Hybrid Markets for Decarbonised Electricity Systems:

Why and How

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Electricity: Five interlocking issues challenge security of electricity supply in current EU energy-only markets

- Electricity provision poses five distinct but interrelated challenges to the hypothesis that decentralized energy-only markets (EOM) will self-organize to deliver welfare-optimal equilibria:
  1. **Low storability and inelasticity of demand**
  2. **Security of supply externalities (scarcity pricing works in theory not in practice)**
  3. **Innovation and industrial externalities + social preferences for specific technologies**
  4. ***Net zero* requires massive investment in capital-intensive low carbon technologies**
  5. **Missing long-term hedging markets**

- On its own, each issue may be amenable to specific *ad hoc* remedies. Together, they challenge the idea that deregulated electricity markets with short-term marginal cost pricing deliver first-best solutions, especially under deep decarbonization and energy transition trajectory.

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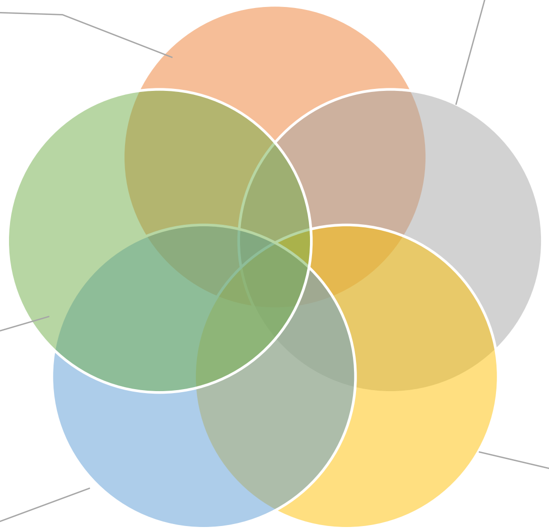
Five interlocking issues challenging market provision and associated ad hoc remedies



1# Low storability and inelasticity of demand

The issue: Inelastic demand & limited cost-effective storage challenge standard market mechanics

Illustration of *ad hoc* remedies: Demand response and storage

Limits of remedy:
- Volatile retail prices impact the risk profiles of consumers and downstream investments
- No seasonal storage

2# Security of supply externalities

The issue: SoS has public good features (wedge between private and socially optimal levels of capacity)

Illustration of *ad hoc* remedies: capacity mechanisms

Limits of the remedy:
- Capacity mechanisms best-suited for carbpn-intensive dispatchable generation + demand response
- Some capacity mechanisms produce too volatile price signals to efficiently guide long term decisions

3# Industrial externalities + social preferences

The issue : Generation mix determined by the market does not correspond to deep-seated political and social preferences

Illustration of *ad hoc* remedies : Haphazard across-the-board interventions that confuse market participants and drive up risk and the cost of capital

Limits of the remedy:
- Distortions on short term markets (negative prices)
- Sunk costs for assets built before RES policies and increased uncertainty for unsupported market segment

4# Net zero and low carbon investment

The issue: climate change mitigation requires a transition to capital-intensifies low-carbon generation technologies; magnifies all other issues

Illustration of *ad hoc* remedies: EU ETS

Limits of the remedy:
- Volatile EU ETS prices with uncoordinated policy overlap have failed to convey robust, credible long-term investment signals
- MSR patch introduced to tackle historical oversupply, but long-term impact is uncertain.

5# Missing long-term hedging markets

The issue: electricity related markets do not spontaneously produce enough/adequate long term hedging instruments implying 'too high' a capital cost (incomplete financial market, transaction costs))

Illustration of *ad hoc* remedies : RES supports schemes based on long-term contracts (e.g., FiP/CfD)

Limits of the remedy:
- RES support schemes based on LT contracts tackle the issue for RES (but not for all low carbon technologies)

Diagnosis: Patchwork of *ad hoc* remedies lacks coherence

- Decentralized short-term energy-only markets fall short of conveying effective long-term investment signals and producing outcomes in line with strong policy preferences
- Issues have been addressed independently of one another with the introduction of various *ad hoc* remedies (e.g., EU ETS, capacity mechanisms, RES support schemes)
- Failure and uncoordinated implementation of *ad hoc* remedies have created additional issues of their own → need to have "remedies for the remedies" (e.g., EU ETS market stability reserve)
- Incoherence and unintended interactions between *ad hoc* remedies increase risks and uncertainties and hence capital costs and thus reduce investment.

