Group Overview

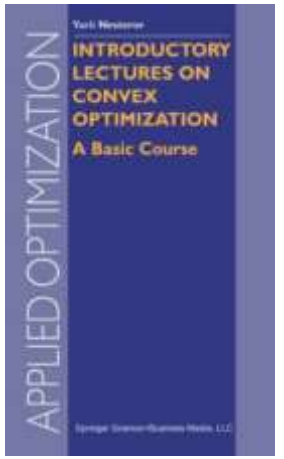
Anthony Papavasiliou

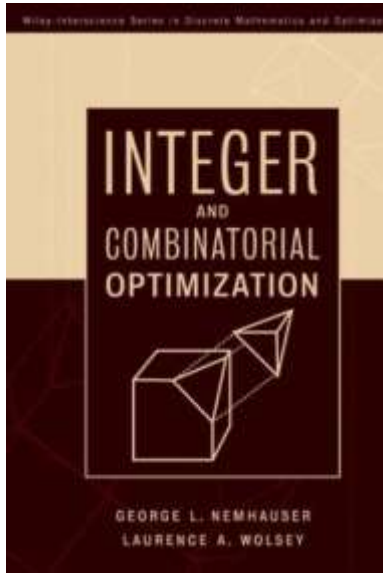
Center for Operations Research and Econometrics (CORE)

CORE @ UCLouvain

The Center of Operations Research and Econometrics is a research division in UCLouvain with a grand tradition in optimization and power system economics

- **Yurii Nesterov**
  - Accelerated gradient descent, complexity analysis of interior point methods, semidefinite programming
  - Dantzig prize, John von Neumann theory prize, EURO gold medal, ERC advanced grant
- **Laurence Wolsey**
  - Integer programming
  - Hays prize, Lanchester prize, Dantzig prize, John von Neumann theory prize, EURO gold medal
- **George Nemhauser**
  - Integer programming
  - Professor at Georgia Tech, former director of CORE, US National Academy of Engineering, INFORMS fellow, SIAM fellow, Kimball medal, Lanchester prize, John von Neumann theory prize
- **Yves Smeers**
  - Power system economics
  - GDF-Suez chair, INFORMS fellow
- **Philippe Chevalier**
  - Former director @ CORE
  - Co-founder of N-SIDE

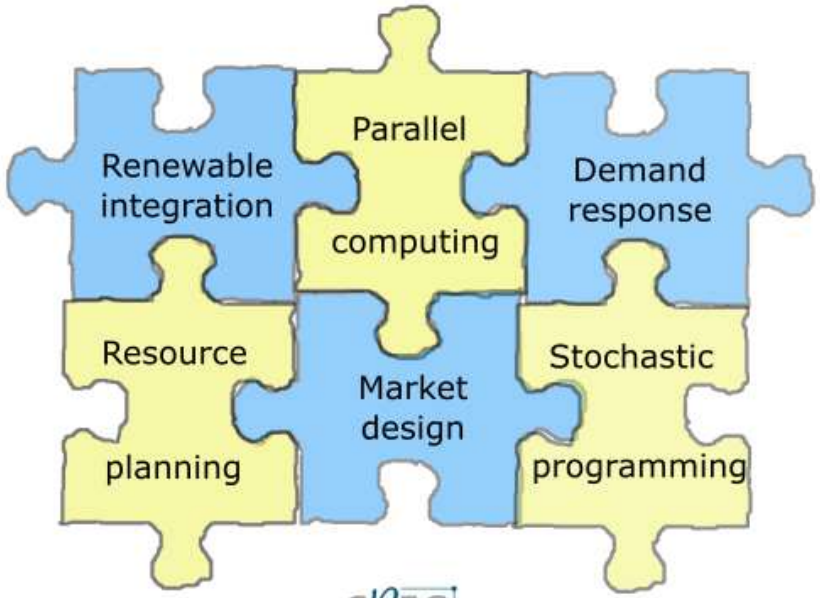




Solving the Sustainability Puzzle

ENGIE Chair research problems and methodology

Lawrence Livermore National Laboratory



European Research Council
Established by the European Commission

ICEBERG: Integrated transmission/distribution operation

ENGIE

ColorPower: residential demand response business models based on quality differentiated service

European Commission

FEVER: Flexibility platforms

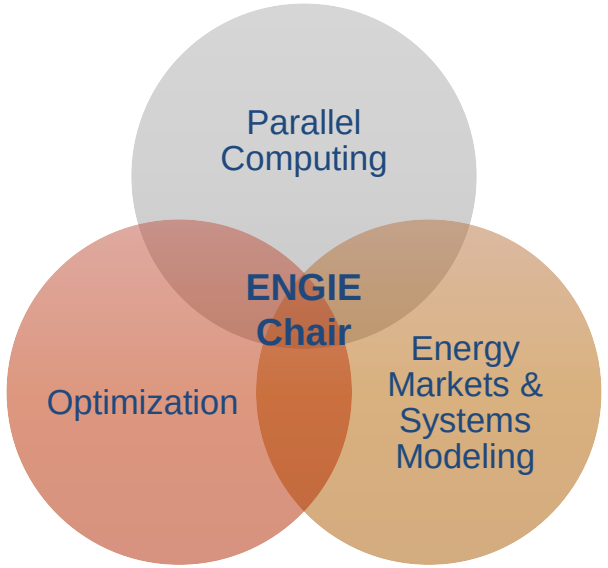
Francqui foundation research professorship 2018-2021

