CO_2 prices and system costs - a multi-scenario analysis with an agent-based electricity market model

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Strommarkttreffen, 25.10.2019

Supported by

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Use of agent-based models in energy sciences

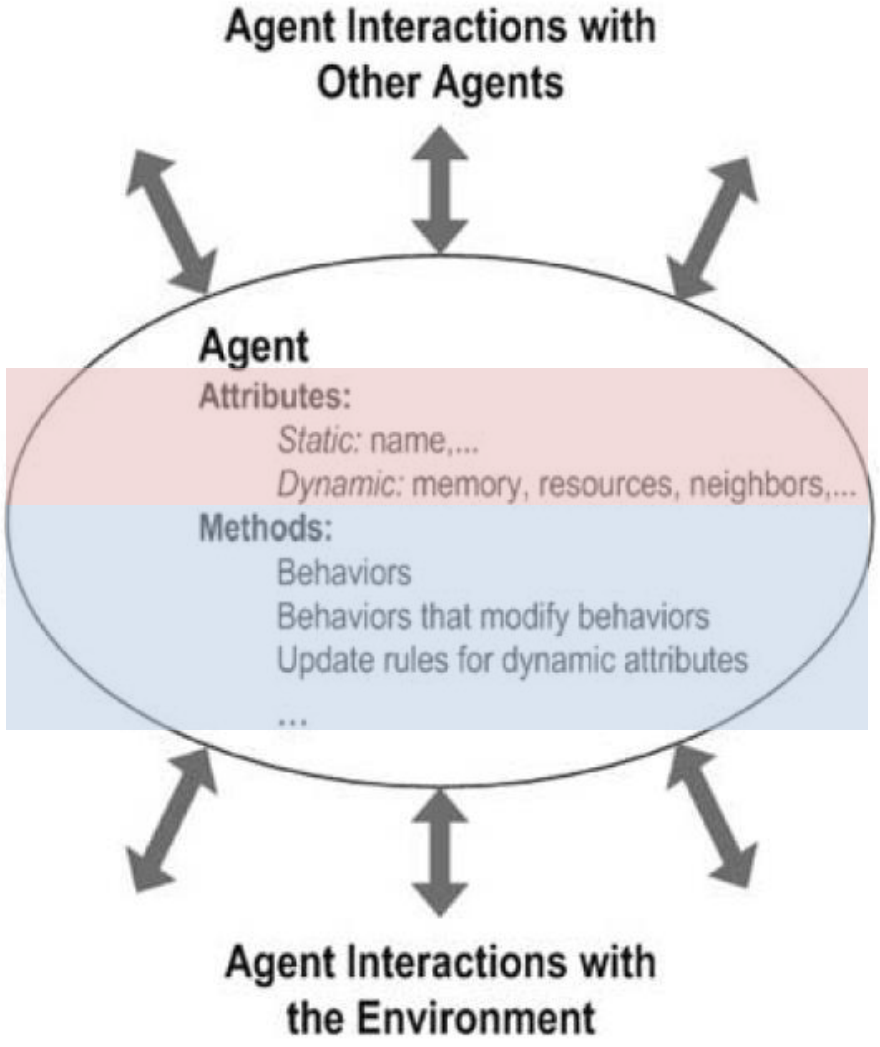
Agents:

Attributes + Methods (+ Interfaces)

Central: Behaviors / decision rules

Decision rules can be based on **any** model

- Logic (if… , then…; else…)
- Machine learning algorithm
- System dynamics model
- Dispatch model
- …



Macal & North 2010 - Tutorial on agent-based modelling and simulation, *Journal of Simulation, 4*, 151 - 162

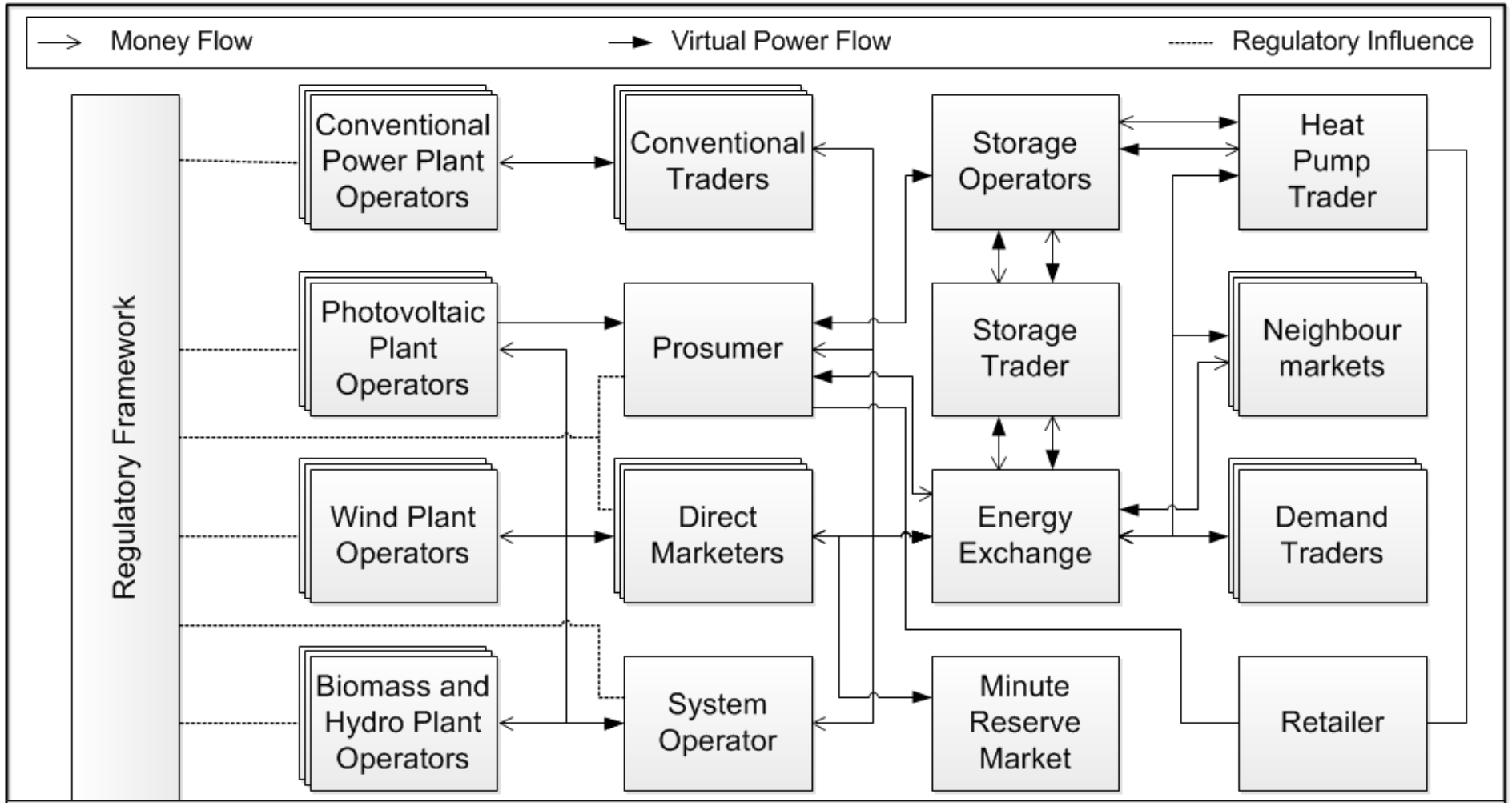
AMIRIS architecture

Input

- RE generation
- Load curves
- Power plants
- Efficiencies
- Availabilities
- Fuel costs
- CO_2 prices resp. CO_2 cap

Output

- DA electricity price
- Power plant dispatch
- Storage dispatch
- Market values
- CO_2 emissions resp. CO_2 prices
- System costs



Advantages of AMIRIS

AMIRIS can incorporate:

