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Integrated District Heating and Cooling Systems: Overview of the results of the international cooperation project IEA DHC Annex TS3

7th International Conference on Smart Energy Systems
21-22 September 2021; #SESAAU2021

This presentation was done in the framework of the international cooperation program IEA DHC Annex TS3 „Hybrid Energy Networks".
More information at https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3
The Austrian participation in the IEA DHC Annex TS3 is financed by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)

Federal Ministry
Republic of Austria
Climate Action, Environment, Energy, Mobility, Innovation and Technology

IEA Research Cooperation
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Motivation

- **Integrated energy systems/ sector coupling / integration is considered one of the key measures for decarbonizing the energy system.**

- District heating and cooling (DHC) networks are **traditionally linking the heating & cooling and the electricity sector** (+ the gas sector) through combined heat and power (CHP) plants.
- However, **the role of CHP plants will significantly change**
  - competition for renewable fuels with hard-to-decarbonise sectors
  - increasing share hydro, wind and PV, less CHP electricity required

→ **We will need other heat (and cold) sources**

→ **We will need other coupling points to provide flexibility**

Relevant sector coupling technologies

- Waste and ambient heat, solar and geothermal energy often require **heat pumps** (HPs) for upgrading their temperature level;

- **electric boilers** (eBs) enable high temp. heat generation at fast gradients and low costs;

- **power-to-gas** (PtG)[1] processes generate fuels, that can be used in

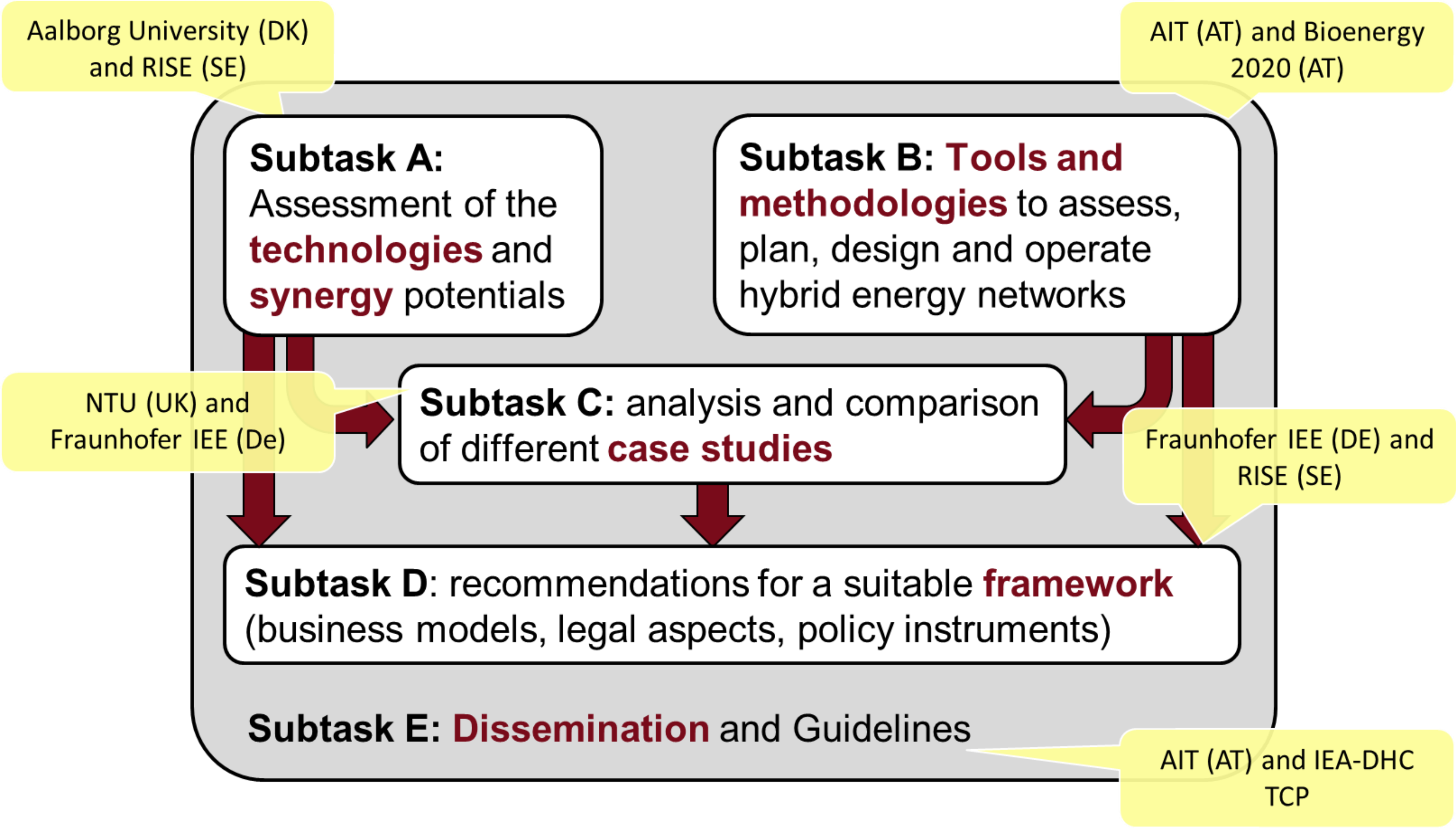
- **CHP** plants for generating electricity and heat.