CREG

Rewarding flexible capacity in the Belgian electricity market

A New, Interdisciplinary Frontier

Lawrence Livermore National Laboratory



CORE | LIDAM
Louvain Institute of Data Analysis and Modeling in economics and statistics

HARVARD Kennedy School
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

Inter-disciplinary expertise and collaborations, backed by robust funding

- CORE houses towering experts in optimization, energy markets
- LLNL provides access to unique supercomputing infrastructure
- Interaction with international electricity market experts

Ongoing PhDs

Energy Research @ CORE

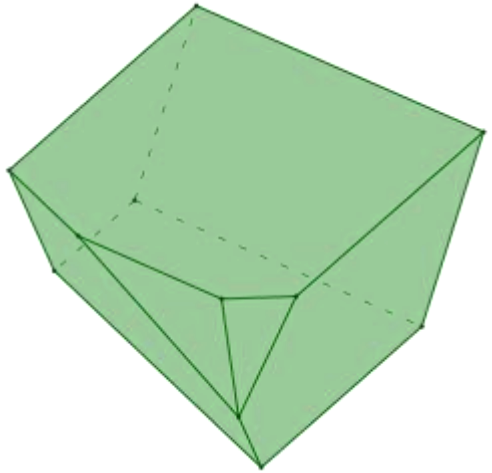
Seven ongoing PhDs

- **Quentin Lété**: flow-based market coupling
- **Jacques Cartuyvels**: scarcity pricing
- **Ilyes Mezghani**: T&D coordination
- **Daniel Avila**: parallel SDDP
- **Jehum Cho**: real-time market clearing platforms
- **Céline Gerard**: demand response aggregation
- **Gilles Bertrand**: intraday trading using reinforcement learning

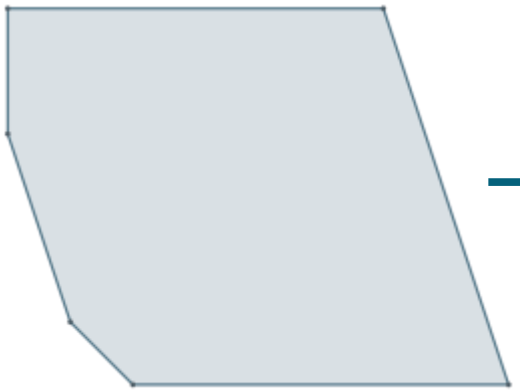
FBMC and transmission switching

- **Goal** of the research: 1. Precise modeling of **flow based market coupling**
- 2. Measure the impacts of **transmission switching** on FBMC
- ? Does DA transmission switching improve the performance in **unit commitment** ?

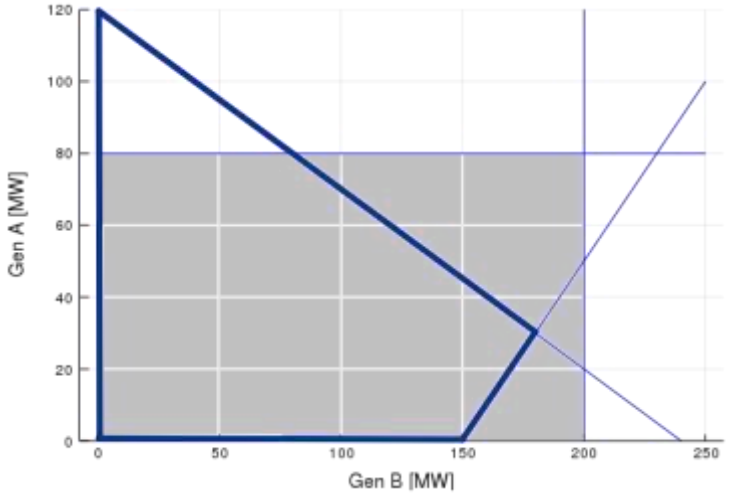
Nodal net injections



Zonal net positions



Transmission switching

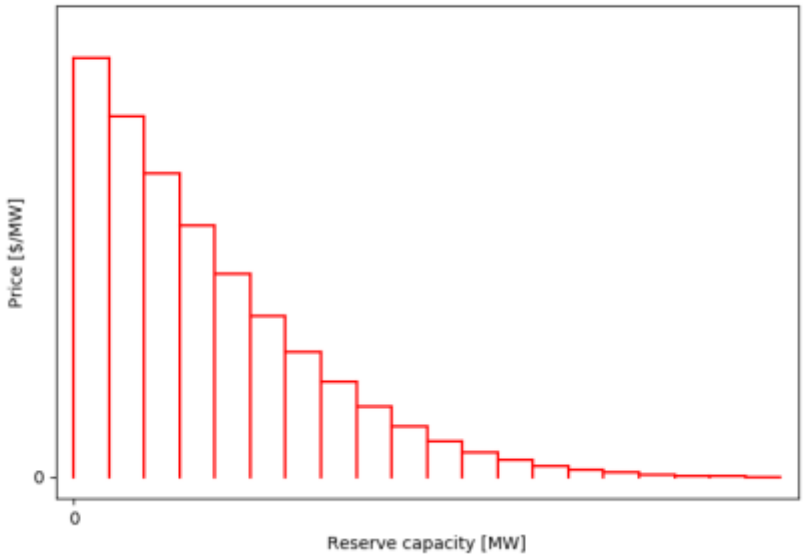


Three papers submitted:
1: modeling of zonal market coupling (OPRE)
2-3: TS, algo and case study (IEEE-TPWRS)

