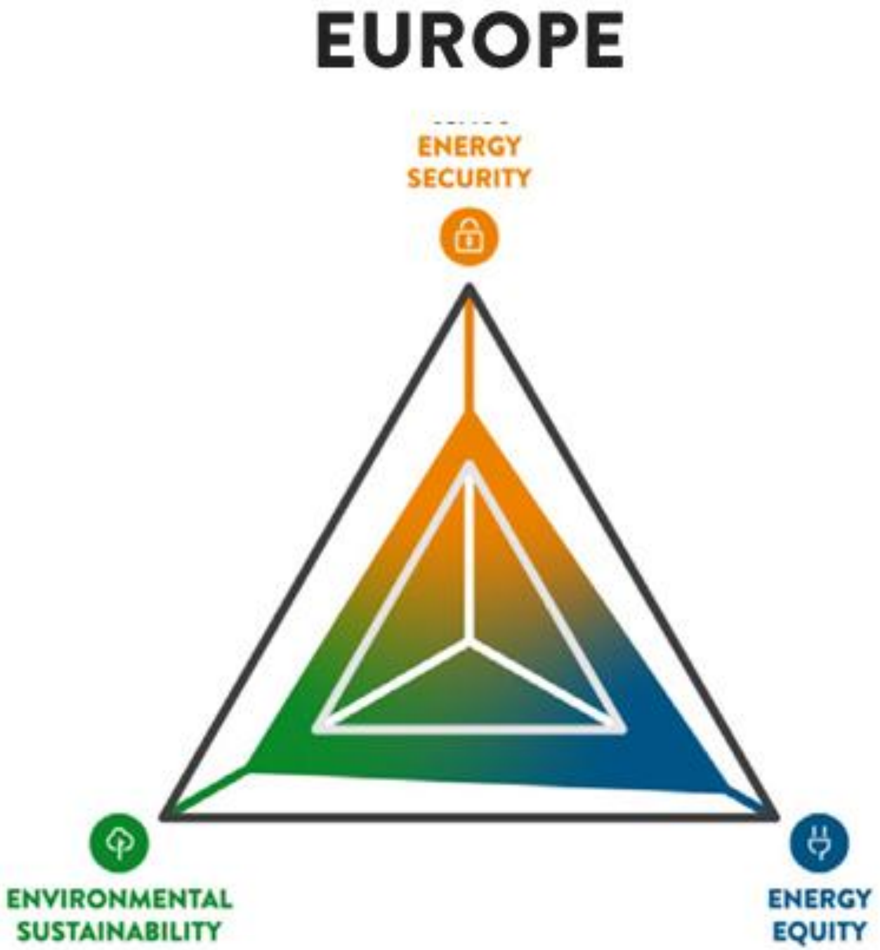
- Electrification and digitalisation
- Massive shift toward renewable electric power
- New technologies, such as electric heat pumps, electric vehicles and Power-to-X (PtX)
- New business models
- **Value creation** across technologies will become **more important than cost reduction** in a system in which power is sometimes abundant and other times lacking

PARADIGM SHIFTS FOR RENEWABLE ENERGY

- From niche technology that needs ‘integration’ – to becoming the backbone of the whole integrated energy system (> 50% market share)
- Renewable energy as critical infrastructure
- Variable renewable energy as price-setter on markets
- From technology that needs support – to contributor to state finances (?)
- Offshore wind: the only Gigawatt-sized technology that power utilities will invest in from now on?

Energy Policy in a nutshell

Secure, affordable, sustainable



EUROPE

NAVIGATING UNCERTAINTY TO MAINTAIN AFFORDABILITY AND TO ENSURE THE RESILIENCE OF ENERGY SYSTEMS IN RESPONSE TO GEOPOLITICAL SHOCKS

Europe is currently reassessing its energy strategy with a new focus on security in relation to affordability and sustainability. In contrast to a continuing reliance on gas, the rapid move towards diversification, particularly in renewables, reveals the tensions between immediate energy needs and long-term environmental goals. Price surges have prompted significant state intervention and electricity market reforms to protect consumers. Europe's challenge lies in balancing renewable integration, grid variability, and technological independence amidst geopolitical and energy sovereignty concerns, while steering towards resilient, self-reliant, and equitable energy systems.

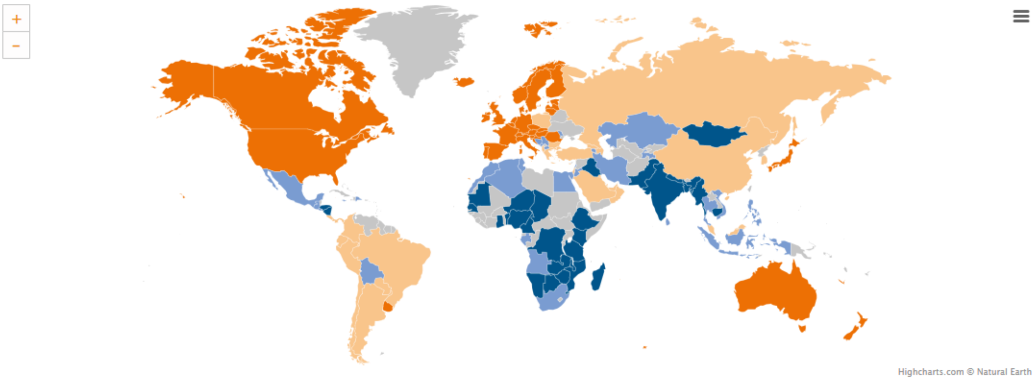
WORLD ENERGY COUNCIL | Energy index | Country profile | Regional profile

Energy Trilemma Index

Full Report

The **World Energy Council**'s Energy Trilemma Online Tool provides an interactive display of the current World Energy Trilemma results and analysis at the regional and country level, breaking down performance across three dimensions; energy security, energy equity, and environmental sustainability. The tool also presents the latest World Energy Trilemma Index rankings, measuring a country's overall performance, as well as a balance grade highlighting how well a country manages the trade-offs of between the dimensions, with "A" being the best.

Index rank | Energy Performance: Top 25% | >25% -50% | >50% -75% | Bottom 25%



2023 Country rankings

Index rank	Country name	Balance grade	Trilemma score	Energy security score	Energy equity score	Enviromental sustainability score
1	Denmark	AAAa	83.2	72.2	95.8	83.5
1	Sweden	AAAa	83.1	73.4	93.4	85
2	Finland	AAAa	82.7	75.9	92.3	80.8
3	Switzerland	AAAa	82.1	64.5	98.1	85.7
4	Canada	AABa	81	76.6	96.2	72.8
5	Austria	AAAa	80.9	71.8	95.3	78.6
6	France	AAAa	80.6	69.4	93.7	83.2
7	Estonia	ABAa	80.2	69.9	94.8	78.5
7	Germany	AAAa	80.2	72.9	94.4	76.6
8	United Kingdom	AAAa	80	67.7	95.7	79.2
8	Norway	BAAa	79.9	62.7	94.4	84.3
9	New Zealand	AAAa	79.6	68.2	95.4	76.4

trilemma.worldenergy.org

EU Commission’s influence on national support schemes

- MS free to choose their own support mechanism in their national legislation (STILL)
- Mechanisms with state aid elements need authorisation by DG COMP as a rule
- State-aid guidelines suggest: competitive, premium-based schemes
- **In practice 80% of all energy policy is made in Brussels, then nationally implemented**

What is State Aid? Article 107(1) (TFEU)

“any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market.”

State Aid is

(1) a competitive advantage selectively

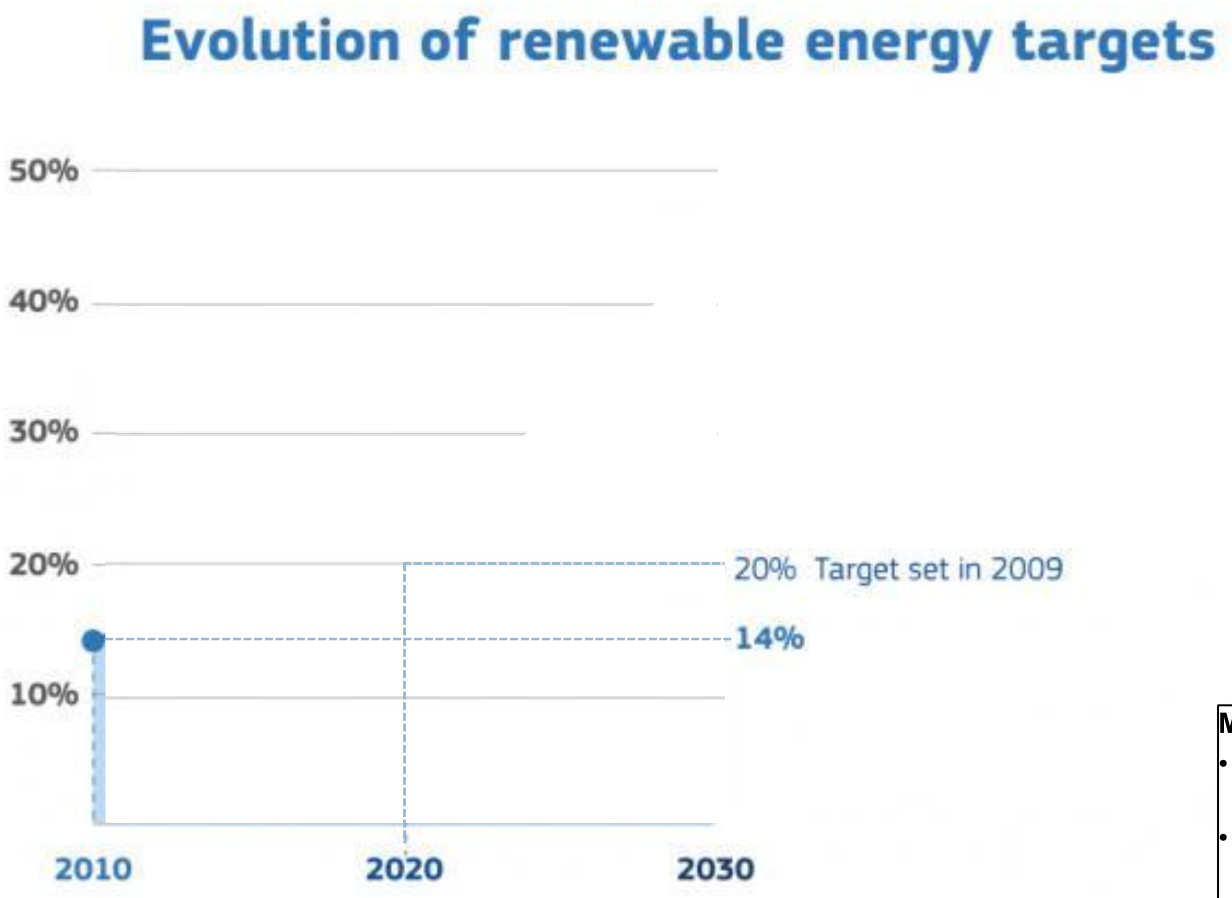
(2) conferred to one undertaking or group of undertakings

(3) by the State or through State resources

(4) which distorts or threatens to distort competition

(5) affects trade between the Member States (5).

Renewable Targets and EU Governance



https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en

MONITORING:

- All EU countries explained in national renewable action plans how they intended to achieve their goals by 2020
- Every 2 years between 2001 and 2018, EU countries reported on their progress towards the EU's 2020 renewable energy goals
- The EU overachieved its target in 2020 with a 22.1% share of gross final energy consumption from renewable sources.
- Detailed assessment on 2020 target achievement at EU and national level published in 2022: Report on the achievement of the 2020 renewable energy targets (see also: Eurostat's renewable energy statistics from January 2022)

Energy Policy in a nutshell

- Policies are active, legislated requirements
- Your key question is: What is energy policy for?
- Once you know, and you have set your targets
  then you have 2 primary choices as to how to achieve them:
  1) Policies to regulate
  2) Policies via markets
- Markets are social constructs – they are no natural phenomenon
- Some elements may be better regulated (ie energy efficiency roll out); some better as markets

- Core is to understand the importance & relation of action and reaction...
  and most of this is governed by economics and finance – **cost, price, and risk**

GROUP REFLECTION

1) **How is your own research impacted by energy policy?**

2) **How may your own research impact energy policy?**

STEP 1: Individual reflection (3min)

STEP 2: Discuss in groups of two (5min)

STEP 3: Write down a few bullets – to bring back up in the end (2min)

Markets, Risk and Investment

What you might think about Economics…

A firm produces a good q for which it incurs production costs of $C(q)=12q^3-270q^2+2700q$. The market price for each unit of the product sold is $p=2439$.

Derive the first and second order conditions.

$\pi(q) = 2439q - (12q^3-270q^2+2700q)$

$\pi'(q) = 2439 - 36q^2+540q - 2700 = 0$

$\pi''(q) = -72q+540 < 0$ *satisfied for q larger than 7.5*

What is the firm's marginal revenue?

$MR(q) = price = 2439$

What are the firm's marginal and average cost functions?

$C'(q) = MC(q) = 36q^2 - 540q + 2700$

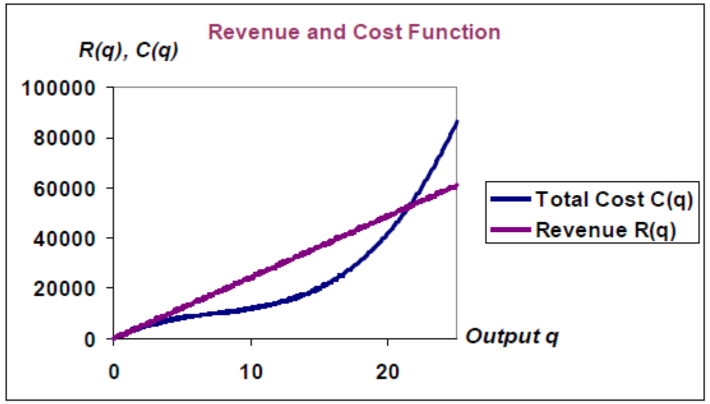
$AC(q) = (12q^3-270q^2+2700q)/q = 12q^2-270q+2700$

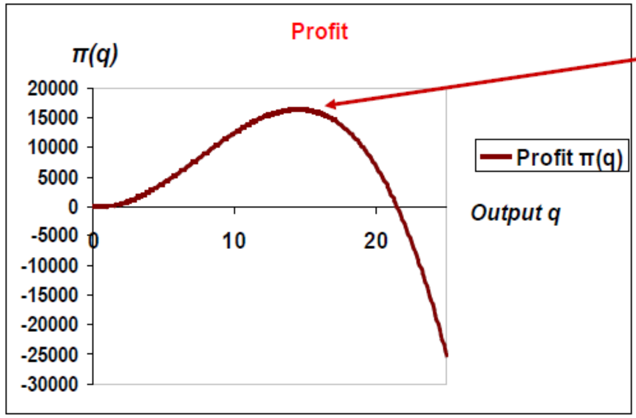
Which output level q does the firm choose to maximize profit?

$\pi'(q) = 2439 - 36q^2+540q - 2700 = 0$

$540q - 36q^2 - 261 = 0$

A solution to this equation is $q = 14.5$; $\pi(q) = 16399.5$





SOLUTION

Profit maximum

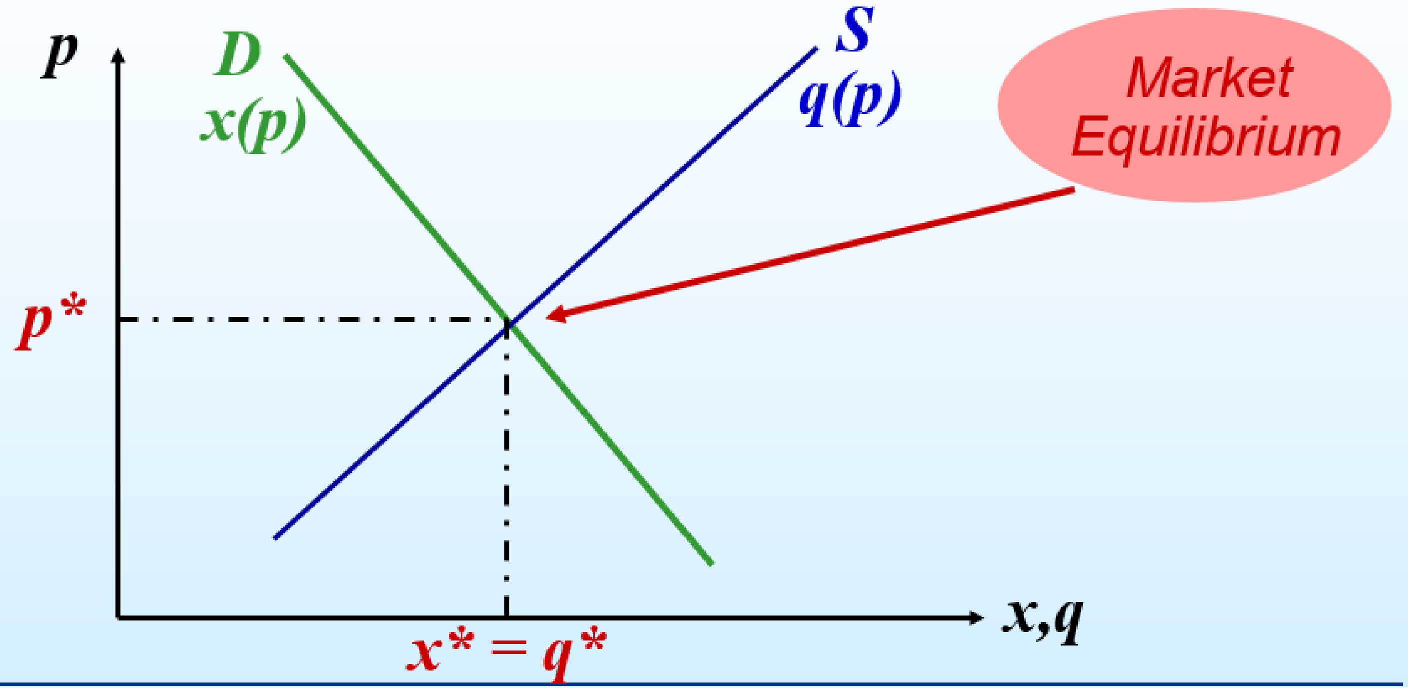
Profit maximizing quantity:

$q^*=14.5$

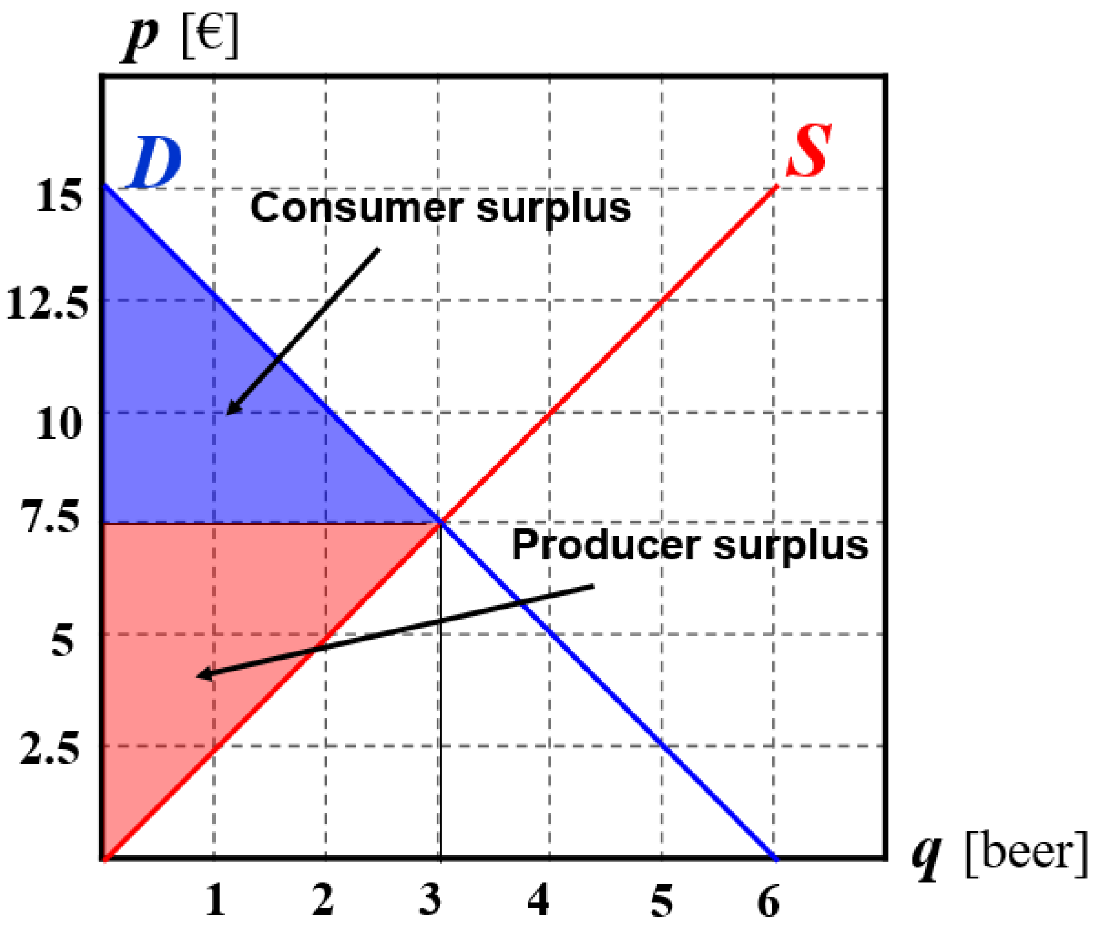
…and yes, we love our demand-supply functions

Market Equilibrium

- **Equilibrium**: a point at which there is no tendency for the market price to change as long as exogenous variables remain unchanged (*market clearing price*)



Demand Curve: Consumer Surplus



- **Consumer surplus (CS):** difference between the maximum willingness to pay of a consumer for a good and the amount the consumer actually pays when purchasing it.
- **Producer surplus (PS):** amount that producers benefit by selling at a market price which is higher than they would be willing to sell for; measures monetary benefit of producers from selling a good.
- **Welfare: W = CS +PS**

Perfectly Competitive Markets

- The **market demand curve** reflects the **utility** that all consumers derive from the consumption of a good.
- The **market supply curve** includes **costs** that producers of an industry incur for the production of a good.
- **Price = Marginal cost**.
- Firms operate at maximum efficiency.
- Due to the **atomistic market structure**, no consumer or producer is large enough to exert influence on the market price (no market power!). Market price can adjust freely to balance demand and supply.

=> Market outcome leads to allocation of resources to most efficient use.

…what is also Economics:

<u>Market failures:</u> when the market fails to allocate resources at the socially optimal level

- **In practice, markets rarely lead to social efficiency due to:**
  - Property rights not always defined
  - Information failure >> **price distorsion** >> irrational decisions, or **free-riding** (non-expression of utility)
  - Self-interest (agents disregard the impact of their activities on third parties)
- **Caused by:**
  - Market power (e.g. monopoly)
  - Public goods
  - Common property
  - Imperfect information
  - Externalities

Goods

	Non divisible one person's consumption does not diminish the other's	**Divisible**
Non-excludable once the resource is provided, those who fail to pay for it cannot be excluded	**Pure public good** Biodiversity preservation Air quality Clean natural water Landscape A pod of whales for whale watchers	**Common good** Free electricity with congestion A pod of whales for hunters *congested non-toll roads*
Excludable	**Club good** Clean drinking water *Natural reservation, non-congested toll road,* *Cinemas,* *Satellite TV* Car sharing	**Pure private good** Apple Bike Car

- **Public goods** are often materialised, financed and produced by public entities
- Society pays via taxes, fees, licences etc.

- **Common goods** often have to be regulated to avoid over-consumption and depletion, or privatised ('tragedy of the commons')

- **Externalities** are a type of public good (pollution) >> free-riding and no defined market

Market failures in electricity

1. Electricity is a homogenous product, i.e. consumers cannot directly differentiate the origin of the product (nor its ‘quality’ or nature)
2. Electricity is complementary to the rest of the economy, i.e. societal costs of scarcity (excess demand) are higher than those of excess supply *(large parts of the economy and health-critical machines rely on it, e.g. in hospitals, etc.)*
3. Supply and demand must be kept balanced at all times & storage options are (currently) extremely limited
4. Network is a shared pool (a natural monopoly, often undersupplied by markets)
5. Thermal processes based on fossil fuels cause severe negative environmental externalities. If not adequately internalised, they cause wrong incentives
6. Positive externalities persist (innovation processes, job creation, social and equity issues,…)

Regulation in the electricity system

- Until the 1980s, the electricity system was mainly treated as a physical infrastructure system. It should primarily supply the required services.
- In the 1980's and 1990's, energy was treated more and more as a commodity, which could be left to market forces.
- The electricity system was divided into:
  – a natural monopoly part (--> regulated industry)
  – a commercial part (--> market competition)
- Until 2000, most European countries had newly established commercial markets for the electricity system.
- In the view of many economists, the liberalised supply and trade area should operate in an efficient way when left alone.
- From the 2000s, the view on the markets became more pluralistic: New objectives started to become more important and regulation became more important again.

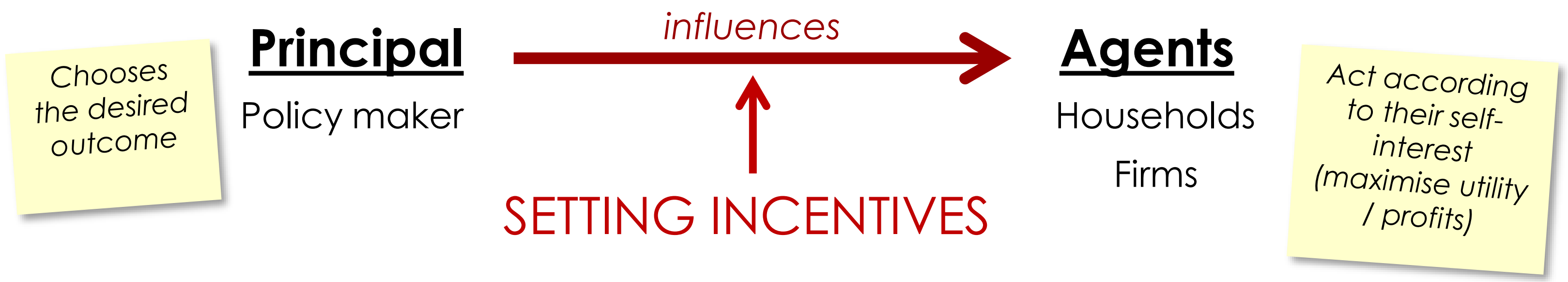
Different approaches: state-owned monopolies (Denmark) or private-owned monopolies (USA), or a mixture of both (Germany).

New objectives:

1. Security of supply (independence from fossil fuels)
2. Climate change

Sources: Helm 2007

Setting the right incentives



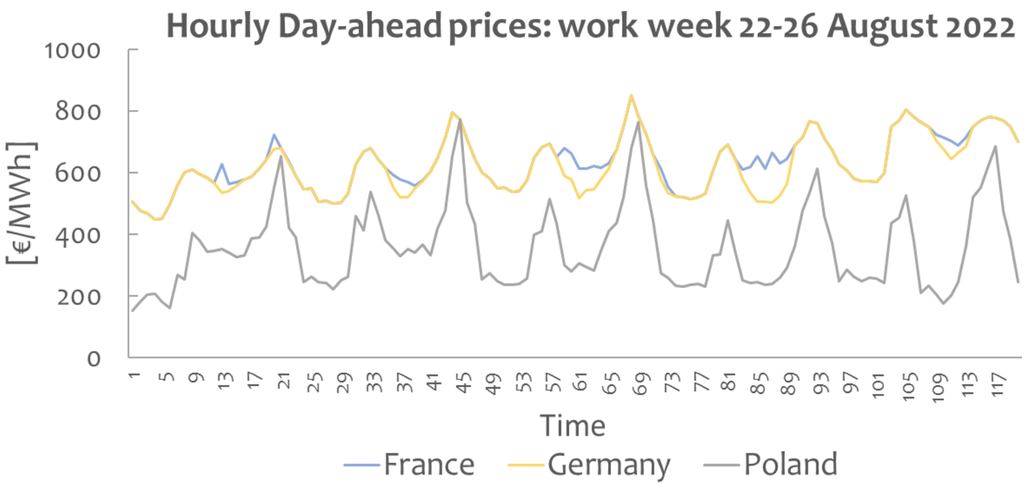
- We need:

1. Incentives for **efficient operation** of the assets at any time
   (--> Market Design)

2. Incentives for the **right investments** at the right time
   (--> Direct and indirect support – if incentives not provided by market)

How do the EU markets work?

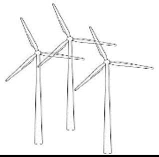
- The European electricity market is the largest integrated electricity market in the world
- The sequential markets allow us to exchange electricity across borders with standardised contracts for different products - *they work efficiently and are saving us 34 billions of Euros every year* [1] – under ‘normal’ market conditions
- Some markets use auctions and marginal pricing (day-ahead)



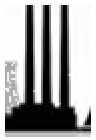
[1] https://energy.ec.europa.eu/topics/markets-and-consumers/electricity-market-design_en

Short re-cap: marginal pricing on the market

Market Player A

	Size	Invest-ment	Fixed operation	Variable operation
	400 MW	500 million EUR	10 million EUR per year	25 EUR per MWh
	200 MW	250 million EUR	15 million EUR per year	n/a

Market Player B

	Size	Invest-ment	Fixed operation	Variable operation
	800 MW	2500 million EUR	200 million EUR per year	5 EUR per MWh
	200 MW	150 million EUR	10 million EUR per year	50 EUR per MWh

Market bid Player A

Market bid Player B

Market Operator:
- Receives bids from demand and supply
- Aggregates all and finds the market price.

What is the market price at demand of 1200 MW?

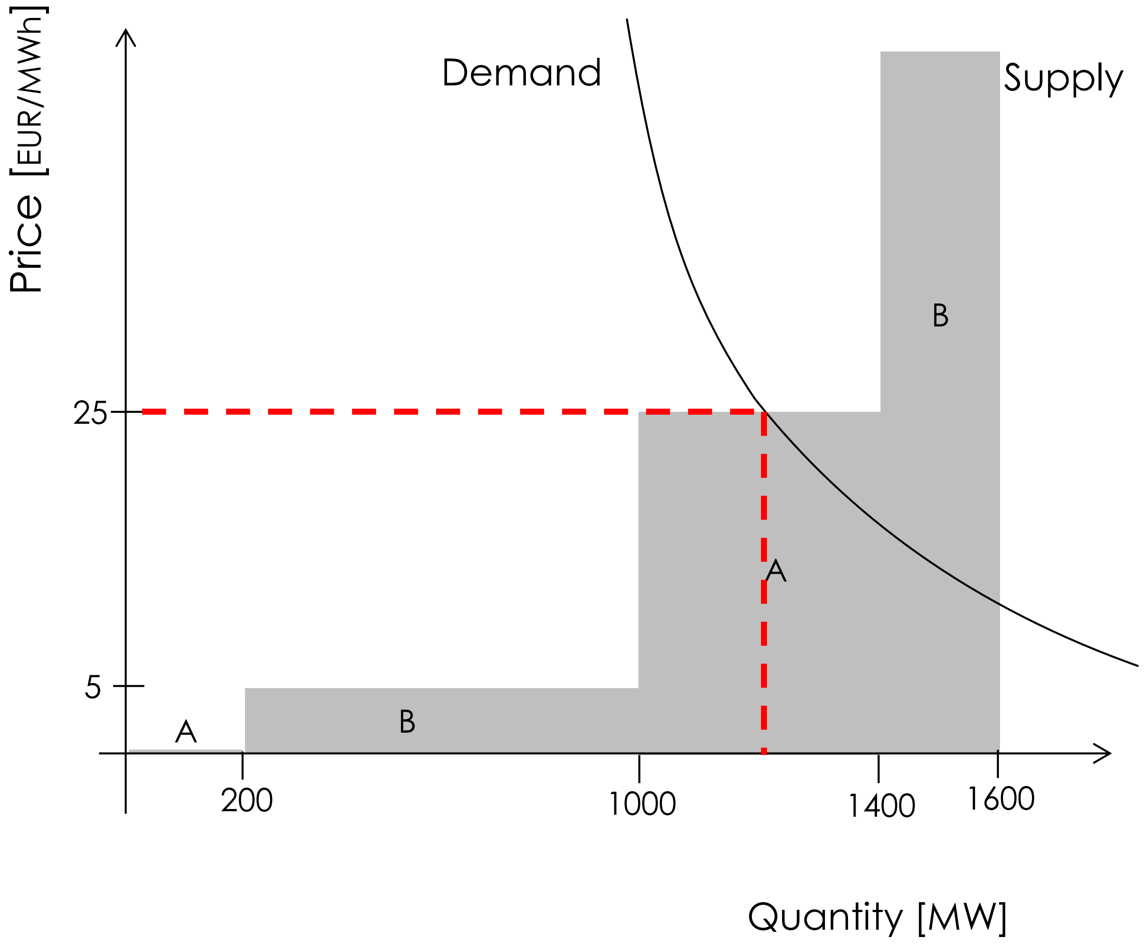
Short re-cap: marginal pricing on the market

Market bid: Player A

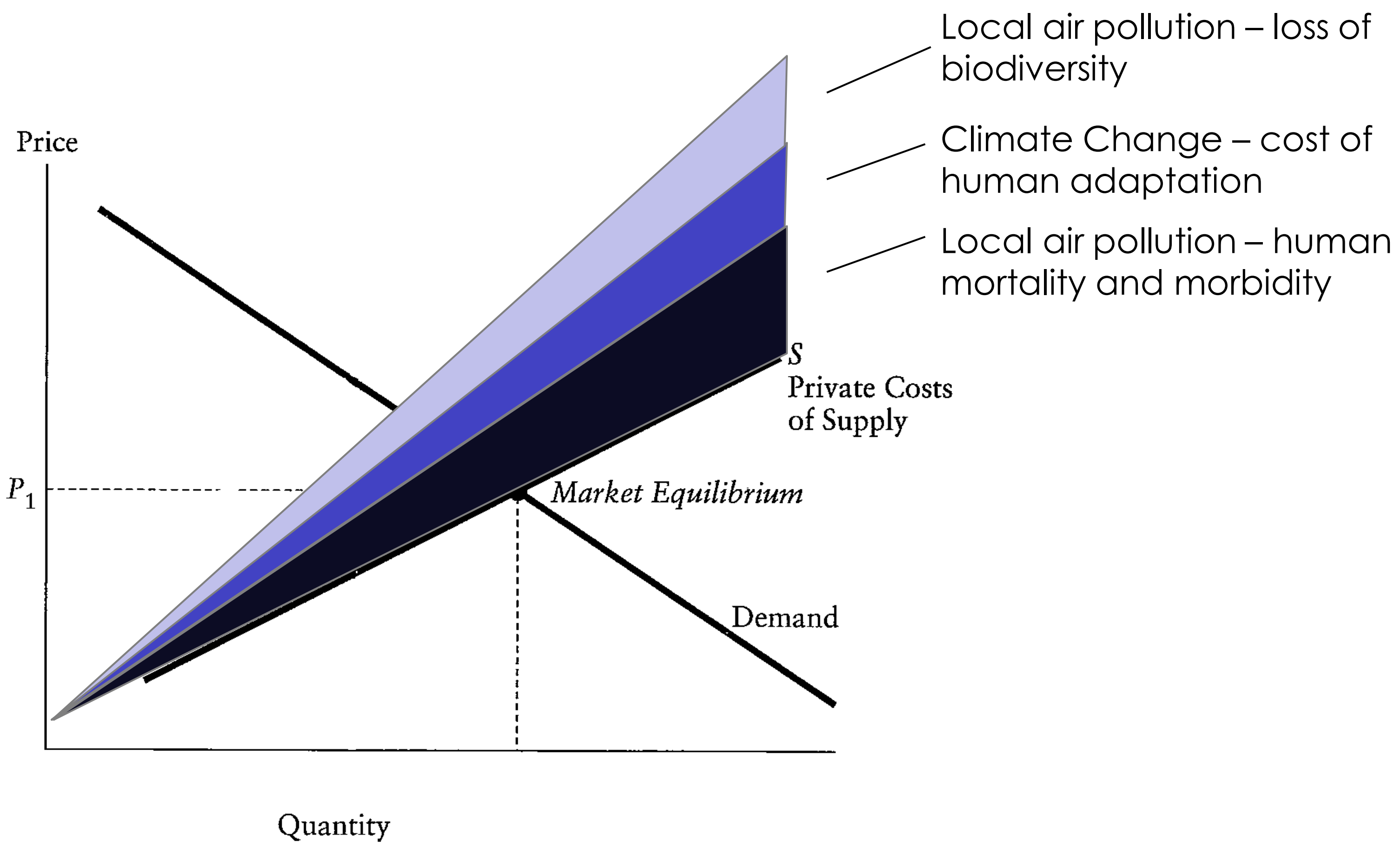
Volume	Price
200 MW	0 EUR/ MWh
400 MW	25 EUR/ MWh

Market bid: Player B

Volume	Price
800 MW	5 EUR/ MWh
200 MW	50 EUR/ MWh



Efficient Markets: Marginal cost and benefits

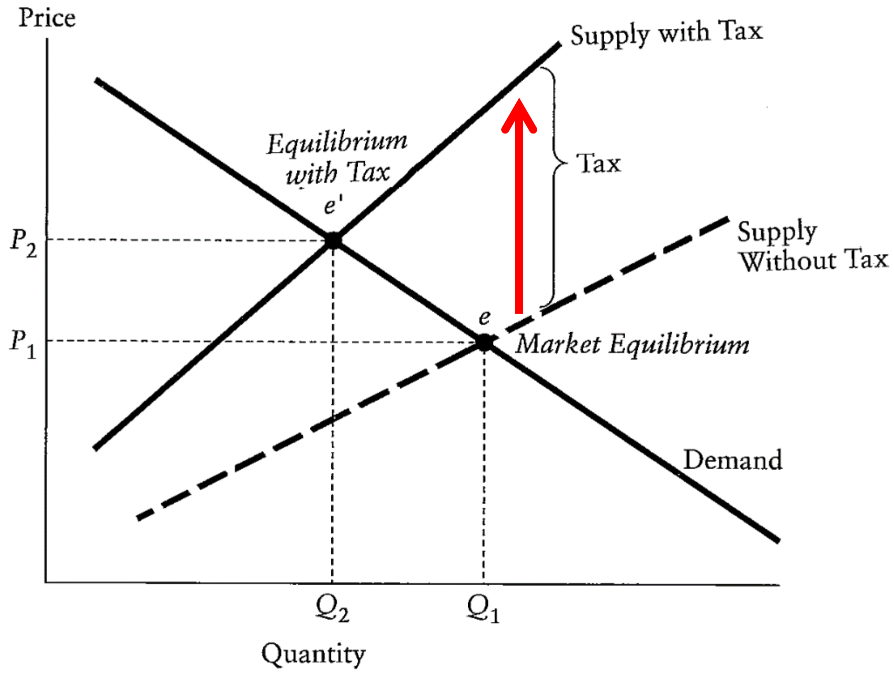


How to deal with external cost?

