

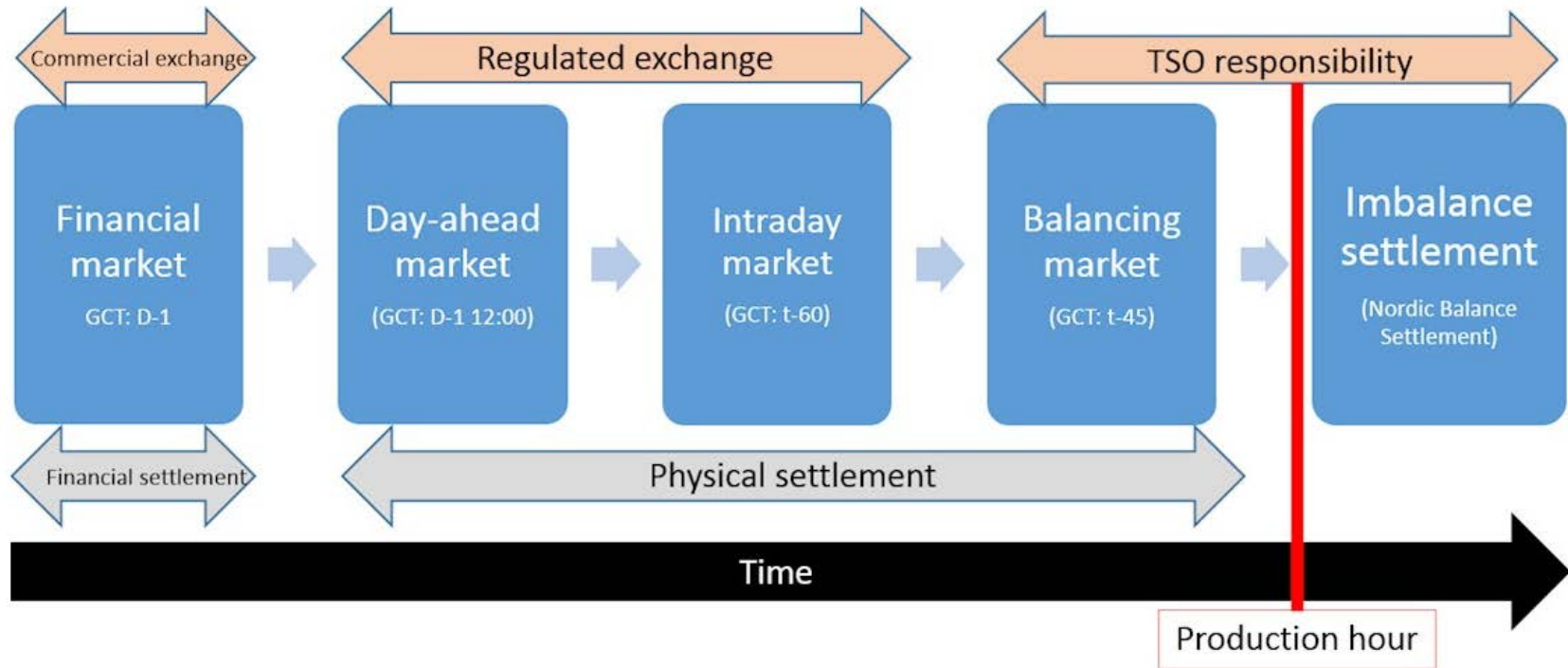
# Coordinated bidding in the Nordic day-ahead and balancing market