Website: glete.github.io
Contact: **quentin.lete@uclouvain.be**

Scarcity pricing in Belgium

- Objective: Use ORDC to give a signal that better represents the stress on the system



Scarcity price:

$$\lambda^R(R) = Lolp(R) \times (Voll - MC)$$

With:

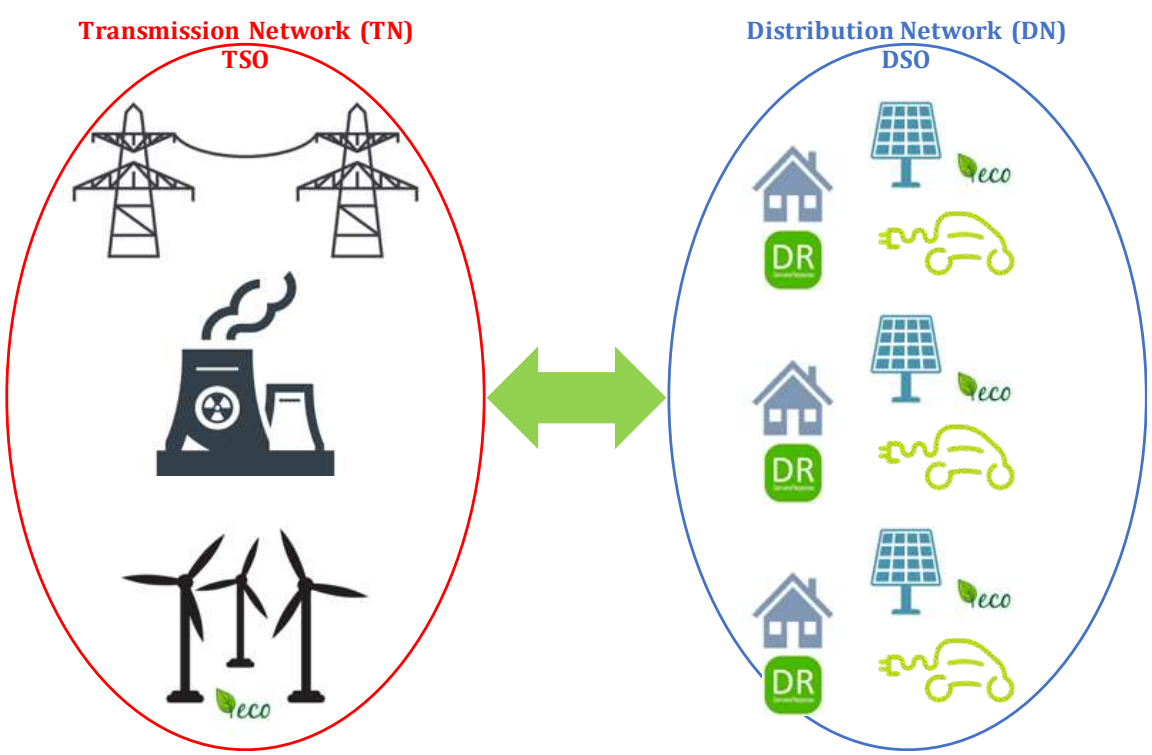
$Voll$: Value of lost load

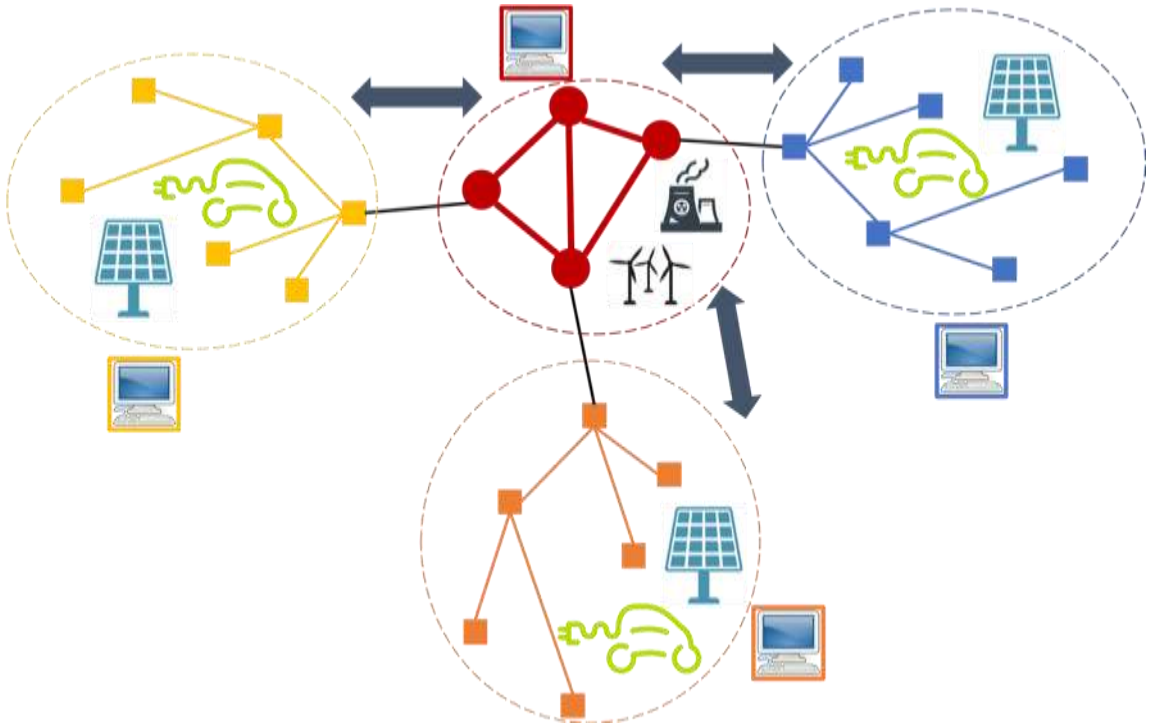
MC : Marginal cost of production

$Lolp(R)$: Lose of load probability in function of reserve capacity R

➢Analysis of the impact of the shape of the loss of load probability

Integrated T&D Real-time Market





Goal: develop a practical market clearing platform able to integrate transmission and distribution constraints as well as complex bids.