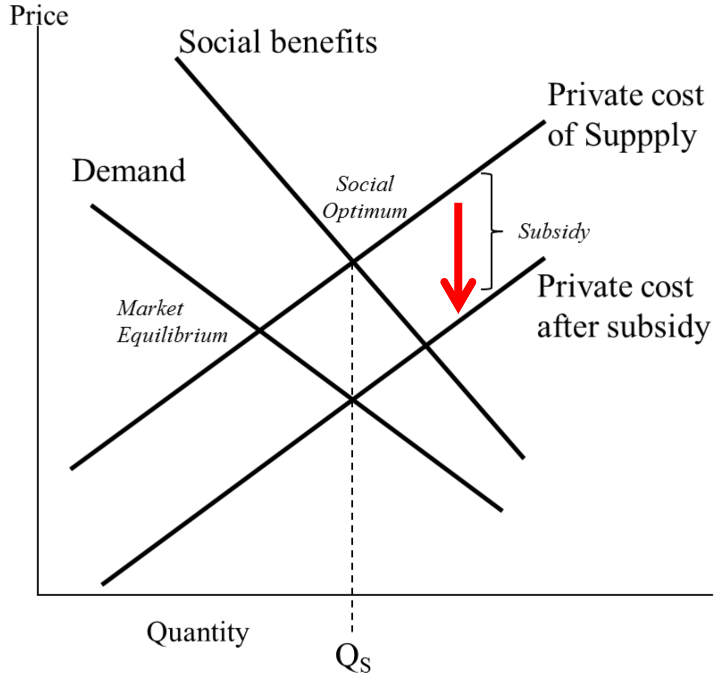
- Additional payments by the polluters (Tax, Emissions trading,…)
- Subsidy payments and other support for alternative (non-polluting) technologies

How to deal with external cost?

Additional payments by the polluters



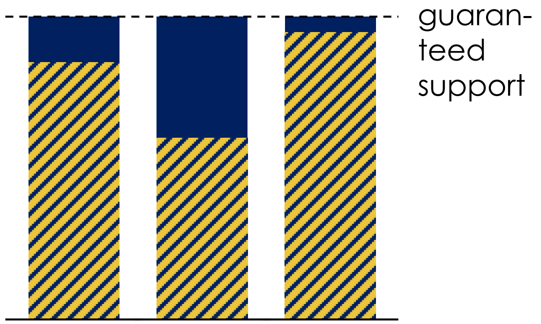
Subsidy payments to alternatives



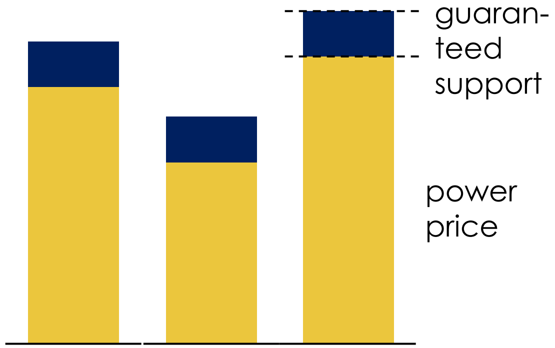
Question to class: what do we do in Europe?

Major support instruments:
Feed-in Tariffs, Premiums, Quota systems

Feed-in Tariff / Contracts-for-difference



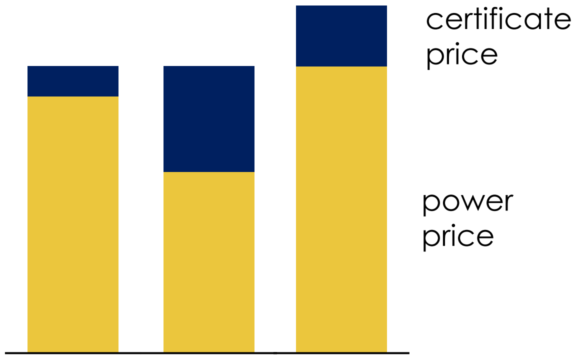
Feed-in Premium (fixed)



Quota Obligations

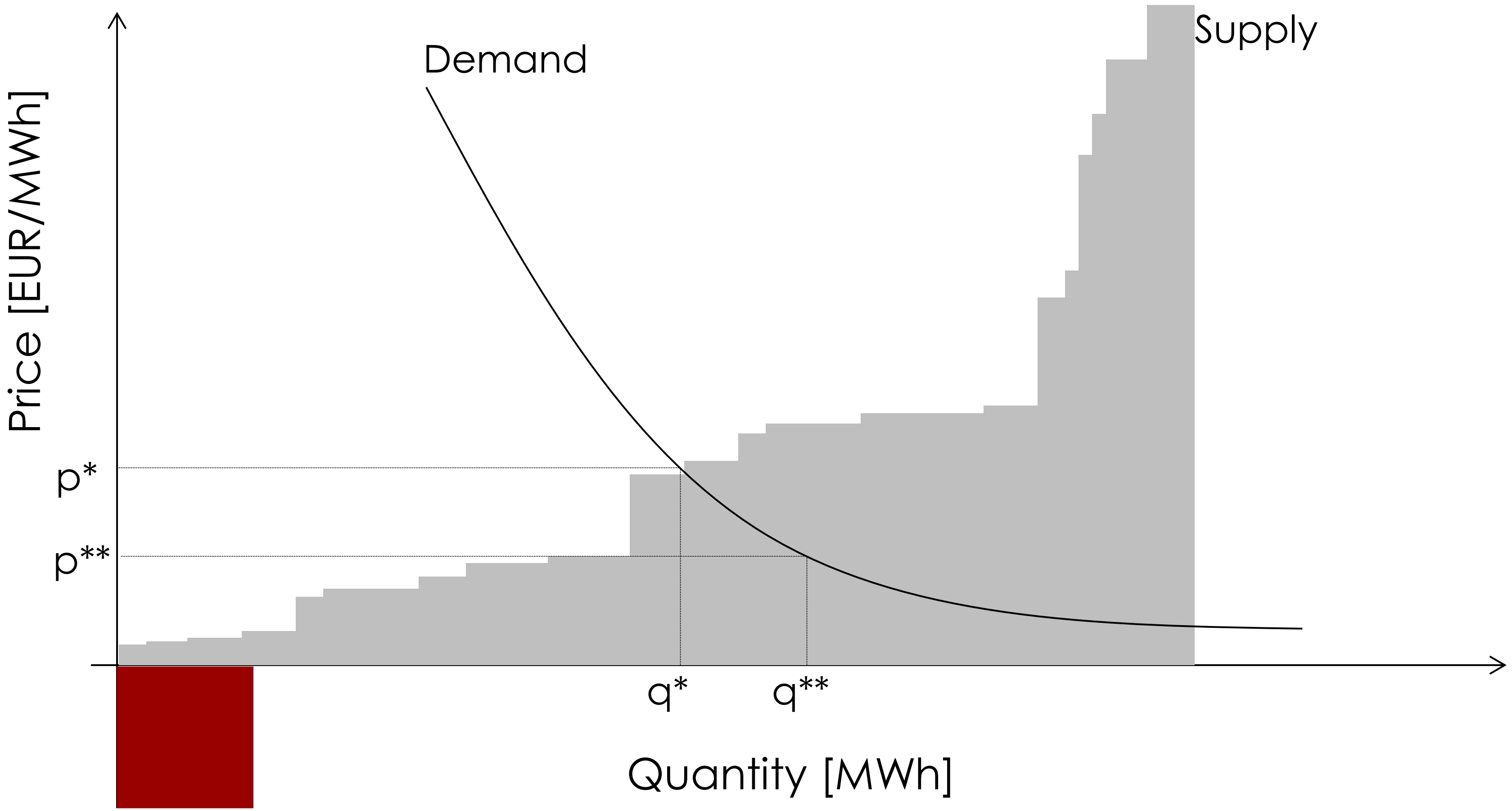
Tradable Green Certificates

Renewable Portfolio Standards



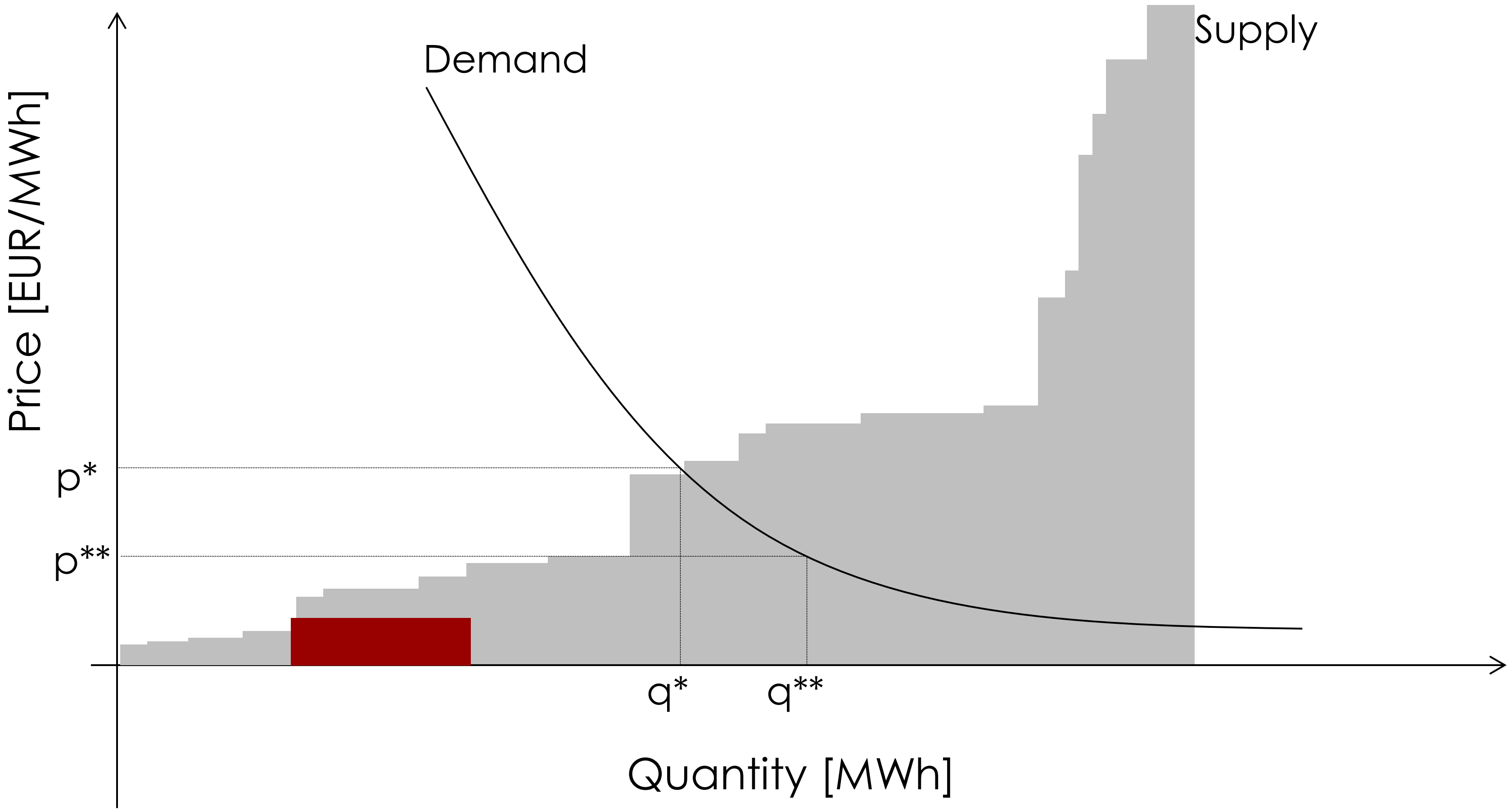
How would a supported wind park bid into the spot market – and what is the effect on market price?

Feed-in tariff: *The park would bid in at minus the tariff*



And what is the effect on market price if the park bid at marginal cost?

There will only be a market price effect when supported units become price setters!



The short-term energy-only markets work very well

for dispatch

...not so much for investment

We need to add strong long-term signals

>>> Now we will answer why this is so – and then how to do it

FOUNDATION FOR INVESTMENTS IN ELECTRICITY MARKETS

Last century

SPREADS

- 80-90% of lifetime cost are variable fuel prices
- Majority of energy investments by state / state-owned companies
- High shares of equity
- No political investment / build-out targets

This century

FINANCING

- 85-90% of lifetime cost are upfront investment
- 73% of global energy investments today rely on commercial financing
- Debt financing a cornerstone of clean energy projects
- Huge investment gap to NZE scenario

Pictures: iea

iea World Energy Investment 2024

DTU

Needs

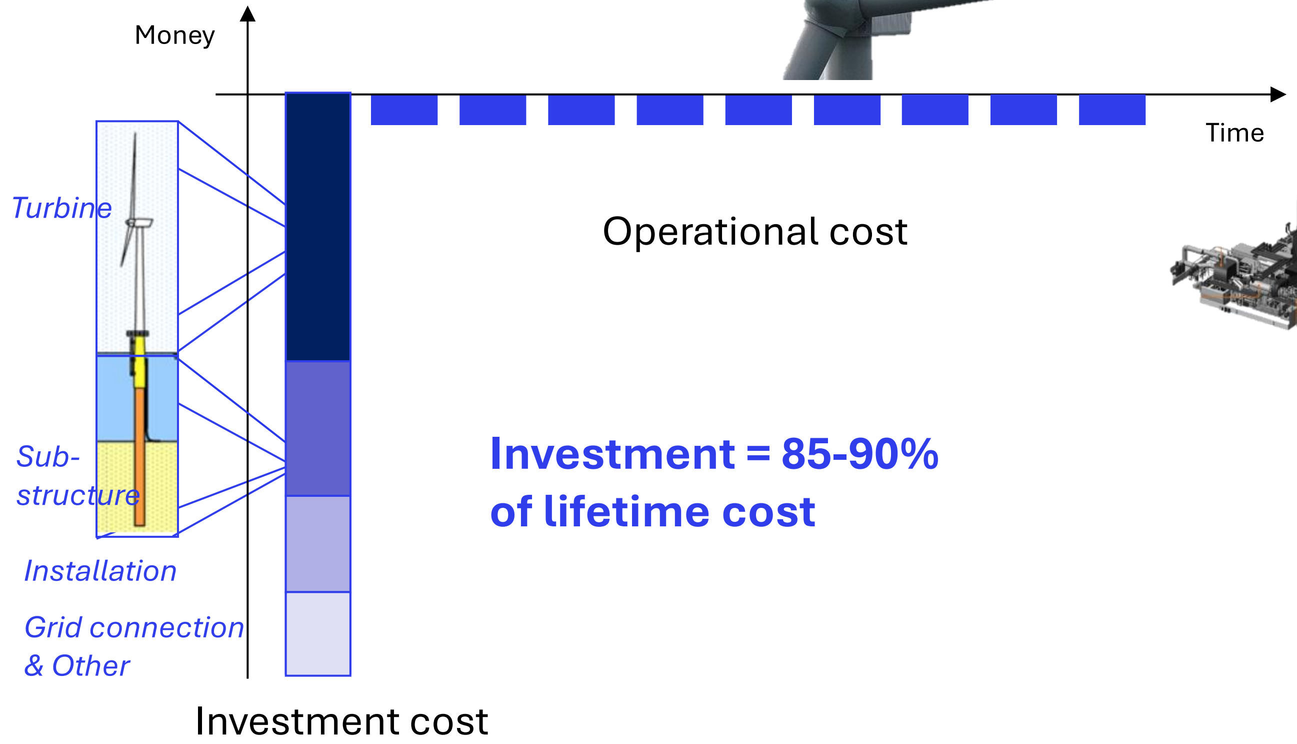
Political targets for fossil phase-out & low cost energy supply require massive low-cost investment in renewables

Issues

1) Mismatch between cost and income structure impedes (low-cost) financing for renewables

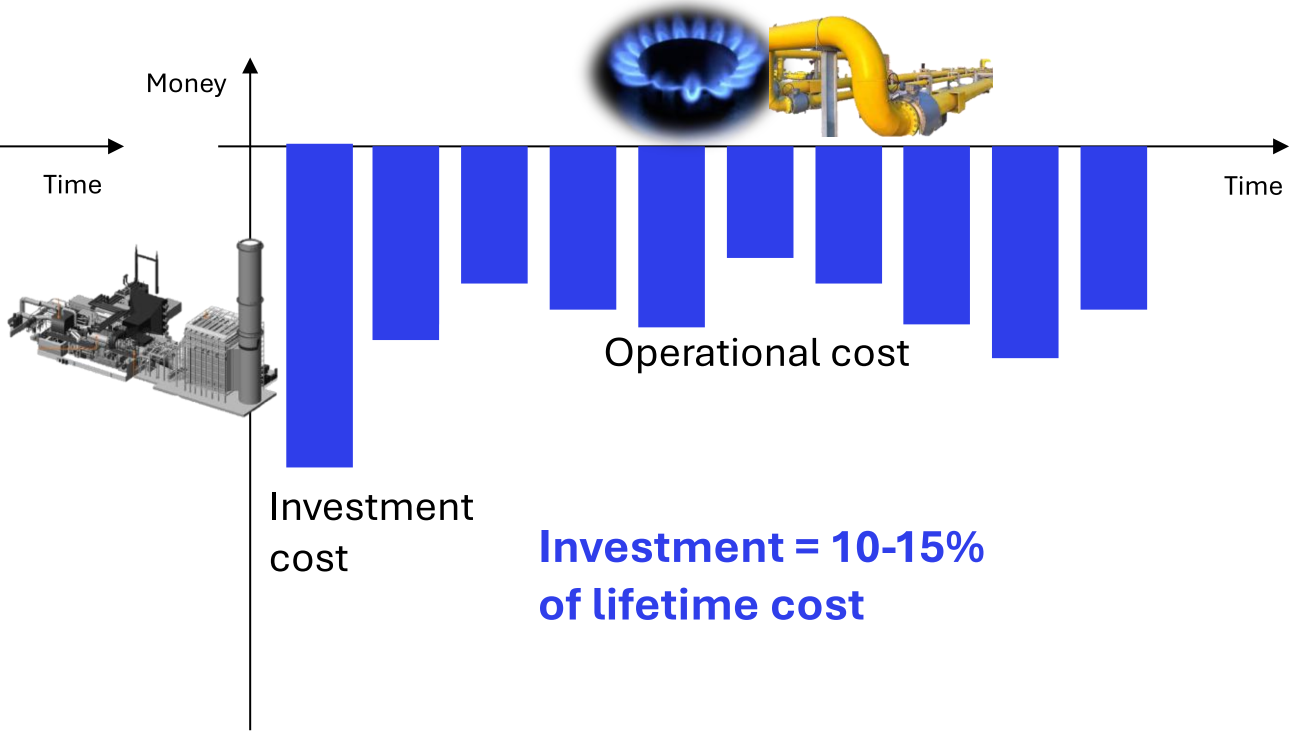
Cost structure of different electricity generation assets