Ellen Krohn Aasgård

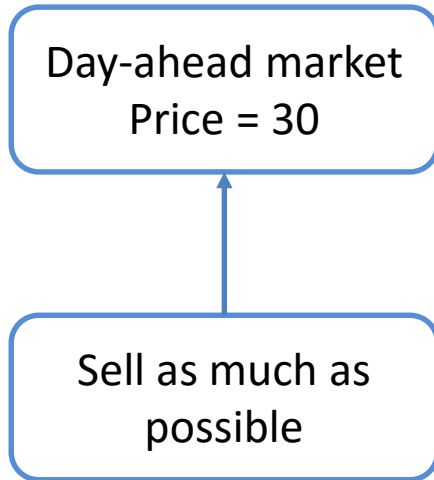
Workshop on hydropower scheduling

Stavanger, 12-13 September 2018

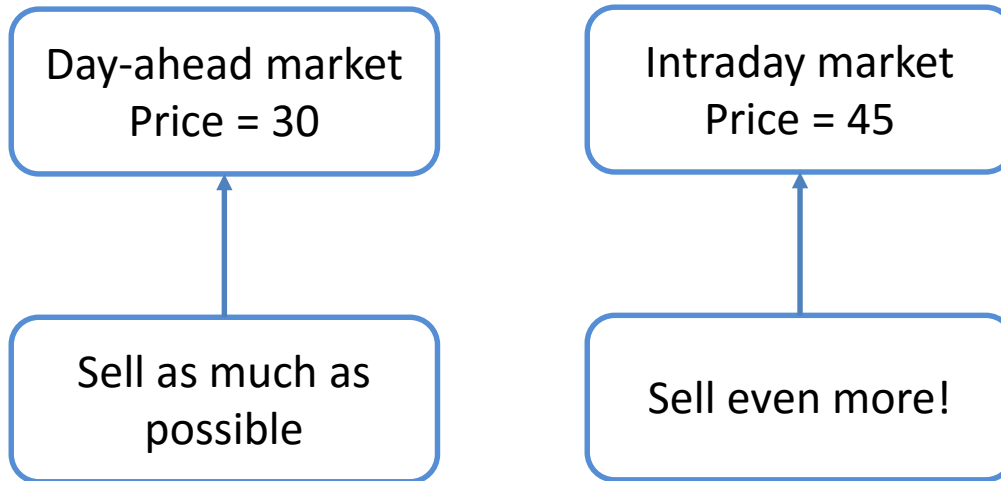
# Sell the same product in multiple markets



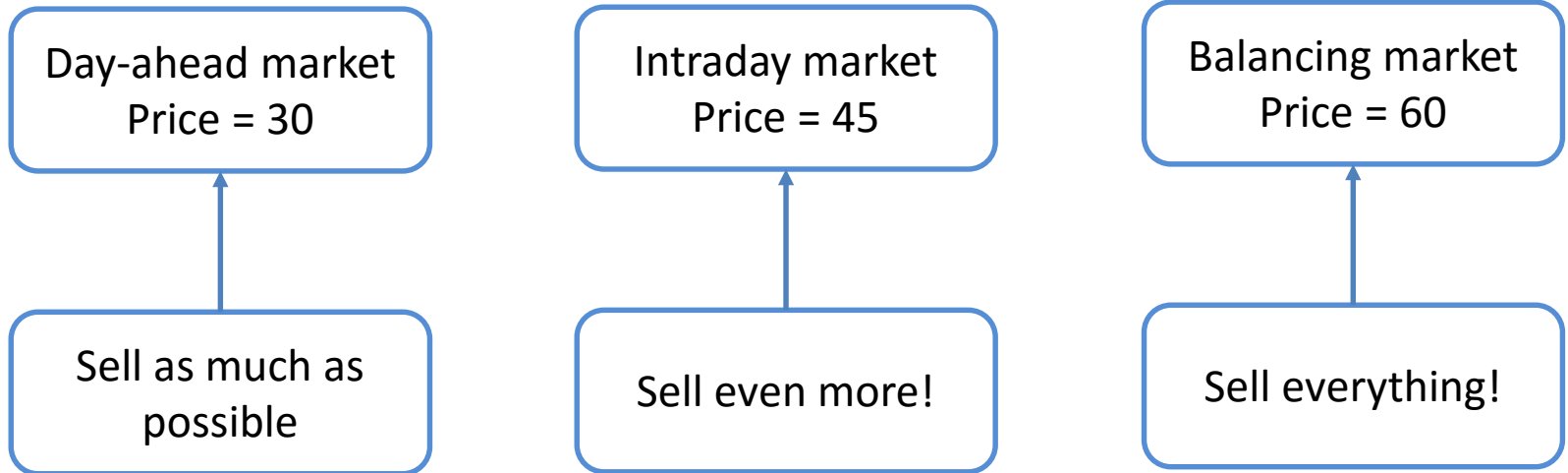
# Easy! Just sell at the highest price!