European project: **FEVER** (https://cordis.europa.eu/project/id/864537)
Personal website: https://sites.google.com/view/ilyesmezghani/

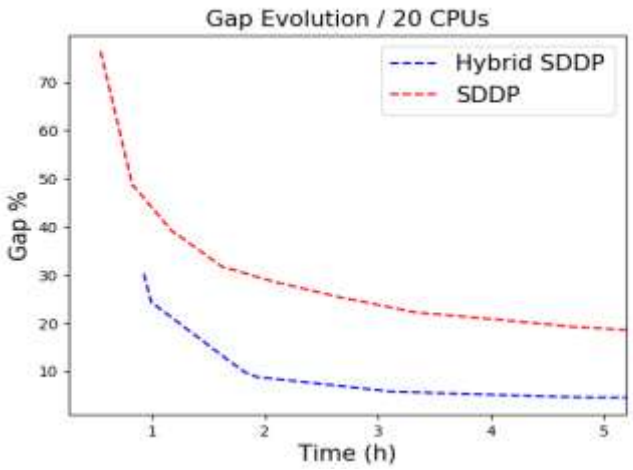
Research - Daniel Ávila

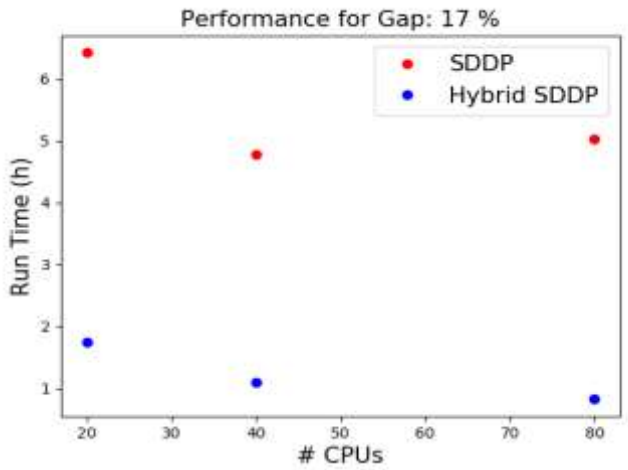
Hybid SDDP

Motivation: Build an algorithm that takes advantage of paralelism.

Issues: SDDP may not scale well with several CPUs.

Idea: Use Backward Dynammic Programming + SDDP

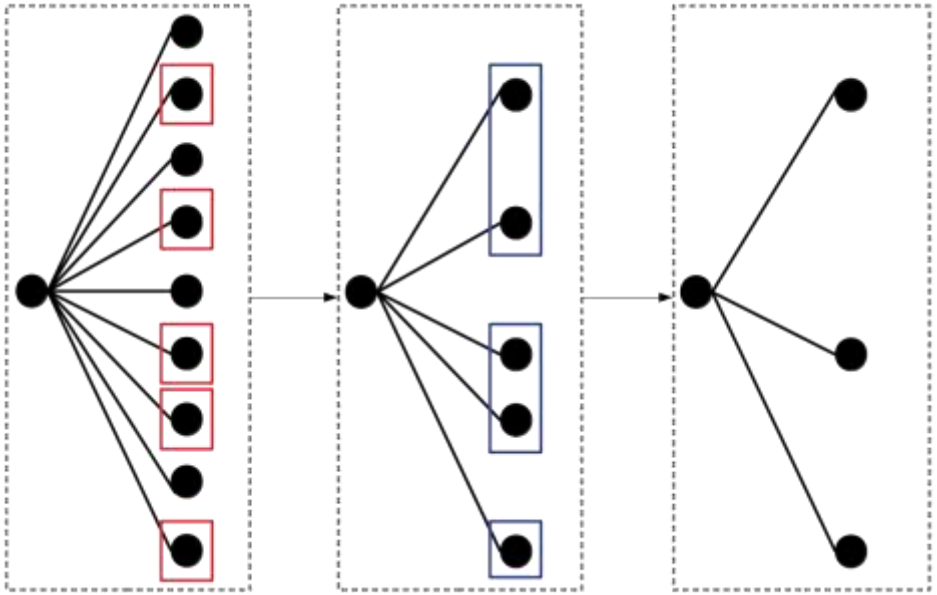




Scenario Reduction

Motivation: How to select a subset of scenarios that capture the relevant properties of the problem?