- „Non-rational“ decision rules
- Policy rules
- Market distortions

AMIRIS allows us to:

- Study emerging effects on power markets
- Yield exactly the same results as optimization model if parametrized the same way

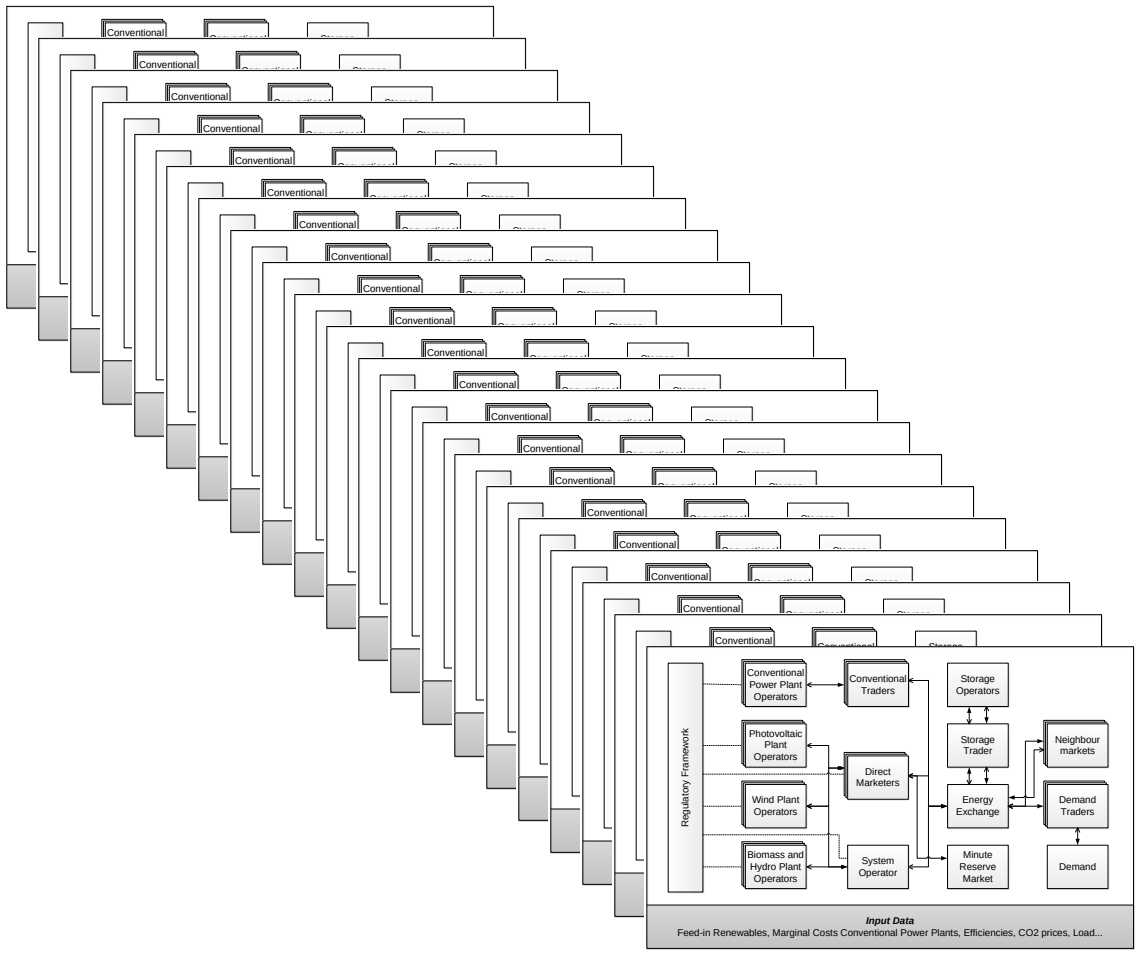
Fast: 10 s/per model year on a standard Laptop with 8 GB RAM

Multi-scenario analysis – exploring the possibility space of power markets

	Low	Mid	High
CO2 price [€/t]	5	50	100
Electricity demand [%/a to 2016]	-1.0	+0.5	+2.0
Fuel prices [% to 2016]	-50	+0	+100
VRE share [%]	40	50	60
Flexibility [GW]	6.2	12.4	18.6
Technological learning [%/a]	1	2	3
Coal phase-out [%]	0	50	100

$3^7 = 2187$ scenarios

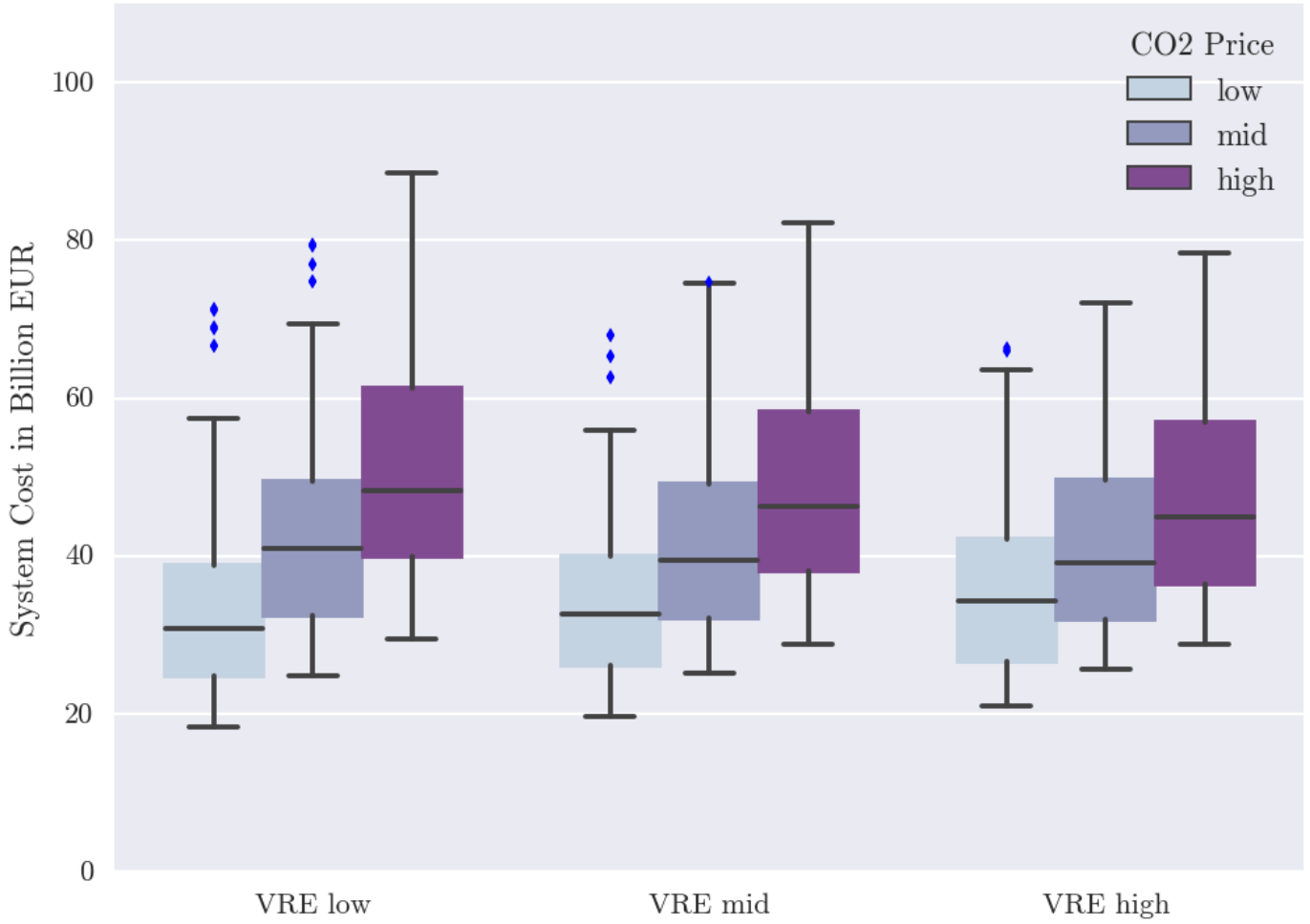
Multi-scenario analysis – exploring the possibility space of power markets