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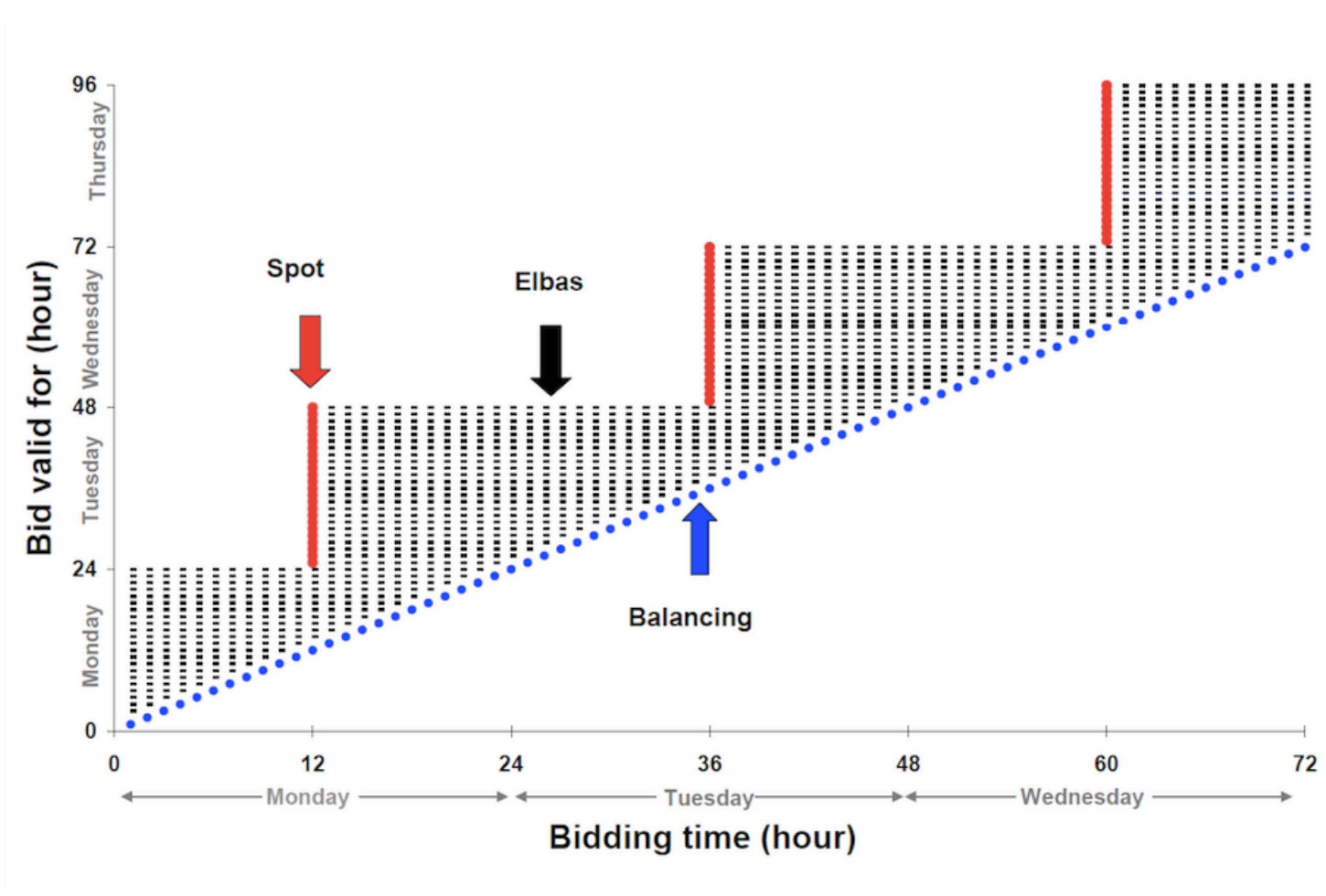
# Allocation problem