[1] *PtG process itself generate significant amounts of waste heat, so a proper term would be power-to-gas&heat (PtG&H) or combined heat and gas (CHG) plants*

IEA DHC Annex TS3: Hybrid Energy Networks

- **Aim:** To promote the opportunities and to overcome the challenges for district heating and cooling (DHC) networks in an integrated energy system context
- **Funded** through a task-sharing approach (participants contribute resources in-kind)
- **Coordination team:** Ralf-Roman Schmidt (AIT, lead); Dennis Cronbach (Fraunhofer IEE, Subtask D), Anton Ianakiev (NTU, Subtask C); Anna Kallert (Fraunhofer IEE, Subtask C); Daniel Muschick, (BEST, Subtask B); Peter Sorknæs (Aalborg University, Subtask A), Inger-Lise Svensson (RISE, Subtask C), Edmund Widl (AIT, Subtask B)
- **Runtime:** Fall 2017 – March 2022
- **More information at** https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3

IEA DHC Annex TS3: structure



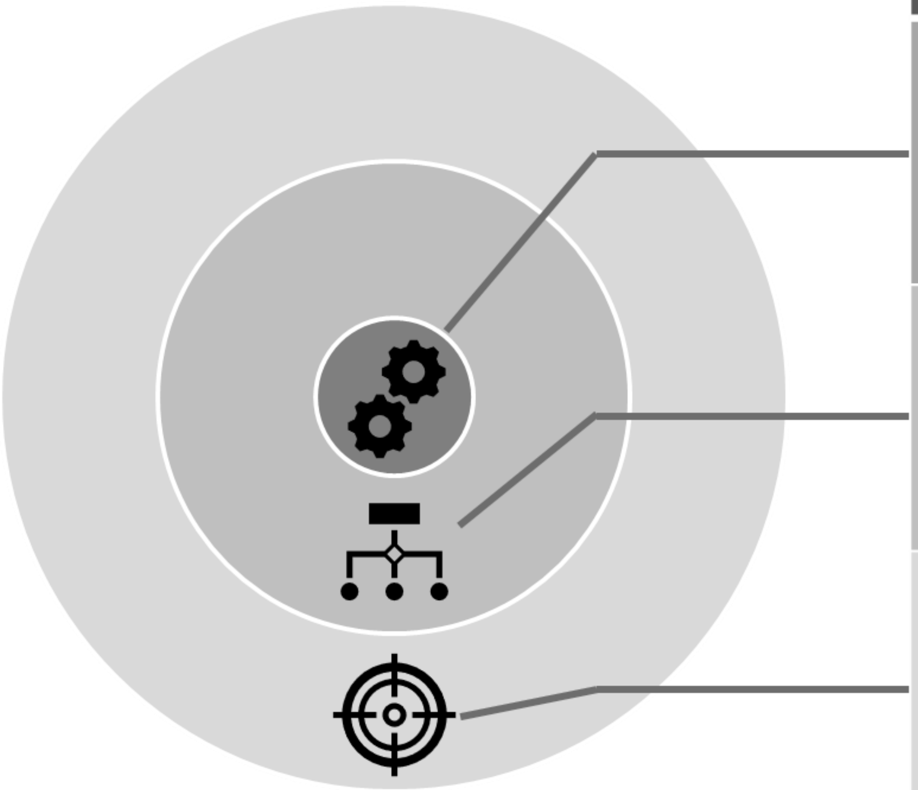
IEA DHC Annex TS3: Schedule

Definition phase	Preparation phase		Working phase						
2017 /Fall	**2018 /Spring**	**2018 /Fall**	**2019 /Spring**	**2019 /Fall**	**2020 /Spring**	**2020 /Fall**	**2021 /Spring**	**2021 /Fall**	
Austria	Stockholm	Berlin with Industry WS	Stockholm shared WS with ISGAN	France – on invitation by CEA	Online TelCo and public Webinar	Online TelCo and public Webinar	Online a side event to the https://missioninnovationaustriaweek.at	Nottingham/ Denmark – part of the symposium/ SES	

reporting phase
2022 /Spring
tbd

more information (previous webinars, presentations, publications …) at https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3

Hybrid Energy Networks: a classification approch*



Layer	Minimum	Maximum
Technology	Single coupling points, central controls of network and coupling points	Multiple and diverse coupling points, high operational flexibility, advanced controls, automation and analytics
Organization	Minimum permissible ownership of coupling points, traditional business models and services offered	Diverse ownership, high share of prosumers, innovative business models and services offered
Strategic	Central structures, integration of coupling points as a reaction to market pressure	Decentralized structures, integrated planning and design, optimized interaction and decarbonization

**This classification differs from the 4G DHC networks concept (Lund et. al=) → the main characteristic of a HEN is the integration between the different networks, and not the supply temperature or the time period where the different generations were dominating.*

Hybrid Energy Networks: a SWOT assessment

