Evaluation of the Need for Capacity Remuneration Mechanisms: Impact of Design Parameters and Key Assumptions

ELDEST

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Outline

1. Introduction
2. Research question
3. Methodology
4. Case study
5. Conclusions
6. Outlook

Introduction

- Due to concerns on generation adequacy, many European countries have installed or are planning to install a capacity remuneration mechanism (CRM)
- The element of uncertainty and risk has become an increasingly important element in the discussions surrounding CRMs
- If agents behaive risk-averse, private interests in an energy-only market diverge from the public interest [1]:
  - risk-averse generation company favour investing in less capacity than to rely on the highly uncertain revenues coming from price spikes during scarcity situations
  - from a public perspective, it is less costly to have a little bit of excess capacity than to have to pay the high social costs of load curtailment

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Research questions

- Do possible **demand elasticities** (emergency measures, active demand response) diminish the need for additional capacity remunerations?

- How does the choice of the **target capacity demand** effects the generation adequacy and total system costs?

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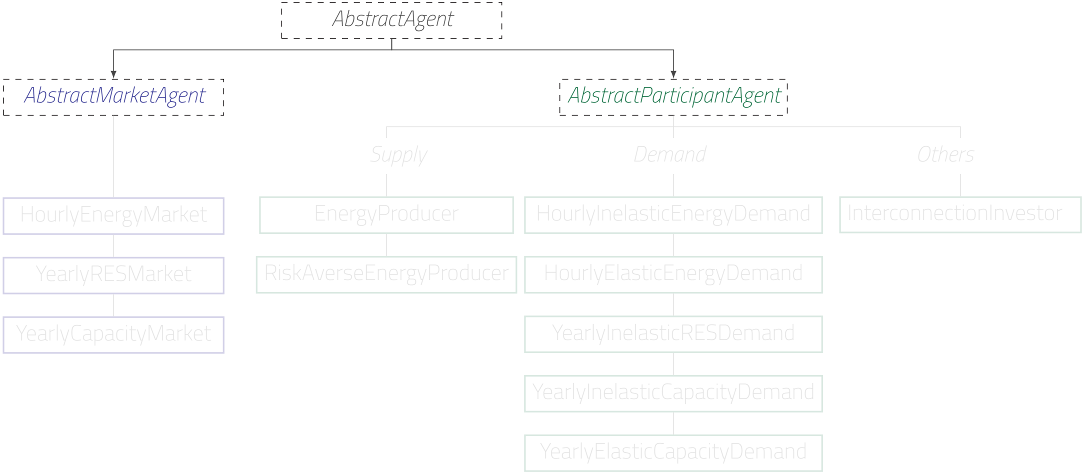
Energy poLicy DEcision Support Toolbox (ELDEST)

- dynamic long-term equilibrium (and agent-based) model for energy systems and markets
- data driven model generation ("plug and play" agents)
- equipped with versatile algorithms that match the challenges of the studied case
- solver independent (julia, JuMP)
- Link: https://www.energyville.be/en/research/eldest-energy-policy-decision-support-toolbox

Model assumptions

- no agent behaves strategically taking other agents decisions into account
- all agents are perceiving the same price (producer agents are price takers)
- no other market distortions (except capacity market and the price cap on energy market)

Agent hierarchy



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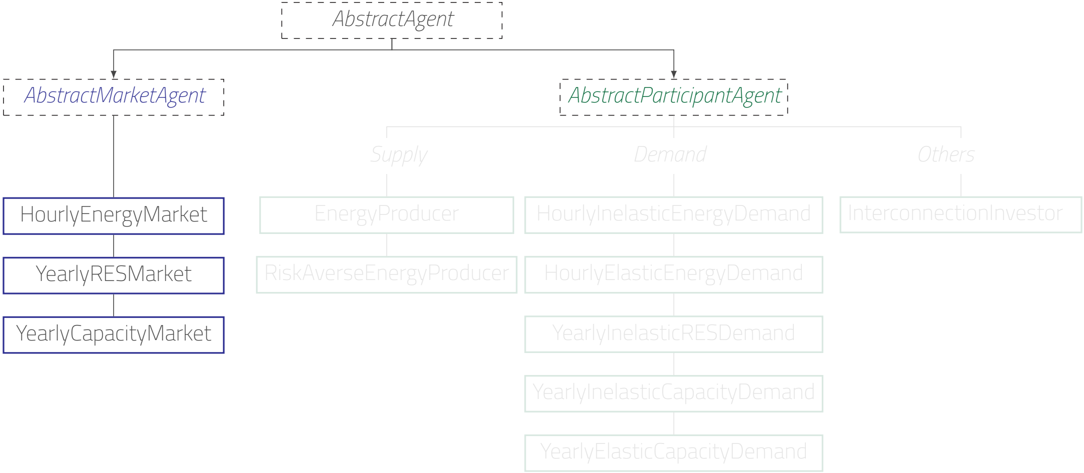