- Calculate 2187 times
- Exemplary evaluation in 2 dimensions

Multi-scenario analysis – exploring the possibility space of power markets

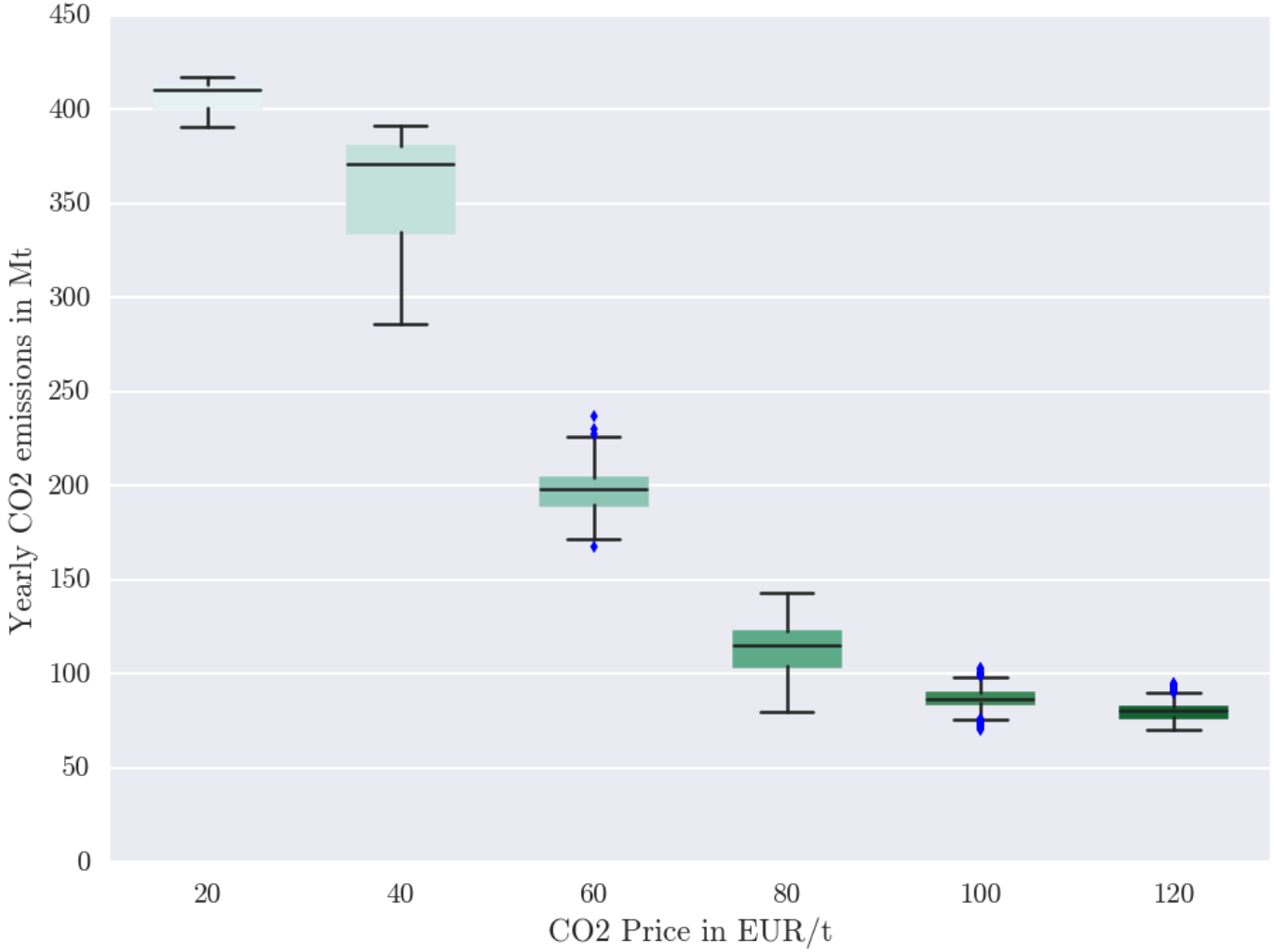
CO_2 prices I



Klein, Deissenroth, Schimeczek (2019) - Mapping the challenge of renewable electricity market integration – Multi-scenario analysis with an agent-based electricity market model, *IEWT Wien*

Multi-scenario analysis – exploring the possibility space of power markets

CO_2 prices II



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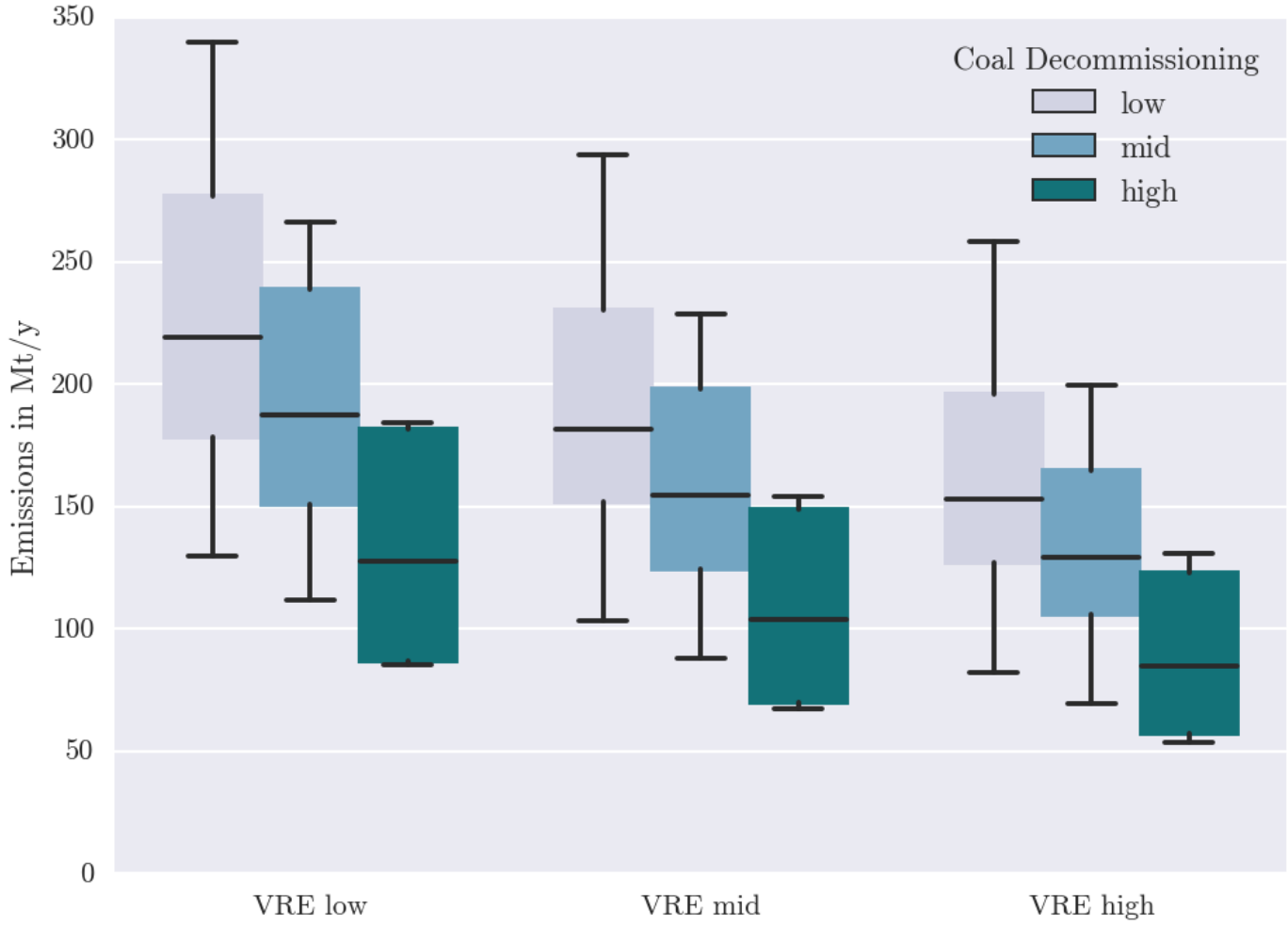
Multi-scenario analysis – exploring the possibility space of power markets