Wind asset



Investment = 85-90% of lifetime cost

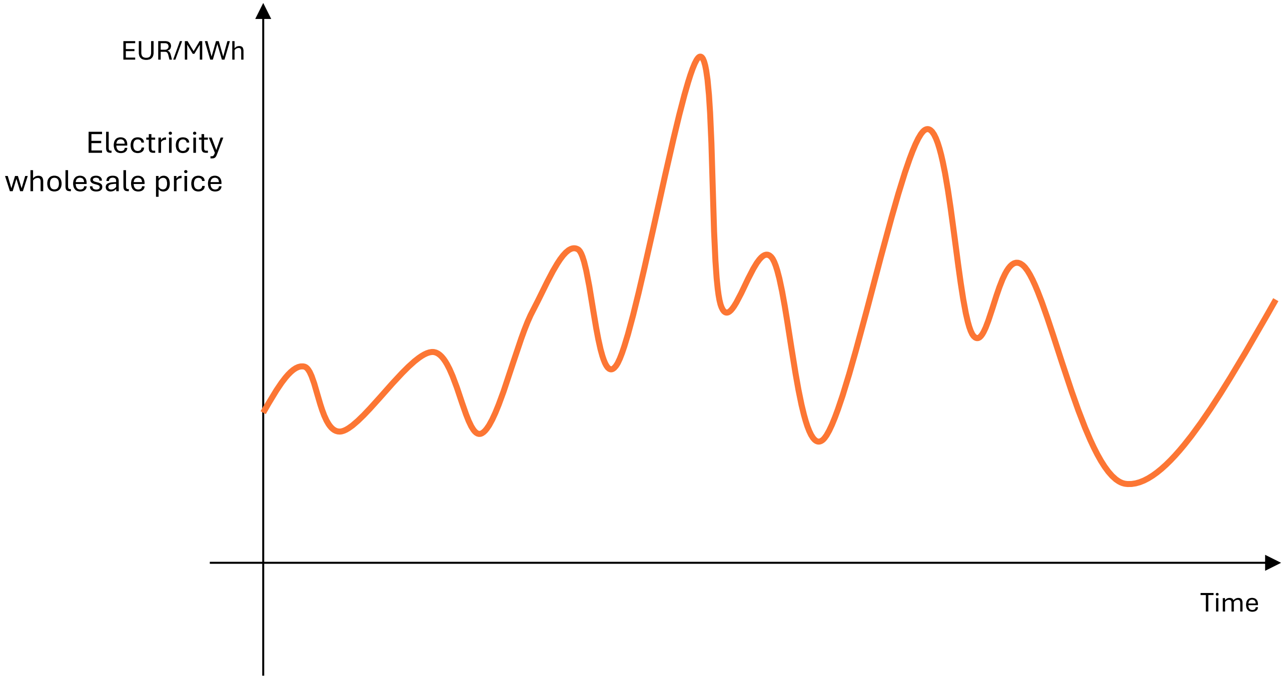
Gas-fired asset



Investment = 10-15% of lifetime cost

Note: highly simplified illustration

Benefit structure of electricity generation



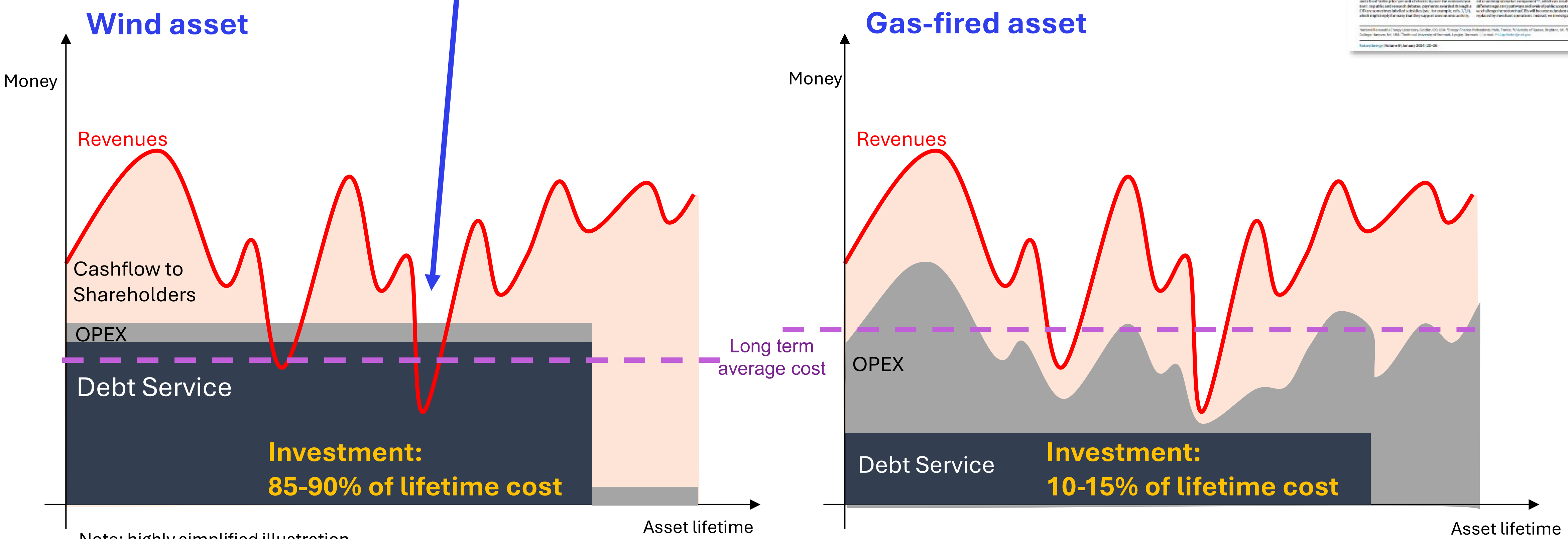
This fundamental mismatch between cost and benefit structure can be problematic!


nature energy

Perspective

The enduring role of contracts for difference in risk management and market creation for renewables

Wind assets are more exposed to financial distress in periods of low power prices – this (at best) increases financing cost



Note: highly simplified illustration

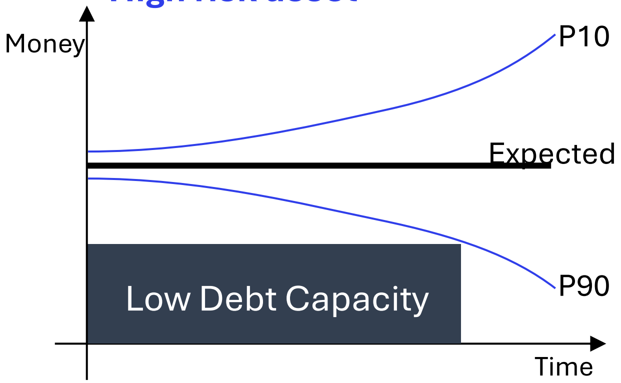
Source: Beiter, P., Guillet, J., Jansen, M., Wilson, E., Kitzing, L., (2023), The enduring role of contracts for difference in risk management and market creation for renewables, ***Nature Energy***, link

Quantifying implications from financial distress risk

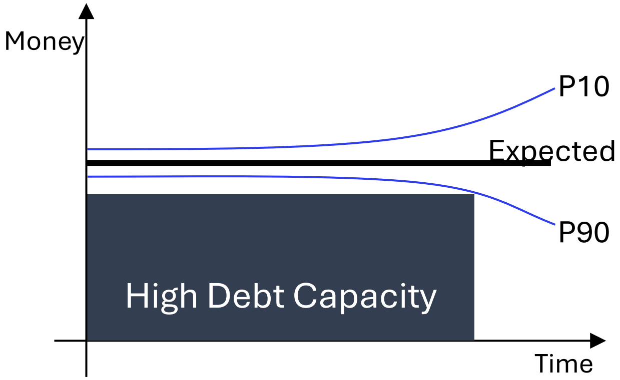
Two issues (out of many):
Exposure to price risk, in combination with cost-revenue mismatch leads to
(1) higher transaction cost and additional cash holdings / liquidity management, and hence higher revenue requirements to retain profitability

(2) lower debt capacity of the assets, limiting the operating space of firms and increasing cost

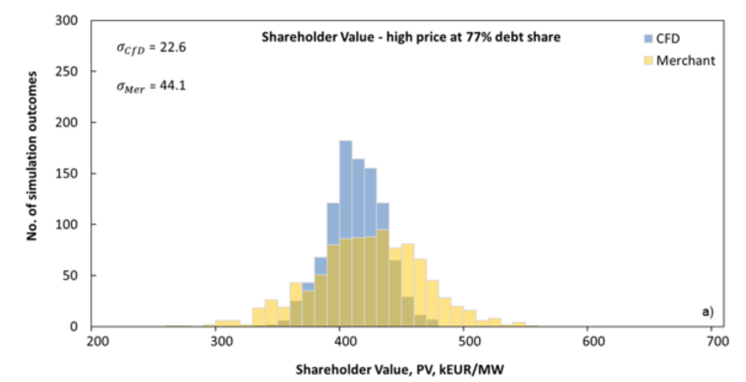
High risk asset



Low risk asset



RESEARCH: combined a stochastic power price and wind-power feed-in model with cash flow liquidity management in wind energy project financing, comparing fixed prices (contracts for difference) with variable price contracts (merchant)

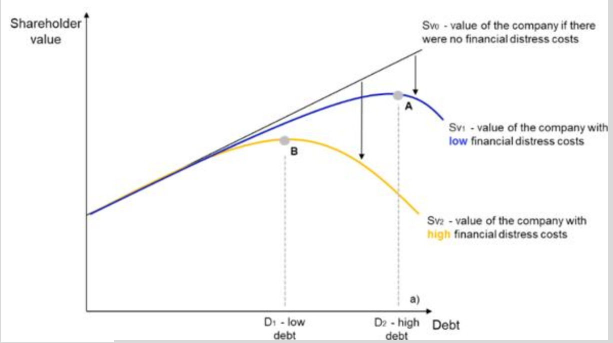


$$SV^i = \sum_{j=1}^{y} CF_y^{sh,a} \cdot \frac{1}{(1+c_e^i)^j}$$

$$CF_y^{sh,a} = D_y - (E_y + \Delta L_y)$$

$$E_y = \begin{cases} \Delta L_y > CF_y^{sh,b}, & E_y = DSRA_y^E - DSRA_y \\ \Delta L_y < CF_y^{sh,b}, & E_y = 0 \end{cases}$$

$$D_y = \begin{cases} \Delta L_y > CF_y^{sh,b}, & D_y = 0 \\ \Delta L_y < CF_y^{sh,b}, & D_y = CF_y^{sh,b} - \Delta L_y \end{cases}$$

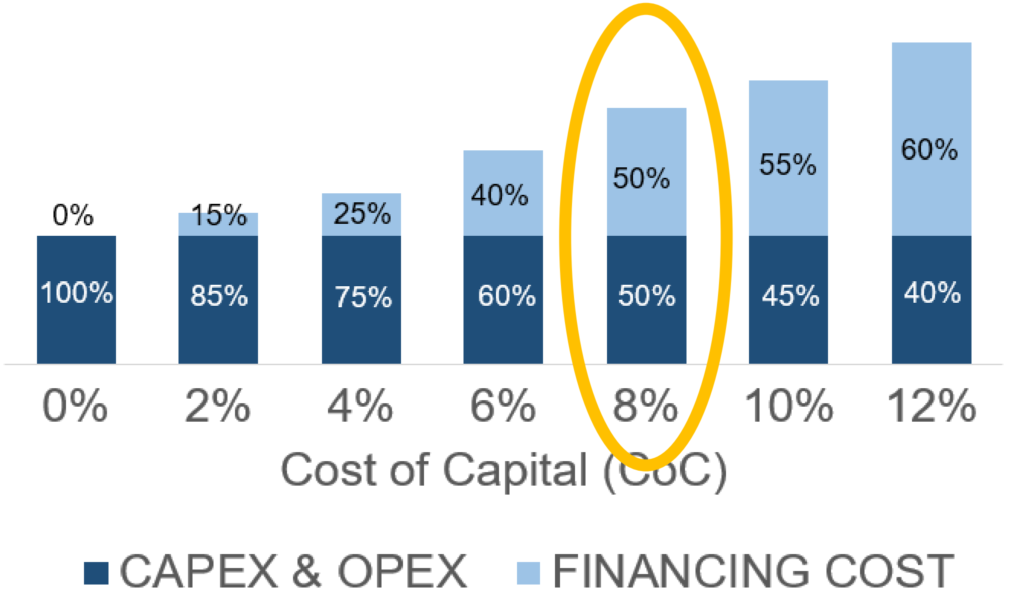


Significantly higher debt shares achievable through price stabilisation: variable price (merchant): 47-68%, fixed price (Cfd): debt shares of 79-90%,

Source: Đukan, M., Keles, D., **Kitzing, L.**, The impact of two-sided contracts for difference on debt sizing for offshore wind farms, ***The Energy Journal***,

Cost of Capital

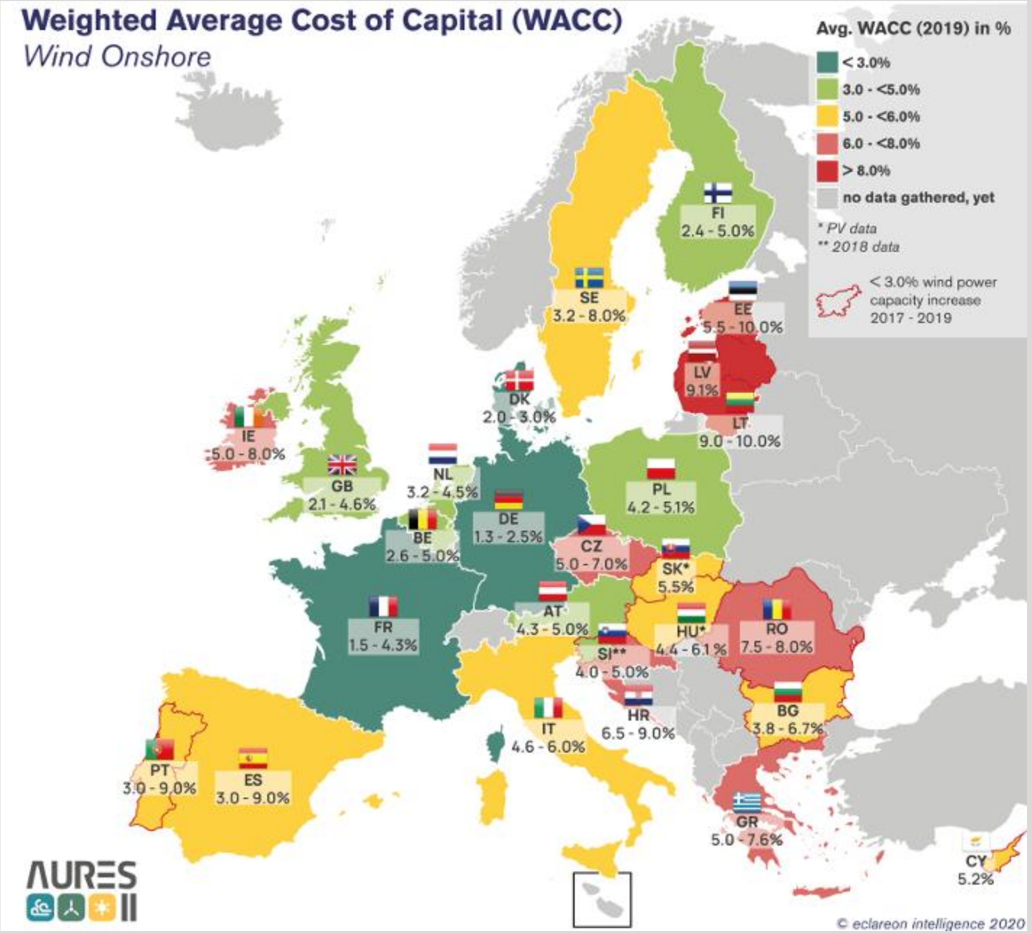
IMPACT OF FINANCING ON LIFETIME COST FOR RENEWABLE ASSETS



(rough example, representative for a solar PV / wind plant)

Source: Adapted from Egli, Steffen and Schmidt (2021)