Idea: Build clusters that produce similar decisions.



Pricing Under Uncertainty in Multi-Interval Real-Time Markets

Uplift Payments

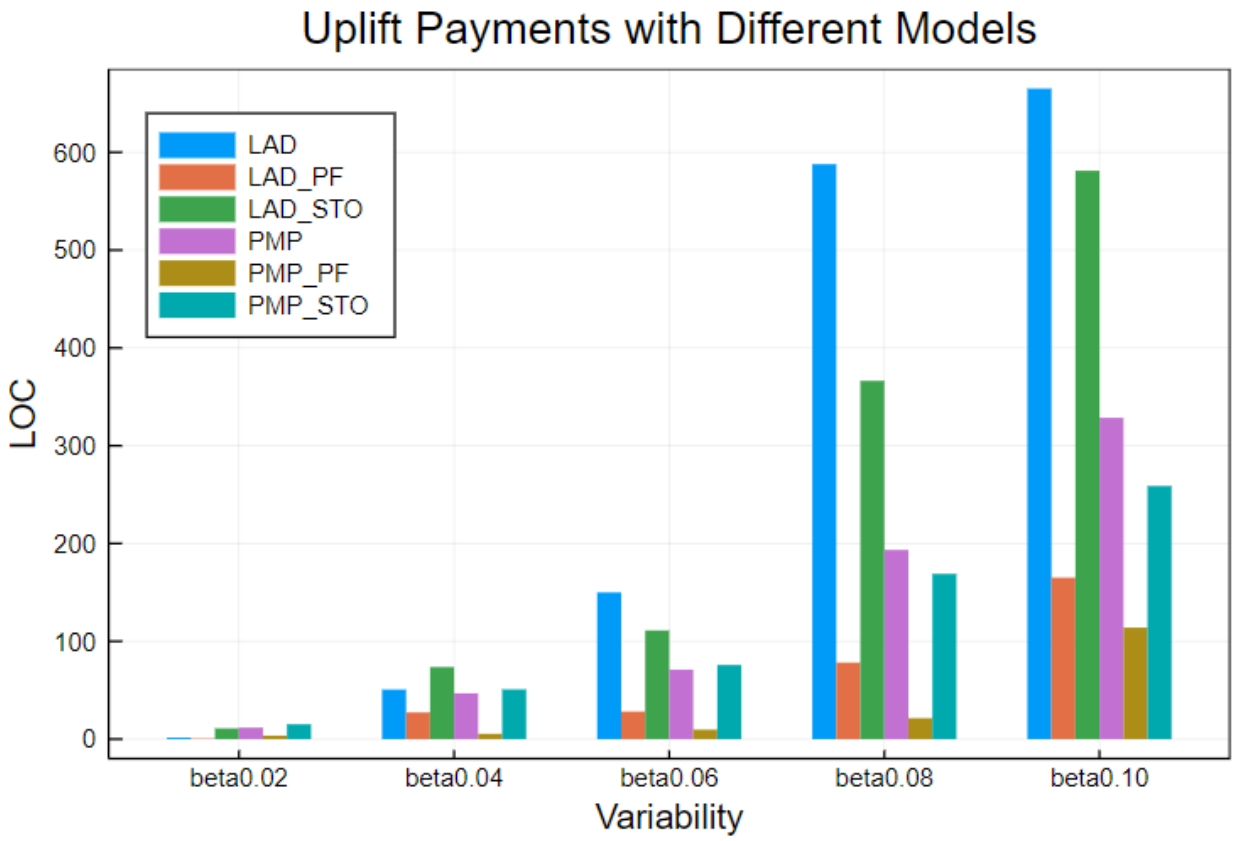
- Recent research has demonstrated that real-time auctions can generate the need for uplift payments, even if the market clearing models are convex, due to the rolling nature of real-time market clearing.

Research in the Deterministic Setting

- This observation has inspired proposals for modifying the real-time market clearing model in order to account for binding past decisions.

Extension to Pricing Under Uncertainty

- We extend this analysis in order to account for uncertainty by proposing a real-time market clearing model with look-ahead and an endogenous representation of uncertainty.
- We proved that our method generates the best policy minimizing the expectation of uplift in a certain horizon.

