About myself

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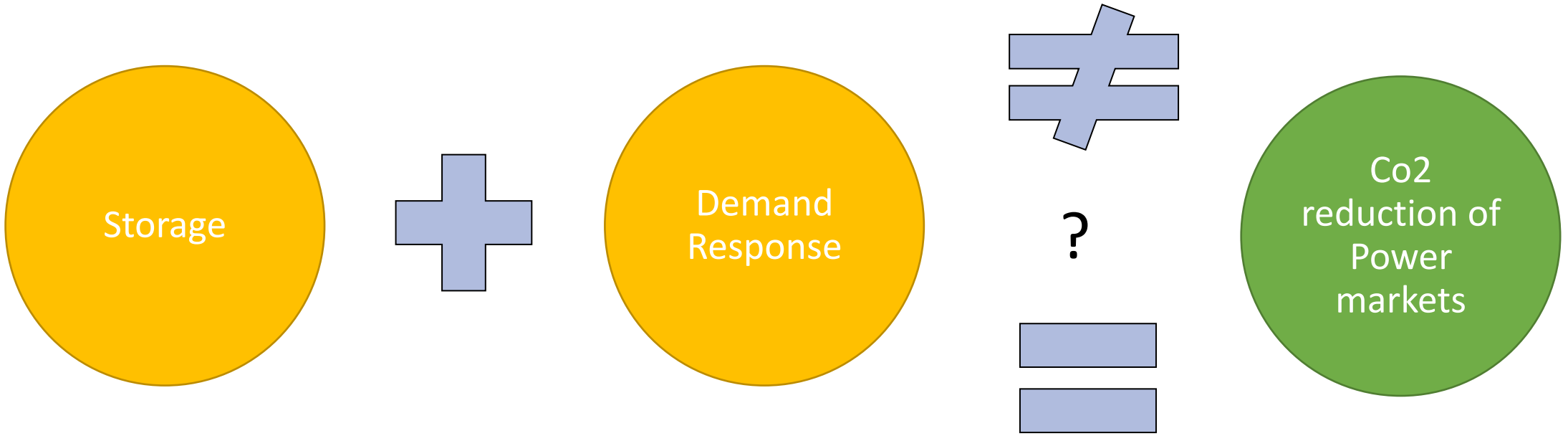
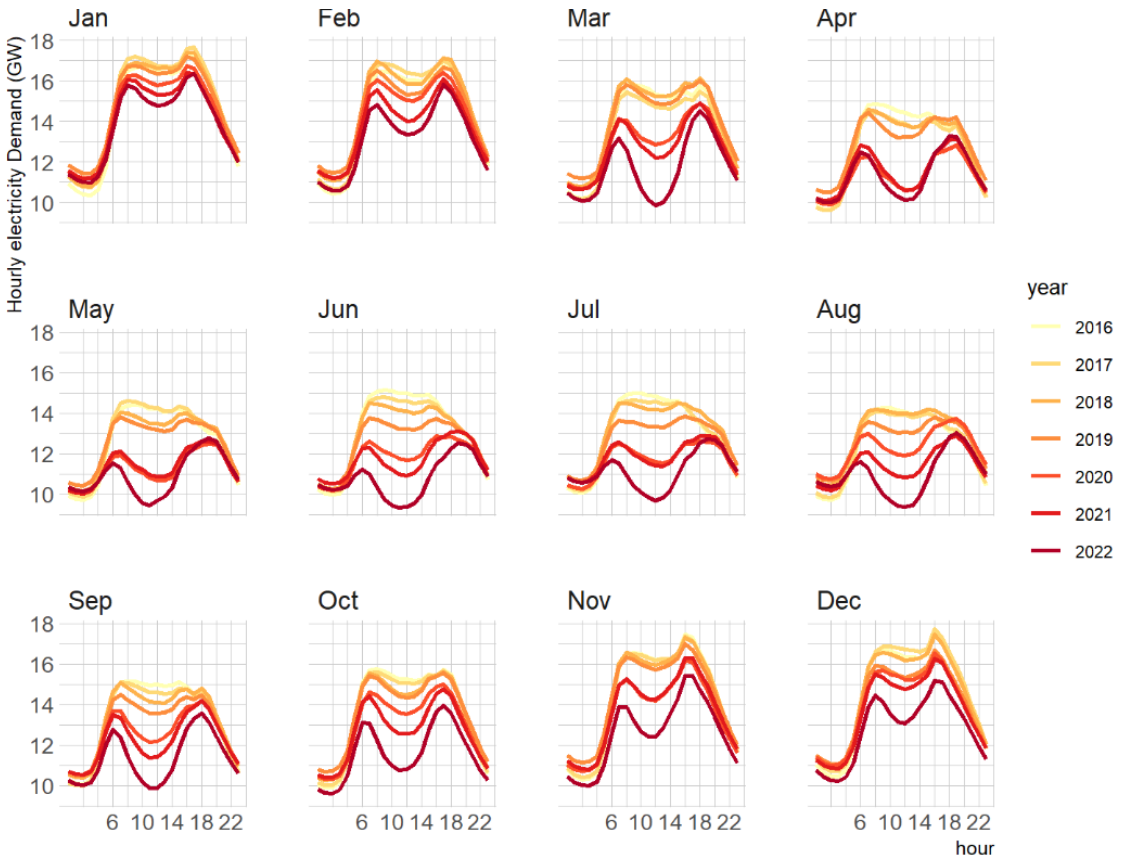