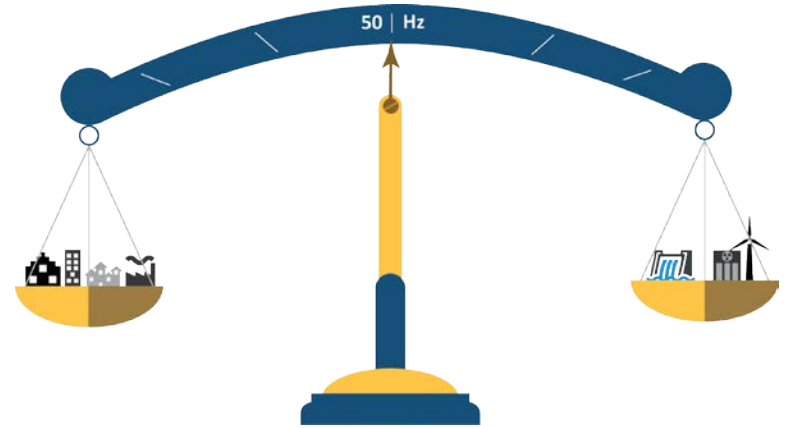
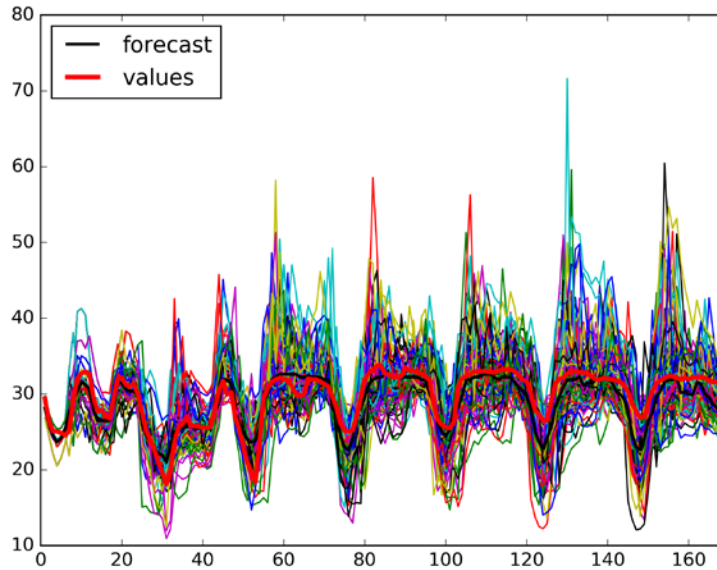
$$\max \sum_{\text{all markets}} \text{sale volume} * \text{price}$$