Coal exit variations



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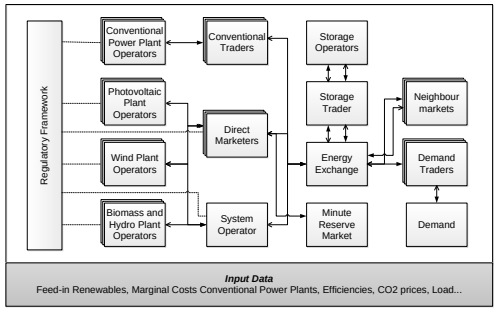
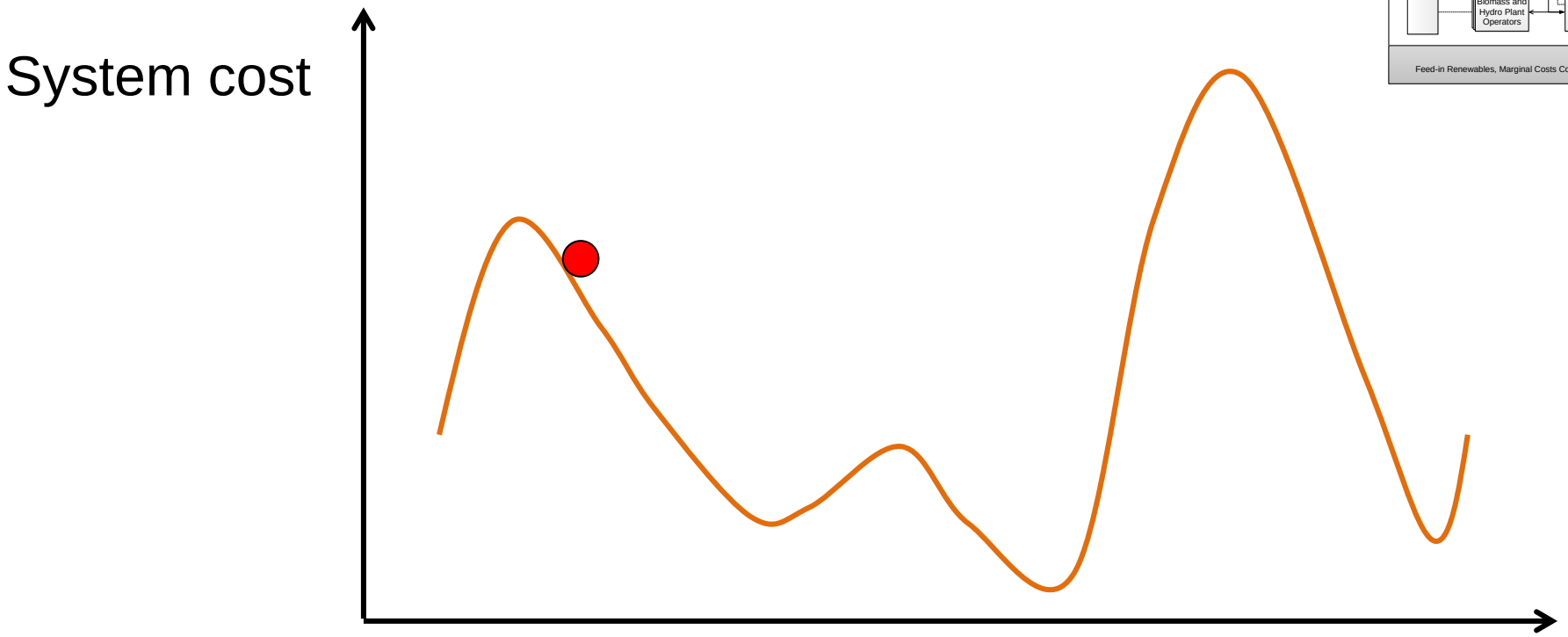
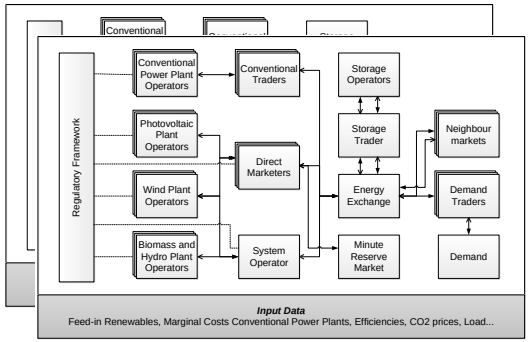
Agent-based optimization – new way of optimizing power systems