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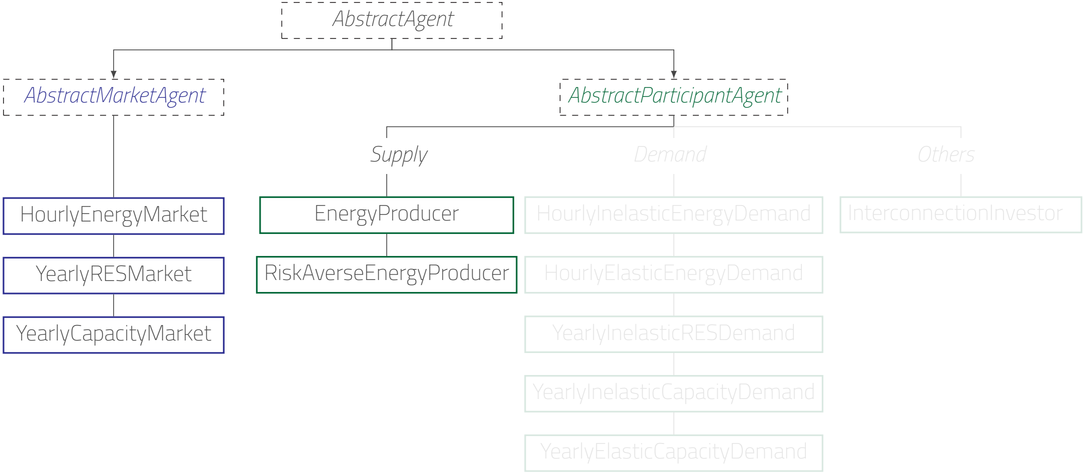

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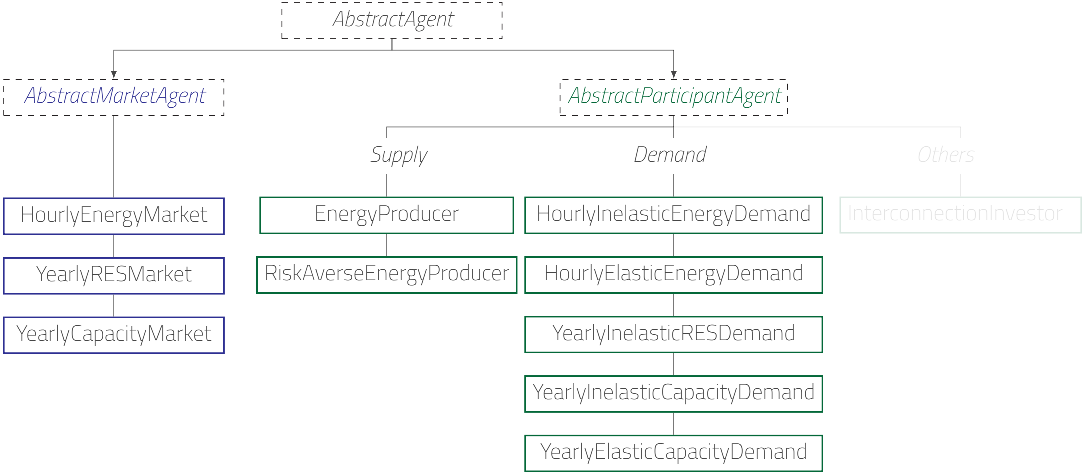