Rotterdam School of Management
Erasmus University

When Load shifting increases Co2 emissions: Environmental impact of load shifting and political instruments

C. Dupont, Y. Ghiassi Farrokhfal, D. Bunn, O. Kuryatnikova

Motivations : Need for low-carbon flexibility



Duck curve for the NL, Matteo de Felice

Load shifting agents

- ✓ Storage
- ✓ Demand response

Participation In DA market by price arbitrage:

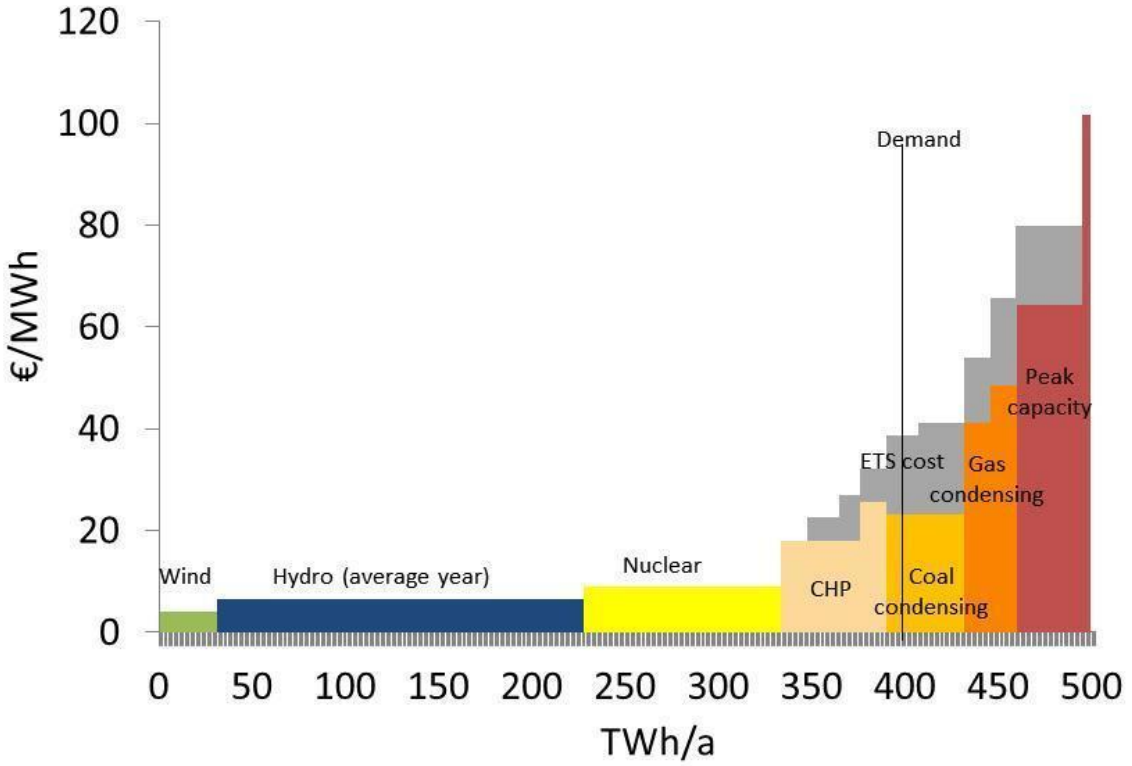
=> Effect on Carbon emission ?