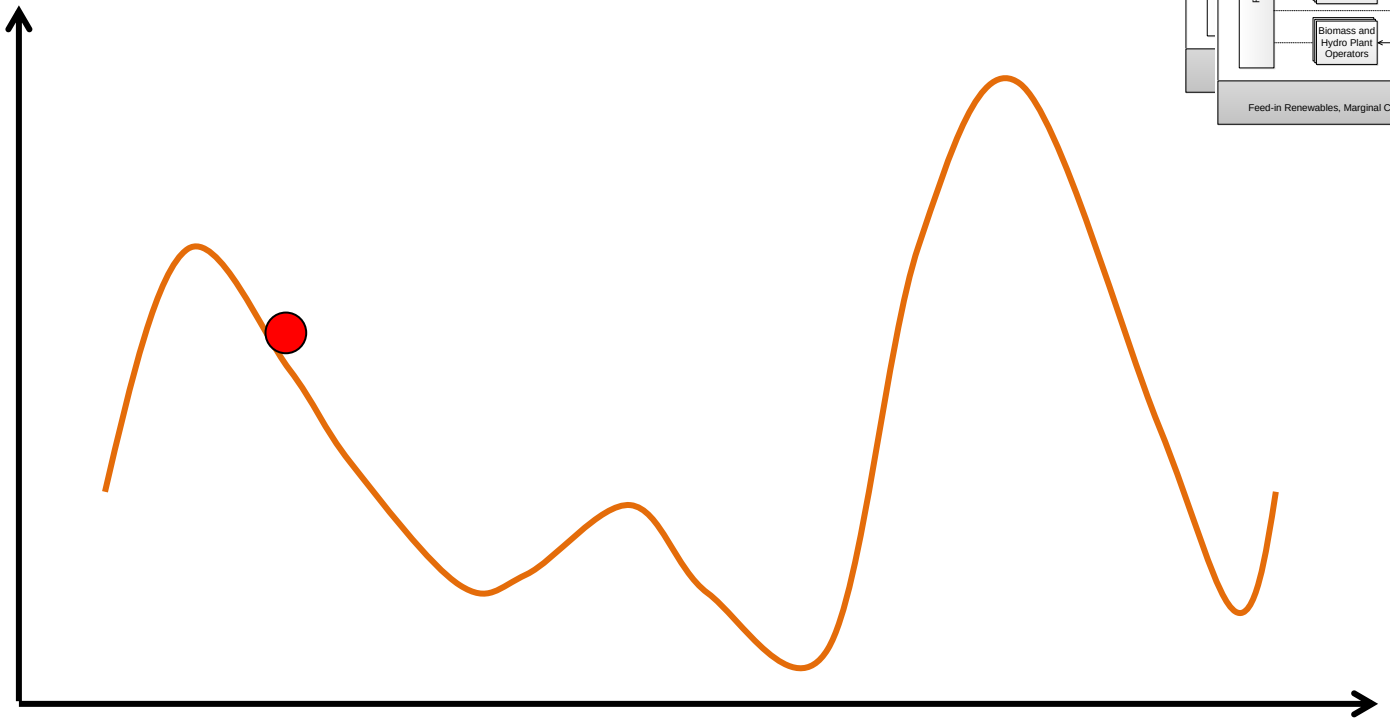




Agent-based optimization – new way of optimizing power systems



System cost



Multi-dimensional parameter set

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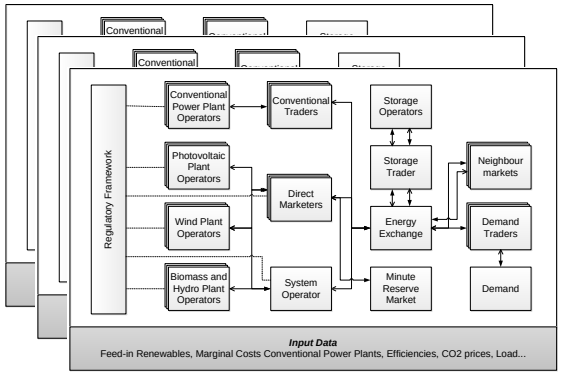

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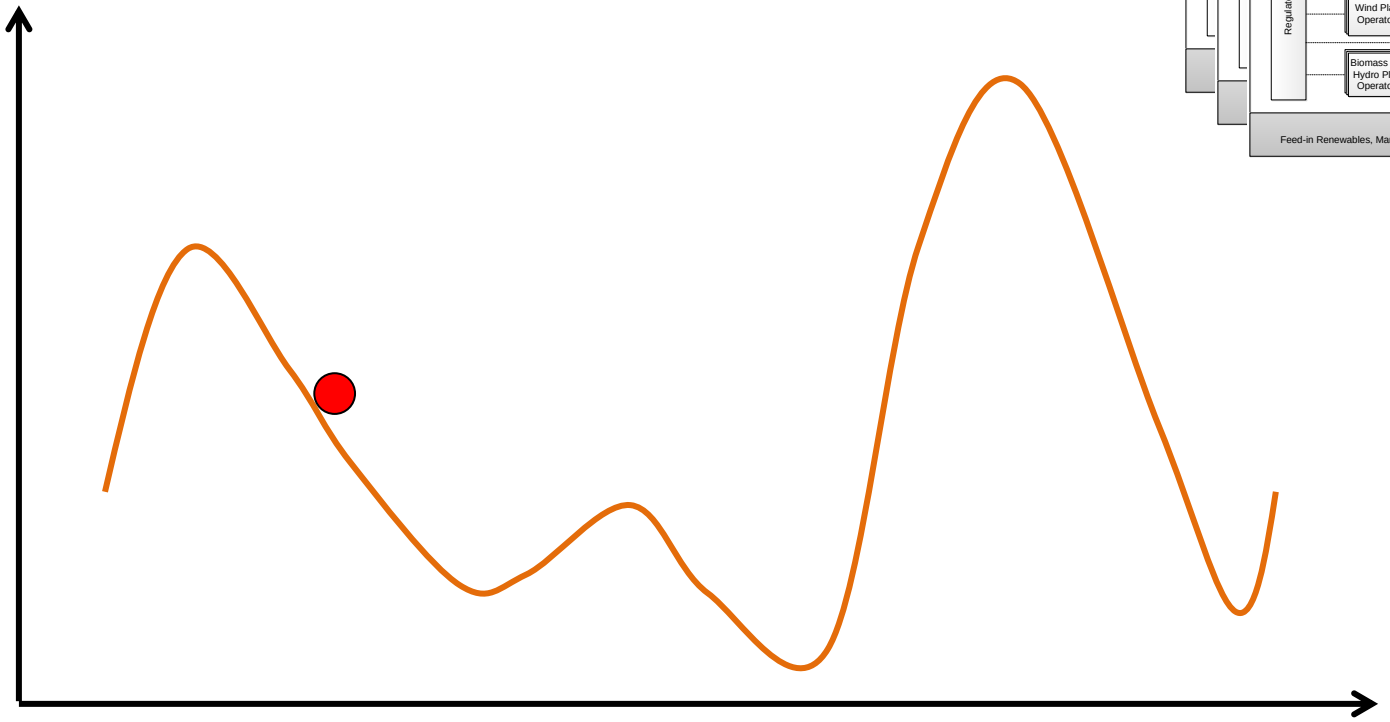

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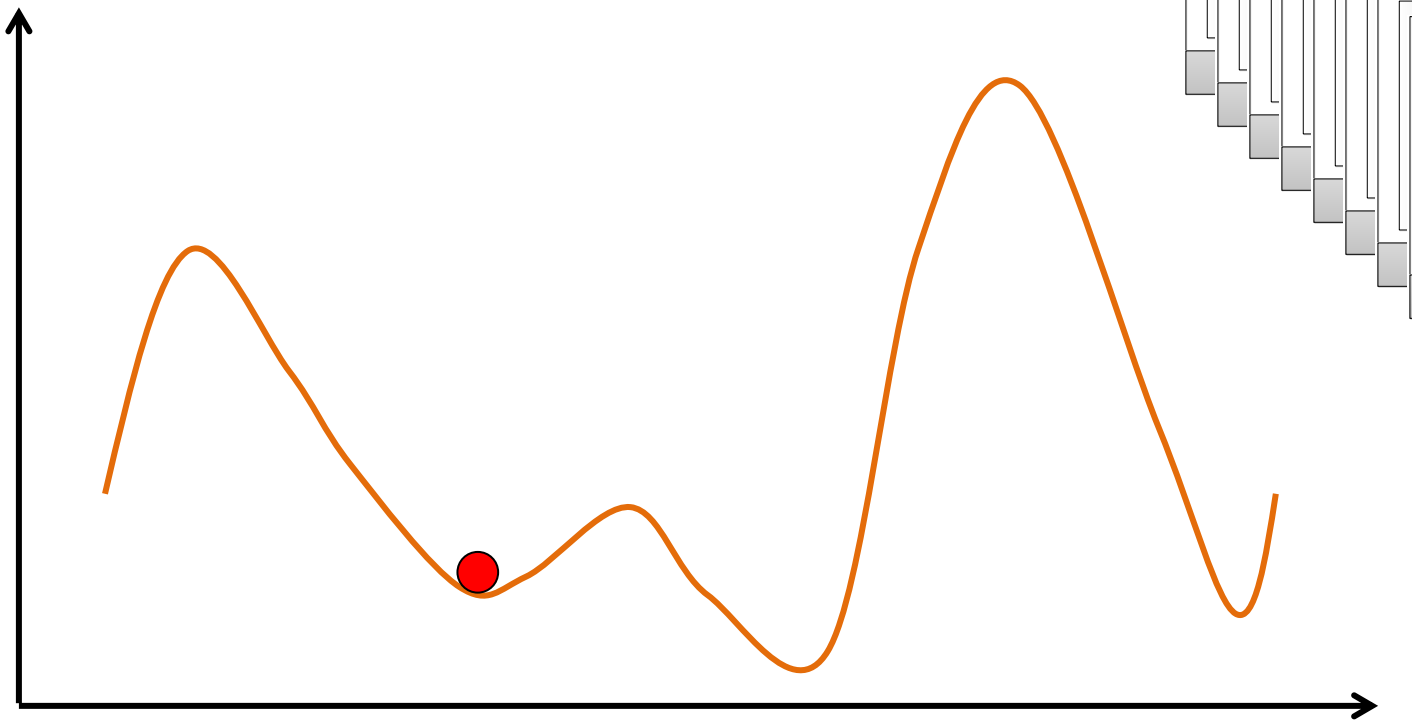

