Categorization of tools and methods for modeling and simulating hybrid energy networks

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IEA DHC Annex TS3, Subtask B “Tools and Methods”

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Power Networks

- tools for system planning
- tools for design optimization
- tools for operation
- etc.

Heating / Cooling Networks

- tools for system planning
- tools for design optimization
- tools for operation
- etc.

Gas Networks

- tools for system planning
- tools for design optimization
- tools for operation
- etc.

Hybrid Energy Networks

???

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Why are the tools we have used so far not enough?

- domain-specific tools for energy networks → **single domain only**
  - at best, only coupling points to other domains can be modelled
- established multi-energy modelling tools → **no focus on energy networks**
  - no network capacities, imports/export from/to external grid, etc.

Are there other tools available? What can we do with them?

1. started with **online survey** among tool developers and simulation experts
2. additional **literature review** for complementing the survey results
3. apply **selection criteria** on survey and literature review results
4. perform **expert review** based on **classification categories**

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Selection criteria for considered tools and methods:

- **focus on energy networks**
  - at least two types of energy networks must be considered
  - energy networks must be considered at least on the level of energy balances (implicit network model)
- **availability**
  - an implementation of the tool / method must be publicly available
  - either commercially or otherwise (open source, freeware, etc.)
- **documentation**
  - an application in the context of hybrid energy networks must be publicly documented
  - for instance via a manual, a journal article or otherwise

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Selected tools and methods (out of a total of 31 survey and literature review results):

- Pandaplan [1]
- Co-simulation of network simulators
  - for instance Dymola and pandapower [2]
- Modelica [3]
  - with dedicated libraries such as the IBPSA Library, DisHeatLib or Modelon Library Suite
- energyPRO [4]
- EHDO [5]
- EnergyPLAN [6]
- ESSIM [7]
- GasPowerModels.jl [8]

Classification categories for tools and methods:

- spatial resolution of component models
  - components, buildings, districts/settlements, cities, regions, nations, continents
- temporal resolution of component models
  - seconds, minutes, hours, days, weeks, months, years
- targeted scale of system model
  - components, buildings, districts/settlements, cities, regions, nations, continents
- targeted time horizon of system model
  - seconds, minutes, hours, days, weeks, months, years
- application class
  - technical, economical

Classification categories for tools and methods (continued):

- type of power network model
  - none, energy balance (implicit: no lines, cables, etc.), quasi-static (power flow), electro-mechanical, electro-magnetic transients
- type of thermal network model
  - none, energy balance (implicit: no pipes, etc.), quasi-static (pressure equilibrium), hydraulic transients
- type of gas network model
  - none, energy balance (implicit: no pipes, etc.), quasi-static (pressure equilibrium), hydraulic transients
- energy storages included
  - yes, no

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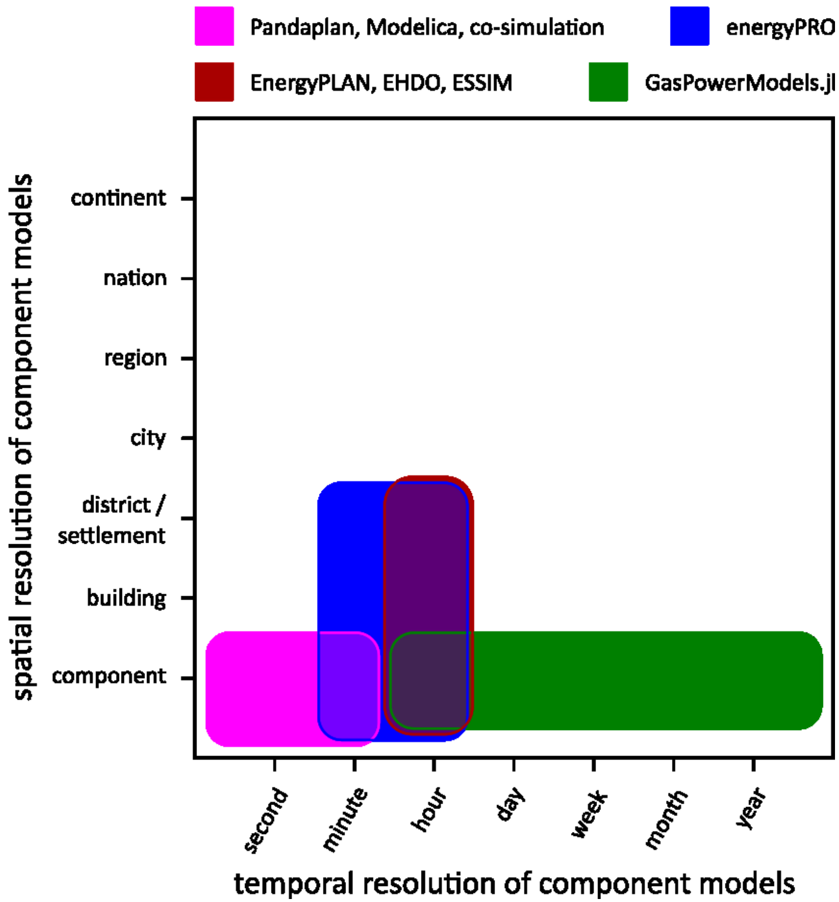

