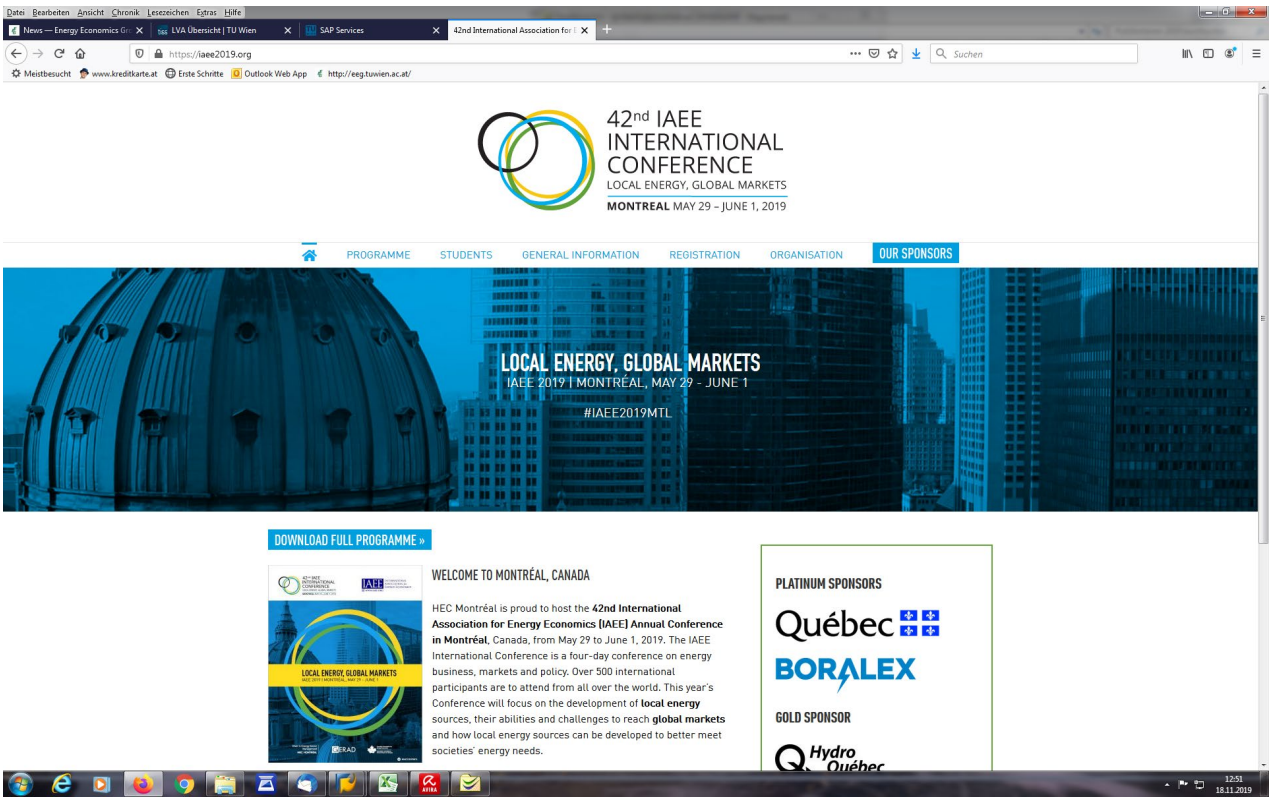
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Resource adequacy with increasing shares of wind and solar power: a comparison of European and U.S. electricity market designs

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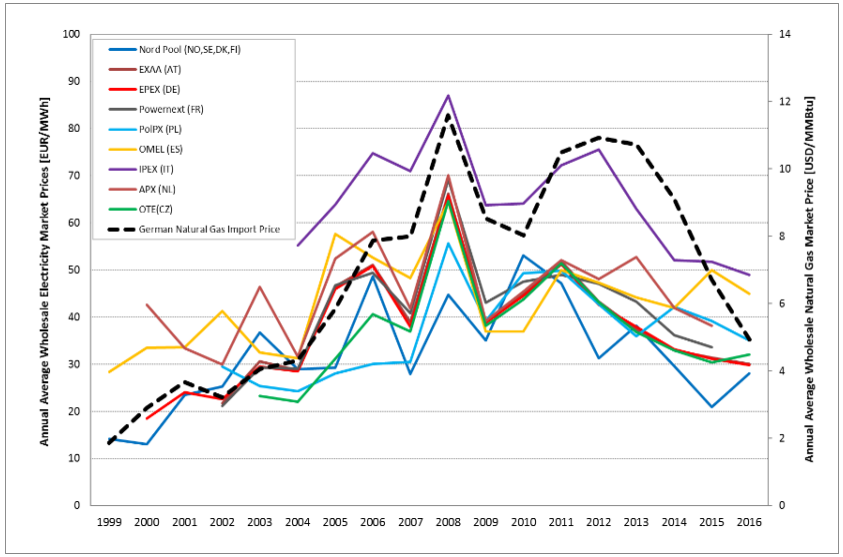
42nd IAEE International Conference: Local Energy, Global Markets
Montreal May 29 - June 1, 2019