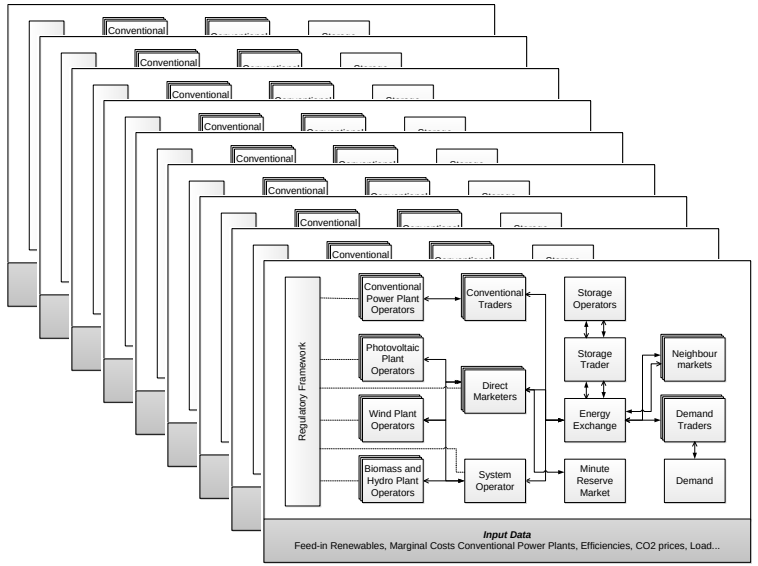

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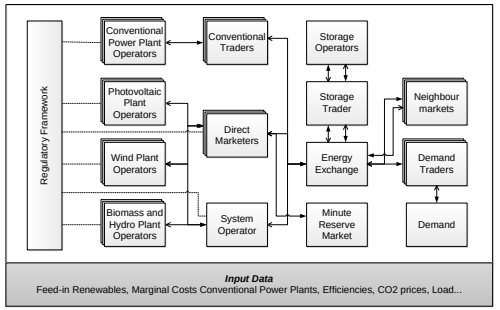

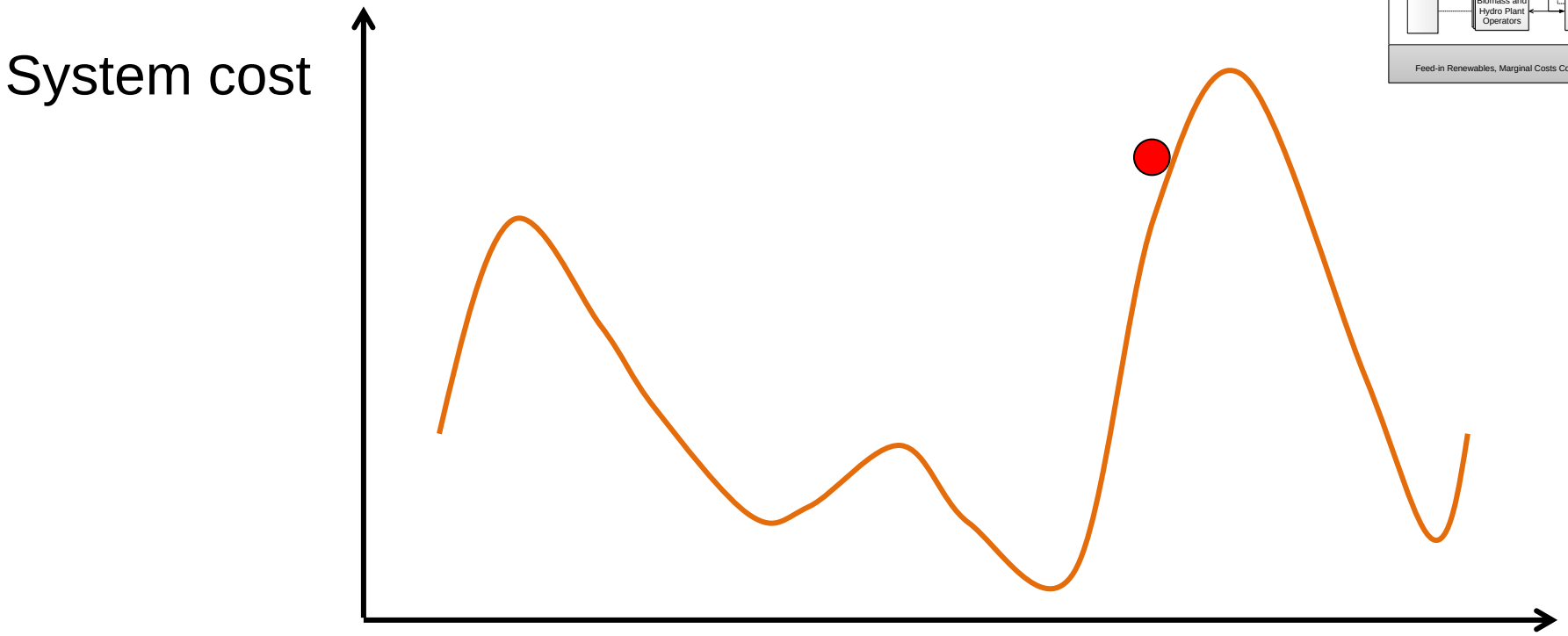

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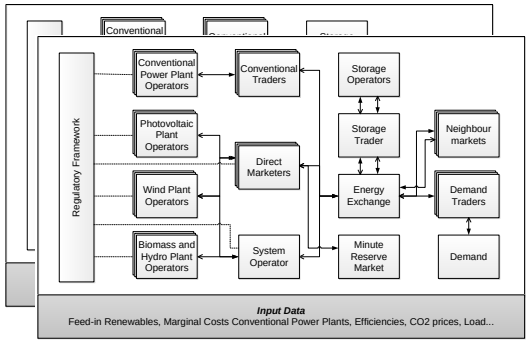

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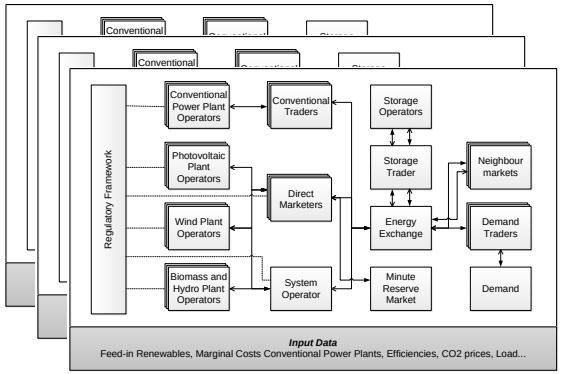

