EMPIRISCHE STUDIE ZUR ENTWICKLUNG VON CO-SIMULATION VON ENERGIESYSTEMEN

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Motivation

Background:

- Energy systems increasingly complex
- Subsystems best modelled with different tools
- Co-simulation couples different tools in one simulation

Issues:

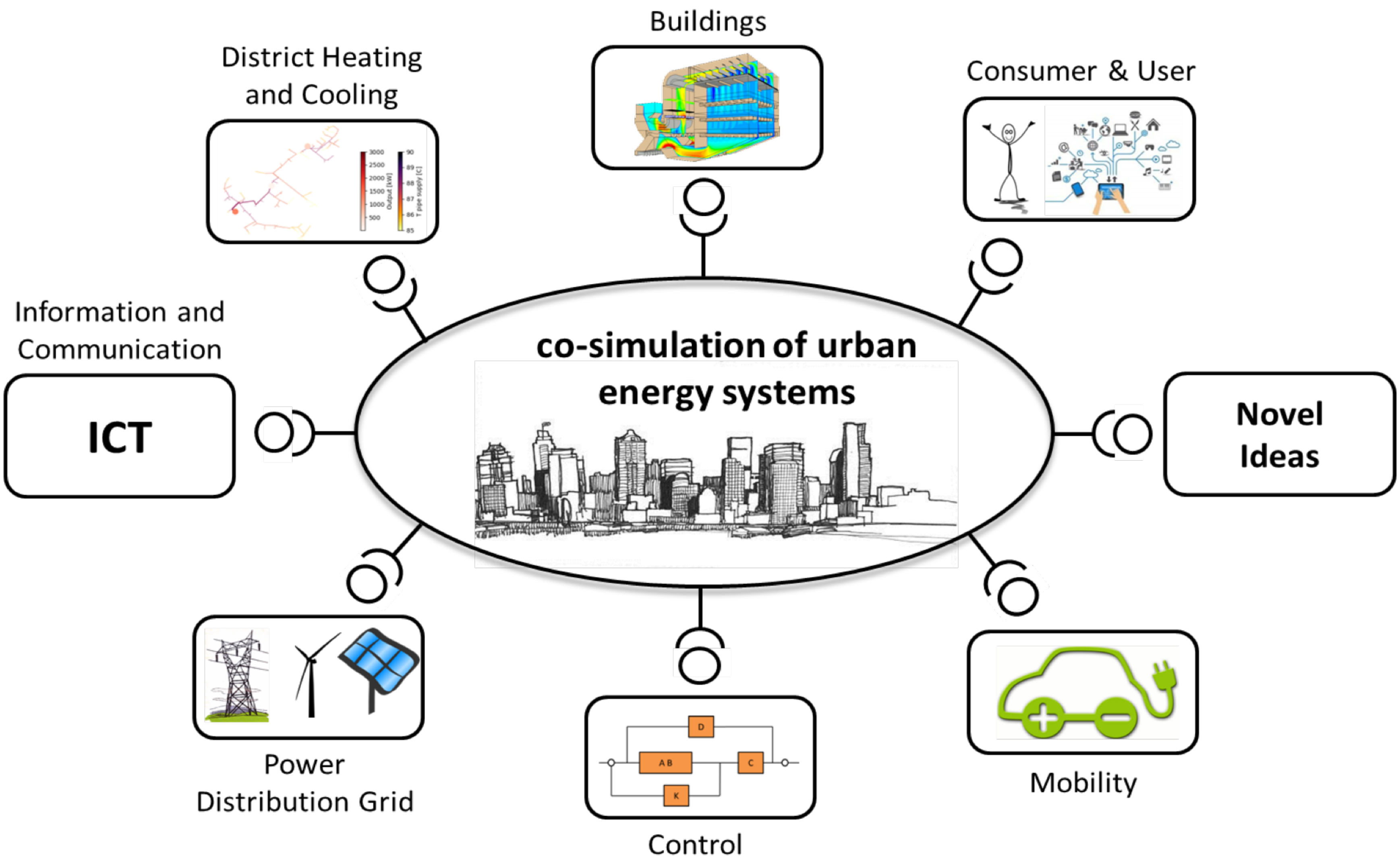
- Which co-simulation interface to choose?
- Which further developments are needed?
- SWOT for co-simulation?
- […]

Suggest:

- Literature research, case studies: DONE
- Present work: Empirical study (expert questionnaire) to address remaining issues

source: www.all-battery.com

Background: Challenges in Urban Energy Systems



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Background:
Challenges in Urban Energy Systems II

- Integration of volatile energy sources (PV, wind)
- Match with flexible demand side management
- Include sector-coupling

- Simulation-driven assessments as key methods for:
  - optimal design/control of systems
  - decision-support system for policy makers

- New challenges for modeling and simulation:
  - increasing complexity
  - sector/domain coupling / heterogenity

- Individual simulation tools overstrained
- New solutions? - - - Co-simulation!