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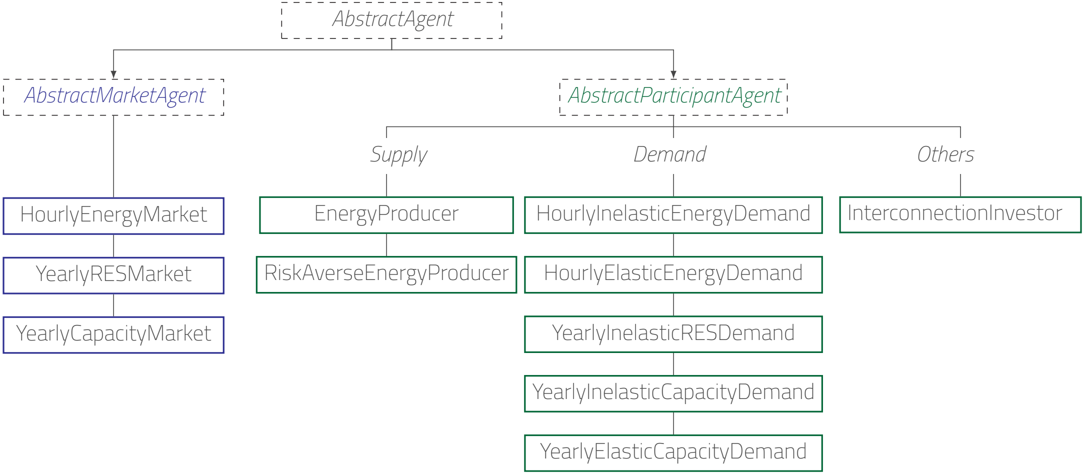

Different agents with different objectives

AbstractMarketAgent

- Utility:
  - Minimize excess demand
- Decision variables:
  - Market price
- Set of Strategies:
  - Defined by price floor and cap

$$\min_{\text{Price}} \text{Price} \cdot \text{Volume}$$

s.t.

$$\text{Price floor} \leq \text{Price} \leq \text{Price cap}$$

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Endogenous formulation to determine the V@R and select the scenarios taken from [5]:

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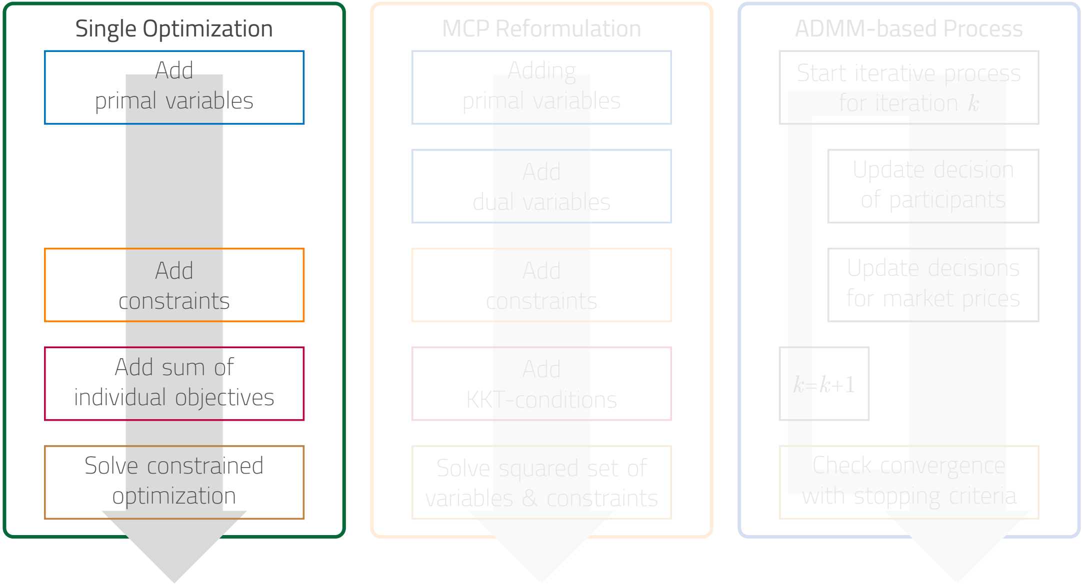

