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# Nodal and Zonal Market Clearing

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# Outline



Impact of market design on day-ahead operations



Impact of market design on real-time operations

- Real time as a market versus real time as a service
  - European balancing operations
  - Active network management
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# DAY-AHEAD OPERATIONS



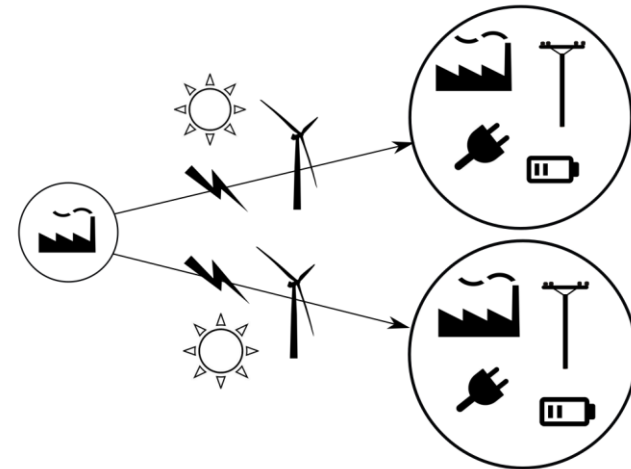
# Efficient Decisions in Day-Ahead and Real-Time Operations

Short-term operational efficiency depends on

(i) Efficient **irrevocable** day-ahead decisions

(ii) Real-time **coordination**

Renewable supply, failures



Day ahead:  
- Generators on/off

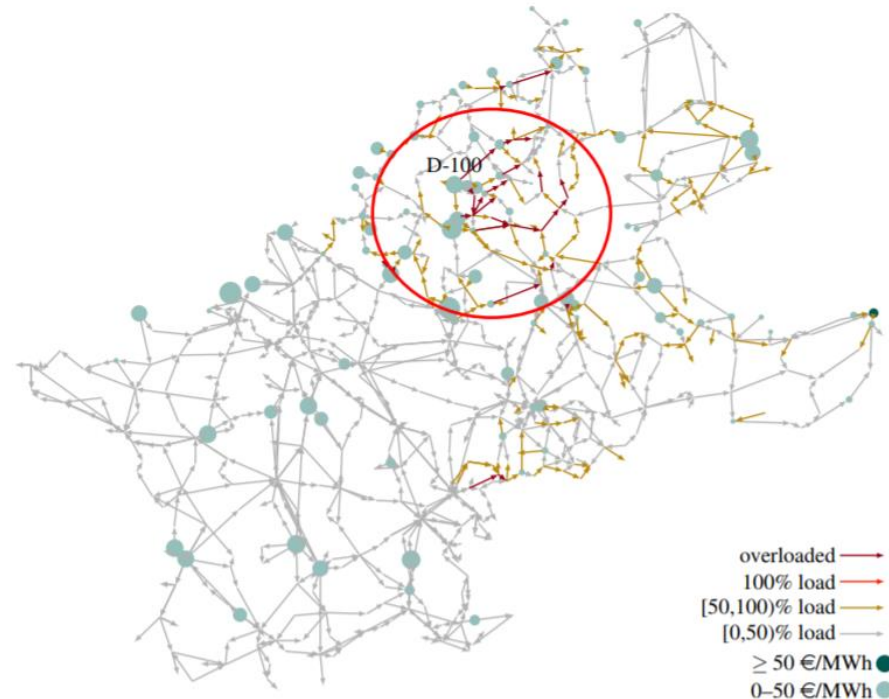
Real time:  
Generator production



## Market Design Matters in Turning on the Right Generators in Day-Ahead

- Zonal models can result in **infeasible** power flows (e.g. starting up cheap coal)
- Power flows can be made feasible in real time, but it is costly, e.g.
  - ▶ reduce production of coal
  - ▶ start up combined cycle gas turbines)

=> **operating costs that could be avoided**



Source: [Aravena, 2017]



## Estimate of Day-Ahead Inefficiencies in Central Western Europe

Policy	Day ahead (M€/year)	Real time (M€/year)	Total (M€/year)	Efficiency losses
Nodal	11,248	534	11,818	-
Flow-based zonal	10,458	1,963	12,420	<b>602 M€/year</b>
ATC-based zonal	10,470	1,949	12,419	<b>601 M€/year</b>