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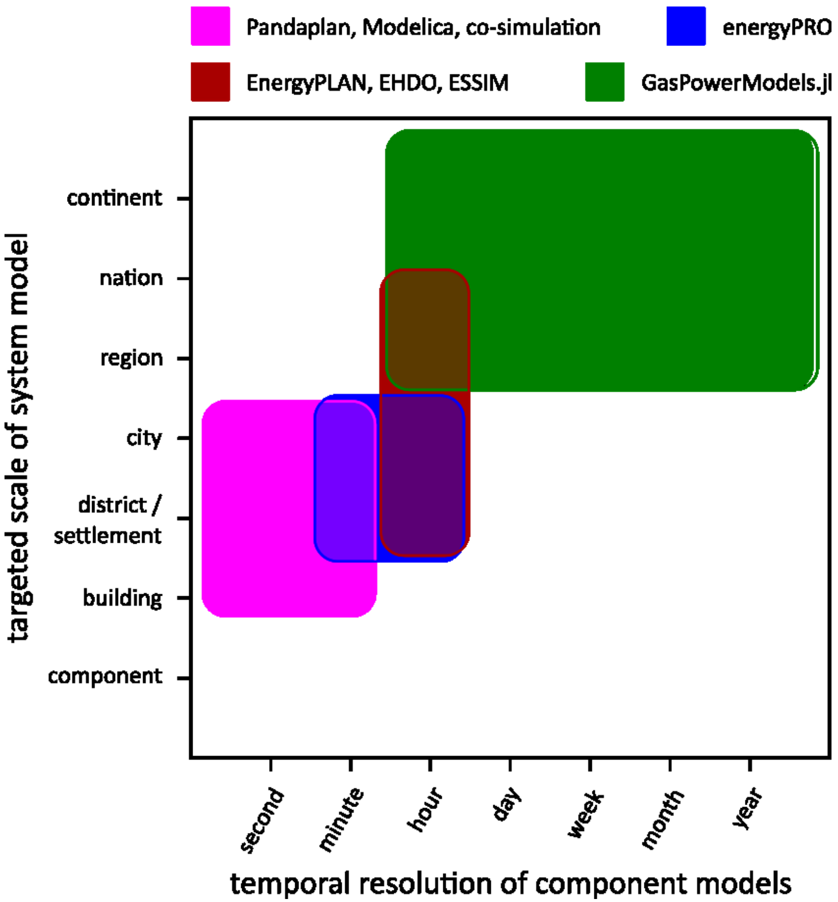
Pandaplan, Modelica, co-simulation
energyPRO
EnergyPLAN, EHDO, ESSIM
GasPowerModels.jl
targeted scale of system model
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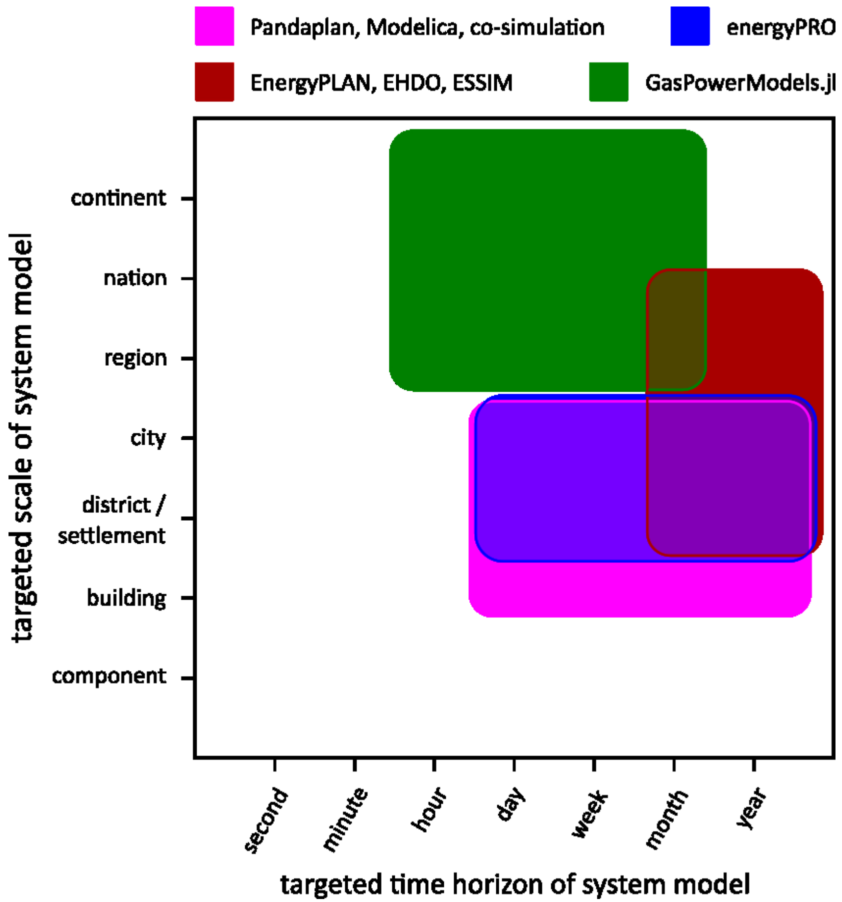
temporal resolution of component models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Tool / method	power network model	thermal network model	gas network model	energy storages included
Pandaplan	quasi-static (power flow)	quasi-static (pressure equilibrium)	quasi-static (pressure equilibrium)	☑
Co-simulation *	quasi-static * (power flow)	hydraulic transients *	not modeled *	☑
Modelica **	electro-mechanical **	hydraulic transients **	hydraulic transients **	☑
energyPRO	energy balance (implicit: no lines, cables, etc.)	energy balance (implicit: no pipes, etc.)	energy balance (implicit: no pipes, etc.)	☑
EHDO	energy balance (implicit: no lines, cables, etc.)	energy balance (implicit: no pipes, etc.)	energy balance (implicit: no pipes, etc.)	☑
EnergyPLAN	energy balance (implicit: no lines, cables, etc.)	energy balance (implicit: no pipes, etc.)	energy balance (implicit: no pipes, etc.)	☑
ESSIM	energy balance (implicit: no lines, cables, etc.)	energy balance (implicit: no pipes, etc.)	energy balance (implicit: no pipes, etc.)	☑
GasPowerModels.jl	quasi-static (power flow)	not modeled	quasi-static (pressure equilibrium)	☒