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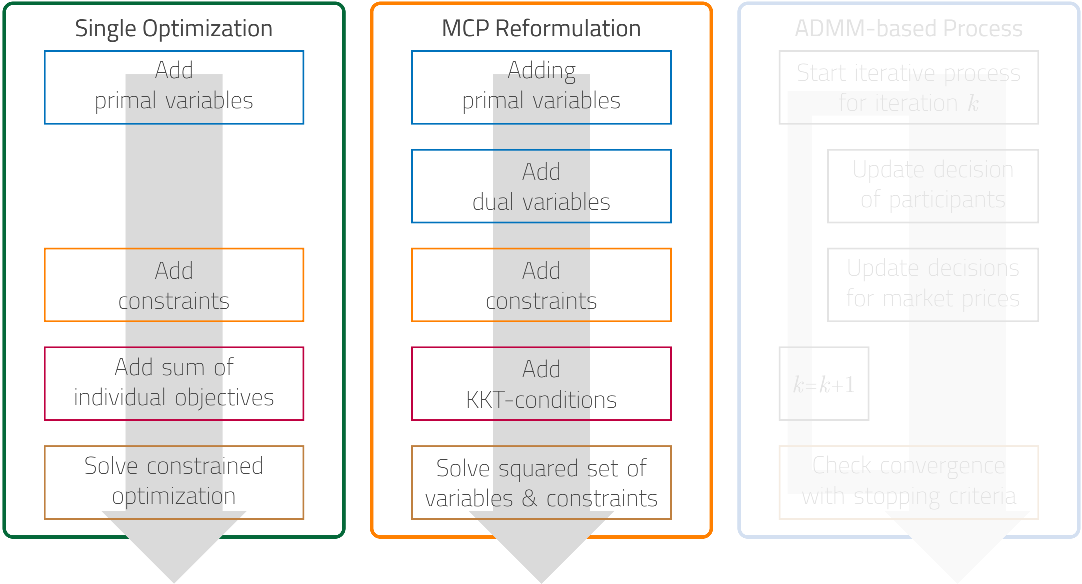

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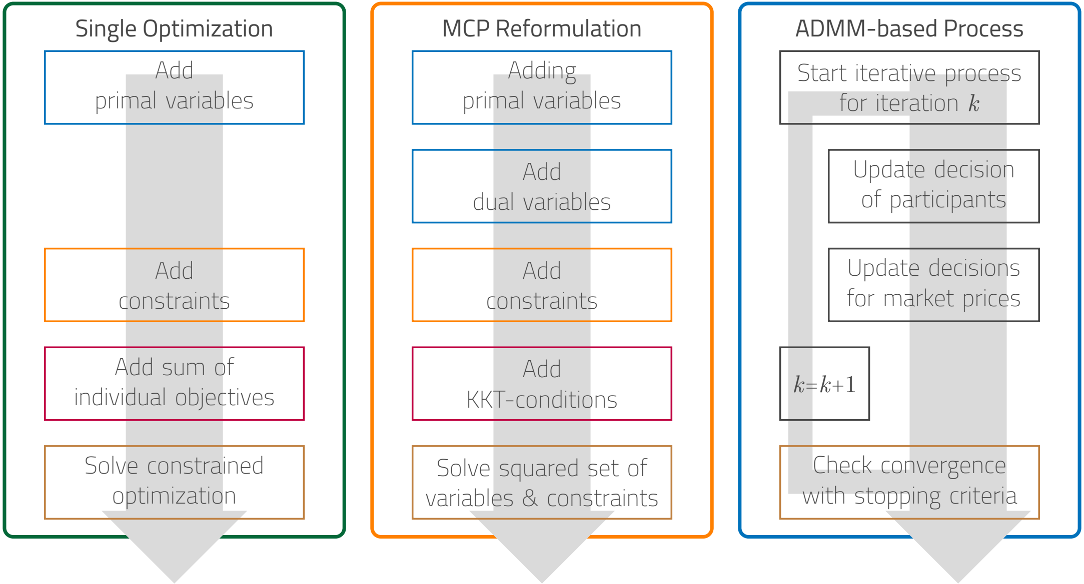

Alternating Directions of Multiplier Method (ADMM) [2, 6]

- Risk-averse energy producer's update step:

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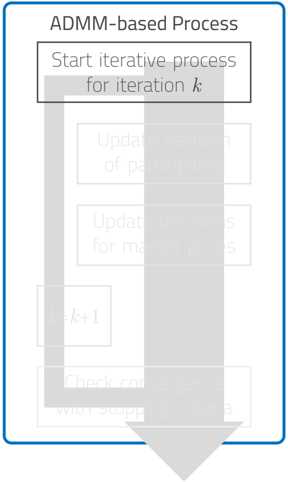

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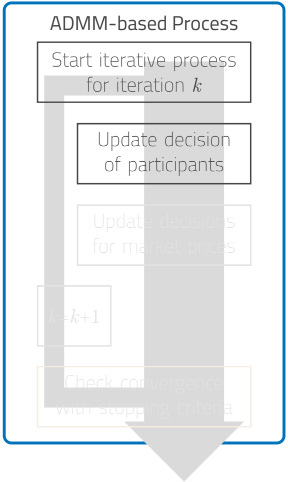

