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King Abdullah Petroleum Studies and Research Center

Market designs with adequacy and renewable objectives

Insights on interactions between capacity market, carbon pricing and renewable portfolio standard

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Reliability and resiliency is crucial for power systems

Recent events in Texas call us to challenge power systems’ organization: on technical aspects but also on economic aspects.

Market design is a key element in reliability and resiliency of power systems.

The energy-only market model has been discussed in the previous presentation.

Here, we focus on multiple-layer organizations and interactions between mechanisms.

Market and regulatory failures in face of climate adaptation and mitigation?

Will be discussed in the next presentation.

From energy-only market to multiple-layers electricity markets

Liberalized power systems are rarely energy-only market, but are organized with multiple layers to deals with:

- Resource adequacy
- Environmental externalities
- Penetration of certain technologies (renewables)
- Other objectives (e.g. energy efficiency)

Research studies with simulation models tend to indicate that the energy-only market is not well appropriate, particularly in the context of energy transition.

When being implemented, detailed rules matter. Interactions between mechanisms are also of key importance.

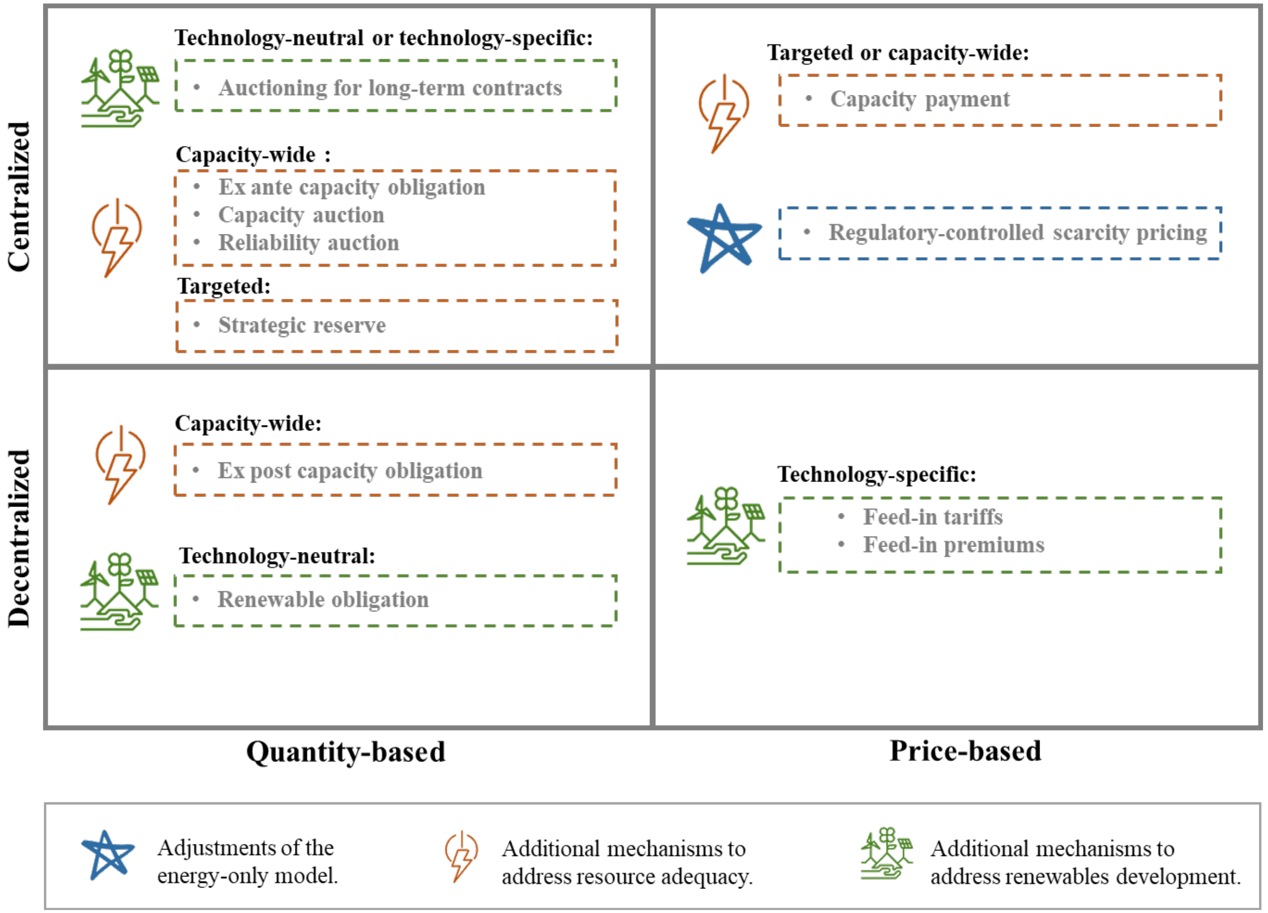
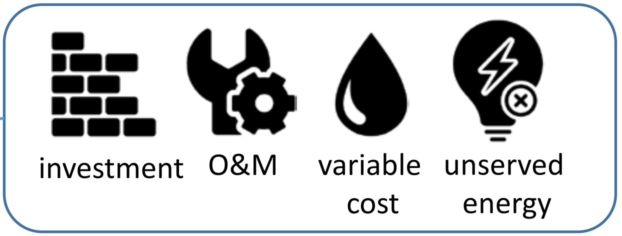