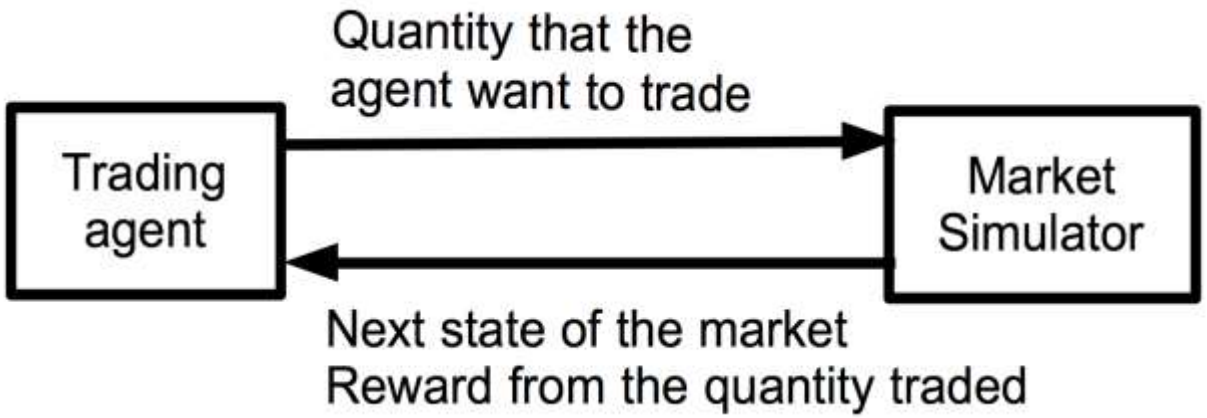


Experiment Results from a Toy example

- LAD generates prices without considering past decisions, and PMP accounts for past prices. Here, beta is a parameter related to amount of variability of loads. PF stands for perfect foresight where we assume to know for the future demands. STO is our model incorporating uncertainty information. The graph shows the average LOC (a measure of uplift) of 100 sample paths for each cases. Observe that our model performs better than the deterministic case. Also, as variability increases, the gap between the deterministic case and our model is getting bigger.

Reinforcement learning for electricity markets

Methodology



The trading agent will improve his trading strategy by interacting with the market simulator.

Applications

- Develop an high frequency trading strategy for the Continuous Intraday Market which outperforms state of the art methods by **18 %.** *Published in IEEE Transactions on Power Systems.*
- Compare the efficiency of different European balancing market designs by comparing their outcome when we let several trading agents compete against each other.

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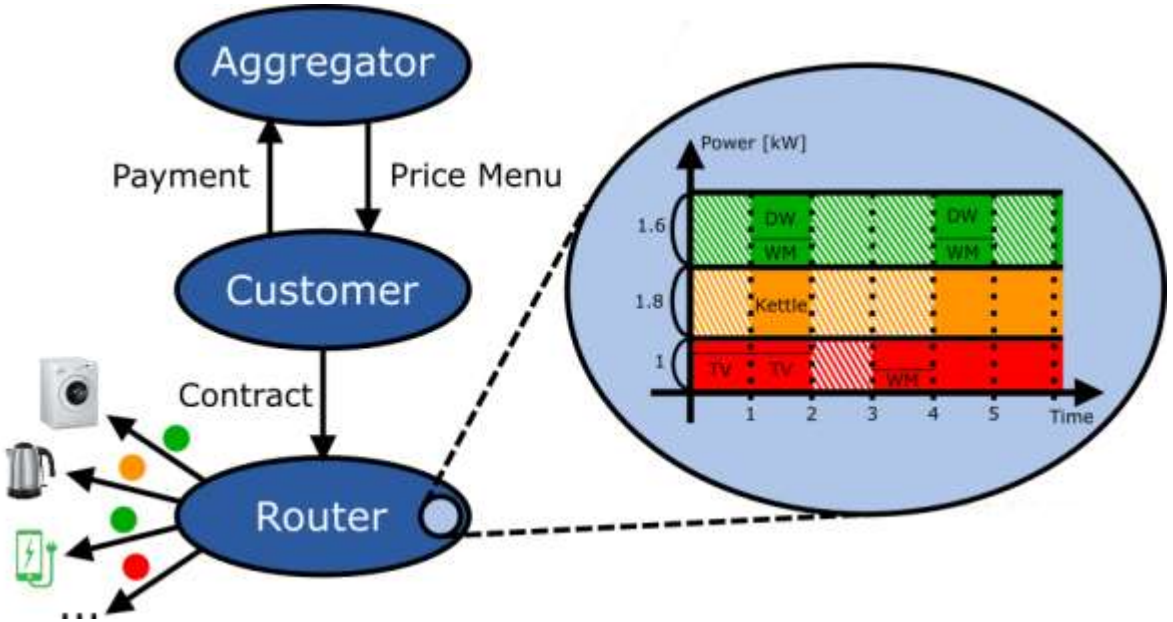
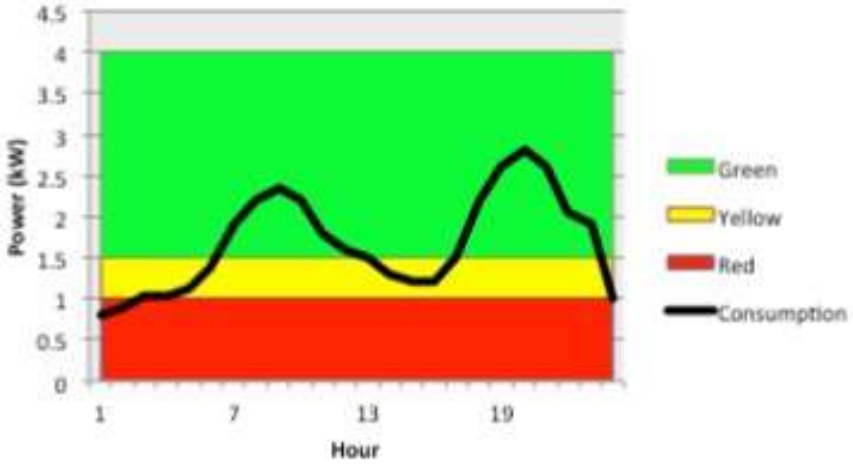
https://sites.google.com/site/gillesbertrandresearch