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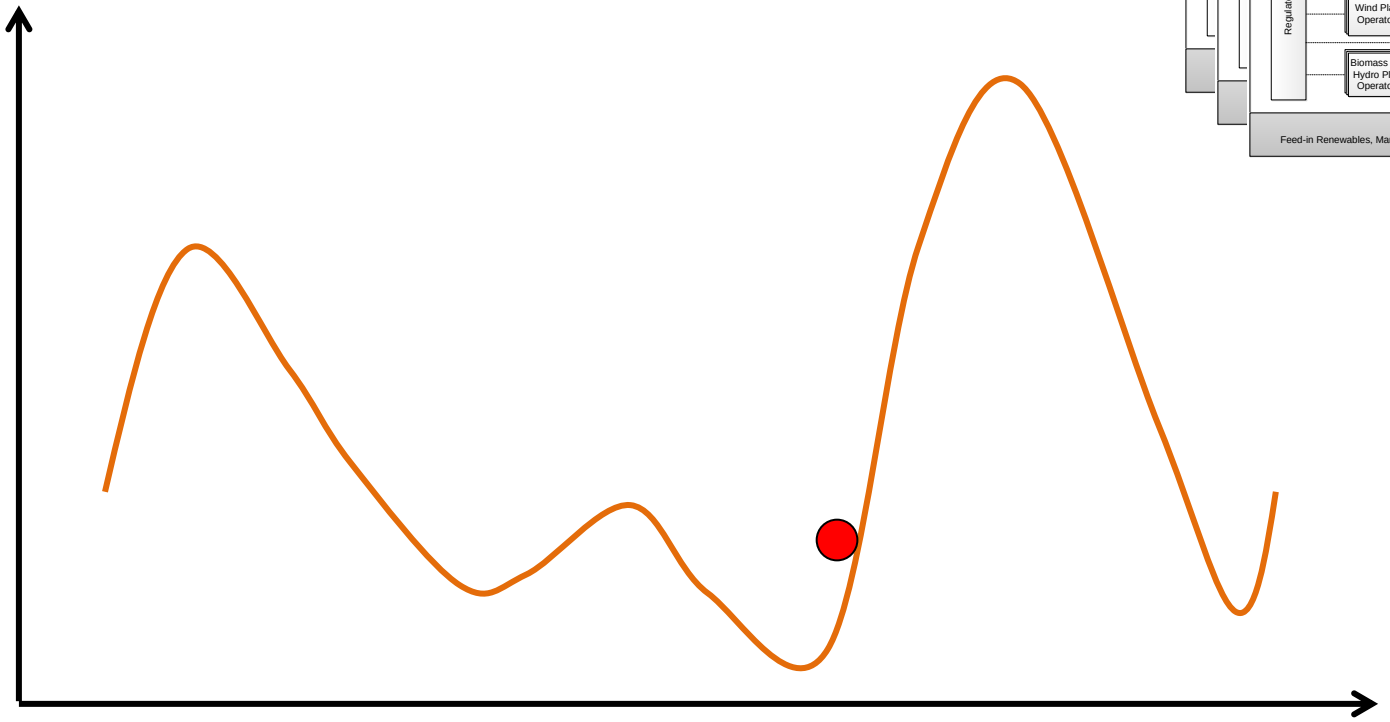

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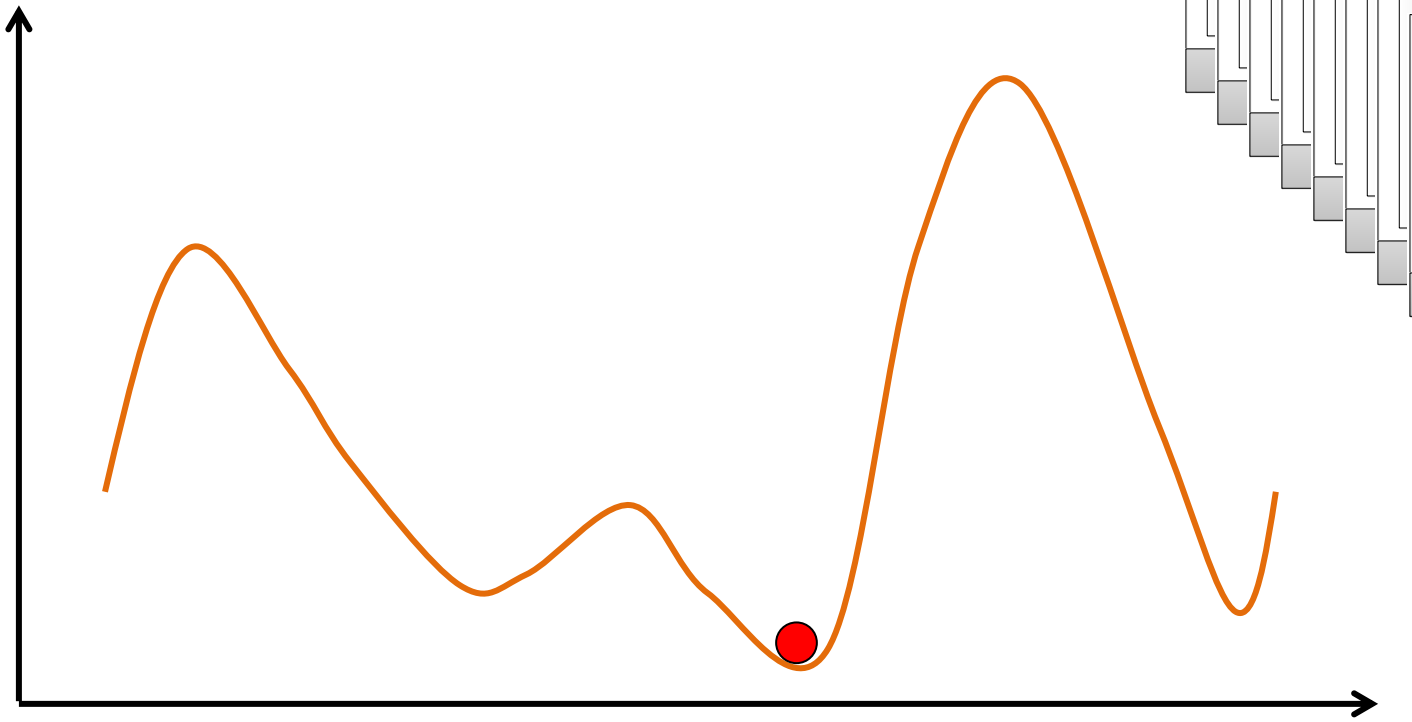

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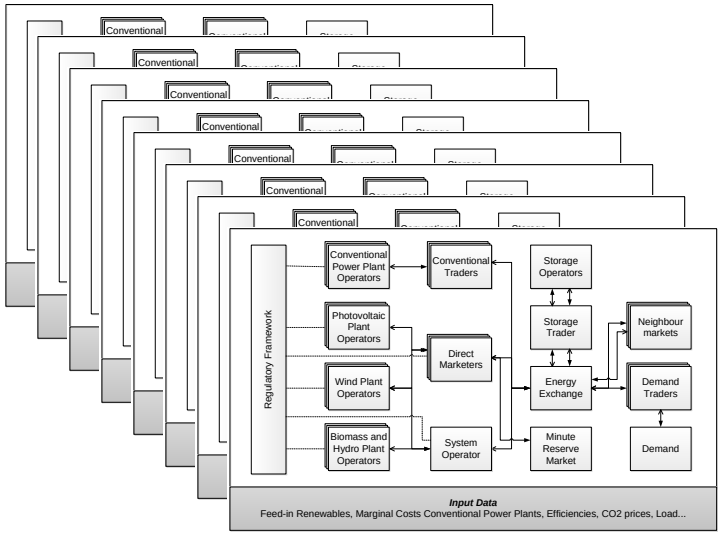