Mechanisms influencing LSA Co2 emissions

1. Efficiency

2. Shape Marginal emission curve

Interrelated influence

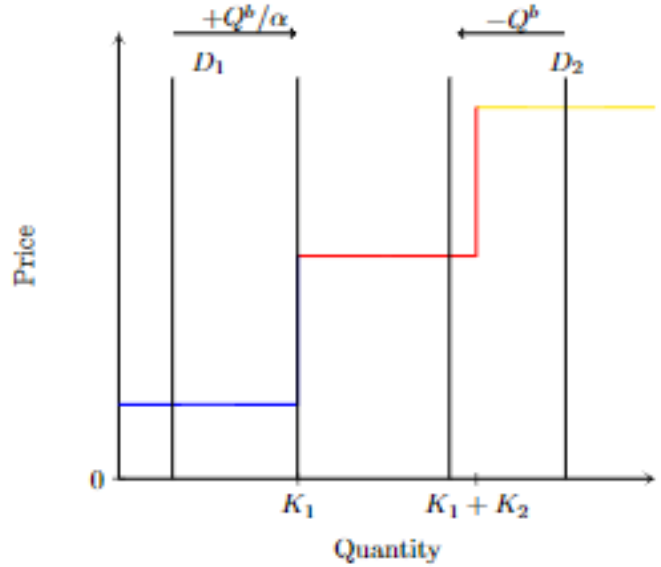


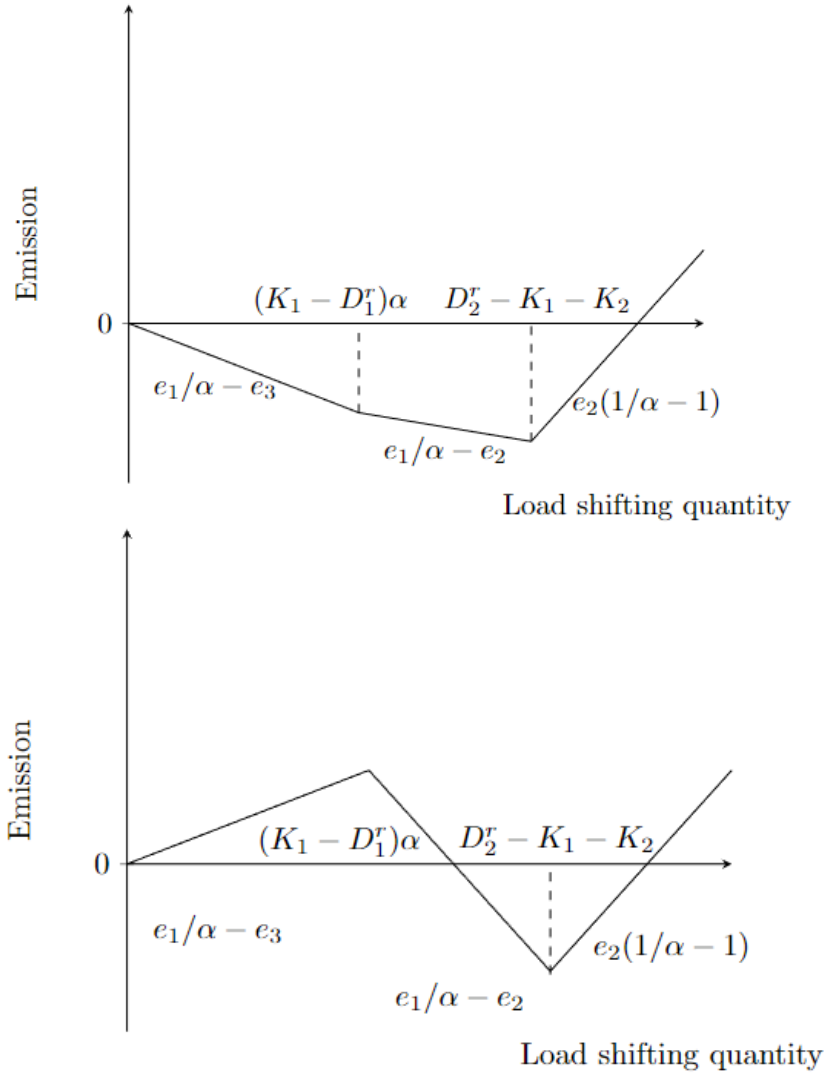
Our study

- Stylized model :
  - Conditions for controlling Co2 emissions of LSA at level P
  - Policy recommendation to control Co2 emissions : Taxes and capacity cap

- Numerical Analysis :
  - Data from DA market Netherlands 2019 and 2022
  - Simulation of different LSA
  - Emission impact
  - Evaluation of our solutions

Analytical formulation : stylized model



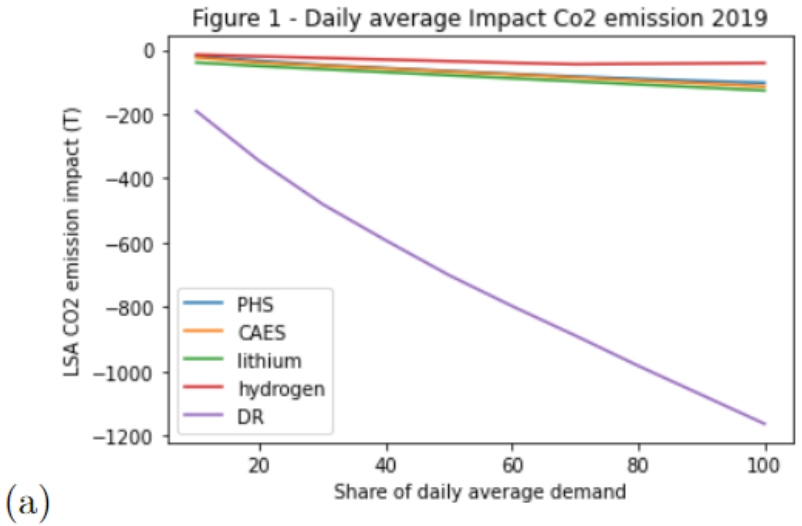


Our results:

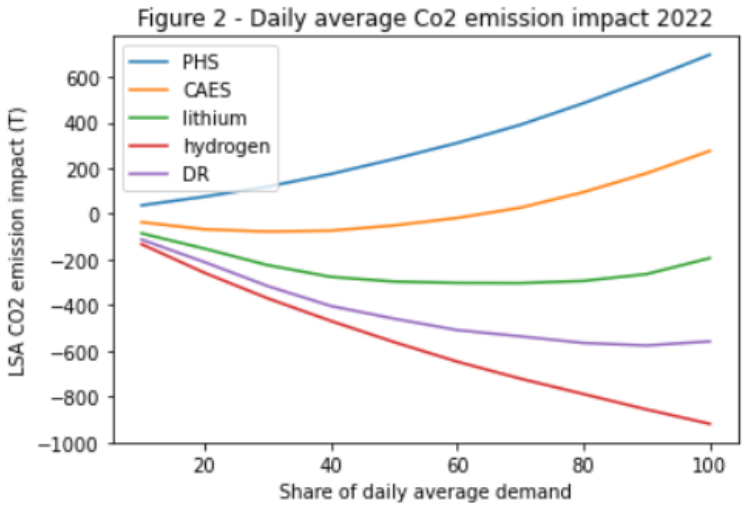
- ✓ Multi period can be decomposed into a finite nb of two periods
- ✓ Conditions for controlled pollution rate P:

1. Non decreasing marginal emission curve
2. $$\frac{\mathcal{E}(Q_t)}{\eta} - \mathcal{E}(Q_u) \leq P.$$

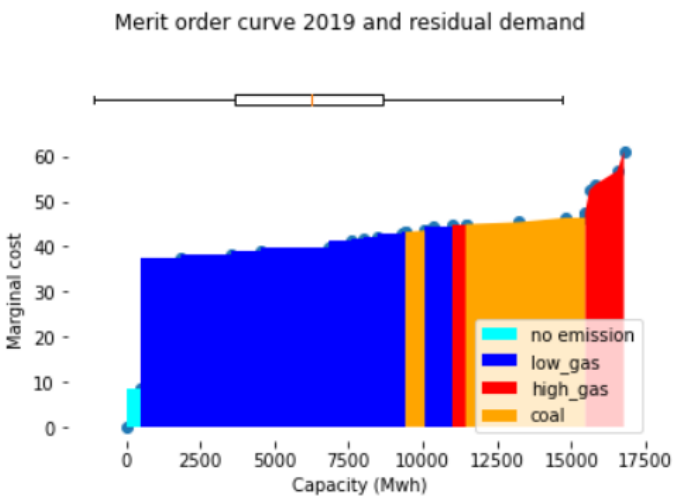
Co2 impact of LSA : Illustration



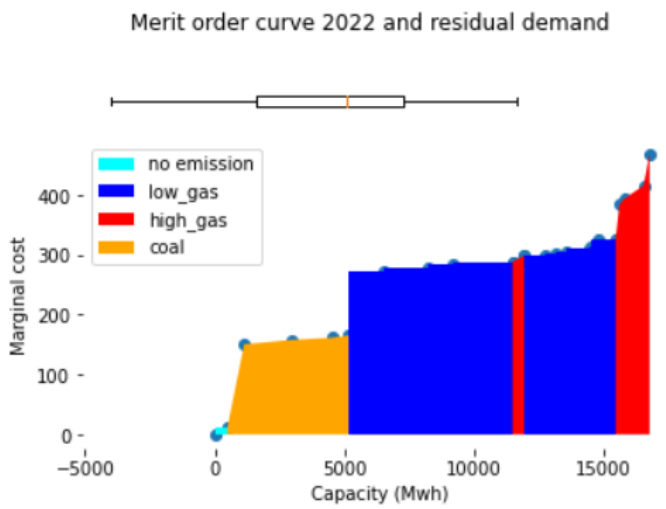
(a)



(b)

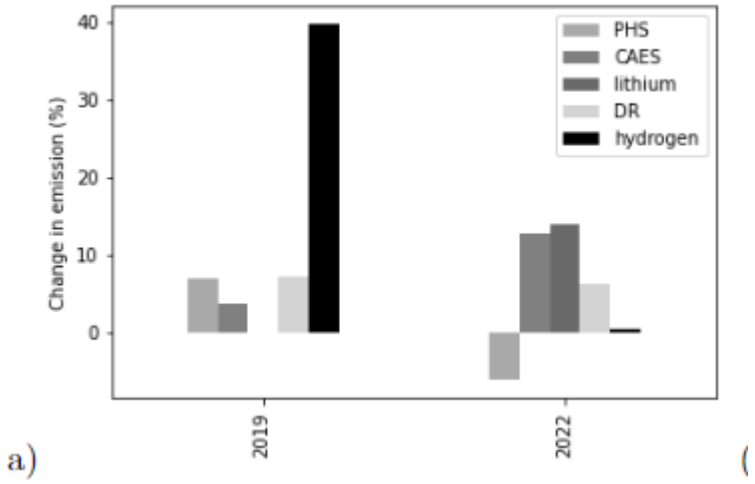


(a)