Illustration with stylized optimization model

Multiple layers can be represented in a stylized optimization model:



$$\min_{capacities} \; \boldsymbol{total\ cost}$$

subject to: $demand = supply + unserved\ energy$ — hourly

capacity market $\sum capacities = K^T$ — annual

carbon pricing $\sum emissions = CE^T$ — annual

renewable development $\sum generation\ from\ renewables = R^T$ — annual

N.B.: This approach can be expanded to multiple years.

Testing different market designs

Numerical illustration

Case study from IEEE RTS (details in appendix) with 3 technologies (CCGT, OCGT and wind turbines)

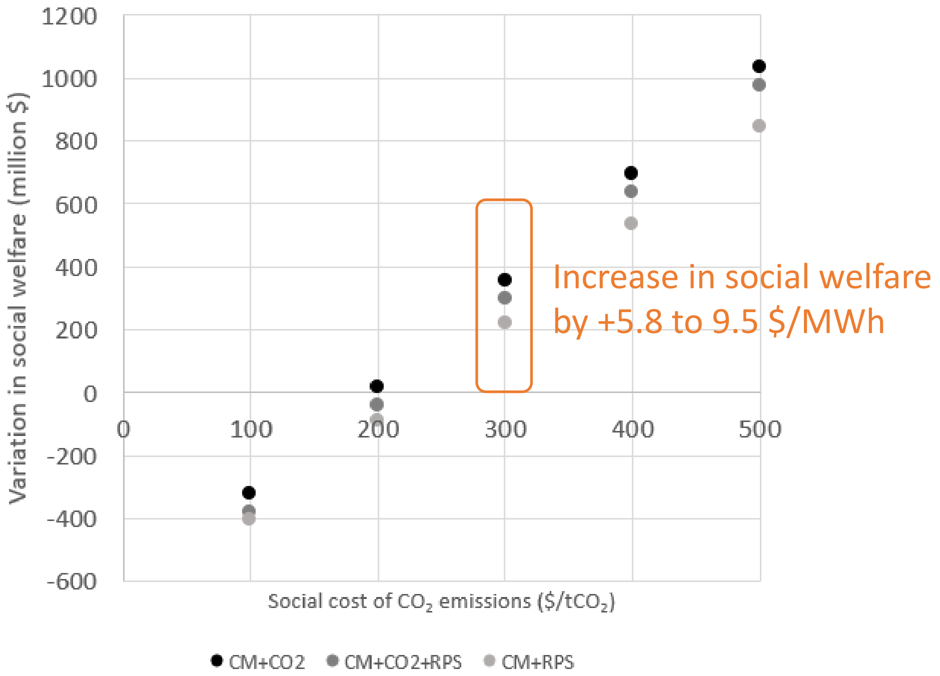
Results “from scratch” (no pre-existing technologies)