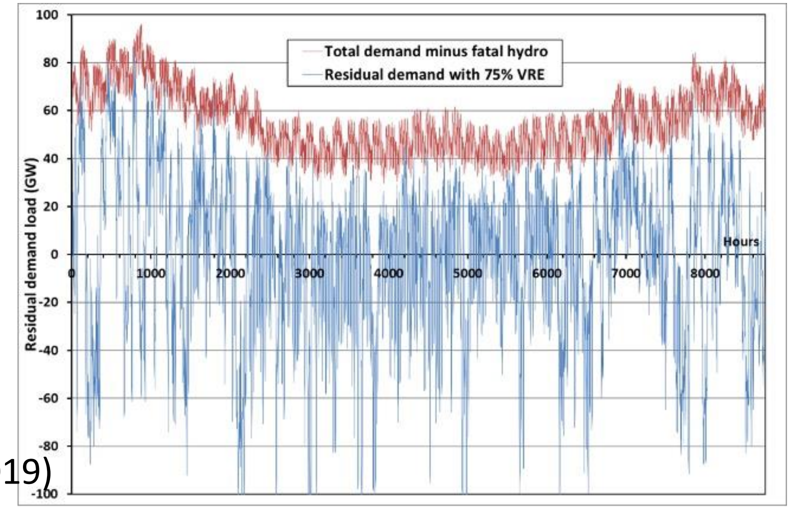
Deep decarbonization (*net zero*) significantly exacerbates issues

Three main channels through which exacerbating factors materialize:

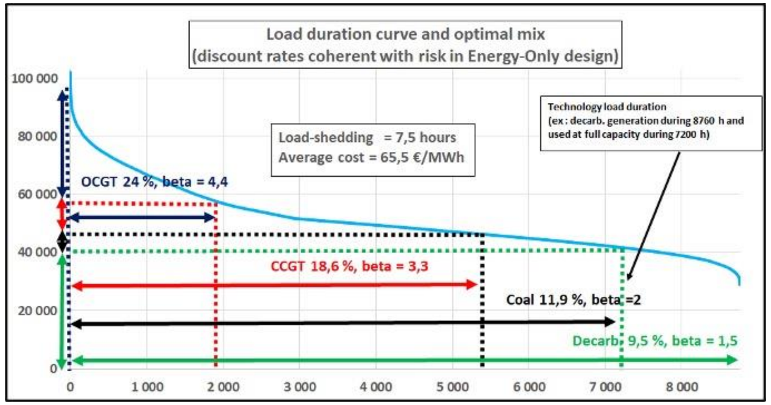
Security of supply in VRE-dominated systems	Investment, uncertainty and high capital cost	Political prerogatives to decide the generation mix
• Deep decarbonization may implies large-scale VRE deployment → intermittency and auto-correlation intensify SoS externalities • Market remuneration of capacity needed for SoS is challenging: rents are concentrated in a small number of high price hours and so very risky • Need to rethink traditional approach to ensuring SoS: no longer tenable to assume statistical independency due to VRE auto-correlation	• Significant capital-intensive investments needed (both upstream and downstream) → capital cost becomes main driver of total electricity costs • Capital-intensive assets strongly affected by unhedgeable risks → higher capital cost • Unprecedentedly high level of uncertainty – VRE increases price volatility – Future wholesale price distributions are deeply uncertain (e.g. which future mix?)	• Policymakers willing to directly drive the mix • Markets do not explicitly account for innovation & industrial externalities or social preferences → proliferation of uncoordinated *ad hoc* remedies to achieve policy targets • Deep decarbonization intensifies these concerns without a market design overhaul that clarifies the roles of market and society/policymakers

Deep decarbonization radically magnifies the long-term incompatibility between sustainable electricity provision and markets based on short-term marginal cost pricing complemented by superposition of uncoordinated *ad hoc* remedies.