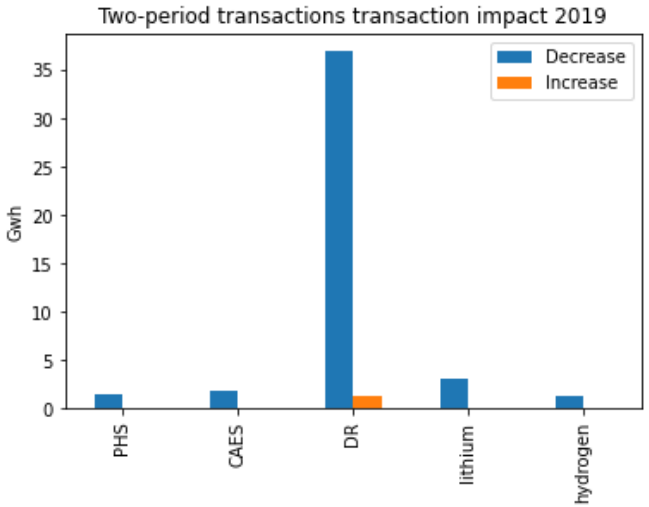
(b)

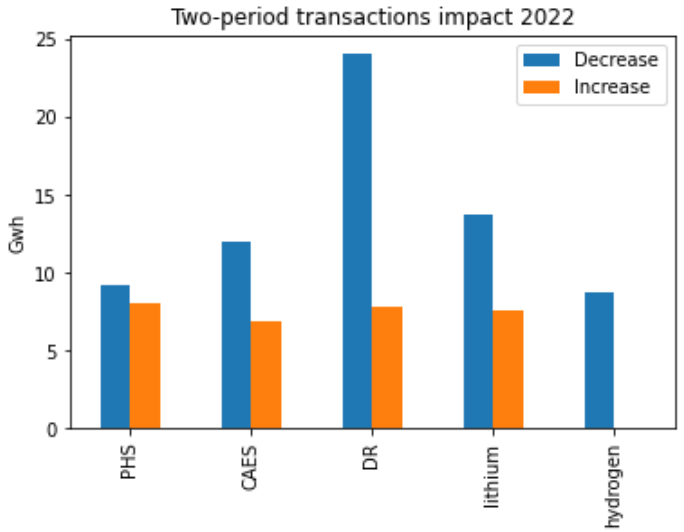
Co2 impact of LSA : Illustration



Comparison strategic versus non- strategic

LSA (Capacity 100%
Daily average demand)