Key Questions

1. What are the pros and cons of the key electricity market design characteristics in Europe and the U.S. for hosting high shares of variable wind and solar PV generation?
2. What is the impact of variable wind and solar PV generation on electricity market prices in the short- and long-term?
3. Is the consideration of capacity mechanism justified to address resource adequacy challenges?
4. What are the electricity market design options for resource adequacy exploiting several flexibility potentials and demand side participation? Good practice examples?

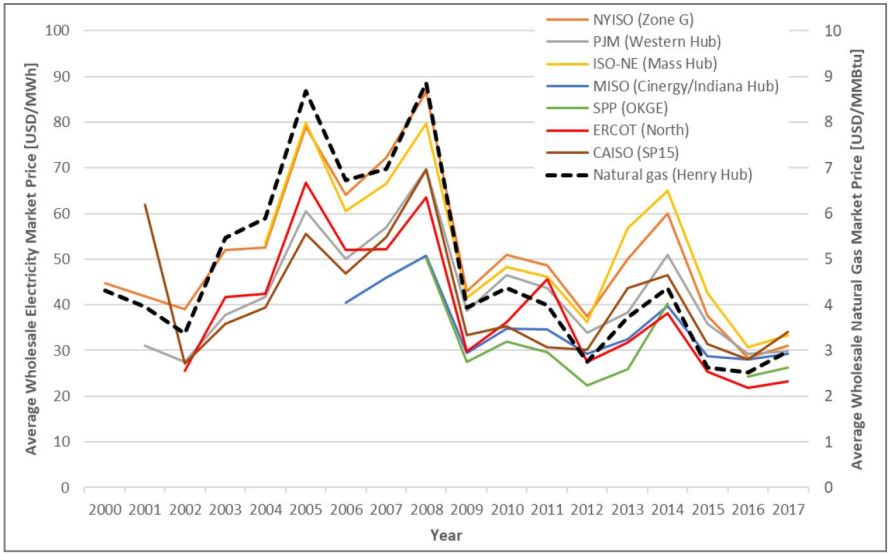
Electricity & Natural Gas Prices in Europe & U.S.

Europe (1999-2016)



Sources: EEG-EEMD (2017) and BAFA (2017)

U.S. (2000-2017)

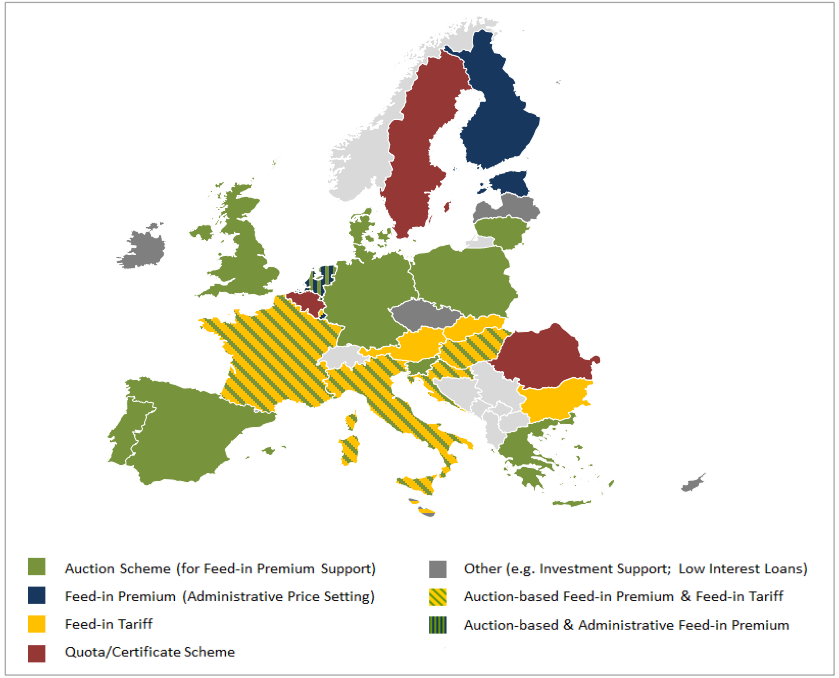


Data Sources: Data Source: ABB Velocity Suite and U.S. EIA

In addition, we frequently have been observing negative electricity market prices in recent years, both Europe and the U.S.