Decarbonisation and the cost capital



Source: OECD (2019)



Source: Peluchon (2021)

- A growing share of low carbon-generators with zero short-run variable costs will increase price volatility – markets will alternate between zero prices, VOLL and the cost of demand response – and thus capital costs.
- A careful CAPM analysis by Peluchon (2021) of the electricity market gives average costs, capital costs for low carbon-generators and load-shedding hours in different market designs:
  - **TODAY's ENERGY ONLY-MARKET with residual carbon emissions:**
    Avg. cost 65.5 €/MWh; capital cost 9.5%; VOLL-hours 7.5;
  - ***NET ZERO* with TODAY'S ENERGY ONLY-MARKET:**
    Avg. cost 118.3 €/MWh; capital cost 22%; VOLL-hours 52;
  - ***NET ZERO* with LONG-TERM AVERAGE COST CONTRACTS :**
    Avg. cost 82.5 €/MWh; capital cost 3.2%; VOLL-hours 3.

1. Low storability and inelasticity of demand

- **The issue**
  - As cost-effective storage is in limited supply, electricity generation remains akin to infrastructure-based service provision with highly inelastic demand. Normal market's mechanics are challenged.
- **The ad hoc remedies**
  - Opening markets (energy, capacity, ancillary services) to storage and demand response.
  - Subsidies for demand response.
  - Dynamic tariffs.
- **Limits of remedies**
  - Industrial demand response remains a bright spot, but the opportunity costs for demand modulation by residential consumers are too high. Too volatile dynamic tariffs considerably modify the risk profiles of consumers and may impact downstream investments.
  - The economics of storage are complicated as profitability is a function of power/energy trade-off, the time horizon and the variance of electricity prices (the higher the better). Uncertainties abound. Long-term seasonal storage remains elusive.

2. Security of Supply externalities

- **The issue**
  - Security of supply externalities in the case of involuntary curtailment under VOLL-pricing; wedge between private and socially optimal levels of capacity; electricity considered merit or public good

- **The ad hoc remedies**
  - Capacity markets hoping that private and social optimality will coincide

- **Limits of remedies**
  - Capacity markets best-suited for dispatchable generation (e.g., carbon-emitting gas-fired plants). Contribution of some low carbon technologies (e.g., RES) or storage to security of supply is not always easy to assess.
  - Some capacity markets produce too volatile price signals. First because economic fundamentals of capacity price may considerably vary over the time (e.g., anticipated availability of power fleet or capacity obligation). Auction formats, regulatory changes (e.g., diesel generators), technological or behavioural changes (e.g., demand response) can also cause volatile prices if supply and demand are inelastic over relevant timeframes.

3. Innovation & industrial externalities and social preferences

- **The issue**
  - In principle, the electricity market ensures full cost recovery of generation mix produced by a long-term decentralized equilibrium (given cost and demand fundamentals).
  - Technology capacity targets justified by industrial or innovation externalities (e.g., learning by doing) or by well-defined social preference for specific technologies (e.g., RES) may imply “overcapacity” (w.r.t the decentralized equilibrium) and result in insufficient cost recovery.
  - This is particularly true for VRE where value sharply declines due to auto-correlation (i.e. cannibalization). In pure market setup: revenues decrease would limit VRE entry at lower, economically optimal levels.
- **The ad hoc remedies**
  - RES support schemes (preferential feed-in tariffs; technology-specific auctions);
- **Limits of remedies**
  - Increased uncertainty for unsupported market segment; Sunk costs for assets built before RES expansion policies.
  - Potential distortions of some supports on short term markets (e.g., negative prices).