Result: trade all available capacity in the market with highest price

# But the real world is more complicated



# Complicating fact no 1: Future prices are not known



**NORD POOL Intraday** 15:00 08-11 NP One

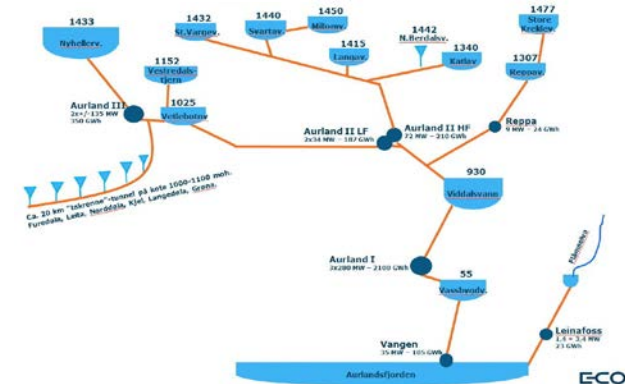
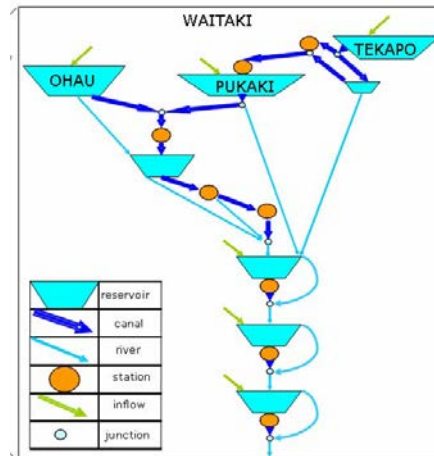
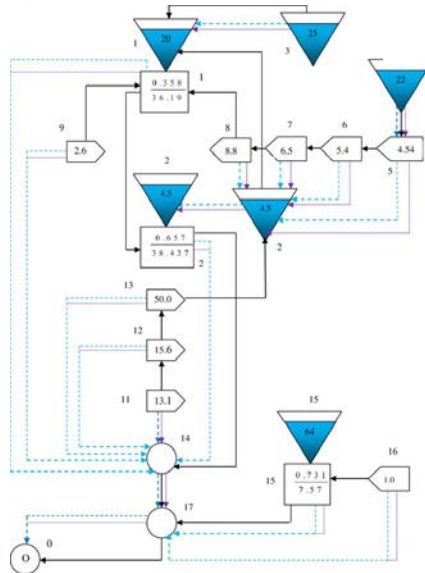
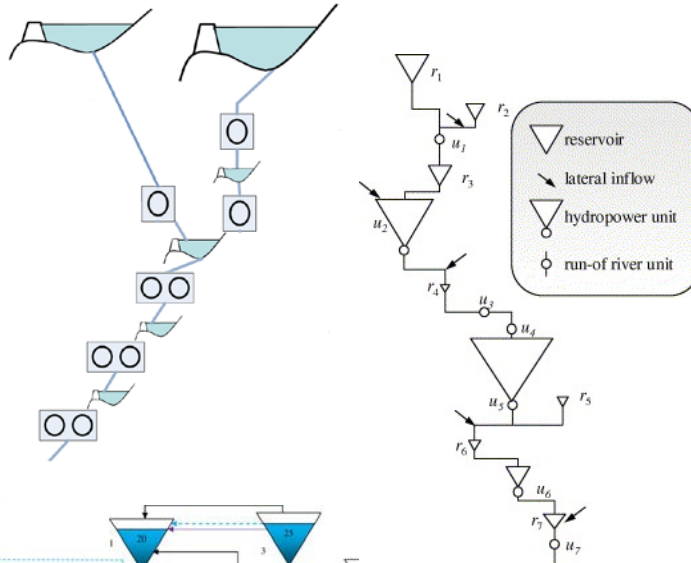
OBSERVER: SIES