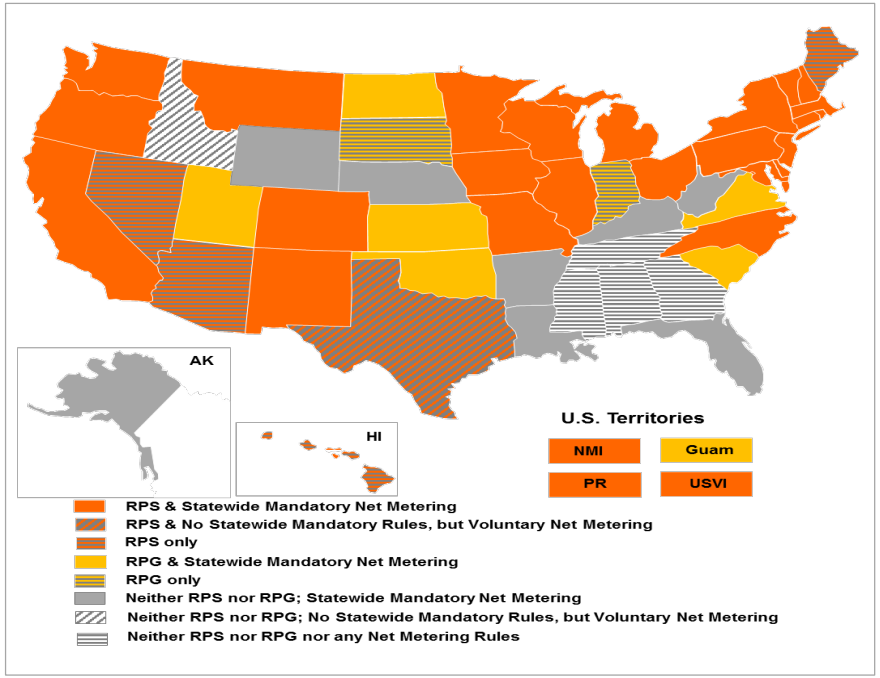
Renewable Support Schemes in Europe & U.S.

Europe (2017; 29.6% RES-E)



Source: EEG Green-X (2017)

U.S. (2017, 15.6% RES-E)

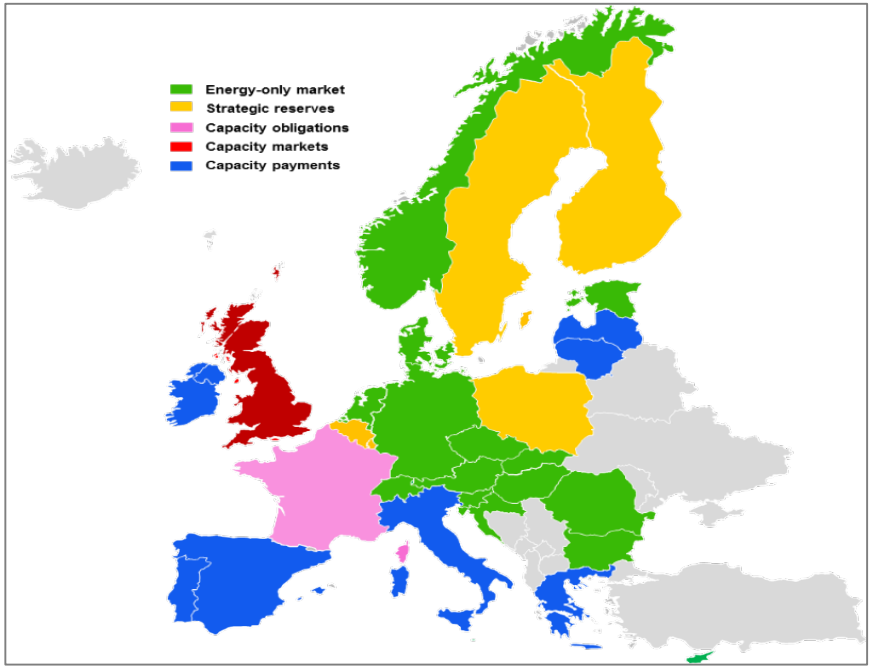


Data Source: DSIRE (2017)

In addition, indirect enablers (e.g. net metering, solar PV sharing in communities, microgrids) and voluntary schemes (e.g. corporate renewable deals, community choice aggregation programs), both Europe and the U.S.