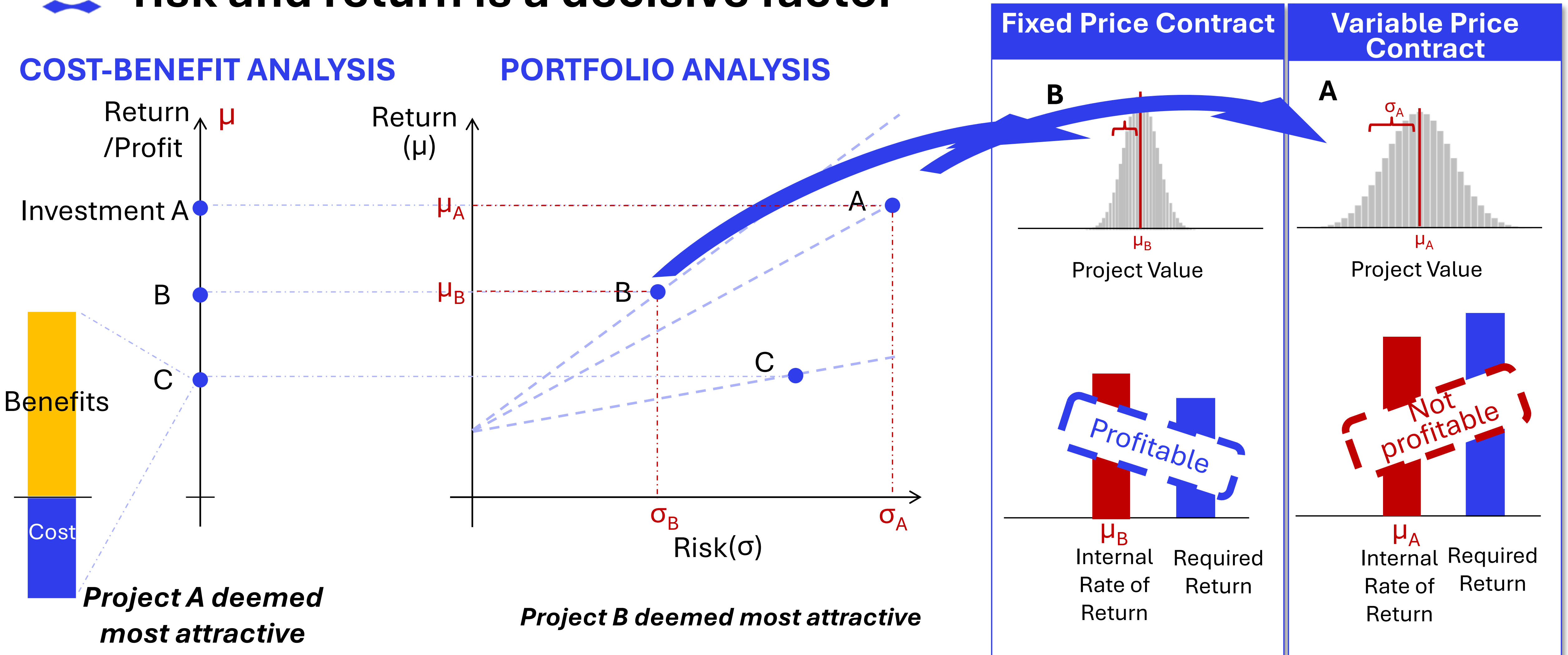
RESEARCH: Survey and impact analysis of renewable energy financing conditions in Europe, based on 140 interviews in most European countries



Source (survey data): Roth, A., Đukan, M., Anatolitis, V., Jimeno, M., Banasiak, J., Brückmann, R., **Kitzing, L.**, (2022), Financing conditions of renewable energy projects – results from an EU wide survey, ***Open Research Europe***, 1:136, link

Source (illustration): Roth, A., Brückmann, R., Jimeno, M., Dukan, M., **Kitzing, L.**, Breitschopf, B., Alexander-Haw, A., Amazo, A., (2021), Renewable energy financing conditions in Europe: survey and impact analysis. Project “AURES II Auctions for Renewable Energy Support”, H2020, grant number 817629, Report D5.2, link

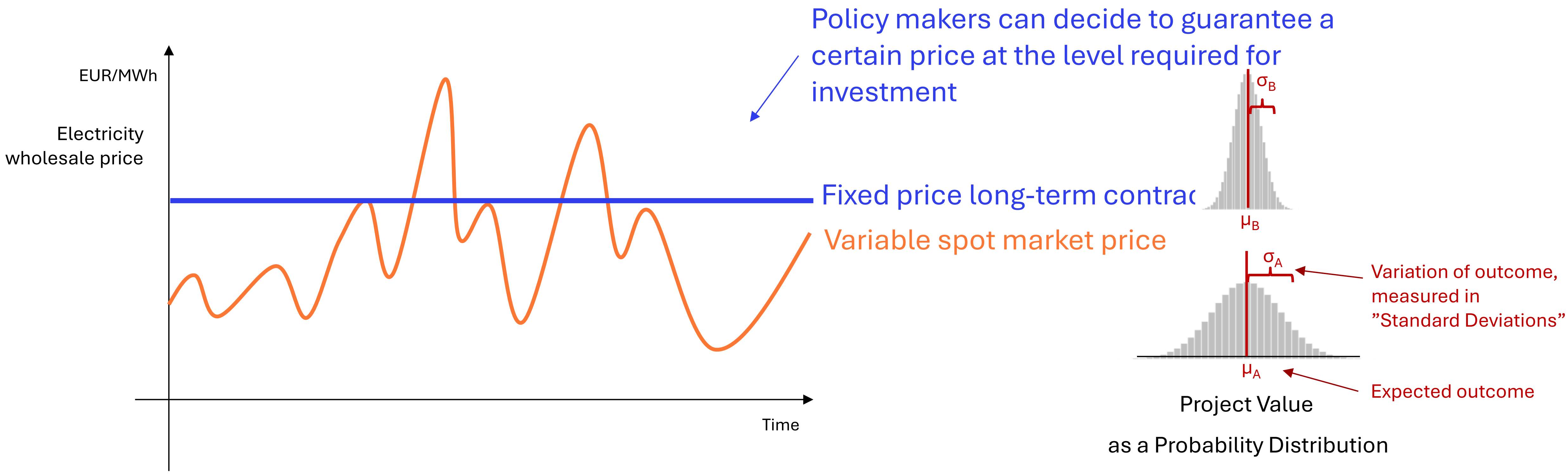
For profitability of investments, the relationship between risk and return is a decisive factor



Source: **Kitzing, L.**, (2014), Risk implications of renewable support instruments: Comparative analysis of feed-in tariffs and premiums using a mean-variance approach, ***Energy*** 64, 495-505

σ = Standard deviation
μ = Mean (expected value)

Benefit structure of electricity generation



Question to class: what are the two functional values of CfDs for supporting RES investment?

Needs

Political targets for fossil phase-out & low cost energy supply require massive low-cost investment in renewables

Issues

1) **Mismatch between cost and income structure impedes (low-cost) financing for renewables**
2) **Limited demand-side participation in long-term contracting & lack of emerging long-term products**

“Missing market” = limited other hedging options

- Suitable hedging options are lacking
  - Futures are liquid (at maximum) until five years
  - Long-term markets not available in many Member States
  - PPA volumes are insufficient
    - For EU’s target annual RE additions of 84 GW are needed
    - 6.5 GW were contracted under corporate (offsite) PPAs in 2022

Sources: https://www.iea.org/reports/is-the-european-union-on-track-to-meet-its-repowereu-goals and https://www.bnef.com/insights/30259

DTU

Needs

Political targets for fossil phase-out & low cost energy supply require massive low-cost investment in renewables

Issues

1) **Mismatch between cost and income structure impedes (low-cost) financing for renewables**
2) **Limited demand-side participation in long-term contracting & lack of emerging long-term products**

Consequence

States must take a more proactive role

What does academia say?

MIT CEEPR
MIT Center for Energy and Environmental Policy Research

Hybrid markets with marginal-pricing on spot, supplemented with capacity remuneration mechanisms and mandated PPAs / CfDs, via competitive procurement and dynamic planning, efficient integration of voluntary corporate PPAs

www.eprg.group.cam.ac.uk/wp-content/uploads/2022/09/Brussels-Session-4-Joskow.pptx

UNIVERSITY OF CAMBRIDGE
Energy Policy Research Group

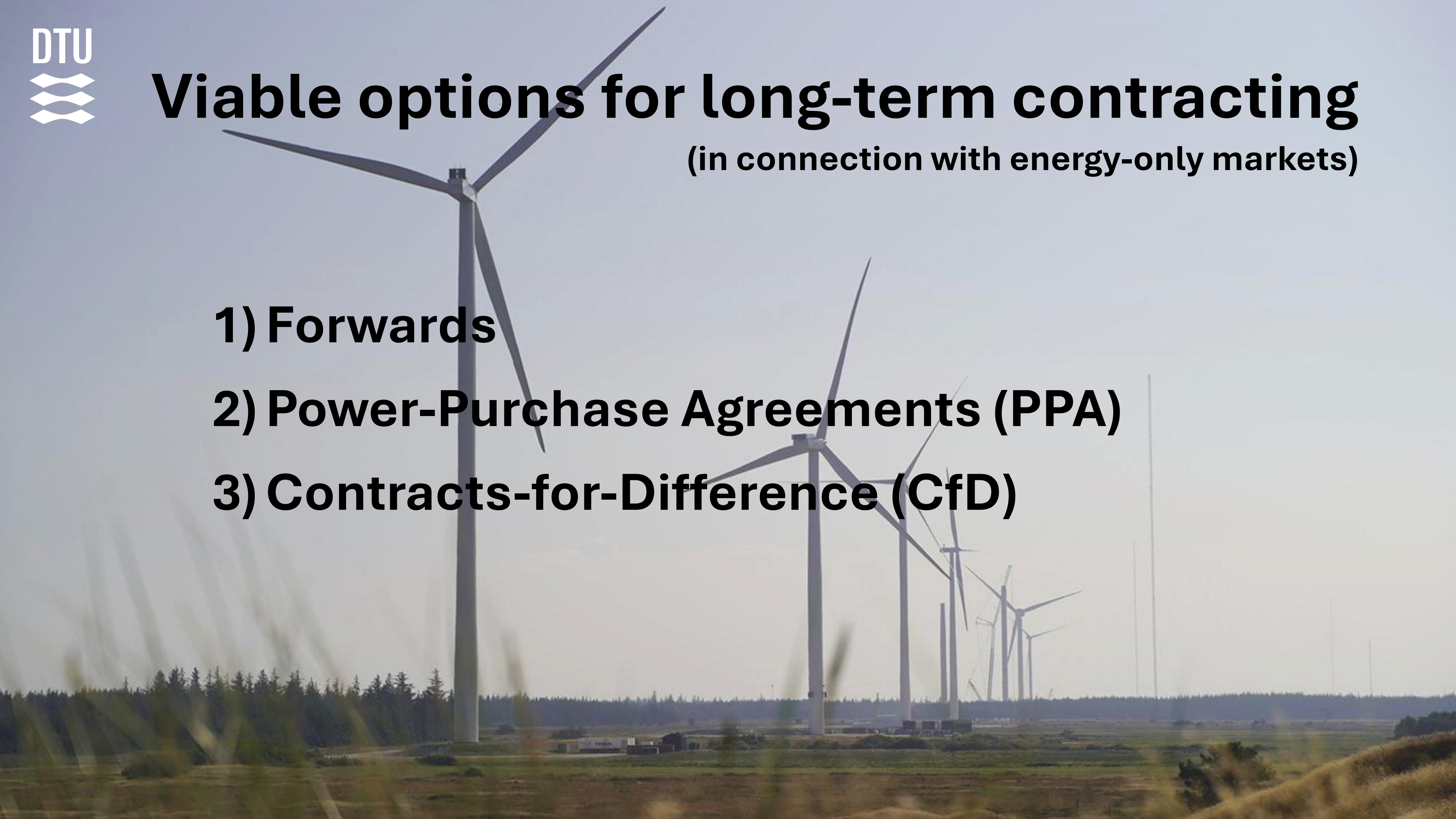
Hybrid markets with marginal-pricing on spot and mandated CfDs, which are capacity not output based, featuring better location and dispatch signals guided by market (and not CfD prices), yardstick pricing (based on forecast, not metered output), contract duration for full operating hours (not years) [2]

www.eprg.group.cam.ac.uk/wp-content/uploads/2022/09/Brussels-Session-4-Newbery-widescreen.pptx

EUI FLORENCE SCHOOL OF REGULATION

Hybrid markets with marginal-pricing on spot and mandated Contracts for Difference (CfD) and/or Power Purchase Agreements (PPA) for renewables, Capacity Remuneration Mechanisms (CRM) for back-up power and flexibility, Energy Communities and Demand-Side Flexibility

https://fsr.eui.eu/the-5th-eu-electricity-market-reform-a-renewable-jackpot-for-all-europeans-package/



Viable options for long-term contracting

(in connection with energy-only markets)

1) Forwards
2) Power-Purchase Agreements (PPA)
3) Contracts-for-Difference (CfD)

Building blocks approach for long-term contracting

Longer term products (10+ years)
More complex products
Ensure liquidity

Strengthening the Forwards market

Boosting the PPA market

Product diversification
Securisation
Simplifed access across regions
Standardisation

Contracts-for-Difference

Contracts-for-Difference as safety net

Smart designs that do not unduly distort market operations

CfDs increasingly solve a ”missing market” problem, rather than a ”missing money” problem

Differentiating short-term and long-term price risk

Not as previously

Either Price Stabilisation ***Or*** Exposure to price risk

- Long-term price volatility
- Short-term price volatility
- Extreme price events

But as state-of-the-art

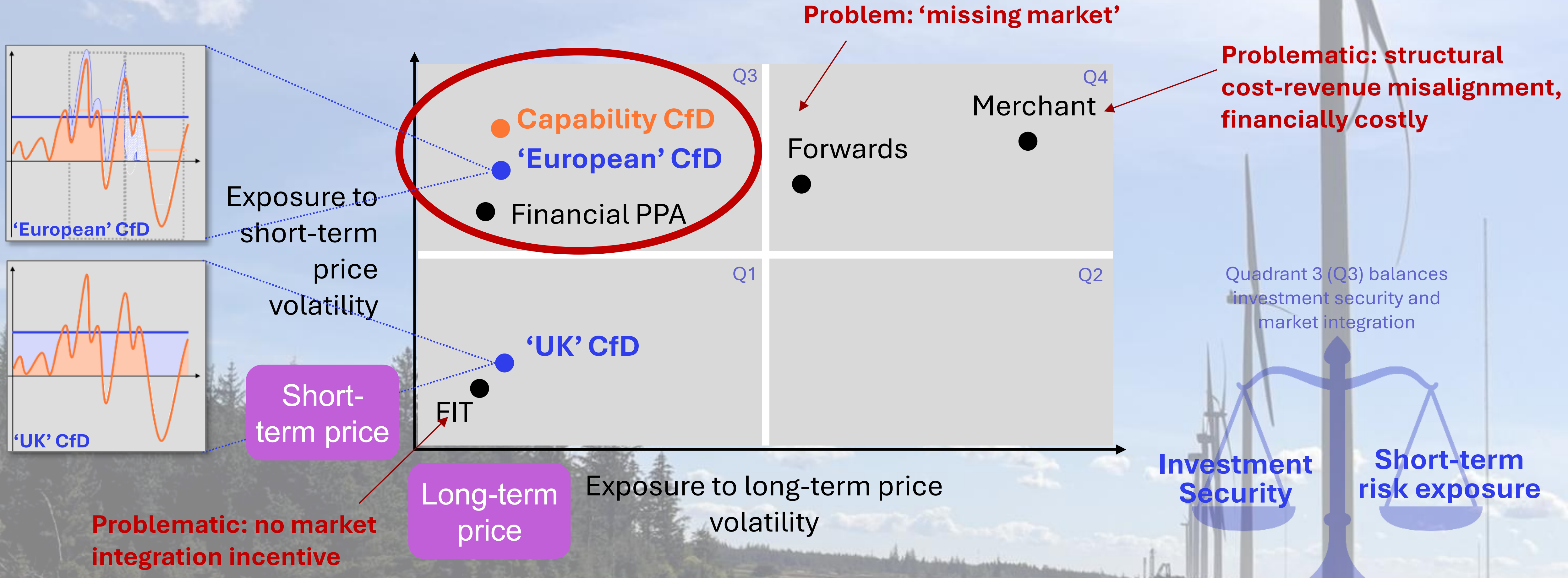
Both Price Stabilisation ***And*** Exposure to price risk

- Stable long-term price
- Variable short-term price

Differentiating short-term and long-term price risk

Two options:

1) **Decoupling reference prices from spot variation though longer-term reference prices**
2) **Decoupling applicable volume from actual production**



Source: adapted from **Kitzing, L.** (2024), European Energy Policy Conference, https://ceepr.mit.edu/events/research-workshops/

Contracts-for-Difference

EU Electricity Market Regulation – new in 2024

Official Journal
of the European Union

EN
L series

2024/1747

26.6.2024

REGULATION (EU) 2024/1747 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 13 June 2024

amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design

(Text with EEA relevance

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNIC

Having regard to the Treaty on the Functioning of the European Union,

Having regard to the proposal from the European Commission,

After transmission of the draft legislative act to the national parliament

Having regard to the opinion of the European Economic and Social Co

Having regard to the opinion of the Committee of the Regions (²),

Acting in accordance with the ordinary legislative procedure (³),

Article 19d

Direct price support schemes in the form of two-way contracts for difference for investment

1. Direct price support schemes for investment in new power-generating facilities for the generation of electricity from the sources listed in paragraph 4 shall take the form of two-way contracts for difference or equivalent schemes with the same effects.

The first subparagraph shall apply to contracts under direct price support schemes for investment in new generation concluded on or after 17 July 2027, or, in the case of offshore hybrid asset projects connected to two or more bidding zones, 17 July 2029.

The participation of market participants in direct price support schemes in the form of two-way contracts for difference and in equivalent schemes with the same effects shall be voluntary.

EC CfD Guidelines – new in 2025

- Clarity & Definitions
- Flexibility in Design
- Balanced focus on production and investment incentives
- Openness to future evolution

Open questions on design details, PPA interactions, 'fusion' CfDs

Official Journal of the European Union

EN
C series

C/2025/6701

19.12.2025

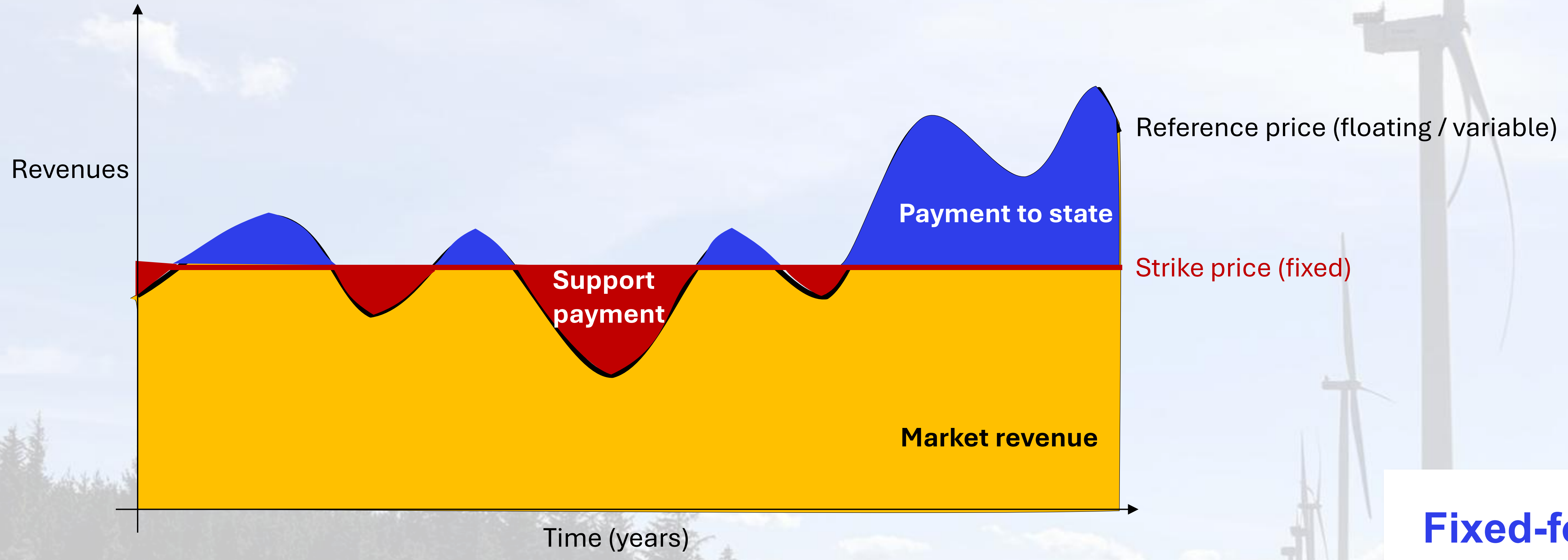
Commission guidance on the design of two-way contracts for difference

(C/2025/6701)

Table of Contents

1. Generate electricity to support the system needs
2. Take optimal investment decisions to foster efficient system integration
3. Offer ancillary and congestion management services ([43])
4. Perform maintenance at appropriate times, given the electricity system needs
5. Offer their output at their marginal cost and considering their technical constraints
6. Ensure that beneficiaries participate efficiently in different electricity market segments, pursuing a profit maximising strategy
7. Ensure minimal impact on the liquidity of forward electricity markets ([44])
8. Support a fair and non-distortive 2w-CfD revenue distribution

CfDs are financial hedges



Wind park owners are trading away market upside to gain price certainty

Fixed-for floating swap

How CfDs provide support: by shielding from (extreme) price risk

- Support is not necessarily through net payments but through **financial stability**
- Risk is reallocated from the producer to the state
- Achieves **bankability** & reduction of **cost of capital**
  → *often necessary because of upfront capital intensity*

- *Can also be used to address risk of market-based downregulation and (to some extent) weather-related risks*

Profitability gap exercise

!! Profitability gap !!