Background: Co-Simulation

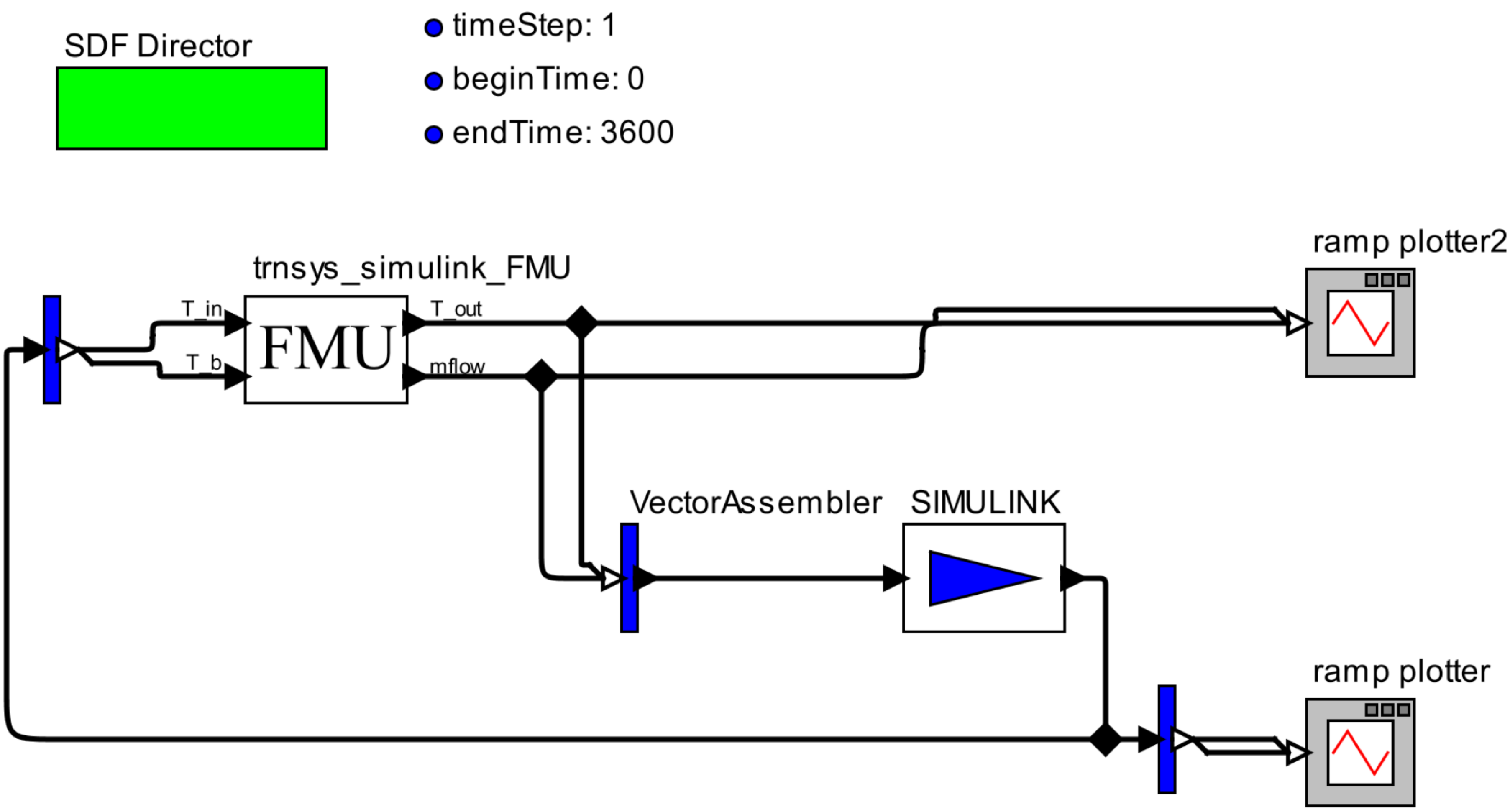
What is co-simulation?