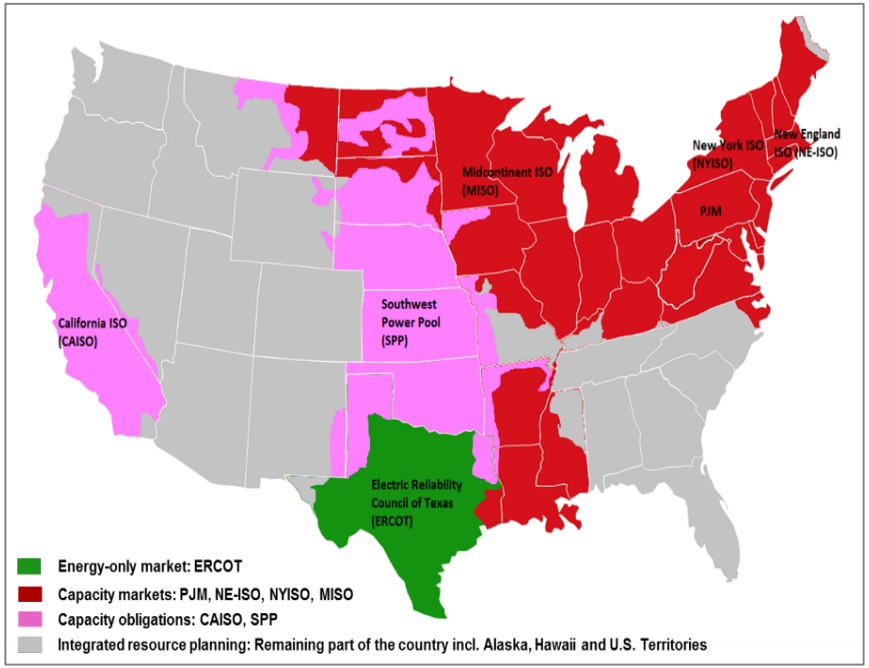
Capacity Mechanisms - Current Status in Europe & U.S.

Europe (2017)



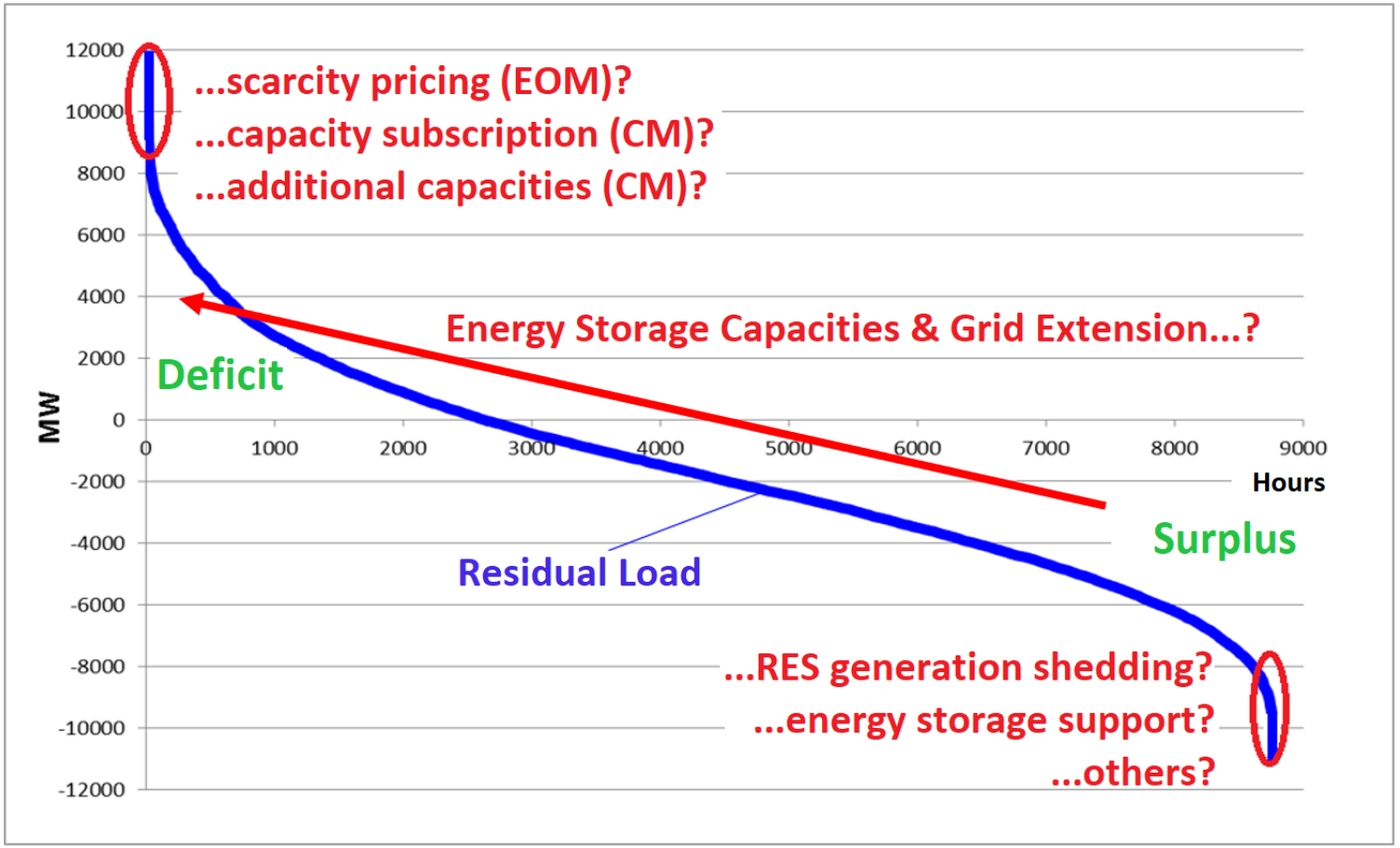
Source: EEG-EEMD (2017)