See also: Ralf-Roman Schmidt; Benedikt Leitner: **A collection of SWOT factors (strength, weaknesses, opportunities and threats) for hybrid energy networks**; Energy Reports, speciall issue for the 17th International Symposium on District Heating and Cooling, 6th–9th September 2021, Nottingham, UK; https://doi.org/10.1016/j.egyr.2021.09.040

STRENGTH
- Higher degrees of freedom for planning/ operation;
- higher security of supply, resilience, flexibility
- counteract limitations of the el. network + reduce losses
- New business models (ancillary services, markets)
- decarbonization of DHC network
- (booster) HPs support Integrate low temp. heat sources
- economic added value (investment in coupling points)

WEAKNESSES
- additional investments into coupling points
- increasing level of complexity
- Present electricity tariffs and taxes are a barrier
- regulatory restrictions for electricity grid operators
- seasonality of the heat demand
- supply competition in DHC (especially in the summer)
- Only renewable, if fossil-free electricity is used

OPPORTUNITIES
- More research, products, demo projects, trainings etc.
- improved performance of coupling points/ controls
- Digitalization supports handling of the complexity
- Increasing PV and wind → more flexibility required
- Green financing options
- tendency for the reduction of DHC temperatures

THREATS
- a possible disruptions of existing business models;
- overall higher electricity demand
- Changing regulatory framework / market design
- market development (alternative flexibility providers)
- availability of waste heat as a source for HPs
- Availability of suitable DHC infrastructures?

Outlook

- **Finalizing the work in the Annex and reporting in winter/ spring**
    - Contribution still possible!

- Presentation of selected results in a **journal papers**

- Development of a short **fact sheet/ summary for policy makers** + recommendations + **a guidebook!**

- **(national) workshop** on the TS3 results in Spring 2022 (ISEC conference?)

Further presentation in the Special Session of the 7th International Conference on Smart Energy Systems

- **Peter Sorknæs: Energy system synergies of hybrid energy network technologies**
- **Edmund Widl: Categorization of tools and methods for modeling and simulating hybrid energy systems**
- *Anton Ianakiev: Hybrid Energy Networks - Demo Case studies*
- *Dennis Cronbach: On business models and the regulatory framework of hybrid grids*

PROGRAMME COPENHAGEN – with the sessions taking place in Copenhagen

ONLINE PROGRAMME – including both live sessions and recorded presentations.