* for approach described in [2]   ** for approach described in [3]

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Tool / method	Application class: technical	Application class: economical
Pandaplan	✖	
Co-simulation *	✖	
Modelica **	✖	
energyPRO		✖
EHDO	✖	✖
EnergyPLAN	✖	✖
ESSIM	✖	✖
GasPowerModels.jl	✖	✖

* for approach described in [2]   ** for approach described in [3]

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Rationale of intended purpose of tools and methods:

- **Characterization**
  - the state of a system is evaluated without changing its properties
  - example: perform load flow analysis for calculating the distribution of voltages and currents in a network
- **Optimization of planned networks**
  - methods useful for planning purposes
  - example: improvement of grid topology or plant and device positions to meet given criteria
- **Operational optimization (technical)**
  - methods for improving the system performance with focus on technical aspects
  - example: control algorithm for P2G plants, which maintains a given gas composition in the network
- **Operational optimization (economical)**
  - methods for improving the system performance with focus on economical aspects
  - example: algorithm deciding on how to use generated PV excess power (grid feed-in or self consumption) based on market price predictions.

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Tool / method	Characterization	Optimization of planned networks	Operational optimization (technical)	Operational optimization (economical)
Pandaplan	✖		✖	
Co-simulation *	✖		✖	
Modelica **	✖			
energyPRO			✖	✖
EHDO		✖		
EnergyPLAN		✖		
ESSIM	✖	✖		
GasPowerModels.jl		✖	✖	✖

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Conclusions:

- **new tools and methods** have been developed that focus specifically on **hybrid energy networks**
  - not simply extensions of established domain-specific or multi-energy tools
  - cover a wide range of approaches for modelling and simulating hybrid energy networks
- based on their **modelling approaches** and **intended purposes**, these tools and methods can be grouped in **4 categories**
  - tools for technical assessments
  - tools for operational optimization (technical & economical)
  - tools for planning on the scale of cities / regions
  - tools for planning on the scale of nations / continents

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