U.S. (2017)



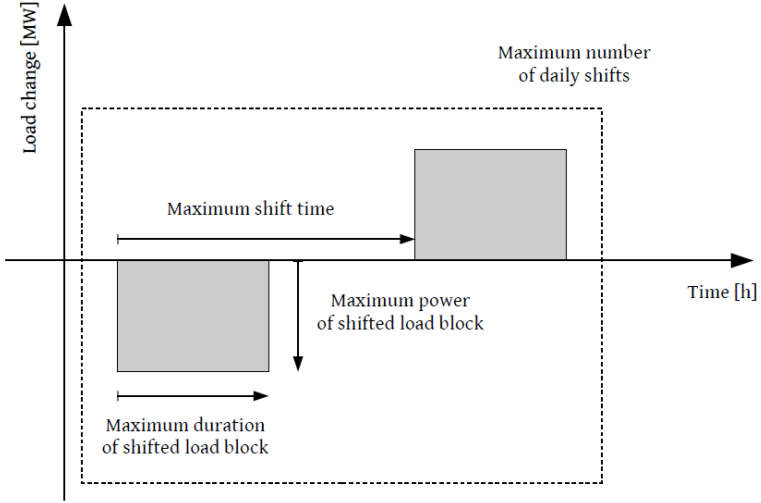
Source: IRC – ISO/RTO Council (www.isorto.org); own research

Residual Load Curve (Total - RES) & Flexibility Options



Scarcity Pricing & Flexibility Exploitation in EOM

- Energy-only Market
  - Prices in energy (and reserves) markets provide investment incentives
  - Importance of scarcity rents (higher offer prices above marginal cost during scarcity situations (to cover the average cost in the longer-term)
  - Exploitation of several existing flexibilities in the electricity system
- Example: Price Sensitive Load Response



Capacity Subscription - Inclusion of Demand Side in CM

The idea *(Doorman 2005)*

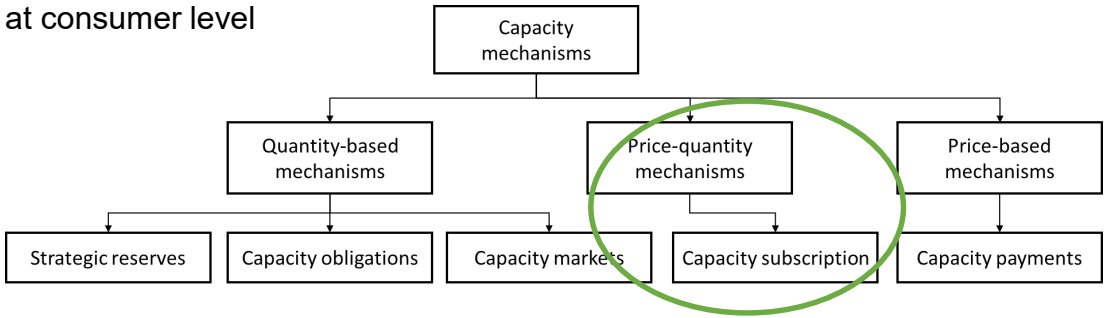
- Consumers buy the capacity they need under system scarcity
- Generators (and storage) receive capacity payments accordingly
- System operator limits consumer demand during scarcity
- A practical implementation of a “priority service” *(Chao and Wilson 1987)*