Product	Order Depth	Price	City	Ticks History	HGR	Low	Last	Time	DMM	VWAP	Turnover	My Purchases	My Sales	My Bid
PH-17 18:00-17:00	10.0	47.00	50.0	10.0	10.0	47.00	47.00	17:00	10.0	47.00	10.0			
PH-19 18:00-18:00	10.0	48.00	30.0	10.0	10.0	48.00	48.00	18:00	10.0	48.00	10.0			
PH-20 18:00-20:00	10.0	49.00	27.0	10.0	10.0	49.00	49.00	20:00	10.0	49.00	10.0			
PH-21 20:00-21:00	10.0	43.00	10.0	10.0	10.0	43.00	43.00	21:00	10.0	43.00	10.0			
PH-22 21:00-23:00	10.0	41.00	1.0	10.0	10.0	41.00	41.00	23:00	10.0	41.00	10.0			
PH-23 22:00-23:00	10.0	49.00	5.0	10.0	10.0	49.00	49.00	23:00	10.0	49.00	10.0			
PH-24 23:00-01:00	10.0	38.00	7.0	10.0	10.0	38.00	38.00	01:00	10.0	38.00	10.0			
PH-01 00:00-01:00	10.0	36.00	80.0	10.0	10.0	36.00	36.00	01:00	10.0	36.00	10.0			
PH-02 01:00-03:00	10.0	35.00	80.0	10.0	10.0	35.00	35.00	03:00	10.0	35.00	10.0			
PH-03 03:00-03:00	10.0	35.00	80.0	10.0	10.0	35.00	35.00	03:00	10.0	35.00	10.0			
PH-04 03:00-04:00	10.0	35.00	80.0	10.0	10.0	35.00	35.00	04:00	10.0	35.00	10.0			
PH-05 04:00-05:00	10.0	36.00	80.0	10.0	10.0	36.00	36.00	05:00	10.0	36.00	10.0			
PH-06 05:00-06:00	10.0	38.00	80.0	10.0	10.0	38.00	38.00	06:00	10.0	38.00	10.0			
PH-07 06:00-07:00	10.0	43.00	10.0	10.0	10.0	43.00	43.00	07:00	10.0	43.00	10.0			
PH-08 07:00-08:00	10.0	52.00	50.0	10.0	10.0	52.00	52.00	08:00	10.0	52.00	10.0			
PH-09 08:00-09:00	10.0	54.00	50.0	10.0	10.0	54.00	54.00	09:00	10.0	54.00	10.0			
PH-10 09:00-10:00	10.0	53.00	50.0	10.0	10.0	53.00	53.00	10:00	10.0	53.00	10.0			
PH-11 10:00-11:00	10.0	48.00	10.0	10.0	10.0	48.00	48.00	11:00	10.0	48.00	10.0			
PH-12 11:00-12:00	10.0	49.00	10.0	10.0	10.0	49.00	49.00	12:00	10.0	49.00	10.0			
PH-13 12:00-13:00	10.0	50.00	10.0	10.0	10.0	50.00	50.00	13:00	10.0	50.00	10.0			
PH-14 13:00-14:00	10.0	51.00	10.0	10.0	10.0	51.00	51.00	14:00	10.0	51.00	10.0			
PH-15 14:00-15:00	10.0	49.00	10.0	10.0	10.0	49.00	49.00	15:00	10.0	49.00	10.0			
PH-16 15:00-16:00	10.0	52.00	10.0	10.0	10.0	52.00	52.00	16:00	10.0	52.00	10.0			
PH-17 16:00-17:00	10.0	52.00	10.0	10.0	10.0	52.00	52.00	17:00	10.0	52.00	10.0			
PH-18 17:00-18:00	10.0	50.00	40.0	10.0	10.0	50.00	50.00	18:00	10.0	50.00	10.0			
PH-19 18:00-19:00	10.0	50.00	10.0	10.0	10.0	50.00	50.00	19:00	10.0	50.00	10.0			
PH-20 19:00-20:00	10.0	53.00	80.0	10.0	10.0	53.00	53.00	20:00	10.0	53.00	10.0			
PH-21 20:00-21:00	10.0	44.00	60.0	10.0	10.0	44.00	44.00	21:00	10.0	44.00	10.0			
PH-22 21:00-22:00	10.0	48.00	30.0	10.0	10.0	48.00	48.00	22:00	10.0	48.00	10.0			

Figures taken from  
 Michal Kaut  
[http://work.michalkaut.net/papers\\_etc/sg\\_forecast-errors.pdf](http://work.michalkaut.net/papers_etc/sg_forecast-errors.pdf)  
 NordPool  
<https://www.nordpoolspot.com/globalassets/download-center/intraday/intraday-user-guide.pdf>  
 SINTEF  
<https://www.sintef.no/en/projects/pribas-pricing-balancing-services-in-the-future-no/>



# Complicating fact no 2: The production system is complex



# Solution

**Implement multiple markets in (the stochastic version of) the production scheduling model used by Nordic hydropower producers**