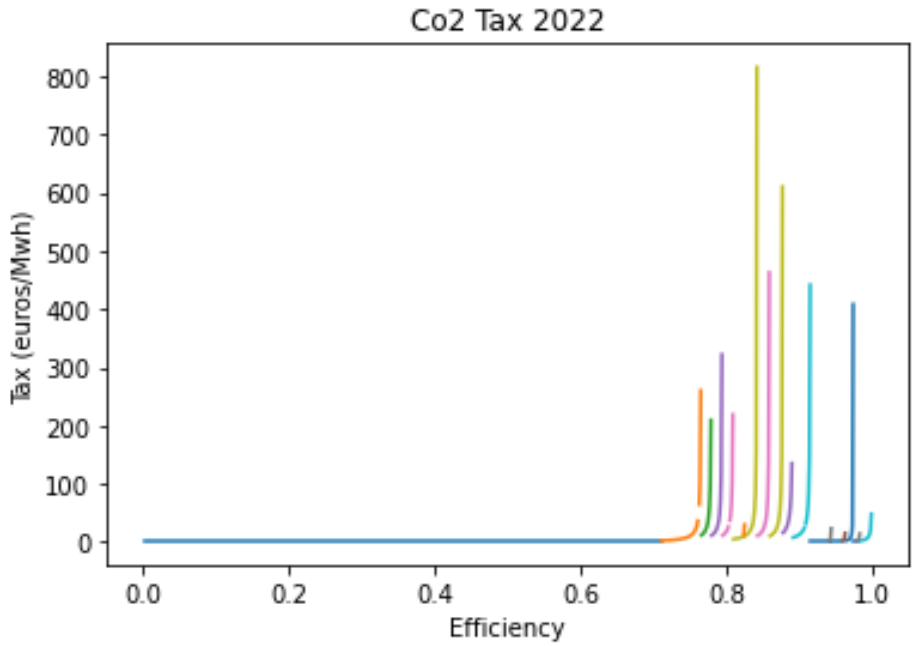


Solution 1: Co2 Tax

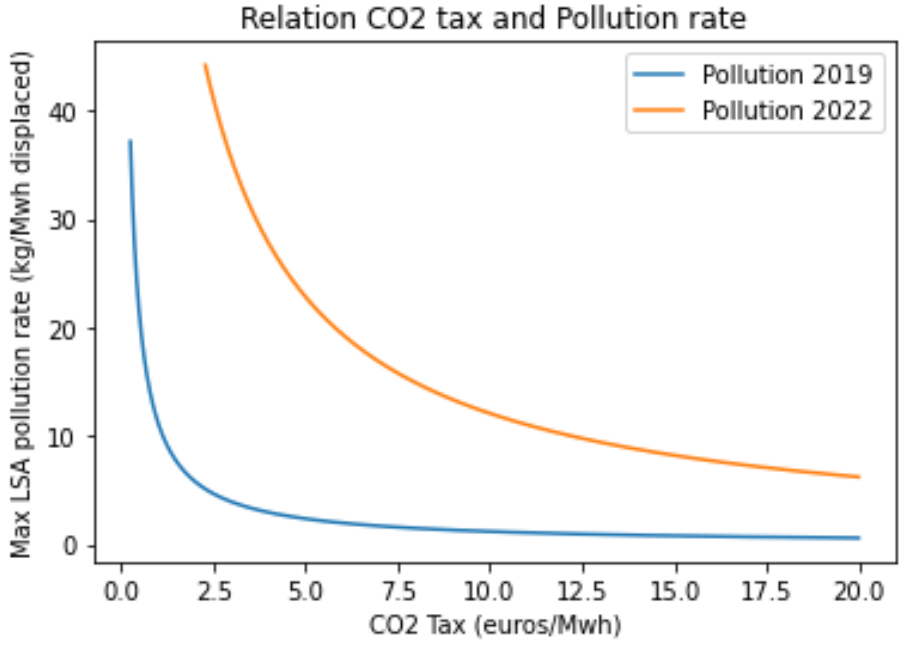
2 parts: ordering generators & unprofitable polluting transactions

⇒ max tax among all two possible two period transactions.

⇒ Dependent on marginal emission, marginal cost coefficients (and efficiency)