Several advantages *(Doorman and De Vries 2017)*

- Consumers pay directly for the scarce resource: generation capacity
- Capacity adequacy moves in the direction of a private good (economically efficient rationing)
- Capacity price and quantity reflecting consumer preferences
- Reduced risk for consumers and producers

Challenges

- Cost of controlling loads at consumer level
  (load limiting devices)



Comparison: Short-term Electricity Market Operations

Europe

Indroduced new power exchanges (PXs)

- Include long-term contracts
- TSOs typically own transmission system
- Emphasize markets and economics

Short-term market operations

- Day-ahead and intraday markets (PX)
- Real-time balancing markets (TSO)
- Simple bids/generator UC
- Zonal pricing/market coupling
- Sequential reserve and energy markets
- **Market-based decentralised balancing through balance responsible parties**

Variable renewable energy

- Strong policy support
- Feed-in tariffs/premiums, tenders/auctions
- VRE as „must-take“

Retail competition

- Retail choice in all countries

U.S.

Build into existing system operators (ISOs)

- Short-term system operation
- ISOs do not own transmission system
- Emphasize physics of the power system

Short-term market operations

- Day-ahead market (ISO - hourly)
- Real-time market (ISO - 5 min)
- Complex bids/ISO UC
- **Locational marginal prices**
- Co-optimization of energy and operating reserves
- More centralized control through ISO