- A coupling of several simulation tools (solvers)

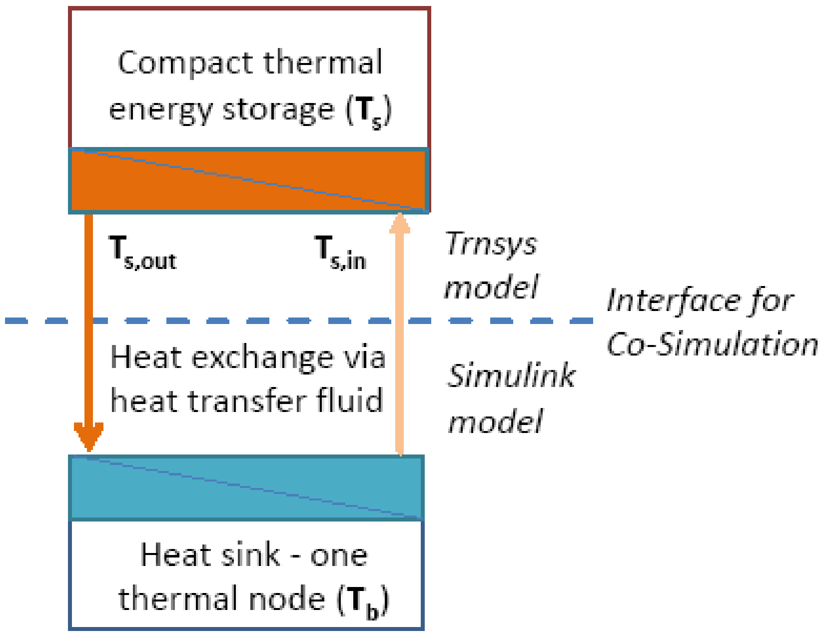
What are its strengths/benefits?

- Cross-discipline collaboration
  (Each subsystem modelled in specialized tool)
- Cross-company collaboration
- Black box modelling / IP protection
- Coupling to hardware (X-in-the-loop)
- Parallelization (speedup with supercomputers)

Background:
Co-Simulation Example (BCVTB / FMU)



Background: Co-Simulation Case Study



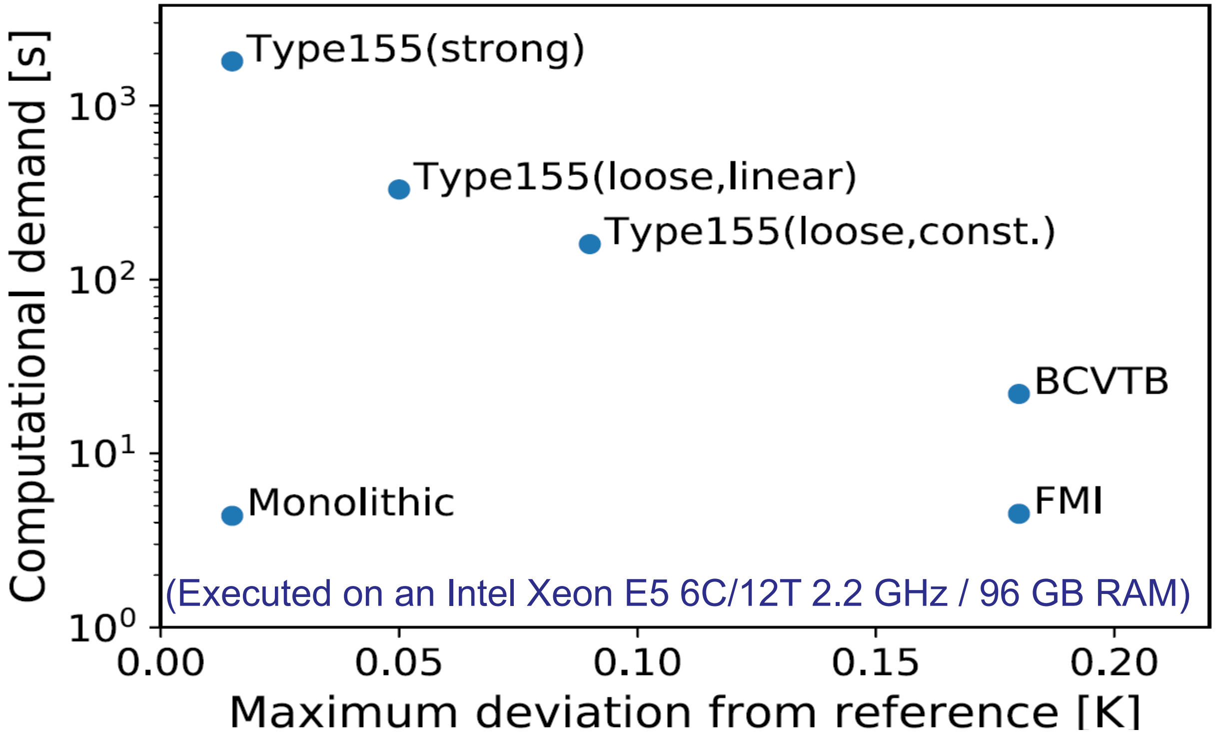
Model:

- Sorption heat storage (Trnsys)
- Heat sink (Simulink)
- Interface: heat transfer fluid

Assessment:

(1) User-friendliness
(2) Accuracy
(3) Computational demand

Background: Co-Simulation Case Study II



- Type155 is flexible but slow
- FMI fast; BCVTB nice for rapid-prototyping
- Choice of co-simulation interface: trade-off depending on actual situation
- Further improvements? Where is it going?