4. Climate externality

- **The issue**
  - Climate change mitigation requires transitioning to low-carbon generation technologies
- **The ad hoc remedies**
  - EU ETS instituted as the cornerstone of EU climate policy package
  - Along with “companion” renewables & energy efficiency policies (e.g., RES support schemes)
- **Limits of remedies**
  - Historically, EU ETS has failed to convey robust, credible long-term investment signals
    - In reality, companion policies have been the main low-carbon investment drivers!
    - Uncoordinated policy overlap and interactions kept ETS prices at moribund levels
  - MSR introduced to tackle historical oversupply and improve supply-side responsiveness
    - MSR contributed to price rally (now 50€/t) but price outlook remains uncertain
    - MSR-induced supply impacts are uncertain (in the long term) and convoluted
    - MSR may not improve synergies with complementary policies (e.g., RES, phaseout)

5. Missing long term hedging markets

- **The issue**
  - Electricity related markets do not spontaneously produce enough/adequate long-term hedging instruments (incomplete financial markets) implying a high capital cost.
  - Forward power markets suffer from poor liquidity beyond two years, as uncertainties are large and too “deep/unknown” (as opposed to “risky/known”) to be hedged.
  - This is particularly important for capital intensive long-lived assets (e.g., low carbon capacity) with high uncertainty created in part by (actual or potential) political interference.
- **The ad hoc remedies**
  - Self-insurance (size, vertical integration,..), capacity markets, RES support schemes (FiT, FiP, CfD, etc.)
- **Limits of remedies**
  - Different forms of self-insurance seem rather insufficient to solve the issue.
  - Capacity markets with multi-year contracts are best-suited for carbon-emitting gas-fired generation but not for capital-intensive low carbon assets.
  - RES support schemes based on LT contracts tackle the issue for RES (but not for all low carbon technologies).

Instead of *ad hoc* remedies: Coherent hybrid market designs

- A hybrid market design is a coherent combination of decentralized short-term incentives and centralized long-term incentives and to overcome the structural weaknesses of short-term marginal cost pricing (the five challenges!) to finance long-term investment in electricity markets in a context of deep decarbonisation.
- An evolution not a revolution! What works well in current markets – efficient dispatch of existing assets – needs to be preserved. However, patchwork of *ad hoc* interventions needs to be made coherent and systematic to ensure fixed cost recovery for low-carbon technologies.
- The generation mix will be explicitly (not implicitly, as today) determined by centralized decision-making negotiated between government, regulators and system operators.
- Simple theory suggests competitive technology-neutral auctions, in which generators bid for long-term support in a ***competition for the market.*** Practice and more complex theory suggest that different lifetimes, risk profiles, system contributions require specific measures for each generation technology or technology group.

Hybrid market designs: General principles

- Hybrid market designs provide adequate incentives for investing in and efficiently operating low carbon generation capacity.
- They work by lowering investor risk and hence lowering the cost of capital for low carbon investments.
- Risks are real! Market design cannot eliminate physical or structural risks (wind and solar PV generating at the "wrong" hour; construction risk for nuclear; consumers resisting demand reduction…):
- BUT: market designs can *reduce the economic cost of risk* allocating them to the party (investors, ratepayers or taxpayers) best able to carry it, notably through centrally implemented risk spreading.
  - Theoretical claim "risk spreading can be ensured by financial markets alone" breaks down due to informational asymmetries, transaction cost and non-codifiable uncertainty, *e.g.,* political preferences.
- Reducing economic risks efficiently requires a careful analysis of the risk structure and value contribution of each specific technology in order to choose the right instrument as part of the hybrid market design.
- Ultimately, hybrid market designs will also need to ensure that downstream revenue collection through consumers tariffs matches the structure of upstream cost recovery, including an increasing share of fixed costs ("flat tariffs") in consumer tariffs.