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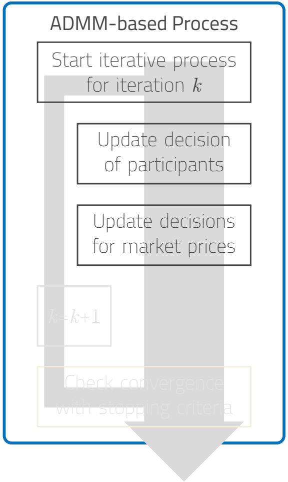

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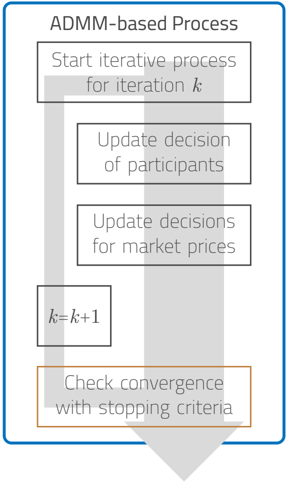

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Methodological Case: Setup

- Greenfield study, optimization horizon 1 year
- Data
  - Load demand data ENTSO-E 2017 (3 representative days)
    - Peak hour considered with a weight of 1h
  - Wind and solar availability ELIA 2017 (3 representative days)
  - Technologies: Nuclear, CCGT, OCGT, Wind (on-, offshore), PV [7]
- Markets
  - Day-ahead (DA) market for energy
    - price cap at 3000€/MWh
  - Centralized capacity market (comparable to GB market)
  - Market for renewable energy certificates
    - demand set inelastic to 18.3% of the yearly energy demand
- Agents
  - One market and demand agent each market
  - one risk averse energy producer (**Portfolio optimization**)

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Optimization parameters and Scenario overview

Technology Parameter[7]

Technologies	Inv. costs in k€/MW	Efficiency	FOM in k€/MW	VOM in €/MWh	Life time in a	Cap. factor	renewable factor
Nuclear	5000[1]	*2	91.35	2.5	40	1	0
CCGT	850	0.6	21.25	2	30	1	0
OCGT	550	0.38	16.5	11	30	1	0
PV	800	0	13.6	0	25	0.0	1
Wind Offshore	2280	0	92.16	0	25	0.12	1
Wind Onshore	1350	0	32.4	0	22	0.25	1

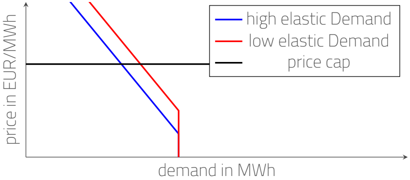
[1] assumed

[2] fuel costs / efficiency = 9.42€/MWh

Scenario definition

Scenario	Gas costs in €/MWh
S01	40
S02	80

Elastic energy demand



First/preliminary results: How does energy demand elasticity affect the need for capacity markets?

Capacities in MW	DA, RES Market		DA, RES, CCM $(D^{CAP}/P^{DA}_{Peak} = 1)$	
Energy demand	inelastic		inelastic	
	risk-averse	risk-neutral	risk-averse	risk-neutral
Nuclear	3352.5	7941.9	4160.0	7934.0
CCGT	5887.7	1453.7	5840.8	1555.2
OCGT	437.8	176.9	2845.4	3594.0
PV	6218.3	7895.8	0.0	6973.3
WindOffShore	2854.3	2379.4	4614.9	2640.6
WindOnShore	0.0	0.0	0.0	0.0
total therm. cap.	9678	9572.5	12846.2	13083.2
Load curtailment in MWh	41460.5	42150.4	0.0	0.0
System costs in M€	7405.9	7790.7	7596.5	7984.0

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- Risk averse energy producer tend to install more gas fired power plants (low fuel price scenario is considered as worst case, because revenues of nuclear/wind/PV is more sensitive to gas prices than revenue of gas-fired power plants)
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- In the DA, RES, CCM case no demand is curtailed, as the installed (and available) capacity corresponds to the peak demand
- Changing the demand elasticity in shown cases did not change in installed capacity (as long as there is curtailment, not shown in the previous slide)
- With increasing demand elasticity less demand is curtailed without CCM