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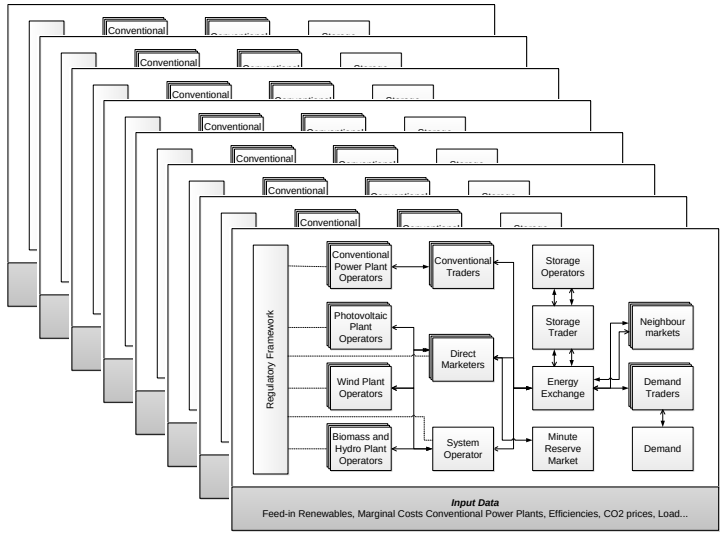
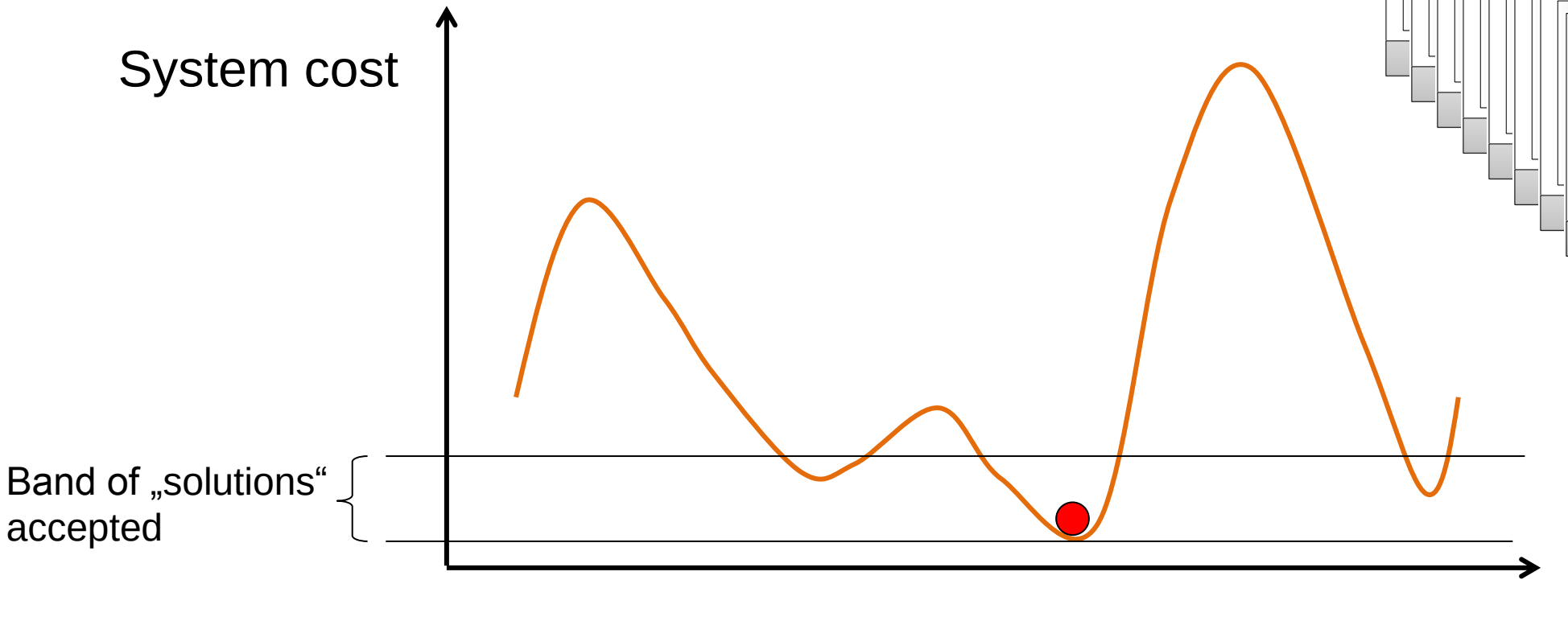
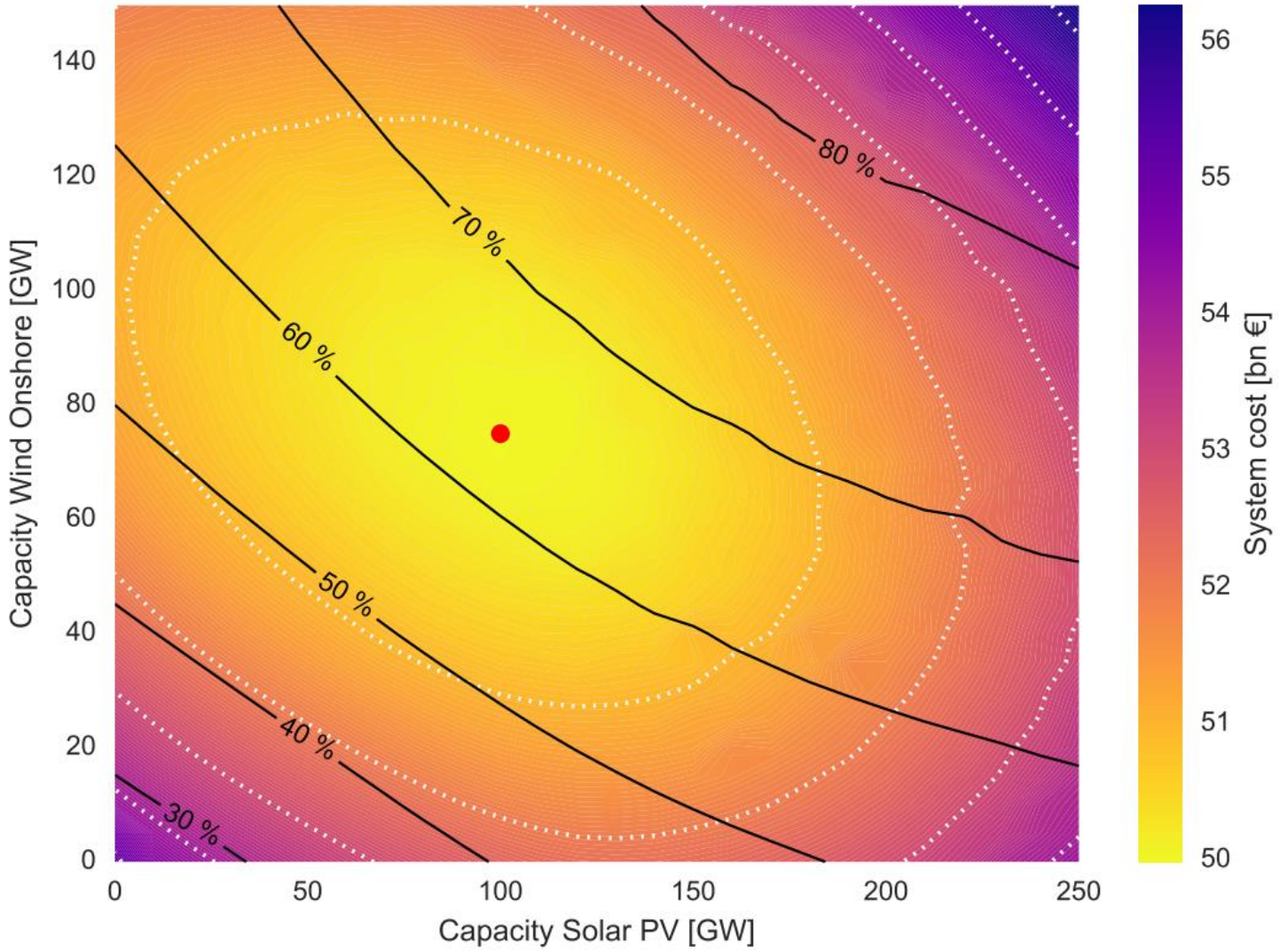




System cost maps – concise way of depicting power market trade-offs



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Discussion and outlook

Scenario exploration using an agent-based energy system model

⇨ Fast model execution allows many scenario evaluations

Analyses reveal multi-dimensional dependencies

CO_2 price turns out to be robust against other parameter configurations regarding reduction of CO_2 emissions

Further research planned on parameter complexity and path dependence of energy systems

- Maps can show power system trade-offs at one glance
- Size and stability of system cost minima

Thank you for your attention!

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