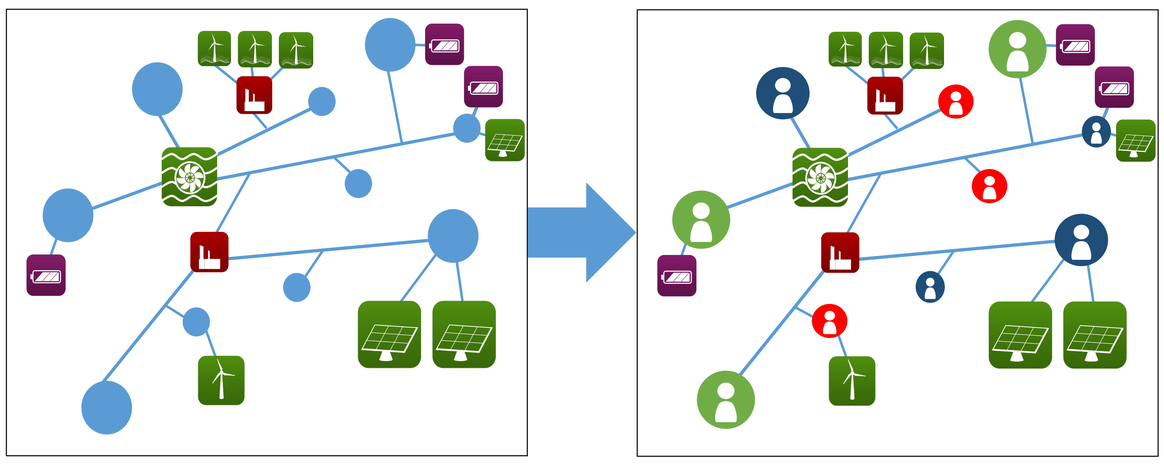
# Towards Verification in Distributed Multi-Agent Energy Systems

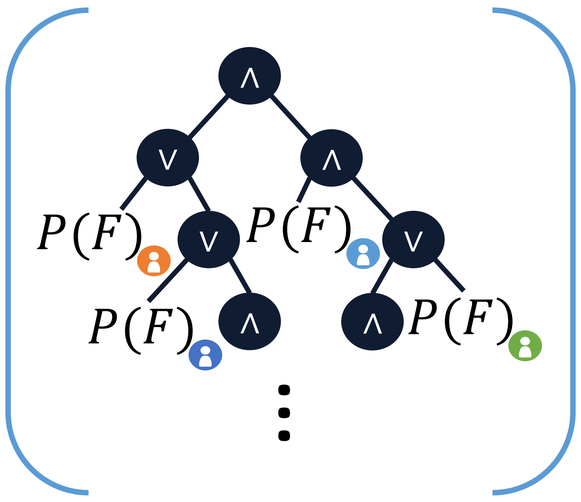
Carl von Ossietzky Universität Oldenburg

## MAS for Energy Systems



MAS are an intuitive model for **open**, **stochastic**, and **heterogeneous** systems and thus for a future **decentralized** energy system that **adapts** itself to changing environment condition with **self-organized** control.