Source: [Aravena, 2019]

**Conclusion:** *Day-ahead* generator on/off decisions have significant *real-time* economic implications





## **REAL-TIME OPERATIONS**

Real time as a market versus as a service

Real-time dispatch procedures

Active network management

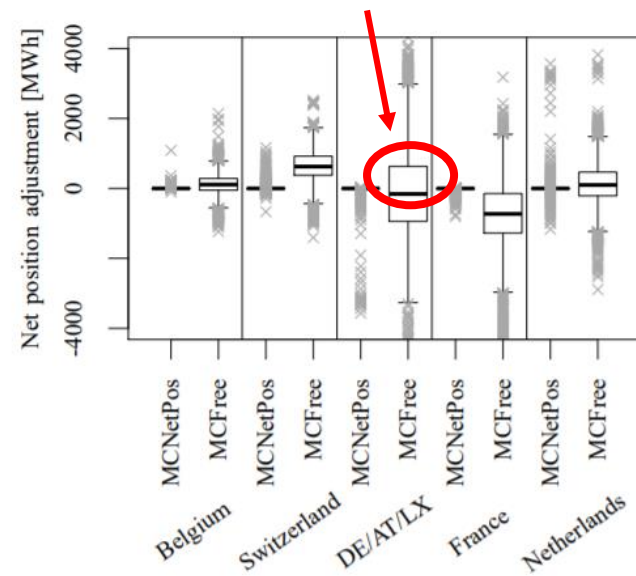


# Real Time as a Market Versus Real Time as a Service

- US view
  - ▶ Real time: spot market
  - ▶ Day ahead: forward market
- European view
  - ▶ Day ahead: spot market
  - ▶ Real time: a service that supports balancing
- Implication of EU view: **balancing responsible parties (BRPs) should remain balanced from day ahead to real time**

RT renewable supply > DA renewable forecast

- (i) Should the BRP stay in balance, or
- (ii) Should the power be exported?



Source: [Aravena, 2017]