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Energy demand	inelastic		low elastic		high elastic	
	risk-averse	risk-neutral	risk-averse	risk-neutral	risk-averse	risk-neutral
Nuclear	4253.9	7932.9	4282.0	7932.9	4160.0	7933.9
CCGT	5623.8	1555.6	5615.6	1555.6	5840.8	1555.2
OCGT	1662.7	2254.9	1637.3	2254.9	1505.4	2254.0
PV	1006.7	6979.4	844.1	6979.4	0.0	6973.3
WindOffShore	4329.9	2638.8	4375.9	2638.8	4614.9	2640.5
WindOnShore	0.0	0.0	0.0	0.0	0.0	0.0
total therm. cap.	11540.4	11743.4	11534.9	11743.4	11506.2	11743.1
Load curtailment in MWh	10995.1	6118.0	0.0	0.0	0.0	0.0
System costs in M€	7498.6	7882.7	7497.9	7882.7	7494.7	7882.7

If capacity target is just getting binding:

- Risk-averse Energy Producer install less peak load powerplants (OCGT), PV and Nuclear and more WindOffShore and CCGT with increasing demand elasticity

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total therm. cap.	11540.4	11743.4	11534.9	11743.4	11506.2	11743.1
Load curtailment in MWh	10995.1	6118.0	0.0	0.0	0.0	0.0
System costs in M€	7498.6	7882.7	7497.9	7882.7	7494.7	7882.7

If capacity target is just getting binding:

- Risk-averse Energy Producer install less peak load powerplants (OCGT), PV and Nuclear and more WindOffShore and CCGT with increasing demand elasticity

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First/preliminary results: How does energy demand elasticity affect the need for capacity markets?

DA, RES, CCM Market (D^{CAP} / P^{DA}_{Peak} = 0.9). Capacities are given in MW.

Energy demand	inelastic		low elastic		high elastic	
	risk-averse	risk-neutral	**risk-averse**	risk-neutral	**risk-averse**	risk-neutral
Nuclear	**4253.9**	7932.9	**4282.0**	7932.9	4160.0	7933.9
CCGT	**5623.8**	1555.6	**5615.6**	1555.6	5840.8	1555.2
OCGT	**1662.7**	2254.9	**1637.3**	2254.9	1505.4	2254.0
PV	**1006.7**	6979.4	**844.1**	6979.4	0.0	6973.3
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First/preliminary results: How does the choice of a target capacity impacts generation adequacy and system costs?

DA, RES and CCM Market, inelastic energy demand. Capacities are given in MW

$\frac{D^{CAP}}{P^{DA}_{Peak}}$	0.95		1.0		1.05	
	risk-averse	risk-neutral	risk-averse	risk-neutral	risk-averse	risk-neutral
Nuclear	4264.1	7934.0	4160.0	7934.0	4160.0	7932.9
CCGT	5648.6	1555.2	5840.8	1555.2	5840.8	1555.6
OCGT	2288.0	2924.0	2845.4	3594.0	3515.4	4264.9
PV	720.2	6973.3	0.0	6973.3	0.0	6979.4
WindOffShore	4411.0	2640.5	4614.9	2640.6	4614.9	2638.8
WindOnShore	0.0	0.0	0.0	0.0	0.0	0.0
Total therm. cap.	12200.7	12413.2	12846.2	13083.2	13516.2	13753.4
Load curtailment in MWh	2590.62	1380.36	0.0	0.0	0.0	0.0
System Costs in M€	7548.6	7933.6	7596.5	7984.0	7646.6	8034.1

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First/preliminary results: How does the choice of a target capacity impacts generation adequacy and system costs?

- In a risk-averse and risk neutral setting more OCGT (peak load powerplant) capacity is installed with increasing capacity target
- Demand curtailment does not occur from on cap target of $D^{CAP} / P^{DA}_{Peak} = 1$
- Due to increasing installed capacity the system costs increase with increasing capacity targets

Conclusions and key messages

- First version of ELDEST with risk-averse agents has been implemented
- Proof of concept und working principle could be shown with methodological case study
  - Setting the capacity target to the peak demand prevents energy not served (aligns with [6])
  - With higher risk aversion the expected costs are increasing (aligns with [6])
- In the preliminary results increasing energy demand elasticity did not show effect on installed capacities as long as load is being curtailed (or the capacity target is not binding)
- With increasing capacity targets more peak load technology is installed

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Outlook and next steps

- Convergence of ADMM algorithm is highly sensitive to ρ (setting the price update step right)
  - How to scale linking constraints and set the price update step right?
- High runtime restricts higher temporal resolutions
  - Handle computational complexity by exploring and advancing different solution techniques (including decomposition techniques for agents update step)

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