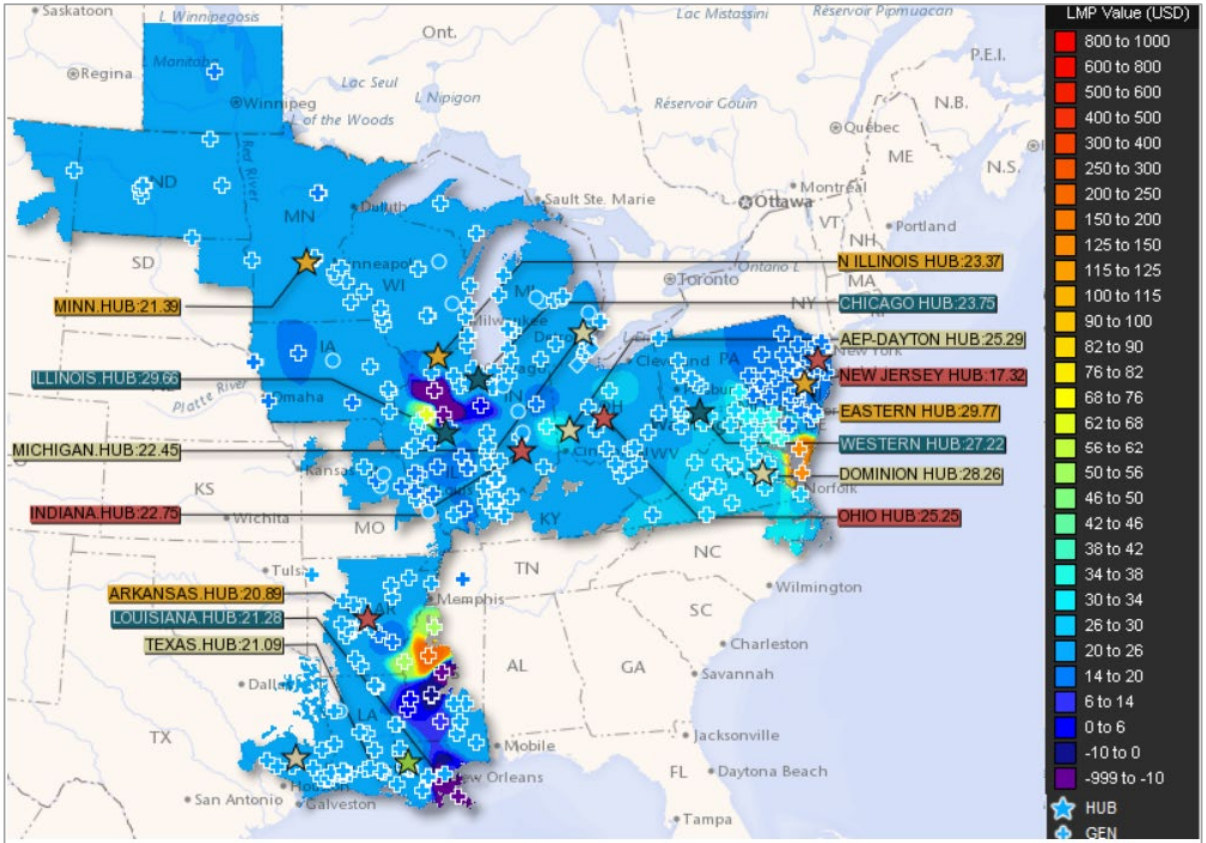
Variable renewable energy

- Intermittent policy support
- Tax credits, renewable portfolio standards
- „Dispatchable“ VRE

Retail competition

- Retail choice in some states

U.S.Good Practice: Locational Marg. Prices & Congestion Mgmt.

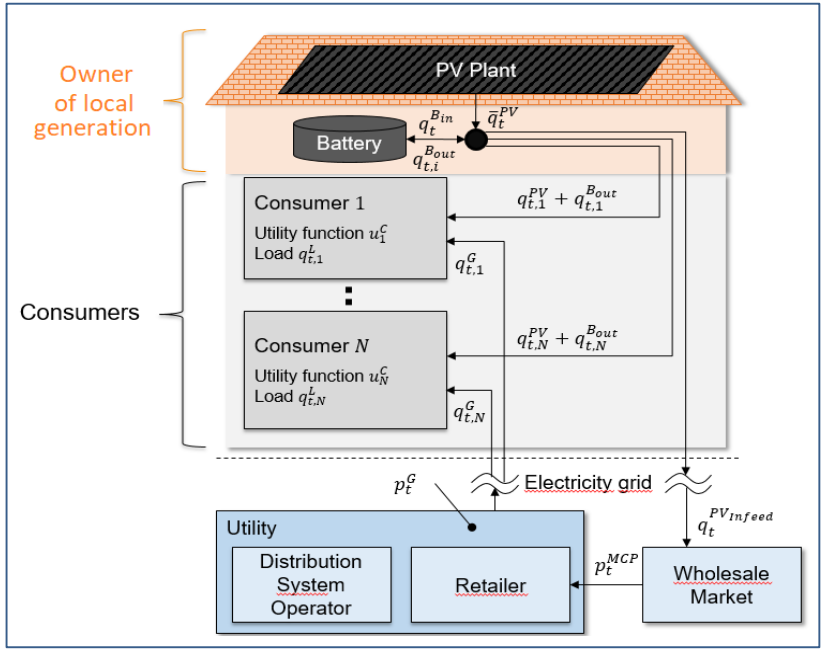


Nov 18 2015, 8.30am *MISO-PJM real-time prices; more than 10,000 nodes* *Source: www.miso-pjm.com*

Europe$_{\text{Good Practice}}$: Renewable Energy Communities

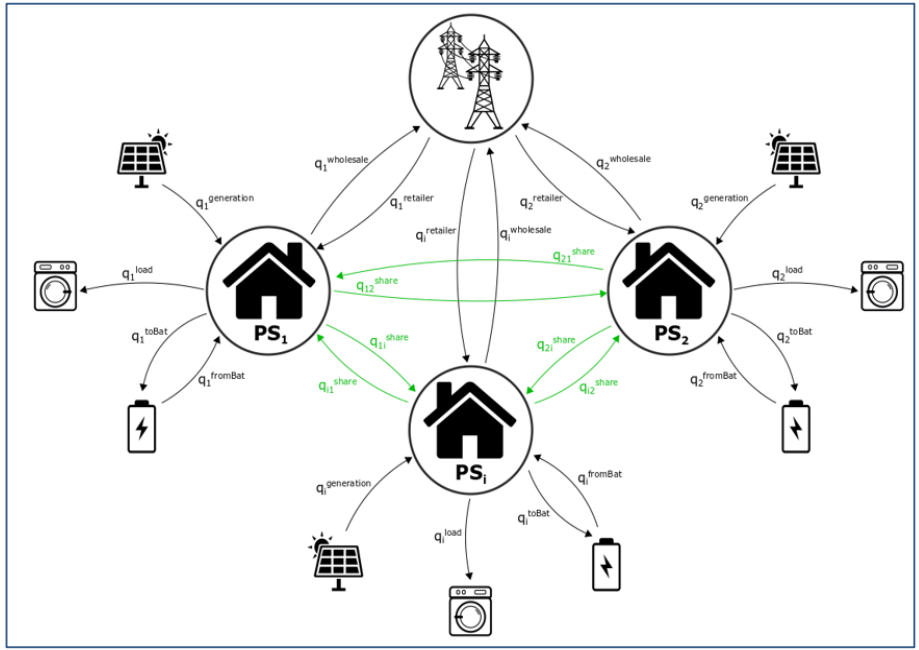
Creating added value for local producers, prosumers and consumers…