## MAS Verification

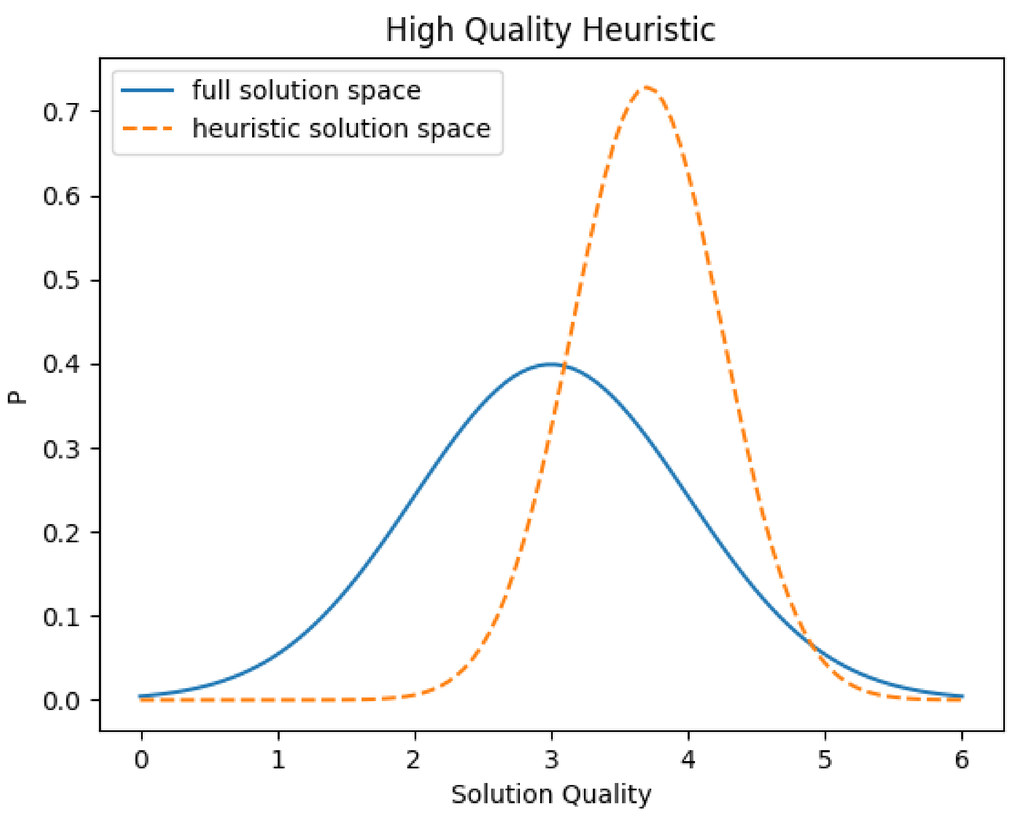



The properties that make MAS attractive for energy systems come with great challenges for formal verification.

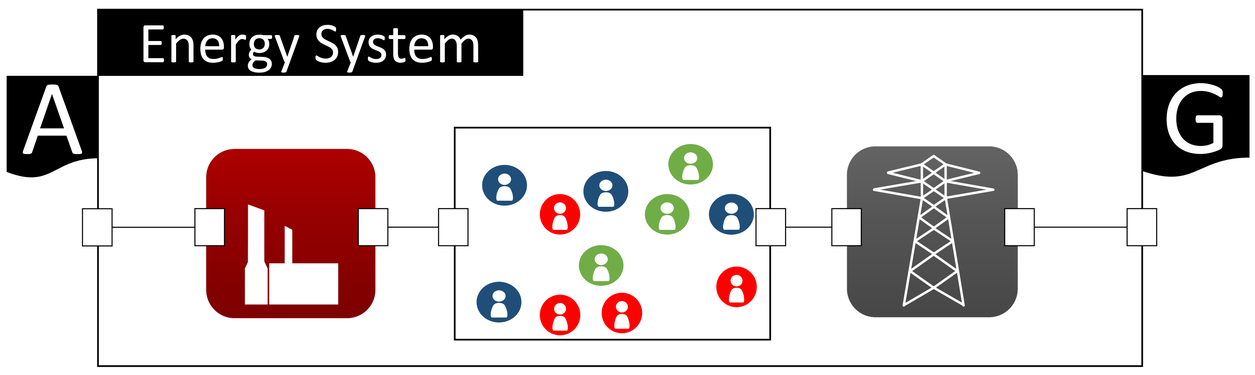
The state space of the system frequently grows much faster than exponential (**state space explosion**), making exhaustive model checking not a viable option.

Consequently, existing approaches **simplify** models in different ways. They may for example use **aggregation**, **symmetries** or independent **control structures** to reduce complexity.