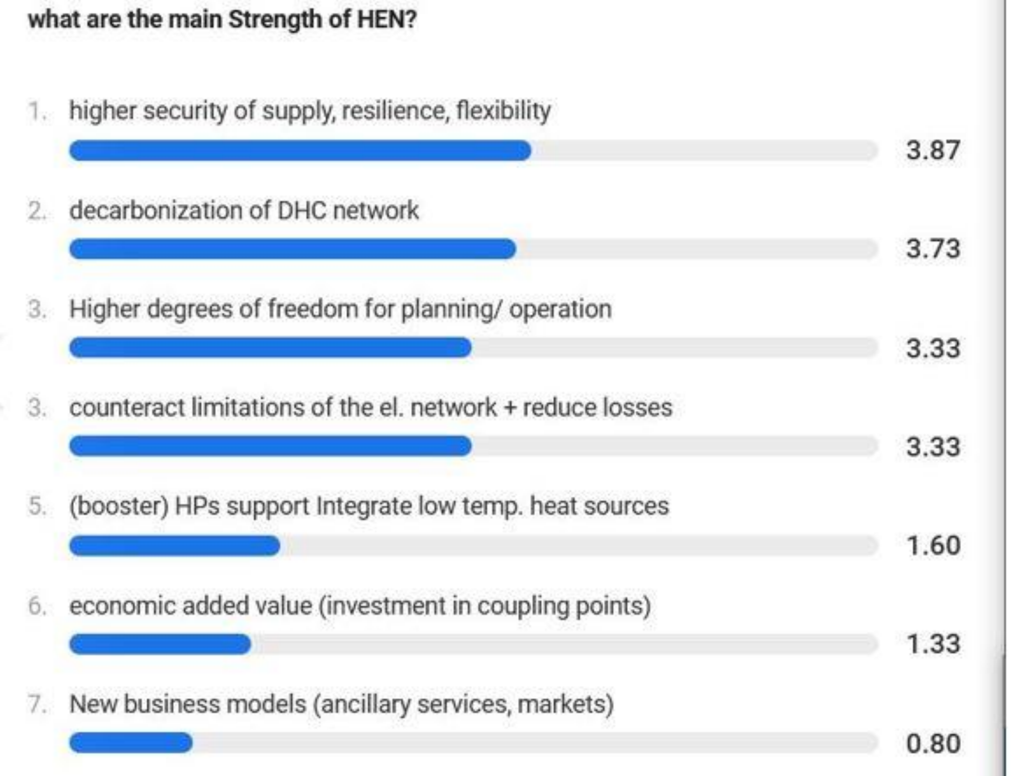
Survey on SWOT factors

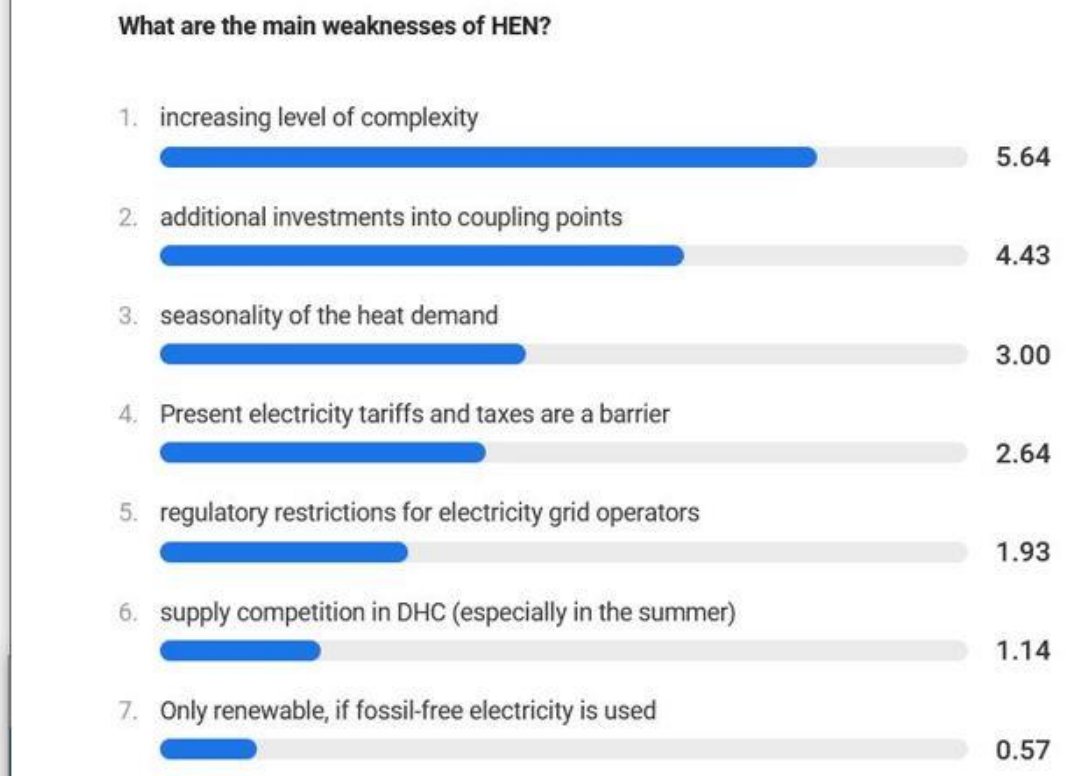
Join at

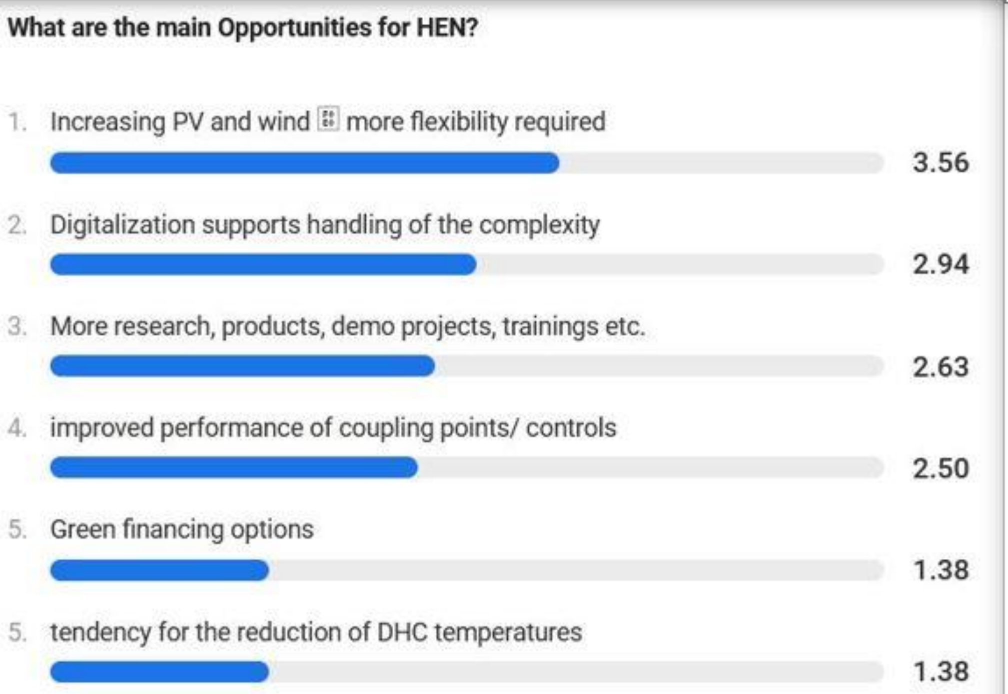
slido.com