Capacity market (CM) with slopping demand curve

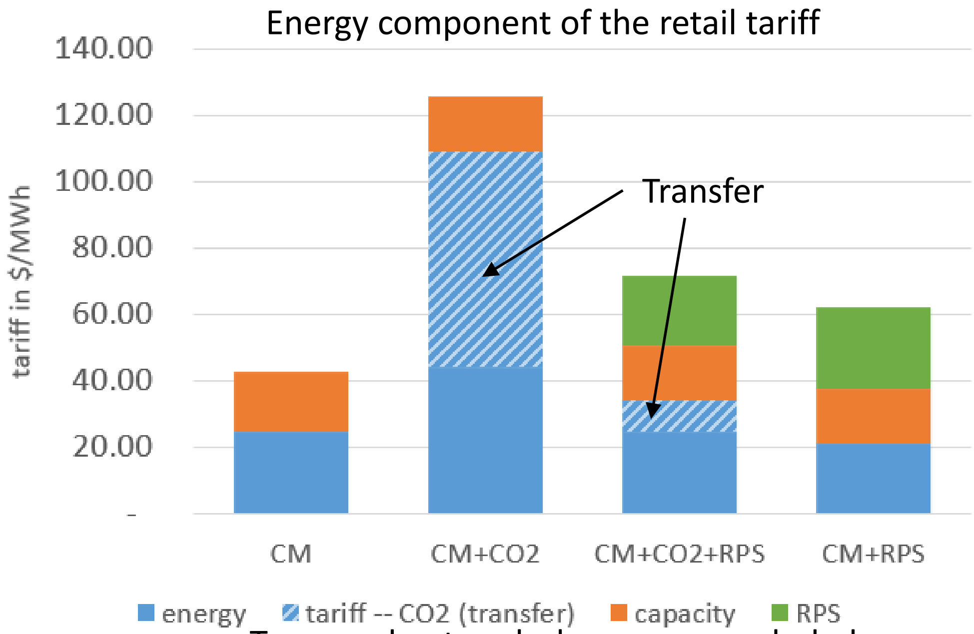
	CM	CM+CO2	CM+CO2+RPS	CM+RPS
LOLP - hours per year	3	6	6	6
CO2 emissions - million tons	13	10	10	10
Wind share	0	22	25	25
Wholesale average price - $/MWh	24.6	109.2	34.1	21.2
Capacity price - $/ MW.day	232.1	209.8	208.0	207.7
REC price - $/MWh	-	-	85.3	97.7

Constraints given the market design

Variation in social welfare with respect to design CM.



Social welfare analysis done with VOLL set to 20,000$/MWh.



Taxes and network charges are excluded.

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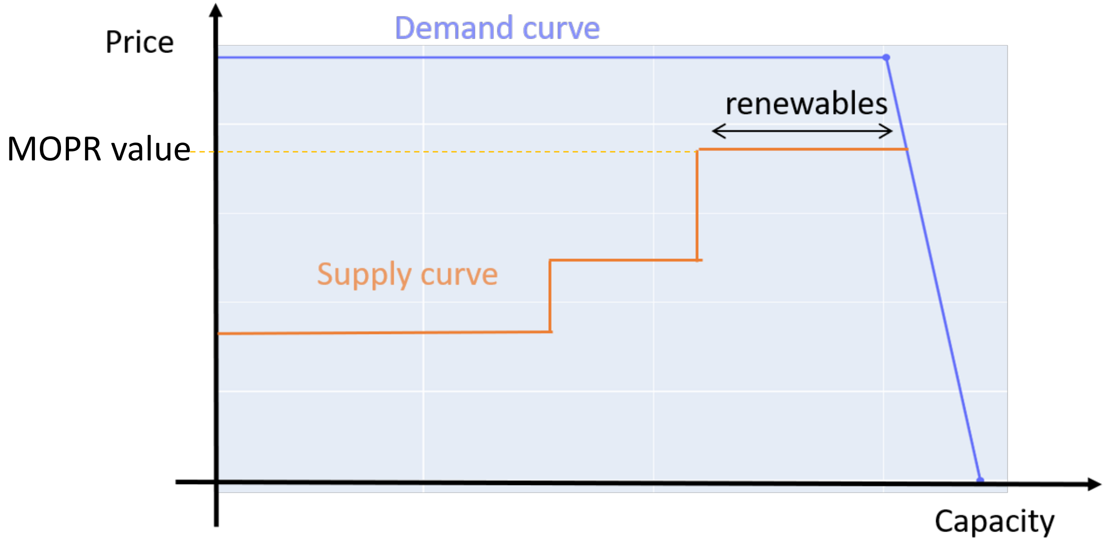
Combined effects of renewable portfolio standard (RPS) and minimum price offer rule (MOPR)

The MOPR has been introduced in some U.S. capacity markets to prevent subsidized technologies to offer at a lower price than what they would do without subsidies.