Formulation depending on efficiency, P=0

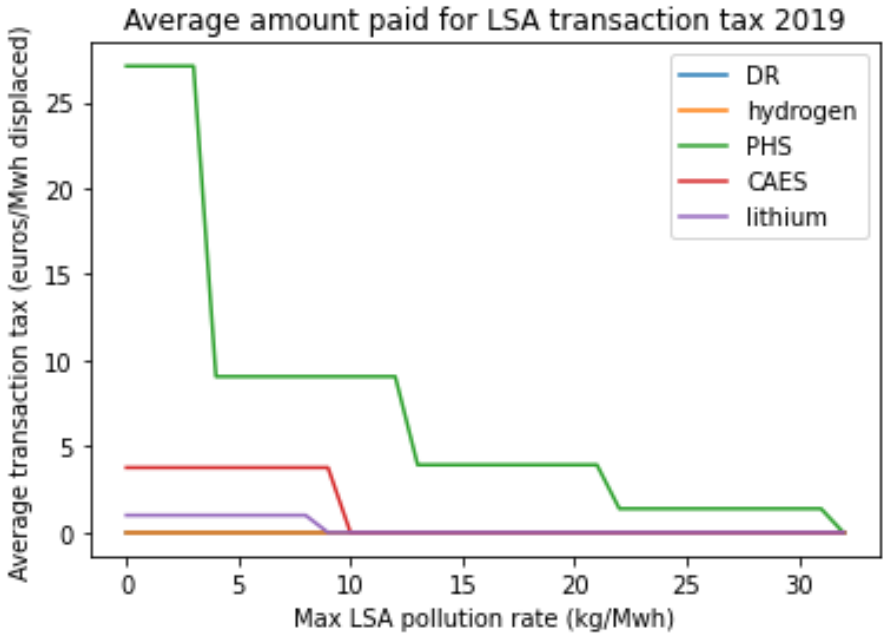


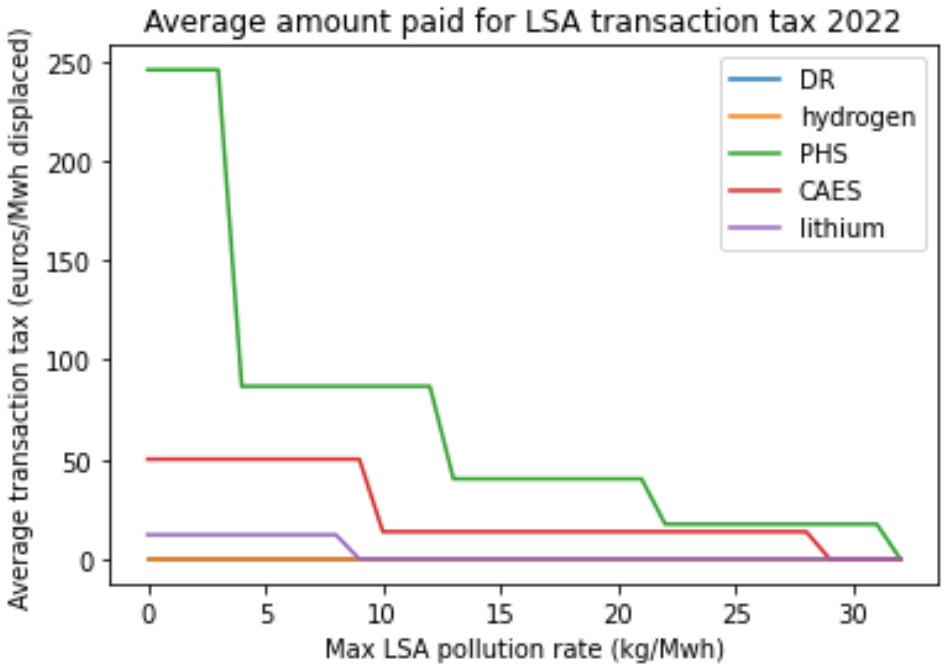
Formulation for all efficiency level

Solution 2: Transaction Tax

Works only with non decreasing marginal emission curve
Set such that polluting transactions are non profitable anymore

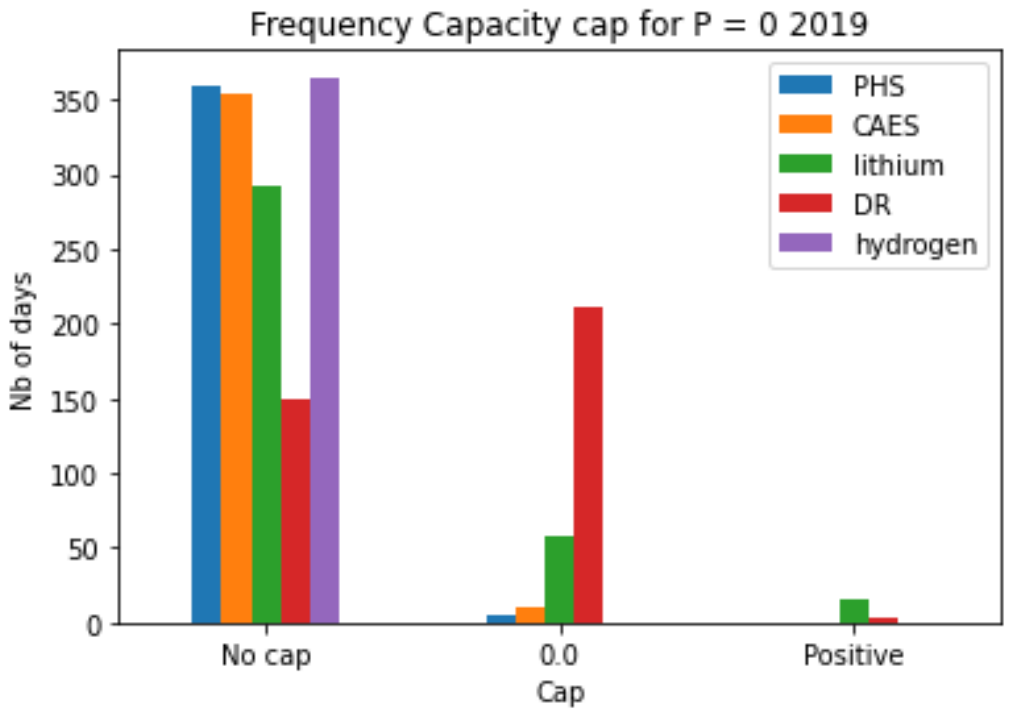
$$\theta \mathbf{v}^{+}_{t,u} / (C^{int}_{u} - C^{int}_{t})$$