Sufficient and timely capacity additions

- Pay support
- Stabilise long term prices

!! Financing gap !!

Sufficient and timely capacity additions

&

System-friendly choices

Pay support

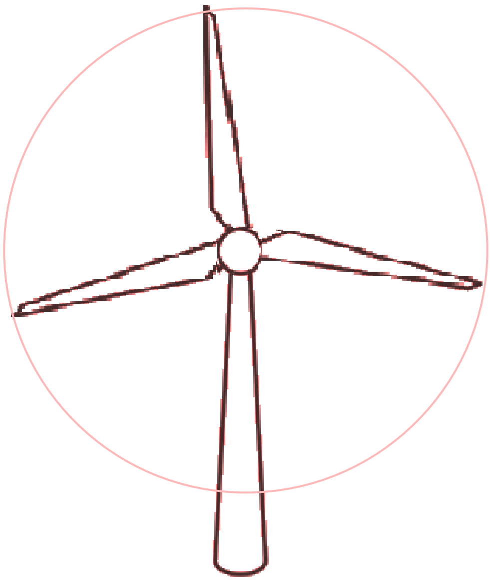
Stabilise long term prices

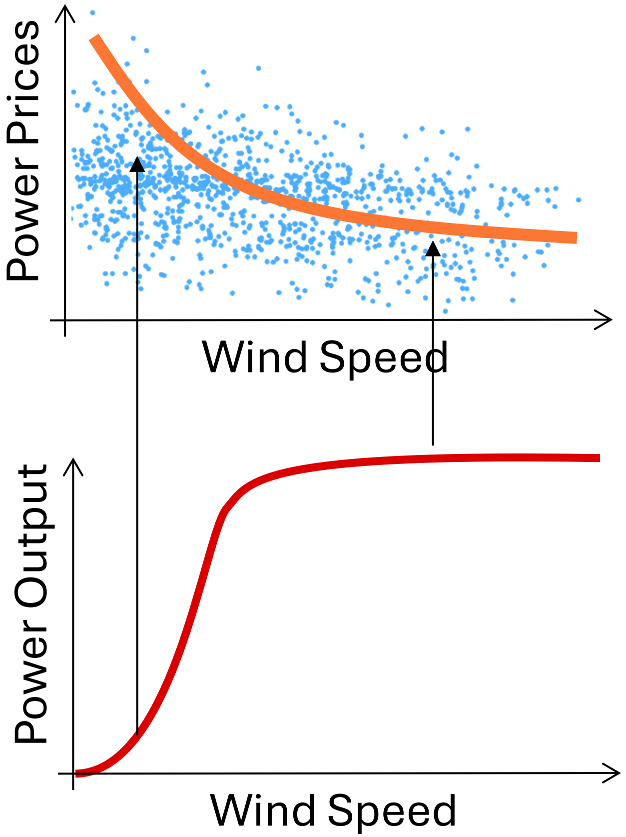
Expose to short term prices

!! Market integration !!

Why do we want to expose renewable energies to short-term price variations? Value creation through technology choice

The concept of market value

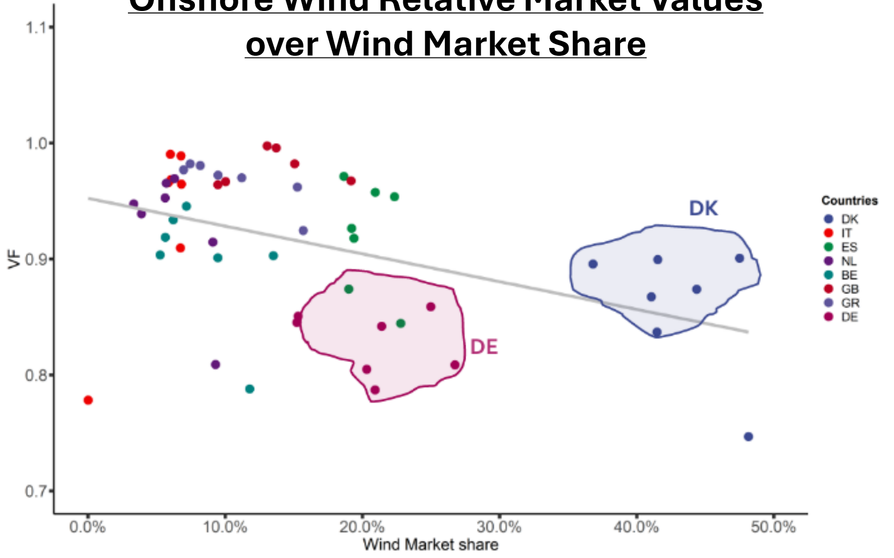




Wind energy production and market prices are negatively correlated…

…and it gets worse with more wind energy in the market

Onshore Wind Relative Market Values over Wind Market Share



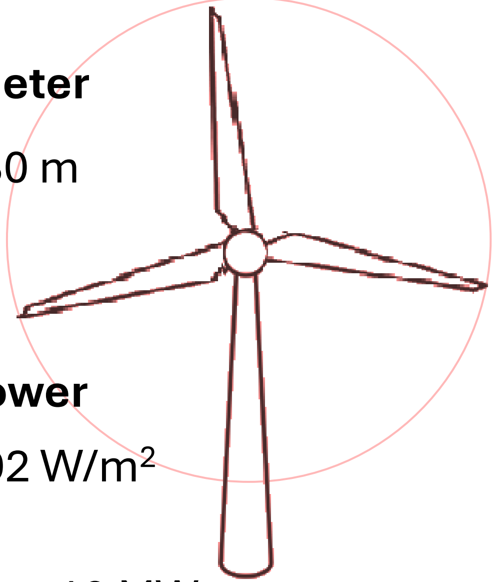
Source: EA Energy Analysis, Tracking Market Value of Wind, link

Low specific power turbines have higher market values!

Rotor diameter 180 m

Specific Power 392 W/m²

Capacity 10 MW



CAPEX

1.3 M€/MW 1.9 M€/MW

Capacity Factor

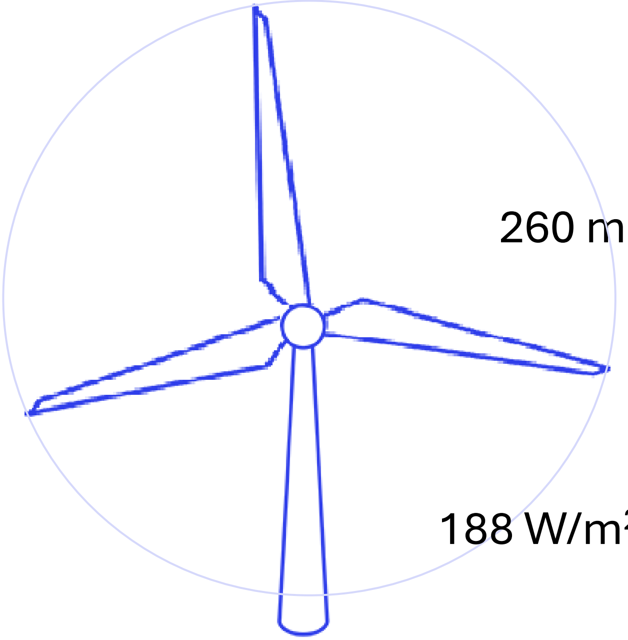
45% 55%

Levelised total cost

Lower 48 €/MWh 50 €/MWh

Average achieved price = Market Value

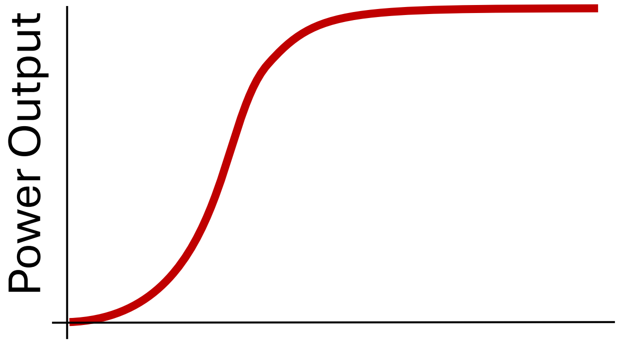
50 €/MWh 55 €/MWh **Higher**

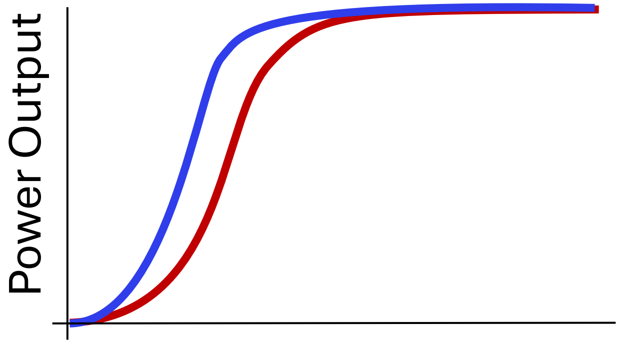


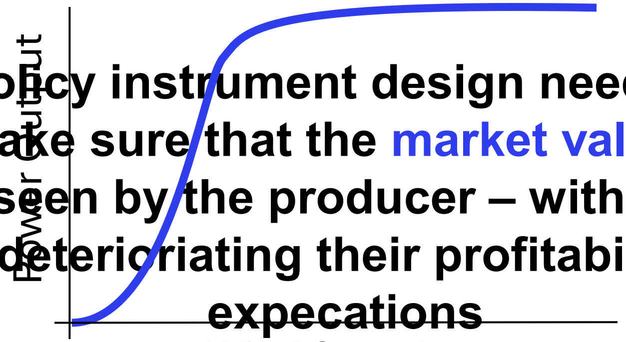
260 m

188 W/m²

10 MW

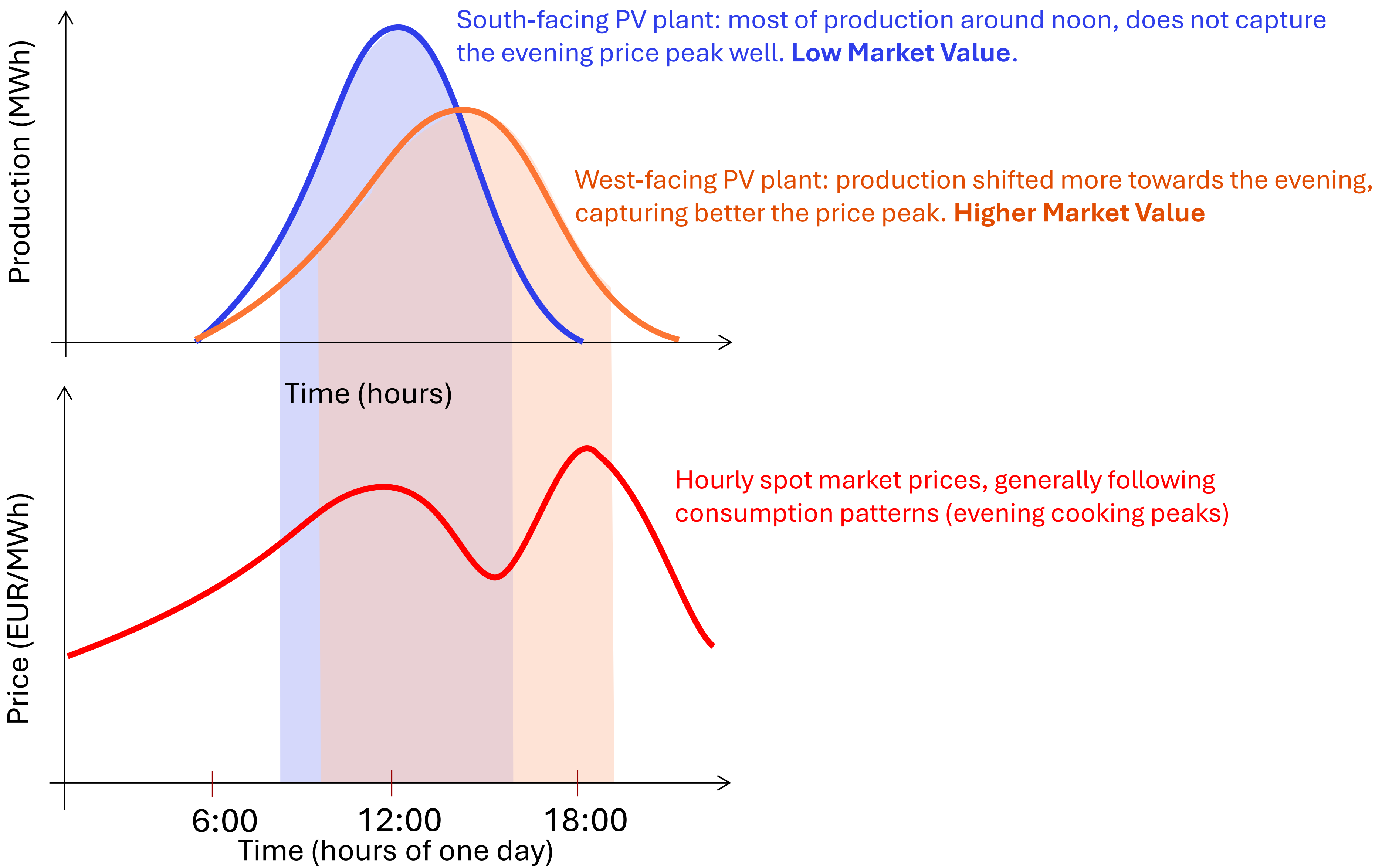






Policy instrument design needs to make sure that the market value is seen by the producer – without deterioriating their profitability expecations

The same holds for non-south facing solar Photovoltaics



Value creation through technology choice

- Focus on value relevant for investment considerations
  - Higher achieved prices (Market Value Factors)
  - Avoiding self-cannibalisation

- BUT ONLY if incentivised adequately by market and remuneration design
  - ”old” (UK) CfD design (as in Danish Horns Rev, Kriegers Flak, Anholt) did not
  - ”new” (EU) CfD design as in Thor would have (averaging of reference periods)
  - Fixed premiums can do (but other issues)
  - Pure market investment might be (depending on potential PPA choices)

Design Criteria for policy: Market incentives

Optimal utilisation (operations)

- Always produce when the price is above, and never when the price is below short-term variable costs (day-ahead, intraday, balancing)
- Schedule maintenance to value-optimal times (instead of cost-minimisation)

Optimal design and siting (investments)

- Generation profile that matches system needs ("system-friendly design", e.g. longer wind turbine rotors, west facing solar panels)

CfD "Families"

CfD Payout = Reference Volume x (Strike Price – Reference Price)

Production-based	"You get paid for what you produce"
Capability-based	"You get paid for what you could produce"
Reference-plant-based	"You get paid for what someone like you should be able to produce"

non-exhaustive list

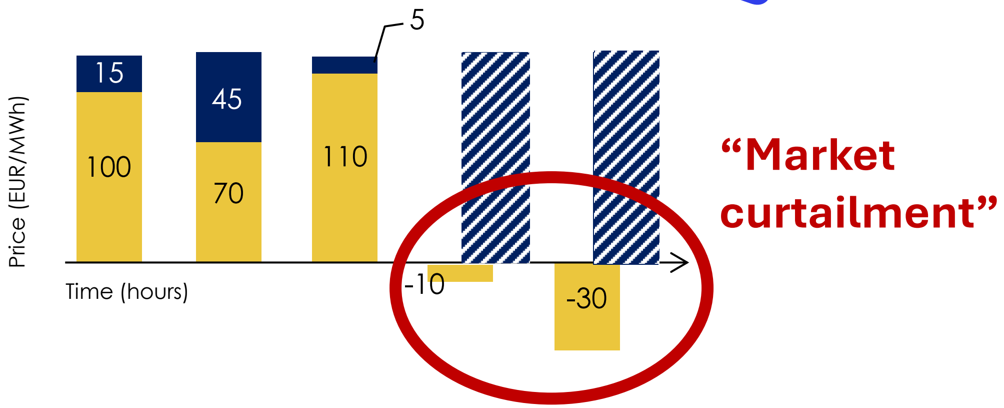
(Averaged) day-ahead reference	Do we take the direct (1/4 hourly) price or a (monthly/ quarterly/annual) average?
(Technology-) Weighting	Should the averaged price be weighted e.g. by your technology group?
Considering negative prices?	Should the average include negative price periods?
Intraday & Balancing markets	Should we be considering sequential markets in the reference?