Introducing a MOPR for renewables when there is a RPS is likely to introduce a "push" effect resulting in over-capacity.

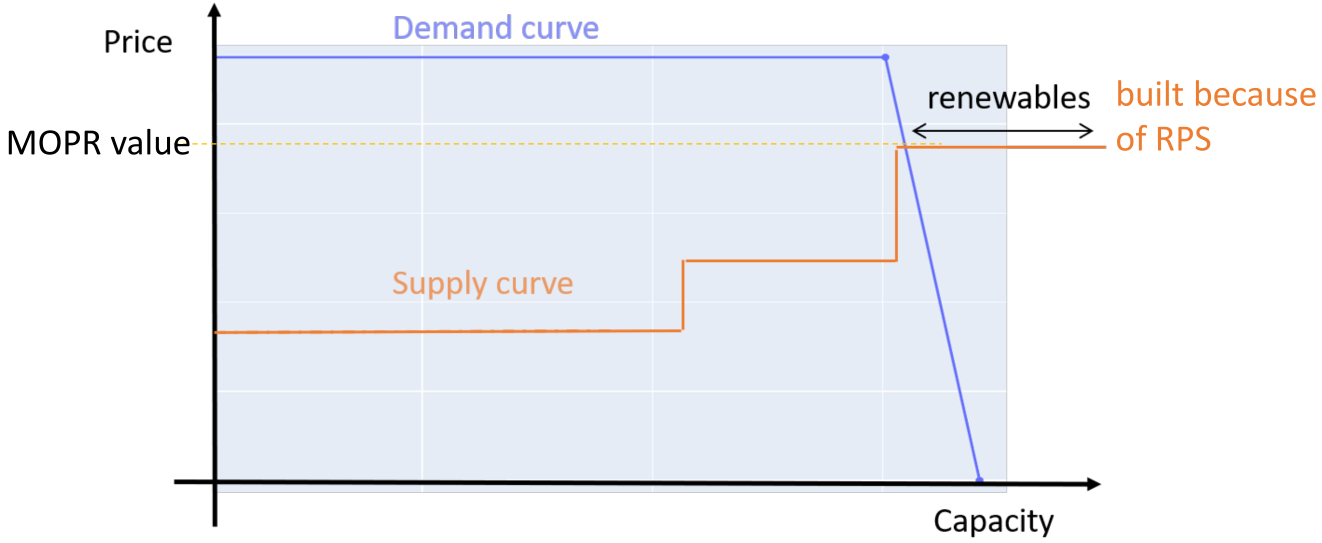
"optimal situation"

What economists would like:



"with the push effect"

What is more likely to happen:



Introducing a MOPR in CM+CO2+RPS design

Numerical illustration

From design CM+CO2+RPS, we simulate the introduction of a MOPR for wind turbines and then consider the push effect.

	CM+CO2+RPS no MOPR	With MOPR – optimal	With MOPR – push effect
LOLP - hours per year	6	8	6
CO2 emissions - million tons	10	10	10
Wind share	25	25	25
Wholesale average price - $/MWh	34.1	35.2	34.0
Capacity price - $/ MW.day	208.0	300.0	300.0
REC price - $/MWh	85.3	84.9	86.5
Energy component of the Retail tariff - $/MWh*	71.4	79.7	78.9

MOPR value

* Taxes and network charges are excluded.

+ 12%

The total social welfare remains almost unchanged with or without the MOPR. However, there is a **significant social welfare transfer from consumers to producers by 7 to 8 $/MWh**.

These market designs ensure exact cost recovery for wind turbines. But conventional units (here CCGT and OCGT) earn an extra revenue in the range 33-40 $/kW per year when the MOPR is introduced.