Methodology: Delphi-Study

- Understood as complementary to literature research
- Solve interdisciplinary heterogeneous research issues
- Predict probable future scenarios

Preparation:

- Prepare Knowledge Resource Nomination Worksheet (KRNW), i.e. define categories
- Fill KRNW with names
- Define first contacts
- Rank expert according to qualification
- Invite experts to fill in the questionnaire

Interviews:

- 1st stage: Open and closed questions
- 2nd stage: Closed question based on first stage

Dalkey, N. & Helmer, O., (1963). An Experimental Application of the Delphi Method to the Use of Experts. Management Science, 9(3), pp.458–467
Hsu, C. & Sandford, B., (2007). The delphi technique: making sense of consensus. Practical Assessment, Research & Evaluation, 12(10), pp.1–8.

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Methodology: SWOT-AHP

- Additional closed questions to assess SWOT:
  - strengths
  - weaknesses
  - opportunities
  - threats

- Analytical hierarchy process (AHP):
  - Compare each of the factors with each other
  - Eliminate bias

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Questionnaire Example: Closed Questions

Co-Simulation - applications, recent developments and future challenges

0%

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

General questions

Where do you work?

Choose one of the following answers

- ○ Research/Academia
- ○ Industry
- ○ Other
- ◉ No answer

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Questionnaire Example: SWOT AHP

Comparison of Strengths of co-simulation

How important do you consider the following three factors? Please **compare the pairs of factors** in the group "Strengths" and **rate their relative importance.**

9 = much more important; 1 = equally important

	much more important 9	7	5	3	equally important 1	3	5	7	much more important 9	
It supports cross-company cooperation (e.g., suppliers and system integrators can exchange virtual "trial components" before signing contracts)	○	●	○	○	○	○	○	○	○	**Every sub-system can be implemented in a tool** that meets the particular requirements for the domain, the structure of the model and the simulation algorithm
It supports cross-discipline developments	○	○	○	○	○	○	●	○	○	**Every sub-system can be implemented in a tool** that meets the particular requirements for the domain, the structure of the model and the simulation algorithm
It supports cross-discipline developments	○	○	○	○	●	○	○	○	○	**It supports cross-company cooperation** (e.g., suppliers and system integrators can exchange virtual "trial components" before signing contracts)

Results: Delphi-Study

- First round finished:
  - 13 participants
  - Many open questions
  - First results for SWOT
  - Results serve as foundation for closed questions in second round
- Second round:
  - 40 expert commitments
  - Questionnaire distributed
  - Results expected until March

Results: SWOT

Strengths	
Cross-discipline developments	**38%**
Cross-company cooperation	**38%**
Particular tool for each sub-system	**54%**
Parallelization (speedup)	8%
Distributed computation for e.g. portability issues	8%
Intellectual property protection	23%
Coupling to empirical models	8%
Solver optimization each subsystem	0%

(Experts were invited to name up to 3 most important factors in the first round)

Results: SWOT II

Weaknesses	
Computational performance	**38%**
Robustness	**38%**
Theoretical expertise in co-simulation required	15%
Various licenses required	**31%**
Expertise in all programs is required	23%
Standardization assumes only the "greatest common denominator" of individual tools	**31%**
Black box nature reduces functionality	15%

Results: SWOT III

Opportunities	
Acausal co-simulation standards	0%
Better communication between theoretical/numerical part, implementation and application/industry	**31%**
Growing community / industrial adoption	**46%**
User-friendly tools	**31%**
Increasing libraries complying standards	23%
Uncovering new theoretical research problems	8%
New markets for the exchange of models	15%

Results: SWOT IV

Threats	
Lack of exchange between theory / implementation / application	**38%**
Improvements in individual tools / ME	15%
Improper use due to insufficient knowledge	**54%**
IPR in conflict with functionality	8%
Incompatibility of standards / approaches	**38%**

Conclusion and Outlook

- Challenges in the energy transition
- Co-simulation a promising approach:
  - cross-domain/company collaborative simulation
  - ready for IPR, HiL, HPC, …
  - promising also for other fields (robotics, automotive…)

- Case studies conducted, questions remain
- Empirical study (Delphi, SWOT AHP):
  - solve interdisciplinary heterogeneous issues
  - predict probable future scenarios
- Results first round ready

- Outlook second round:
  - 40 expert commitments
  - Results expected until March

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IDEA TO ACTION

Thank you
for your Attention