Hybrid markets: Main components

A hybrid market would typically combine a competitive short-term energy market with one or several long-term instruments. This includes:

- **A certain dose of long-term planning**: *Hybrid markets should be consistent with some kind of regulatory planning process to ensure coordination of policies and targets, built as a resilience tool to manage the trade-off between uncertainty of long-run decarbonization paths and visibility that investors need.*
- **Long-term arrangements and competitive procurement**: *To better share risks and reduce the cost of capital, hybrid markets should include some forms of long-term contracts or arrangements (e.g., CfD, hybrid RAB) to ensure full cost recovery for needed investments, e.g. via fixed-price contracts or top-ups to revenues from competitive dispatch determined either by regulation or competitive auctions.*
- **Upstream-downstream articulation mechanism**: *Hybrid markets should also include a mechanism articulating downstream revenue collection and upstream cost recovery. This mechanism should in principle allocate costs between consumers in an efficient, equitable and socially acceptable manner. In general, this implies an increasing share of fixed costs ("flat tariffs") recovery rather than variable cost recovery in consumer tariffs.*

Hybrid markets: General principles II

The principal function of hybrid markets is to provide adequate incentives for investing in and efficiently operating low carbon generation capacity;

This implies *lowering the cost of capital* for low carbon investments;

The cost of capital is a function of *risk*. Lowering the cost of capital implies reducing investor risk;

The three principal sources of risk are: *price risk, construction risk and political risk*

Risks are real. Market design cannot reduce physical or structural risks!

- Wind blowing at the “wrong” hour; solar PV not contributing to peak demand;
- Limited short-term flexibility of nuclear; consumers resisting demand reduction…

Such risks imply costs at the system level no matter who bears them.

Yet, market designs can reduce the economic costs of risk by

- Allocating risk to the party best able to carry it at least cost;
- Allocating risk to the party best able to reduce it through technical or regulatory measures (inventive compatibility).

Hybrid markets: General principles III

There are only three possible parties to carry the economic costs of investment risk:

- Shareholders of generators and distributors (only in the short run)
- Ratepayers (electricity consumers) and
- Taxpayers (government);

Immediate transfers of the economic costs of risk from generators to ratepayers or taxpayers (rather than progressive pass-through of wholesale market failures into consumer tariffs over time) can be justified by the theory of "risk spreading" (Arrow-Lind theorem);

Other justifications may include informational asymmetries and transaction costs, *e.g.*, regulators and governments may have more definite views on the long-run system configuration;

Hybrid markets – due to the risk transfer they operate – need to be mindful of *fairness:*

- If ratepayers (electricity consumers) assume investment risks, ensure that they also eventually benefit from lower tariffs in the long-run;
- If taxpayers (government) assume investment risks, ensure that added costs correspond to clearly identified public goods;
- Control for rent formation through competitive procedures (auctions) wherever possible.

A taxonomy of hybrid markets I

Preliminary remarks

- Each instrument is always used in combination with competitive dispatch in short-term markets, which remains the most efficient way to “sweat” assets and organise the short-run operations of an electricity system;
- There exist two major groups of long-term measures to support investment; they can, in principle, be combined:
  - Long-term pricing arrangements
  - Capital cost support;
- Such support measures should be allocated through competitive auctions (“competition for the market”) for wind and solar PV; the high asset specificity of hydro and nuclear will require bilateral negotiations (competition requires comparability).

A taxonomy of hybrid markets II

Long-term pricing arrangements

- **Feed-in-tariffs (FIT)** guarantee generators *ex ante* a fixed price per MWh; long-term power purchasing agreements (PPAs), regulated tariffs, etc. are comparable;
  - **Pros:** neutralizes price risk; depending on level, high incentive to invest; no quantity risk; regulator can choose capacity mix;
  - **Cons:** higher average tariffs for consumers; no incentive to optimize generation in function of system (overproduction/curtailing); negative prices;
- **Contracts-for-difference (CFD)** also fixed price guarantee but needs to pass through market;
  - **Pros** neutralizes price risk; depending on level, high incentive to invest (but lower than equivalent FIT); regulator can choose capacity mix; efficient dispatch in wholesale market;
  - **Cons:** higher average tariffs for consumers; quantity risk for generators.