Synthesis of the numerical example with the stylized optimization problem

The stylized optimization model allows to identify key effects when combining different market mechanisms:

- Differences in social welfares and retail tariffs (because of the change in the energy mix)
- The combination of MOPR and RPS has notable impact on retail tariffs and social welfare repartition.

To go further (real-life experiments are difficult!):

- Multiple year optimization models (with more details on generation units)
- Simulation models to better represent human behaviors (forecast exercises, risk-aversion, lack of coordination, etc.)

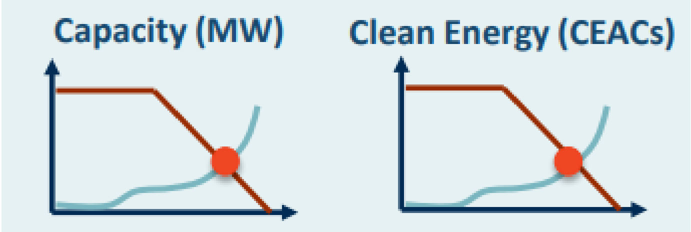
Food for thought

- **Enhancing capacity markets without introducing the MOPR**

Renewable capacity (RPS + voluntary) → Net capacity demand (after subtracting renewables) → Capacity market with no renewables

- **Integrated Clean Capacity Market to avoid interactions between capacity markets and RPS**

Co-optimized auction clearing for capacity and renewables based on a single capacity-clean attribute offer



Proposal from The Brattle Group

- **Hybrid markets**

Auctions for long-term contracts (investments) + short-term electricity markets (dispatch)

Thank you

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APPENDIX: illustrative dataset

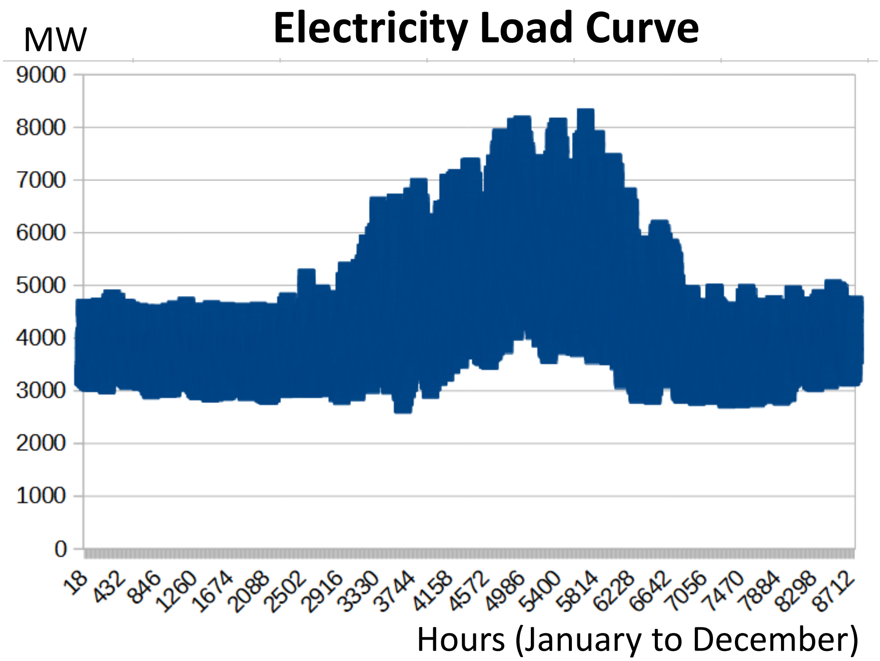
Dataset from IEEE RTS 2020

Available at: https://github.com/GridMod/RTS-GMLC

Aggregation of the 3 zones into a single zone considered as copper plate.

3 technologies: CCGT, OCGT and wind turbines

Wind load factors from 309_WIND of IEEE RTS 2020 dataset (average load factor is 28.1%).



Technologies' assumptions – from IEA-NEA 2020

	O&M cost $/kW-y	Invest. cost $/kW	Lifetime years	Fixed annuity $/kW-y	Fuel cost $/MWh	CO_2 em. factor gCO_2/kWh
CCGT	39	1,055	30	124.0	18.4	340
OCGT	49	554	30	93.6	27.3	505
Wind turbines	40	2,255	25	233.5	0.0	0

Discount rate is 7%.