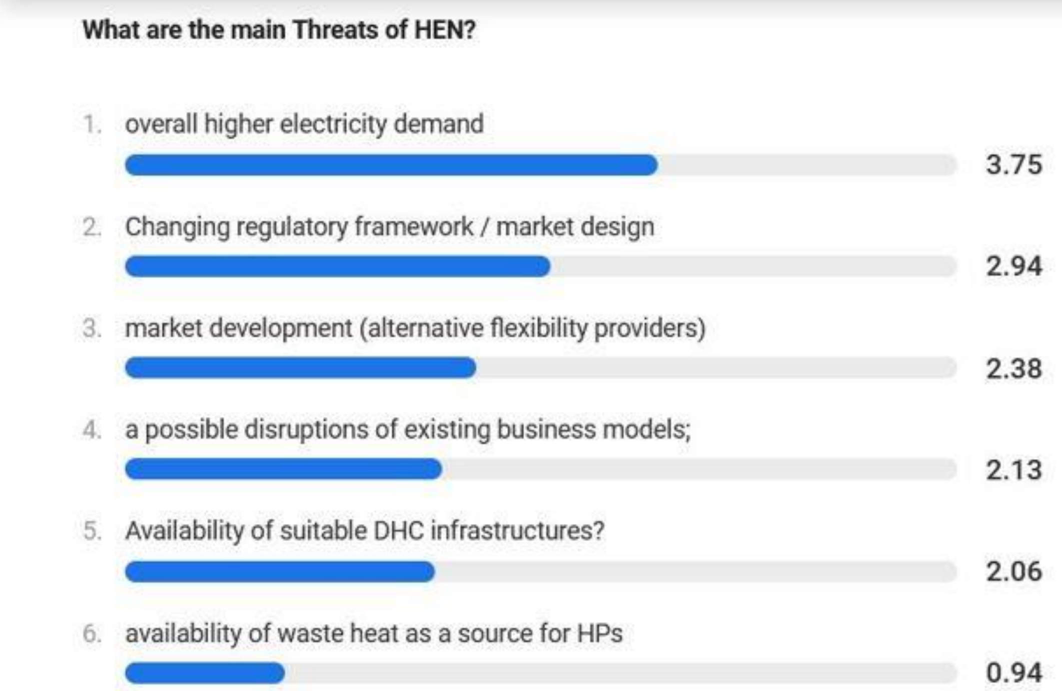
#689 719

Survey on SWOT factors - Results









Survey on SWOT factors - Results

any other aspects you want to add?

Affects of Refurbishment

Lacking actor to drive transit

people do not like changes

Obsulate old technologies

Counties with diverse climate

Thanks for your participation!

Contact:

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More Information at

https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3

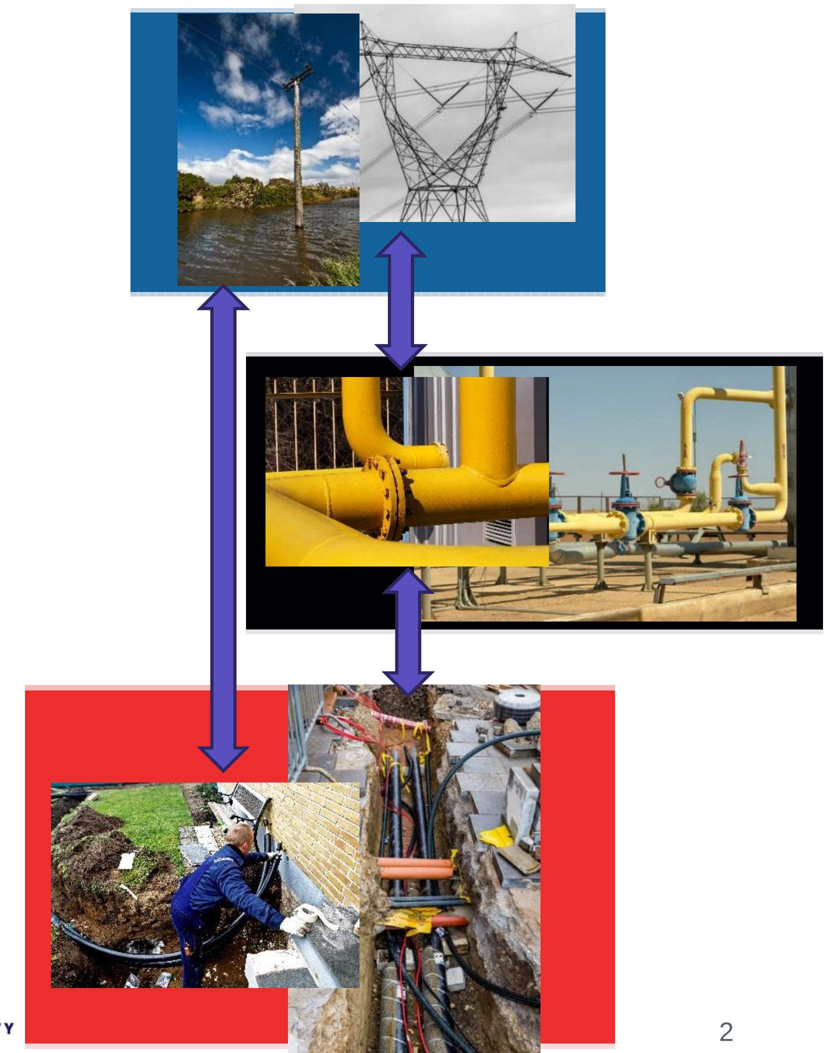
ENERGY SYSTEM SYNERGIES OF HYBRID ENERGY NETWORK TECHNOLOGIES

PETER SORKNÆS

AALBORG UNIVERSITY
DENMARK

Networks

- Electricity
- Gas
- Heating and Cooling



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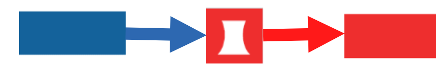
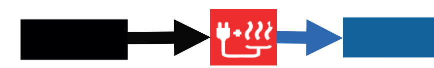
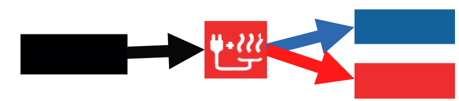
Technologies tested in national energy system scenarios

- Direct electrification of district heating:
  - Electric boilers and electric-driven heat pumps in district heating

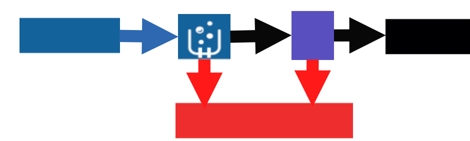


- Thermal plant technologies:
  - No large-scale CHP plants
  - Large-scale CHP as combined cycle gas turbines
  - Large-scale CHP as simple cycle gas turbines
  - Large-scale CHP as biomass-fired

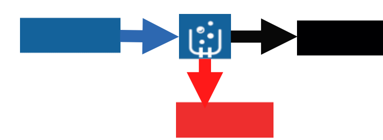




- Excess heat from electrofuels (incl. electrolysis)
  - 0%, 50% and 100% of potential identified in scenarios



- Electrolysis technology. Change all to (with 0%, 50% and 100% excess heat utilization):
  - Alkaline
  - PEM
  - SOEC



Six national energy system scenarios used

Two baseline scenarios:

- Baseline scenarios (2015) for the energy systems of Austria and Denmark.

Four future scenarios:

- Future scenarios with high shares of renewable energy for both Austria and Denmark. High district heating utilisation scenarios from:
  - Austria: ”Heat Roadmap Europe 4” (HRE4)
  - Denmark: ”IDAs Climate Response 2045”
- For each country two different future scenarios topologies are investigated:
  - A system with (relative) **low district heating utilisation** (developed based on high district heating utilisation scenarios)
  - A system with (relative) **high district heating utilisation**