$$\max \sum_{\text{all markets}} \text{sale volume} * \text{price}$$

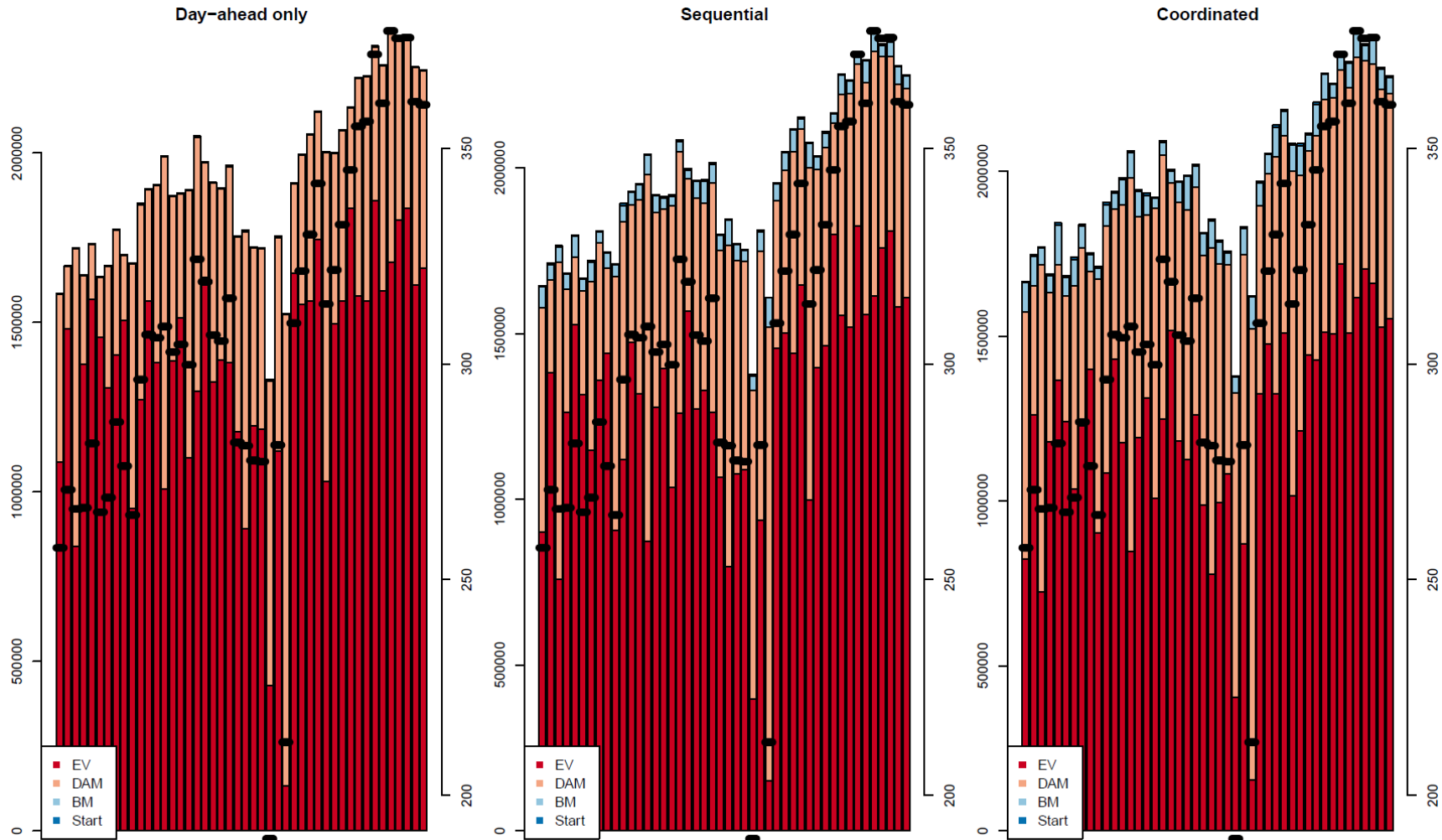
Subject to:

Market dynamics and stochastics

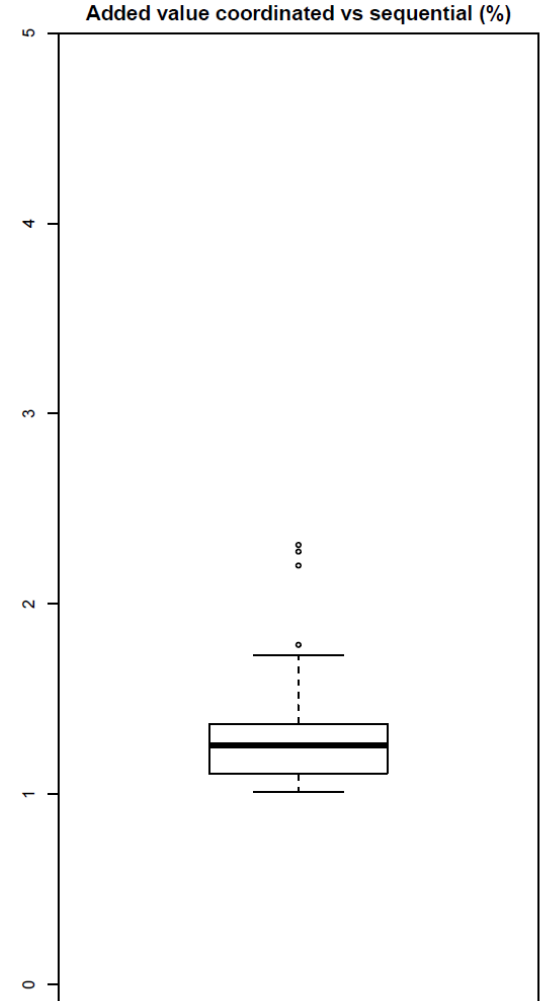
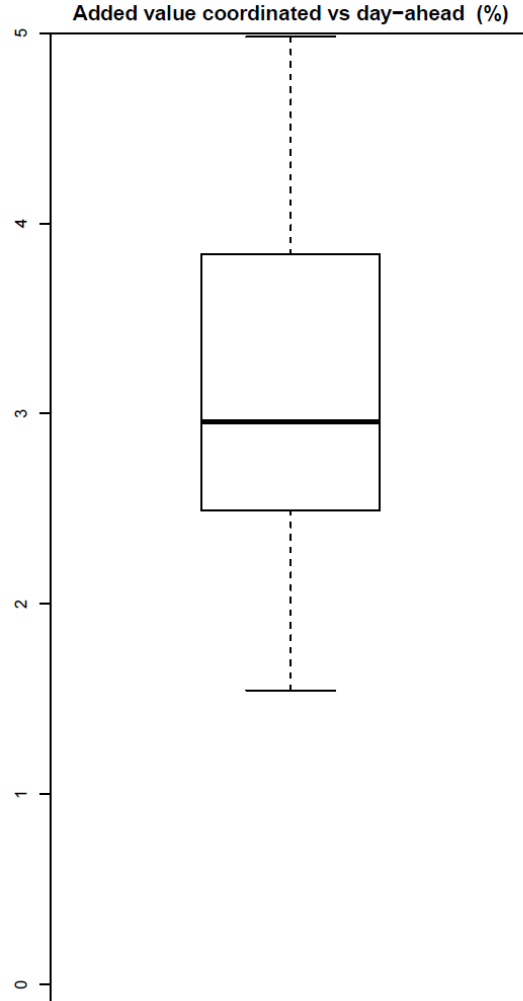
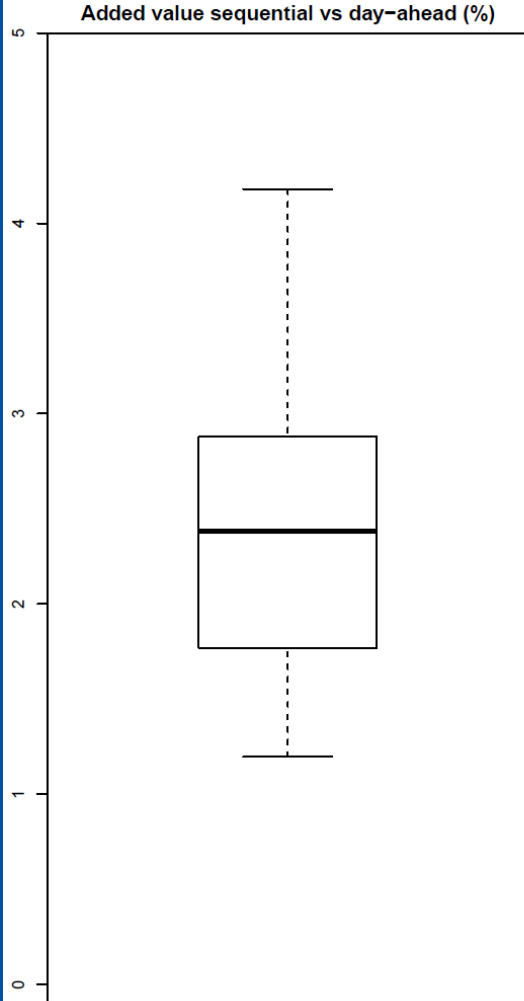
The production system

Result: Something that takes a long time to solve

# Results from example case



# Results from example case



# Results from example case