non-exhaustive list

Profit maximisation under CfDs

Hourly Reference price

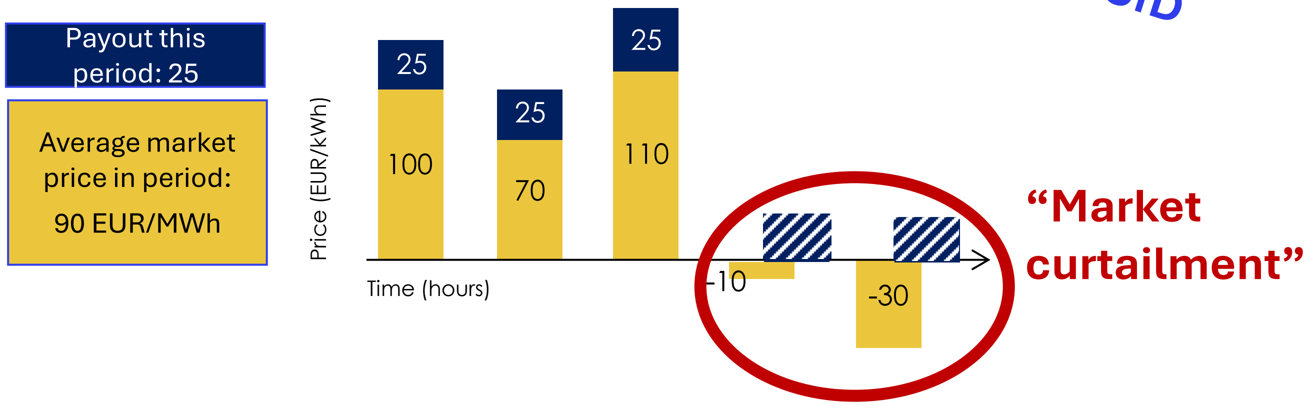
'UK' CfD



Achieved price: 115

Averaged Reference price

'European' CfD



Average Achieved price (across period): 115

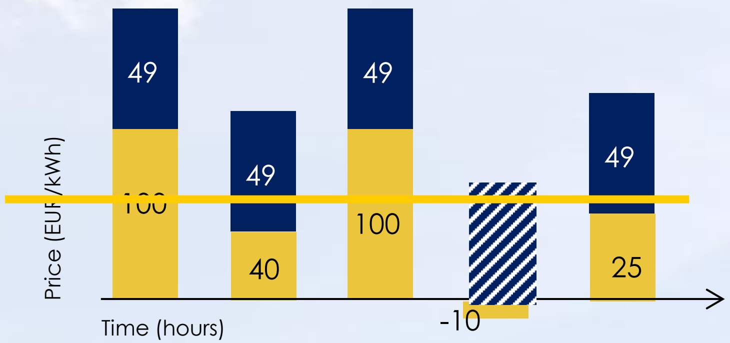
HOURLY SETTLE-MENT	▪ Always achieves strike price, no basis price risk ▪ Incentive to maximise production (in siting, plant design and operations) ▪ Incentive to cost-minimise operations and maintenance

MONTHLY TECHNOLOGY-SPECIFIC VOLUME-WEIGHTED AVERAGE	▪ Achieves strike price if production pattern is the same as the rest of the technology (e.g. offshore wind in market area A), low price risk ▪ Incentive to 'beat the siblings' (medium system integration benefit) ▪ Incentive to value-maximise maintenance within the month
ANNUAL FLAT (BASE) AVERAGE	▪ Achieves strike price if production pattern resembles the market average, medium price risk ▪ Potential liquidity risks in case of large price swings ▪ Incentive to 'beat the market' (large system integration benefit) ▪ Incentive to value-maximise maintenance across seasons

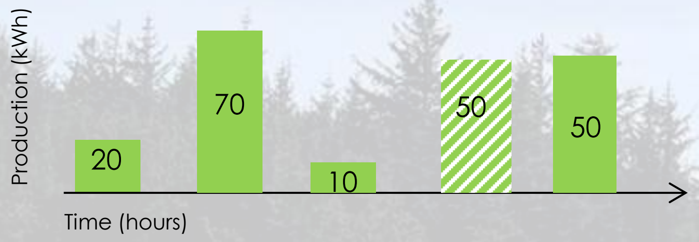
CfD Calculation ex.: Reference price

CfD exercise

Price



Volume



	Ref. Volume [MWh]	Strike price [EUR/ MWh]	Ref. Price [EUR/ MWh]	CfD Premium [EUR/ MWh]	Payout [EUR]
Production-based Flat average (baseload)	150	100	51.00	49.00	7,350
Production-based Volume weighted	150	100	47.00	53.00	7,950
Capability-based Volume weighted	200	100	32.75	67.25	13,450
Capability-based, Volume weighted, w/o negative prices	200	100	35.25	64.75	12,950

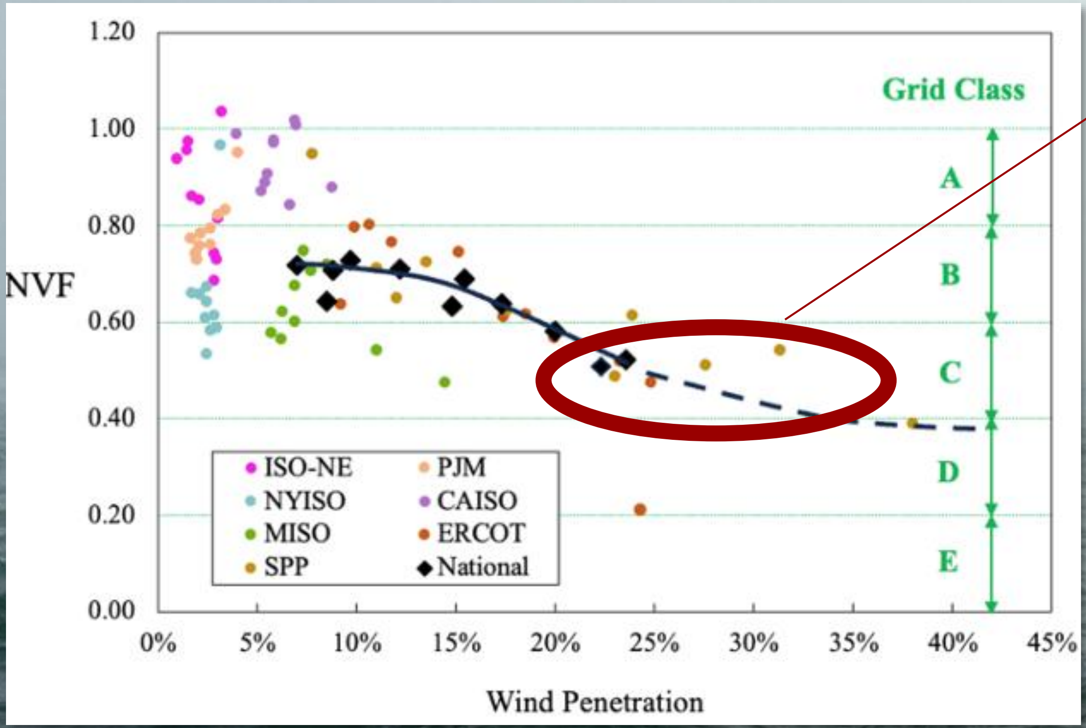
simplified illustration

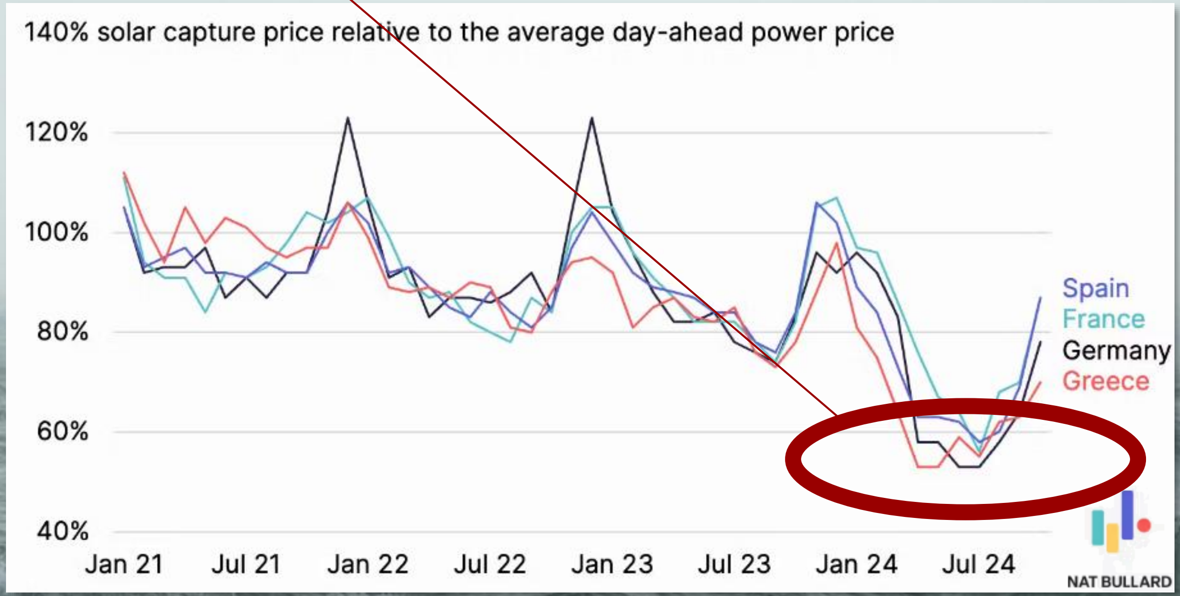
Question to class: Which option would you prefer as investor / as policy maker?


BUT: exposure cannot
be at all cost...

Decreasing Market Value Factor of Wind and Solar

50%





Loth, E., Wind energy value and deep decarbonization design, what's next?, 2023, doi-org.proxy.findit.cvt.dk/10.1016/j.nxener.2023.100059

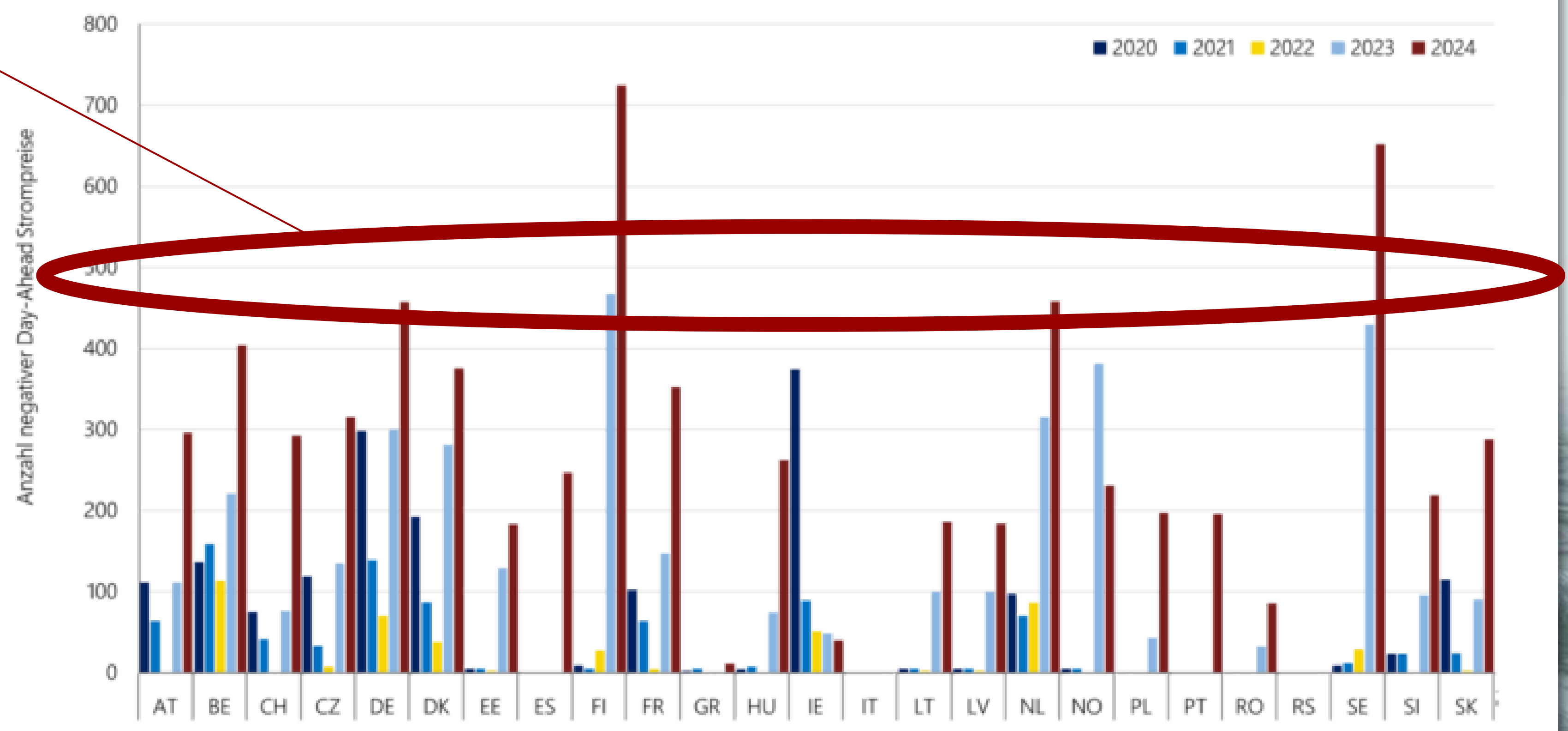
Source: Nat Bullard, January 2025, www.nathanielbullard.com/presentations

Negative Prices = No income

500h

- Increasing share of weather-dependent renewables
- Lack of storage and flexibility solutions

Number of negative day-ahead electricity prices in 25 European countries, 2020-24



Source: Ffe (2025), based on data from ENTSO-E Transparency Platform
ffe.de/en/publications/european-day-ahead-electricity-prices-in-2024/

CfD "Families"

CfD Payout = Reference Volume x (Strike Price – Reference Price)

Reference Volume	
Production-based	"You get paid for what you produce"
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non-exhaustive list

Reference Price	
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Intraday & Balancing markets	Should we be considering sequential markets in the reference?

non-exhaustive list

Dimensions of Contracts-for-Difference design

Contract design

- Duration
- Payment settlements
- Exit option

CfD Implementation

- context specific
- evolving

Reference price design

- Reference market
- Reference period
- Referencing method
- Timing of referencing

Strike price design

- Indexation
- Add-ons / Deductions

Market integration safeguards

- Payout limits at neg. prices
- Dynamic clawback design

Reference Volume

- Generation-based
- Capacity-based
- Generation-potential-based

European CfD Implementations

Table 1: CfD schemes implemented in European countries

Country	Duration (Years)	Reference period	Referencing method	Other features
DK	20	Annual	Uniform	Limited clawback / net payment cap
FR	20	Monthly	Volume-weighted	Premium for curtailment during negative prices
GR	20	Monthly	Technology-specific	-
HU	up to 25	Monthly	Technology-specific	-
IE	20	Hourly	n/a	Compensation for unrealised available energy
IT	up to 30	Hourly	n/a	-
PL	15	Daily	Volume-weighted	-
PO	15	Hourly	n/a	-
ES	up to 20	Hourly	n/a	Adjustment factor for remuneration at market price / Electricity market is regarded
UK	15	Hourly	n/a	-

Source: Kitzing, L., Held, A., Gephart, M., Wagner, F., Anatolitis, V., Klessmann, C., (2024), Contracts-for-Difference to support renewable energy technologies: Considerations for design and implementation, Florence School of Regulation, European University Institute, https://fsr.eui.eu/publications/?handle=1814/76700

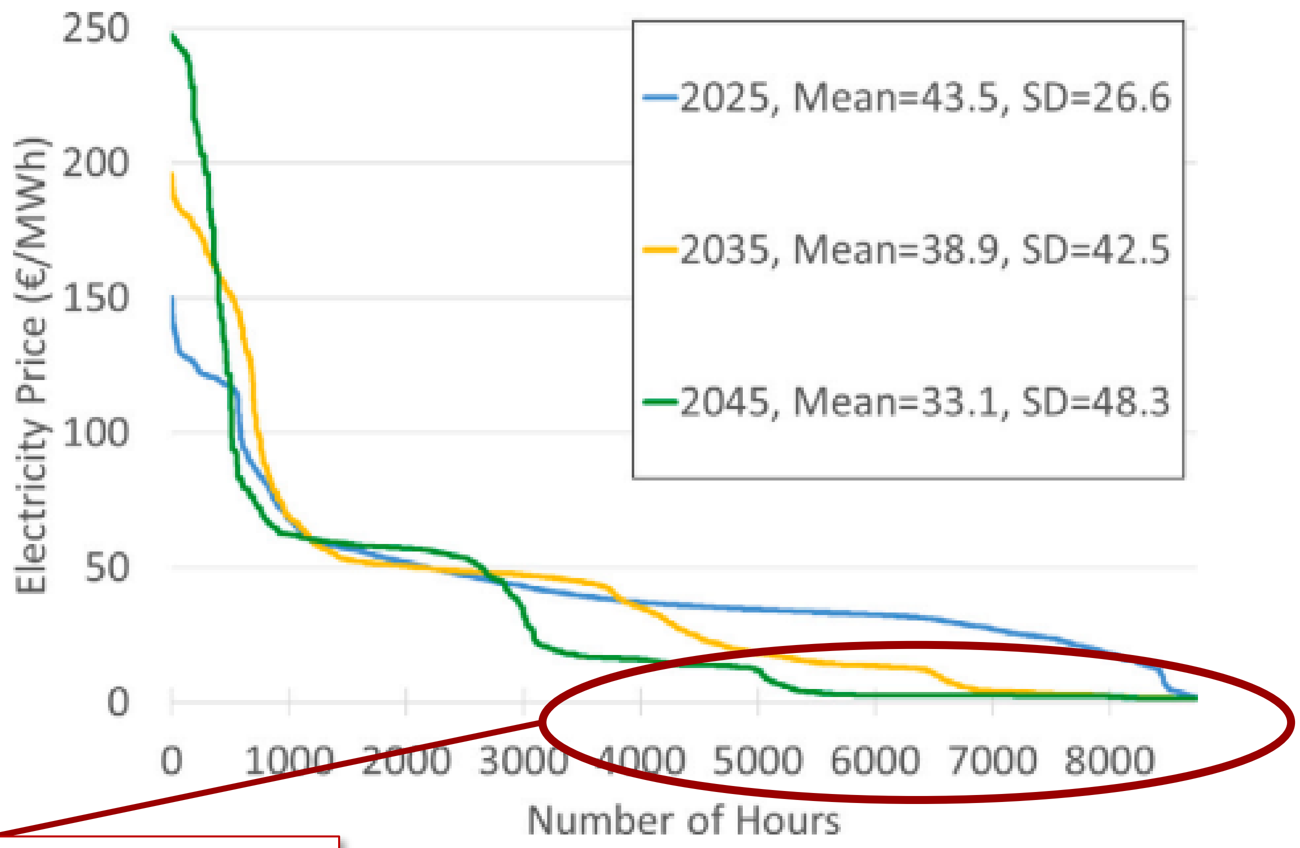
Notable European CfD Designs:

- Denmark: Thor (offshore wind)
  - Annual, baseload reference price
  - Dynamic clawback
- Spain:
  - Mixed-market reference index (day-ahead / intraday)
- France: Normandy (offshore wind)
  - Capacity-based element:
  - Compensation for each hour of pausing production during negative prices (beyond 40 hours annually) = 0.7*strike price*capacity
- Italy: Onshore wind & solar
  - Production-based with capability-based elements (negative prices)
- Belgium: Princess Elisabeth (offshore wind)
  - Capability-based (AAP) *-- postponed*
- Denmark: ongoing 2.8GW Tender
  - Capability-based (AAP)

Beyond CfDs and outlook

Potential Game Changers: Negative prices – and their determinants

- Maintaining the business case for wind energy
- Beneficial system effects from avoiding problematic zero-price hours
- Supporting sector integration, across energy carriers