## Distributed Heuristics with Guaranteed Solution Quality



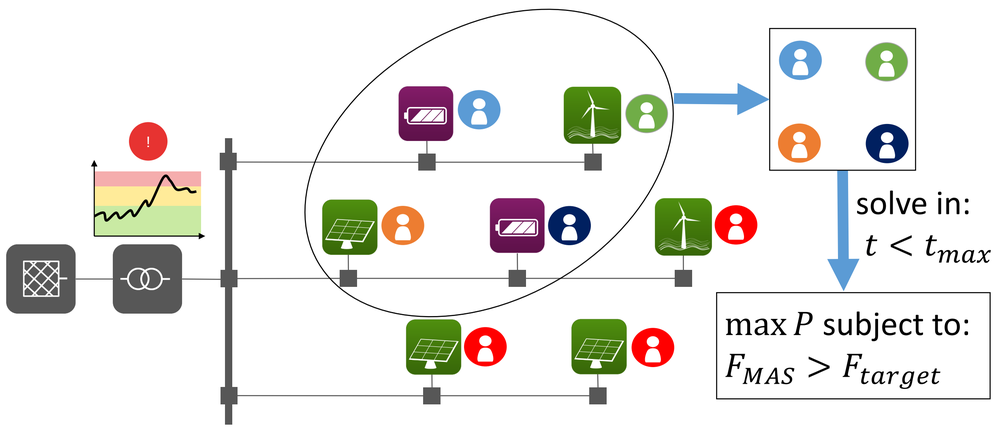

We want to use heuristics to find a good **lower bound** on optimization problems and **prove** that a single solution found by the heuristic lies within a predefined quality threshold with a defined high probability. MAS may then be integrated into existing energy systems by stochastic **contracts** via this **guarantee**.



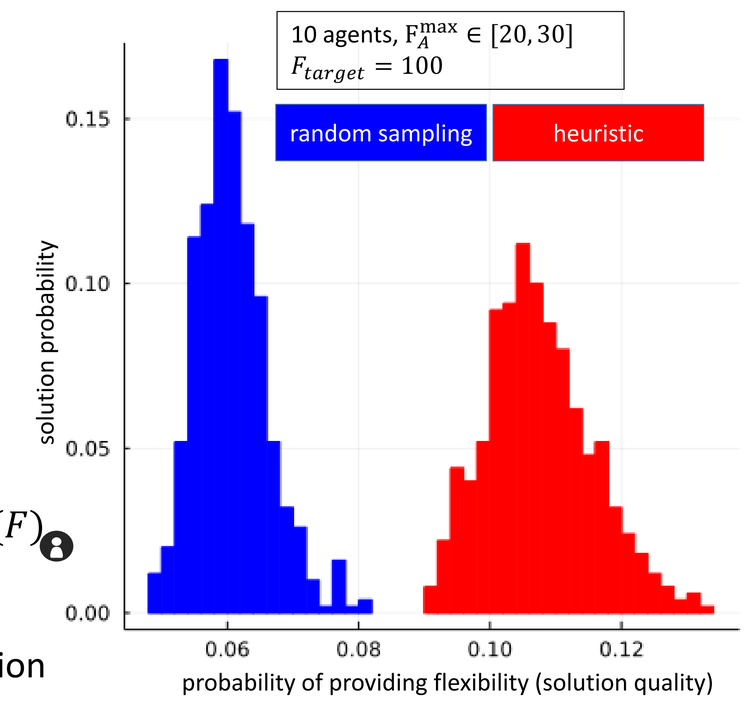

Assumptions:
- environment conditions
- weather forecasts
- load forecasts
- …

Guarantees:
Grid stability can be maintained
- with high probability
- within defined time limits
- …

## Preliminary Results and Future Work




**Congestion Management Model**
- discrete monotone flexibility probability functions $\mathrm{P}(F)$
- combination by stochastic ∨/∧ operators
- optimization problem:
  Find the maximum probability of resolving a congestion of a given size.




**Heuristic Algorithm**

For $n \in [1, x]$:
1. Partition flexibility functions into $n$ groups of roughly equal size.
2. Randomly search best solution within each group.
3. Combine group results with ∨.
4. Save best known result.

$n > x$: Groups too small for $F_{target}$

**Result**

Significantly outperforms taking the best result of a larger pure random sampling.

**Next up**
- further heuristic improvements
- proof of solution quality
- add costs to the optimization problem

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Jens Sager
jens.sager@uol.de

Astrid Nieße

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