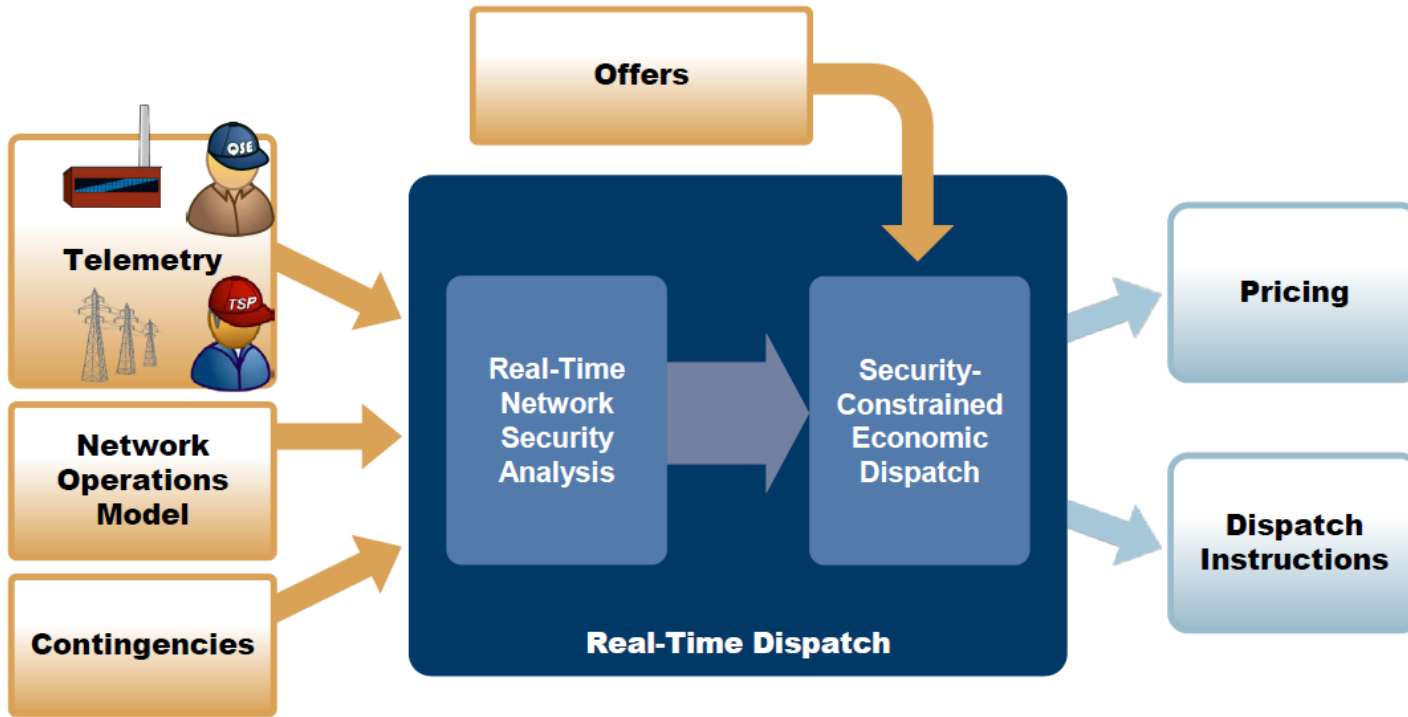


## Real-Time Operations

	USA	Europe
Optimization-based	Yes	Not necessarily (e.g. Belgium: no, France: ?)
Coordination of balancing & congestion management	Yes	No
System operator coordination	Interface scheduling	Move towards coordinated balancing (MARI, PICASSO)
Active network management	Not much (e.g. PJM)	Extensive (e.g. France, Netherlands switches 3x/day (?))



# Example: Texas Real-Time Operations

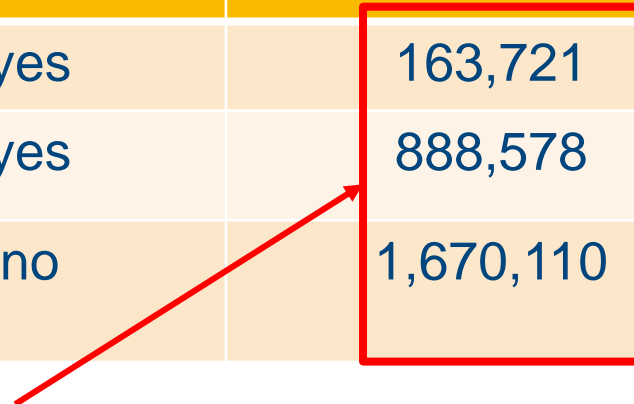


*ERCOT real-time dispatch (source: [ERCOT-RTM])*



## Efficiency of Real-Time Operations

	Inter-SO coordination ?	Optimization in real time?	Real-time cost (€)
<b>Option 1</b>	yes	yes	163,721
<b>Option 2</b>	no	yes	888,578
<b>Option 3</b>	no	no	1,670,110



**Conclusion:** *Coordination and optimization can have a major impact on real-time cost*

*Indicative results based on a single snapshot of Central Western Europe system*



# Active Network Management

- **Active network management (ANM):** bus-bar/line switching ...
- ANM practice in the US
  - ▶ Significant R&D efforts (ARPA-E)
  - ▶ Current view: ANM mostly *reactive* (contingency response)
  - ▶ Switching in practice: limited (?)
  - ▶ Interference with financial transmission rights market
- ANM practice in Europe
  - ▶ ANM is **extensive** in Europe, a chicken-and-egg question
  - ▶ ANM in Central Western Europe is coordinated by the CORESO organization [Han, 2015]



## References

- **[Aravena, 2017]** I. Aravena, A. Papavasiliou. *Renewable Energy Integration in Zonal Markets*, IEEE Transactions on Power Systems, vol. 32, no. 2, pp. 1334-1349, March 2017.
- **[Aravena, 2019]** I. Aravena, A. Papavasiliou, Y. Smeers, *Transmission Capacity Allocation in Zonal Electricity Markets*, under review.
- **[ERCOT-RTM]** ERCOT, *ERCOT Market Education, Basic Training Program, Module 6: Real-Time Operations*.
- **[Han, 2015]** J. Han, A. Papavasiliou, *Congestion Management through Topological Corrections: A Case Study of Central and Western Europe (CWE)*, Energy Policy, vol. 86, pp. 470-482, November 2015.