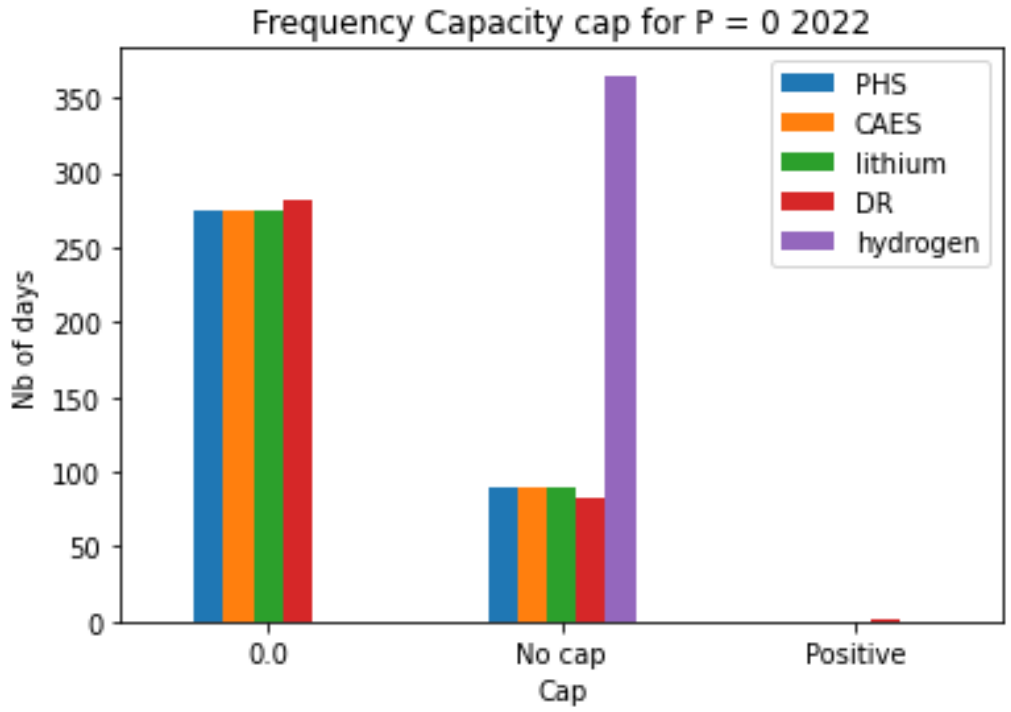




Solution 3: Capacity Cap

Set for each period of arbitrage: minimum quantity such that any feasible, profitable and polluting transaction is impossible

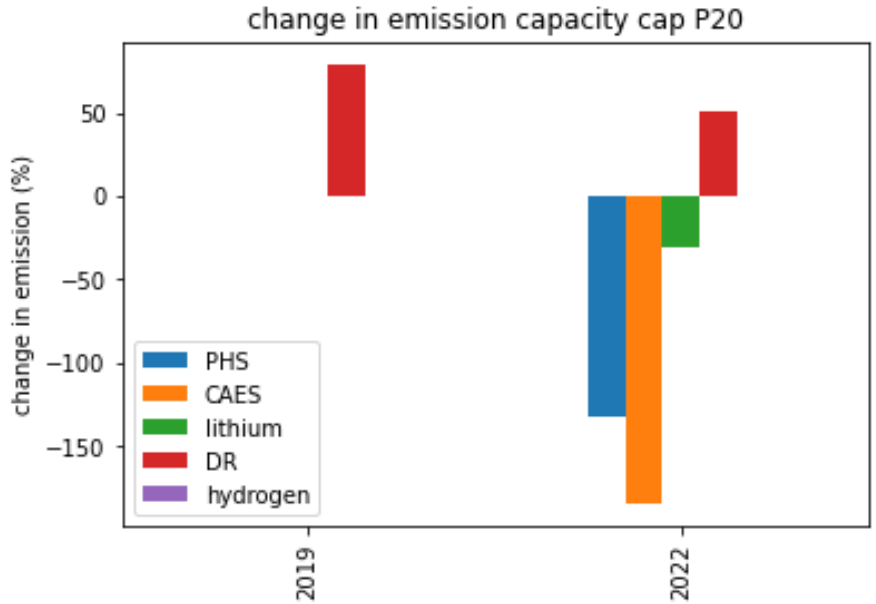




Comparison of the solutions

Factor \Solution	Co2 Tax	Transaction Tax	Capacity Cap
Discrimination among LSA	No	Yes	Yes
Dependency	Fuel cost, Gen Cap.	Fuel Cost	Demand, Gen Cap
Solution Time frame	Once	Once	Review period
Reduction Co2	1	2	3
Finite solution	No	Yes	Yes
Market impacts	Higher prices	Lower LSA profit	Lower LSA profit
Non decreasing $\mathcal{E}(Q_\iota)$	Done by the tax	pre-required	Not required

Table 2 Comparison of solution against LSA Co2 pollution



Conclusion

Our contributions

- Formalize analytically LSA impact on Co2 emissions
- Proposing and evaluating different solutions to control LSA pollution
- Studying the impact of different LSA on the Dutch day-ahead market

Next:

Expand the numerical analysis to larger samples

Compare solutions and evaluate in more complex settings (ramping constraints, self discharge, …)

Thank you for your attention

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Literature review

Azevedo, Hittinger (2015)	In most US sub-grid, negative impact (efficiency dependent)
Arciniegas, Hittinger (2018)	Co2 tax reduce negative impact of Storage
Goteti et al. (2019)	NYISO : **+** , MISO: With more renewable
Arbabzadah et al. (2019)	Storage help RES to reduce emission (California, Texas)
Craig et al. (2018)	ERCOT : **-** now, **+** from 2035/2045
Goteti et al. (2021)	Price Taker ≠ Price Maker
Carson, Novan (2013)	Theoretical model: $\frac{e\prime(Q_o)}{e\prime(Q_p)} < (1-\alpha)$