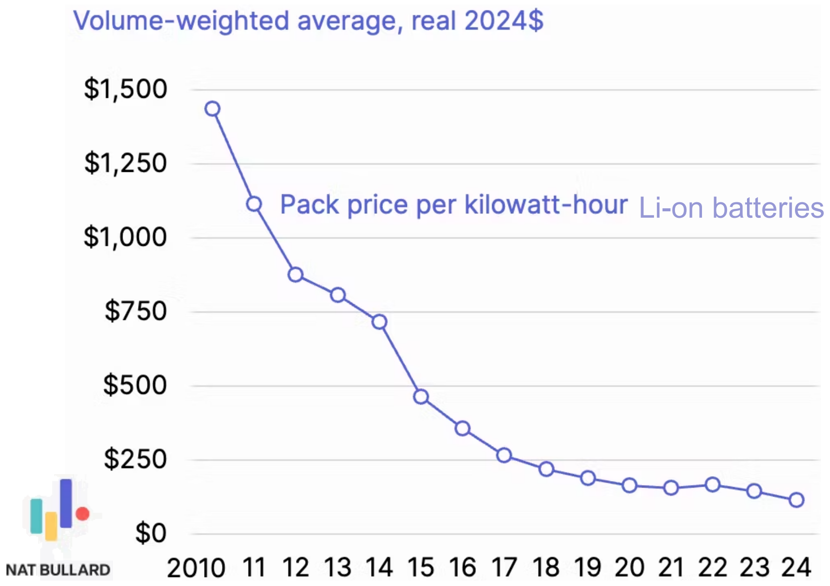


Effort needed to avoid zero-price dominance and maintain value

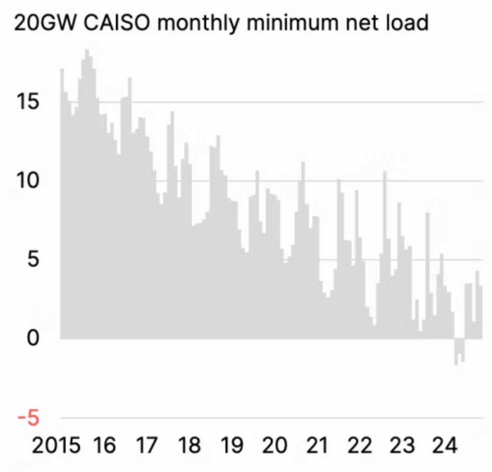
Swisher et al (2022), Competitiveness of a low specific power, low cut-out wind speed wind turbine in North and Central Europe towards 2050, DOI

Potential Game Changers: Negative prices – and their determinants

Batteries

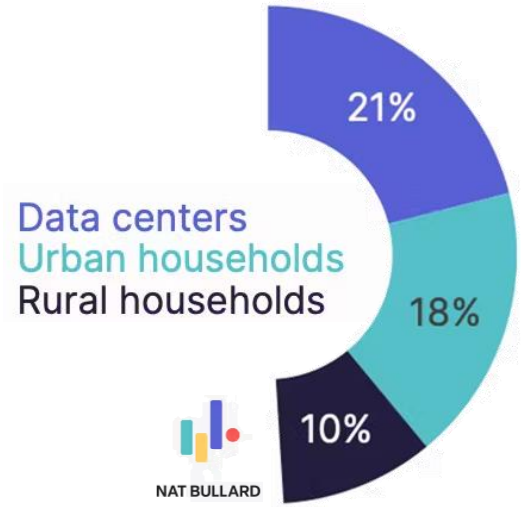


Distributed Generation – Residual Load



Electricity demand split

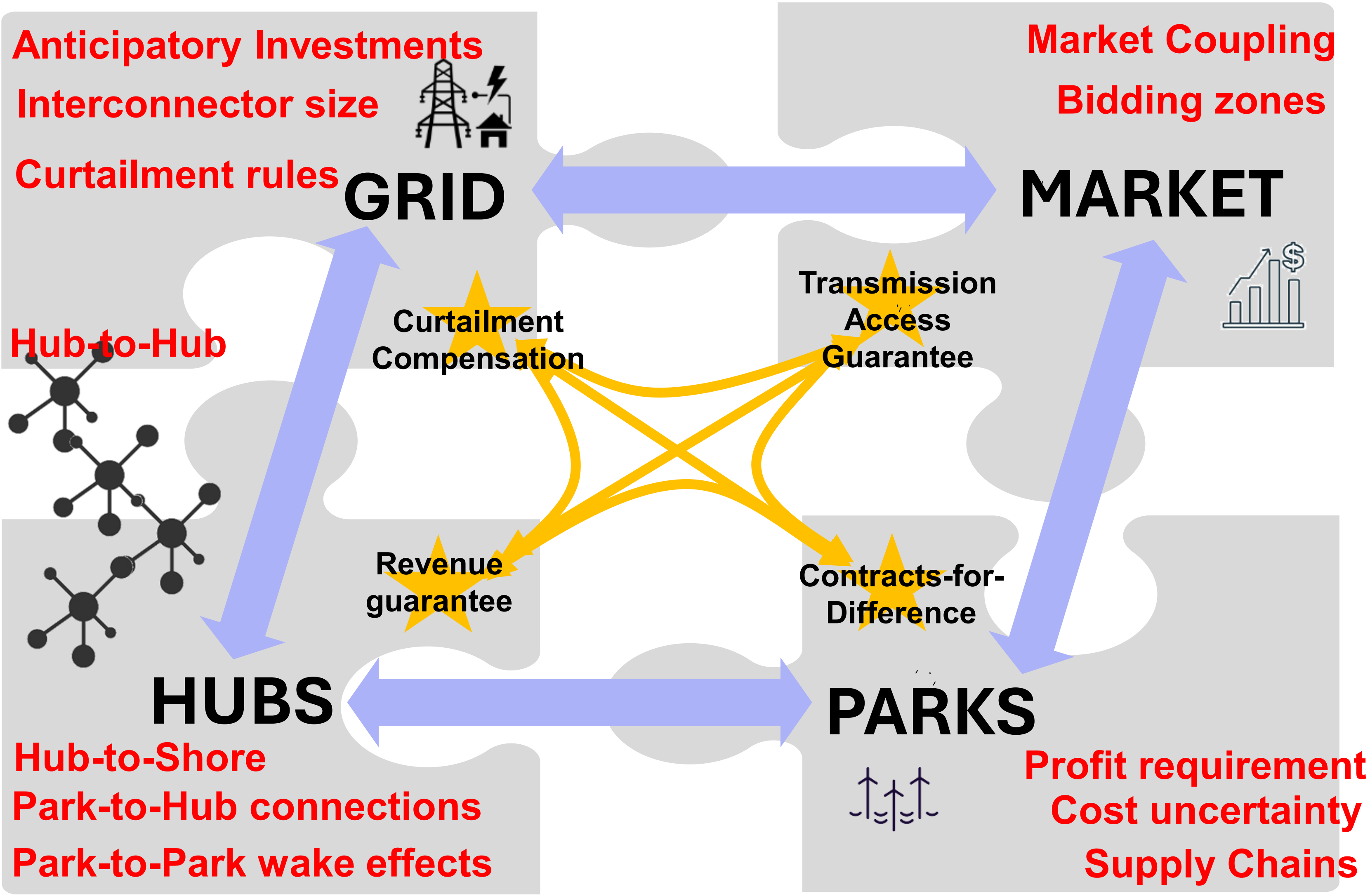
In 2023, Ireland's **data centers** consumed more electricity than urban households



Hydrogen

Europe needs 100 GW electrolyser capacity by 2023 – installed in 2023: 216 MW

Interdependence of policy choices, regulation and market design in the new offshore paradigm



GROUP REFLECTION

1) **How is your own research impacted by energy policy?**

2) **How may your own research impact energy policy?**

STEP 1: Review your bullets from earlier (2min)
STEP 2: Consider how your perspective has changed after this lecture (3min)
STEP 3: Discuss with your neighbour (5min)
STEP4: Discussion in plenum (sharing thoughts with each other) (10min)

“What has Policy to do with Investment Behaviour?”

Everything

(Renewable energy policy is in essence largely a risk allocation exercise)

THANK YOU

CONTACT ME AT:
LENA KITZING, lkit@dtu.dk

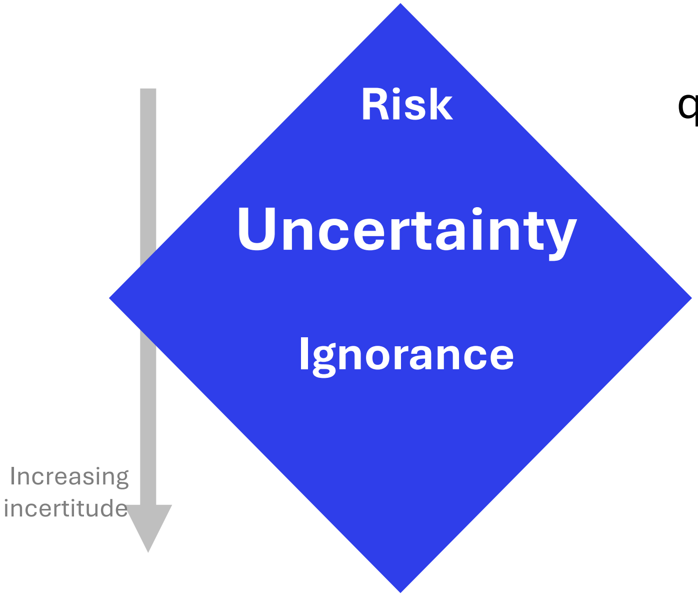
LinkedIn @LenaKitzing

What is risk – in financial theory?

Two necessary conditions:

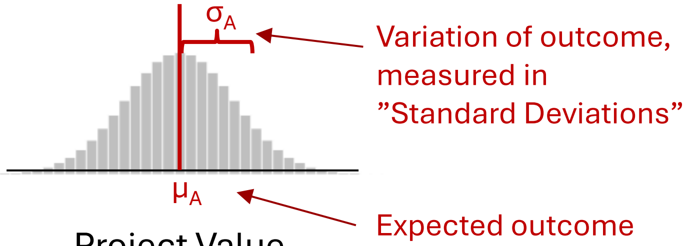
(1) Lack of perfect information (outcomes are not certain)

(2) Exposure to financial **loss or gain** related to the uncertain outcome



quantifiable (”known unknowns”)

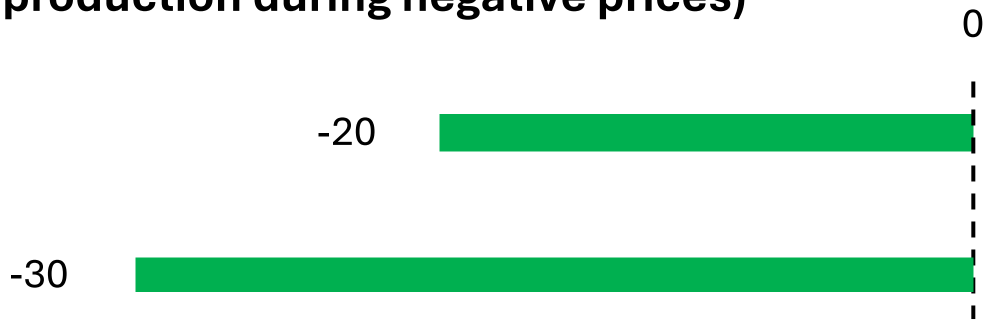
unaware (”unknown unknowns”)



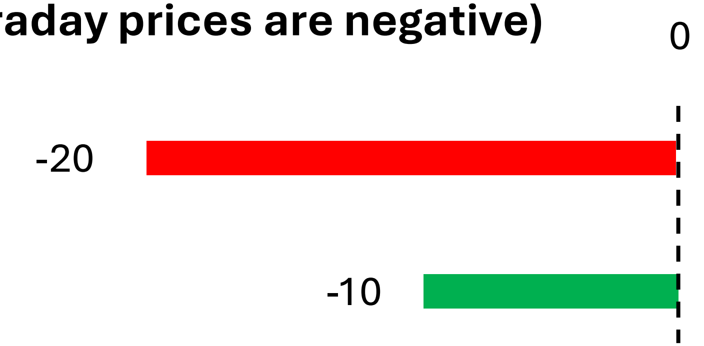
Project Value
as a Probability Distribution

Deep dive on intraday distortions – payout examples

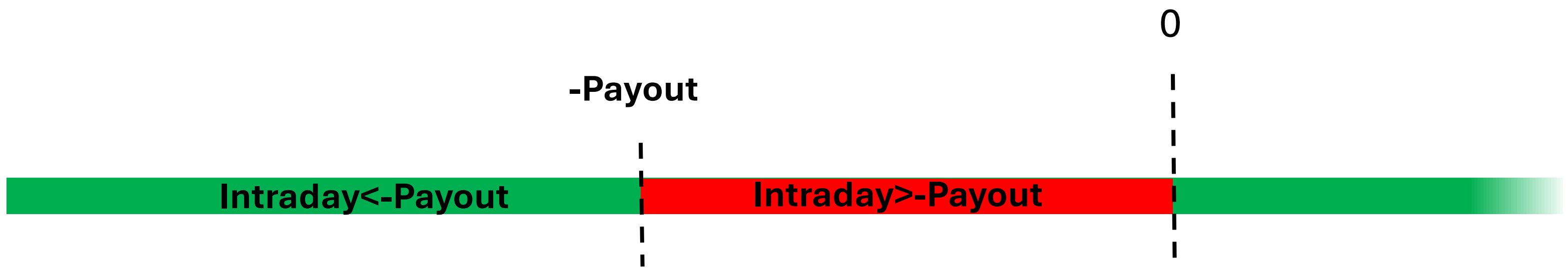
- **No problem during payout (stop production during negative prices)**
  - Payout*(-1)
  - Intraday price



- **Problem during payout (produce although intraday prices are negative)**
  - Payout*(-1)
  - Intraday price

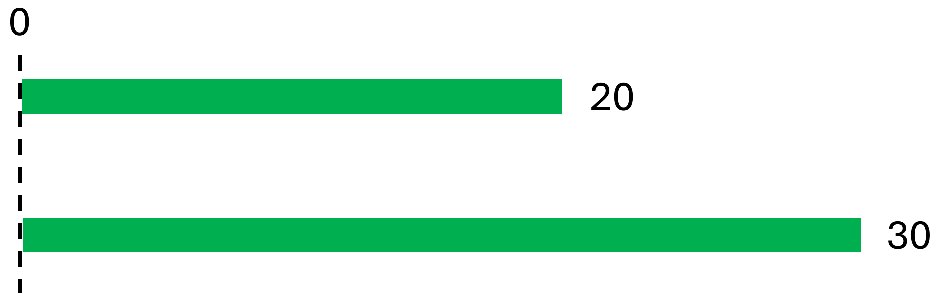


- **Generalisation**

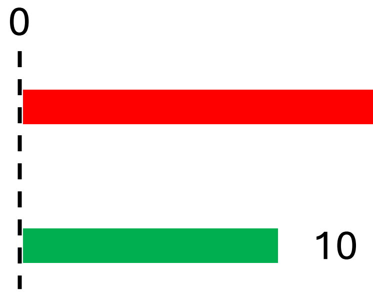


Deep dive on intraday distortions – clawback examples

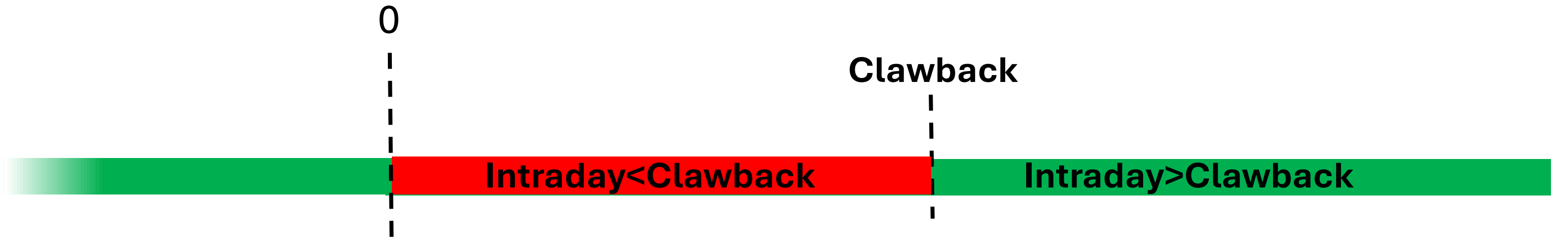
- **No problem during clawback (produce during positive prices)**
  - Clawback
  - Intraday price



- **Problem during payout (stop production although intraday prices are positive)**
  - Clawback
  - Intraday price



- **Generalisation**



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Lena Kitzing, Anne Held, Malte Gephart, Fabian Wagner, Vasilios Anatolitis, Corinna Klessmann, Contracts-for-Difference to support renewable energy technologies: Considerations for design and implementation, Research Report, RSC/FSR March 2024, Robert Schuman Centre, Florence School of Regulation, European University Institute, https://fsr.eui.eu/publications/?handle=1814/76700

Contracts for difference (CfDs) have been used for more than 50% of global offshore wind procurement. In our paper in the scientific journal Nature Energy, we discuss the current and future role of CfDs for offshore wind. We argue that the primary role of CfDs is risk management by creating a market for electricity supply at stable long-term prices. CfDs are often automatically labelled subsidies, suggesting that they support otherwise uneconomic activity. However, similar to its use in other sectors of the economy, they transform a variable to a fixed price and reallocate volatility risks. Such long-term contracts are often necessary for renewables financing due to limited hedging options in existing markets - even if there will be no net payout to projects over their lifetime. We are currently witnessing a shift in perception towards CfDs as a fundamental and lasting market feature. By our contribution, we hope to stimulate a timely discussion about the impact of greater CfD diffusion on electricity market mechanisms, risk allocation and the potential for combining all too fragmented streams of research in energy finance, market and policy.

Free version of the article: https://rdcu.be/dsN3k
Full access: https://lnkd.in/et-cUEZH


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Perspective

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The enduring role of contracts for difference in risk management and market creation for renewables

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Governments procure renewables through a variety of mechanisms. Contracts for difference (CfDs) have been used for more than 50% of the global offshore wind supply. The payments awarded through CfDs are sometimes labelled subsidies, suggesting that they support uneconomic activity. Here, we argue that the primary role of CfDs is rather risk management by creating a market for electricity supply at stable long-term prices. Similar to its use in other sectors of the economy, this contract type transforms a variable to a fixed price to reallocate volatility risks. Such long-term contracts are often necessary for renewables financing due to limited hedging options in existing markets. Our perspective could imply a shift in perception towards CfDs as a fundamental and lasting market feature. We hope to stimulate a timely discussion about the impact of greater CfD diffusion on electricity market mechanisms, risk allocation and the potential for combining fragmented streams of energy finance, market and policy research.

Relevant publications

Contracts-for-Difference to support renewable energy technologies: Considerations for design and implementation, Lena Kitzing, Anne Held, Malte Gephart, Fabian Wagner, Vasilios Anatolitis, Corinna Klessmann, Research Report, RSC/FSR March 2024, Robert Schuman Centre, Florence School of Regulation, European University Institute, https://fsr.eui.eu/publications/?handle=1814/76700

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