…at multi-apartment building level



Source: Fleischhacker et al (2018)

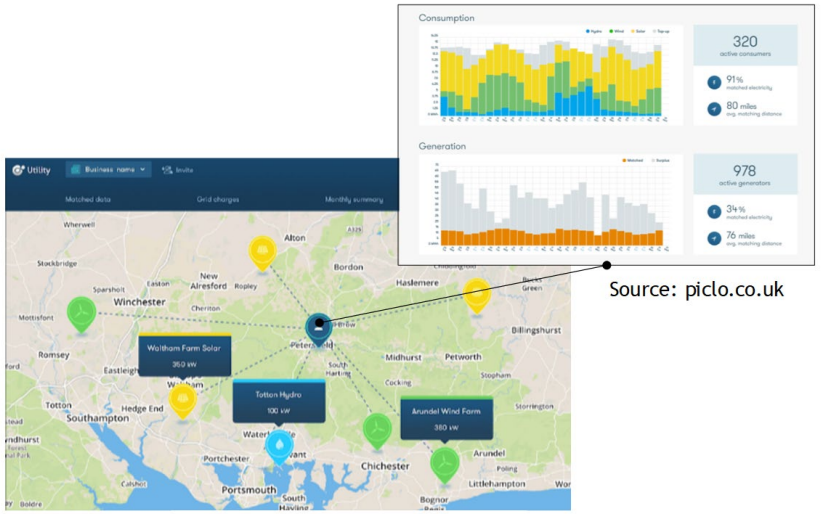
…at wider local energy community level



Source: EEG Model FRESH:COM

Europe$_{\text{Good Practice}}$: Business Models for Aggregators

Business Case: „Peer-to-Peer“ Renewable Energy Matching in UK *(Good Energy)*



Source: piclo.co.uk

EU-Project BestRES: 13 Business Models for Renewable Energy Aggregators

Business models for renewable energy aggregators

BestRES
www.bestres.eu

Automation and control	Providing decentralized units access to balancing markets	Demand Side flexibilization of small customers	DSM residential
“Peer-to-peer” (local) energy matching	Market renewables on multiple market places	Invest and market distributed generation of customers in apartment houses	DSM commercial and industrial
Dispatch flexible generation under changing market design on multiple markets	Trading PV and Wind power	Activation and marketing of end user’s flexibility. (PT + ES)	RES generation flexible
Suppling „mid-scale“ customers with time variable tariffs including grid charges optimization	Using flexibility of customers as third party	Pooling flexibility for local balancing market and energy service provision.	RES generation volatile
			Energy community

Source: www.bestres.eu

(Selection of) Recommendations for Improved Market Design

- Getting the price formation in short-term energy/reserve markets is the key challenge, notably during scarcity conditions.
- Removal of barriers for supply, demand and energy storage technologies at several levels to enable participation in several market segments equally in terms of energy, capacity and ancillary services provision.
- Exploitation of several system flexibility options, notably those for distributed/local generation and demand response.
- Avoidance of further market distortions (capacity mechanisms), but rather removal of technology specific subsidy schemes for variable renewable generation
- Adequate pricing of carbon and other environmental externalities in a more market-compatible manner is essential.

No single solution: lessons to be learned in both directions, Europe <-> U.S.!

Acknowledgement / References

- Collaborators
  - Audun Botterud — Massachusetts Institute of Technology (MIT)
  - Andreas Fleischhacker — Technische Universität Wien (TU Wien)
  - Daniel Schwabeneder — Technische Universität Wien (TU Wien)
  - Lukas Wachter — Technische Universität Wien (TU Wien)
  - Georg Lettner — Technische Universität Wien (TU Wien)

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