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A taxonomy of hybrid markets III

Capital cost support I

- **Feed-in-premium (FIP)** provides fixed subsidy per MWh sold; can also come in form of production tax credit (PTC);
  - **Pros:** mitigates price risk; depending on level, good incentive to invest; regulator can choose capacity mix; optimizes dispatch if $p > 0$;
  - **Cons:** somewhat higher tariffs for consumers; negative prices up to level of per MWh top up;
- **Direct capital support for low carbon technologies** can come in form of direct per MW support, loan guarantees, low interest loans, public equity;
  - **Pros:** directly tackles externality of insufficient investment incentives; does not affect dispatch; could, in principle, allow for open technology competition;
  - **Cons:** without *ex post* controls, no incentive for efficient generation or generation at all; costs fall on taxpayers; notion of “subsidy” can be politically loaded.

A taxonomy of hybrid markets IV

Capital cost support II

- **Regulated asset base (RAB)** like construction work in progress (CWP) implies financing construction costs through advance inclusion in electricity tariffs;
  - **Pros:** substantial reduction in capital costs due to transfer of construction risk to ratepayers; does not affect dispatch;
  - **Cons:** *ad hoc* measure for selected projects; limited incentives for cost control;
- **Mankala** industrial shareholders receive share of output at cost for use or resale;
  - **Pros:** stable long-term financing without involving ratepayers or taxpayers;
  - **Cons:** auto-production, vertical integration; attractive due to Finnish tax incentives;
- **Carbon pricing** is capital cost subsidy for gas-fired generation if quotas are allocated at no cost;
  - **Pros:** supports financing gas-fired *capacity*, while limiting gas-fired *production;*
  - **Cons:** of limited relevance in decarbonizing electricity markets with auctioning of quotas; opportunity cost of grandfathered quotas.

A EU hybrid market design fit for purpose

Time Horizon and Purpose	Allocation mechanism	Contract type	Technology	Challenge	Why should we care?
Short term for dispatch	Competitive spot markets	Pay-as-clear at variable cost of marginal technology (EUR/MWh)	All technologies	Missing money, no investment in LC technologies	Efficient dispatch, “sweating assets”

In conjunction with targeted top-up payments to incentivise investment

Long-term for investment	Competitive auctions for long-term contracts	Capacity payments at fixed cost of marginal technology (EUR/MW)	CCGT, dispatchable REN, storage, demand response	Price risk due to high variable costs	Reliable capacity at reasonable cost
		Feed-in tariffs (FIT) or feed-in premia (FIP) (EUR/MWh)	Variable renewables (wind, solar PV)	High price risk due to auto-cannibalisation	Low carbon electricity, high social preferences
	Negotiated LT *sui generis* contracts	CFD, RAB, CWP, local concessions at avg. costs (EUR/MWh)	Hydro, nuclear	Construction risk, political risk	Reliable low carbon baseload electricity

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In a nutshell: Key questions and take-home messages

Why hybrid markets for deep decarbonization?

- Why pure market-based designs (EOM) do not function satisfactorily? → ***various market failures, externalities and other issues***
- Why current EU market design is not up to the task? → ***patchwork of uncoordinated ad hoc remedies***
- What does deep decarbonization change? → ***significantly exacerbates design issues***

What is a hybrid market?

- What are its basic ingredients? → ***long-term arrangements*** *allocated by* ***competitive procurements, a balanced dosage of planning, short-term markets to operate dispatch***
- Are hybrid markets a return to the regulated world of old? → ***no, competition remains a central pillar*** *(for the market and in the market)*
- Are hybrid markets a radical change? → **no,** ***market design evolution (not revolution!):*** *more coherent and holistic use of existing policies alongside wholesale markets working as at present*
- Is there one best design? → ***no,*** *different measures are appropriate for different circumstances and technologies*
- Do we know everything about hybrid markets? → ***no, but ongoing research (OECD, CEEM) is expected to bring useful insights***