Color Power

- **Research Goal:** Focus on the application and comparison of **demand response** schemes ***at individual household level***:
  - Compare performance of **Priority Service Pricing** with **Real-Time Pricing** at consumer level by means of a **home energy management system**
  - Infer level of flexibility that can be leveraged without excessively ***impacting consumer's quality of life*** while ***reducing electricity bill***





- **Priority Service Pricing:** Electricity considered as a **service** with **different level of reliability**
- **Research Funding:** Céline Gérard is Aspirant for the Fonds de la Recherche Scientifique – FNRS.
- **Contact Information:**

celine.gerard@uclouvain.be

FREEDOM TO RESEARCH

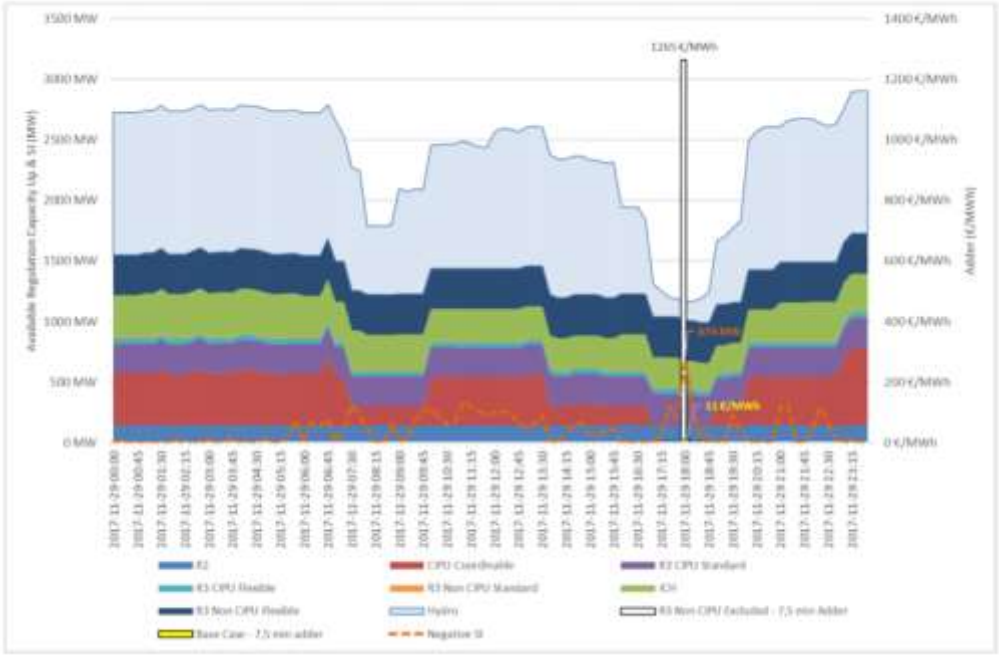
Impact

The Belgian Scarcity Pricing Studies

- **First study (2015)** [1]: How would electricity prices change if we introduce ORDC in the Belgian market?
  - **Finding**: it could enable the majority of combined cycle gas turbines, which are currently operating at a loss, to *recover their investment costs*
- **Second study (2016)** [2]: How does scarcity pricing depend on
  - strategic reserve
  - value of lost load
  - restoration of nuclear capacity
  - day-ahead (instead of month-ahead) clearing of reserves
- **Third study (2017)** [3]: can we take a US-inspired design and plug it into the existing European market?
  - **Finding**: the energy adder in itself will not suffice, the first step is to put in place a *real-time market for reserve capacity*

ELIA Ex-Post Simulation of Scarcity Prices

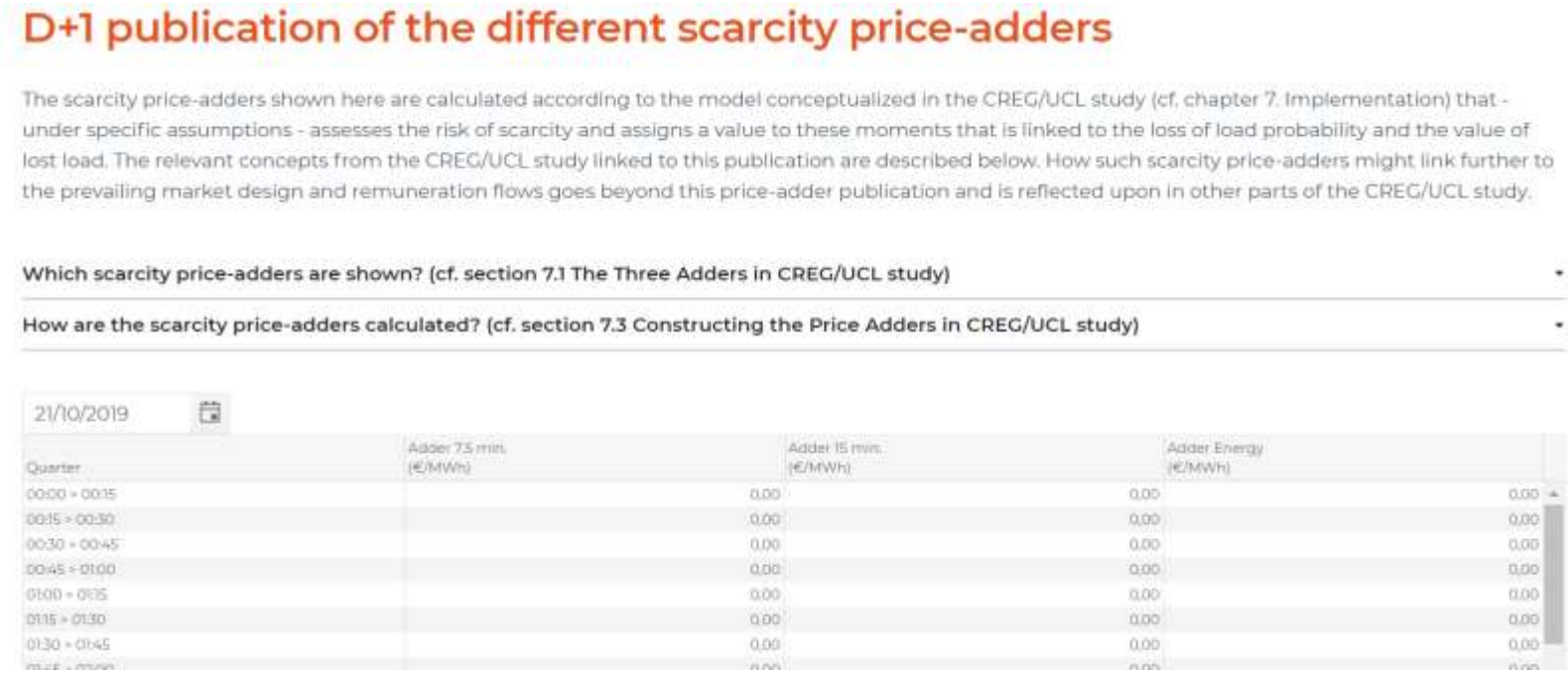
- **ELIA ex-post simulation (2018)** [4]: ELIA (Belgian TSO) releases report on the simulation of scarcity prices in the Belgian market for 2017
  - **Finding**: comfortable year, infrequent occurrence of adders



ORDC adder on November 29, 2017
Source: ELIA [4]

Publication of Scarcity Prices by ELIA

- **ELIA D+1 publication of adders (2019)**: Effective October 2019, ELIA is publishing adders in D+1



D+1 publication of the different scarcity price-adders

The scarcity price-adders shown here are calculated according to the model conceptualized in the CREG/UCL study (cf. chapter 7. Implementation) that - under specific assumptions - assesses the risk of scarcity and assigns a value to these moments that is linked to the loss of load probability and the value of lost load. The relevant concepts from the CREG/UCL study linked to this publication are described below. How such scarcity price-adders might link further to the prevailing market design and remuneration flows goes beyond this price-adder publication and is reflected upon in other parts of the CREG/UCL study.

Which scarcity price-adders are shown? (cf. section 7.1 The Three Adders in CREG/UCL study)

How are the scarcity price-adders calculated? (cf. section 7.3 Constructing the Price Adders in CREG/UCL study)

21/10/2019

Quarter	Adder 7.5 min. (€/MWh)	Adder 15 min. (€/MWh)	Adder Energy (€/MWh)
00:00 > 00:15	0,00	0,00	0,00
00:15 > 00:30	0,00	0,00	0,00
00:30 > 00:45	0,00	0,00	0,00
00:45 > 01:00	0,00	0,00	0,00
01:00 > 01:15	0,00	0,00	0,00
01:15 > 01:30	0,00	0,00	0,00
01:30 > 01:45	0,00	0,00	0,00

Source: ELIA https://www.elia.be/en/electricity-marketand-system/adequacy/scarcity-pricing-simulation

ARPA-E Grid Optimization Competition

- In 2018, the Secretary of Energy of the United States, Rick Perry, announced the ARPA-E Grid Optimization competition: https://www.youtube.com/watch?v=hZwX3P9vS8M
- The first phase of the competition was aimed at solving the security constrained optimal power flow problem
- Ignacio Aravena (former group member) and his team placed first in the competition, and received recognition by ARPA-E for their significant margin: https://gocompetition.energy.gov/kudos-livermore

arpa·e
CHANGING WHAT'S POSSIBLE

Lawrence Livermore National Laboratory

Consulting and Trainings