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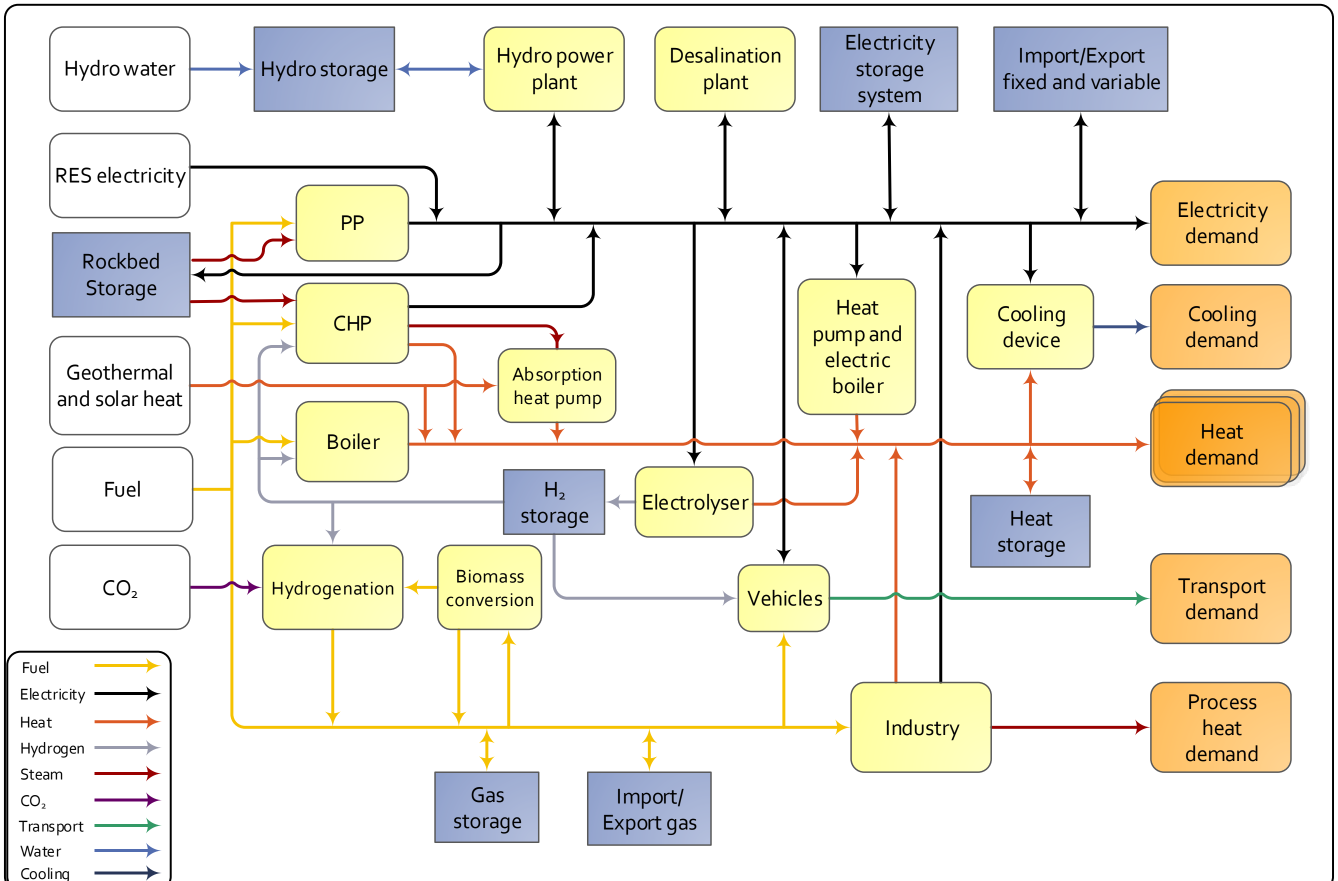
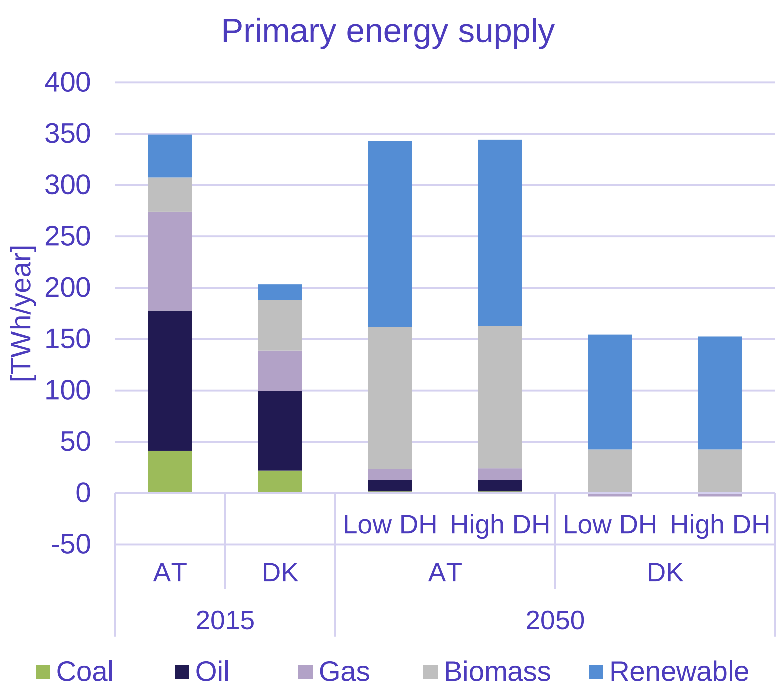
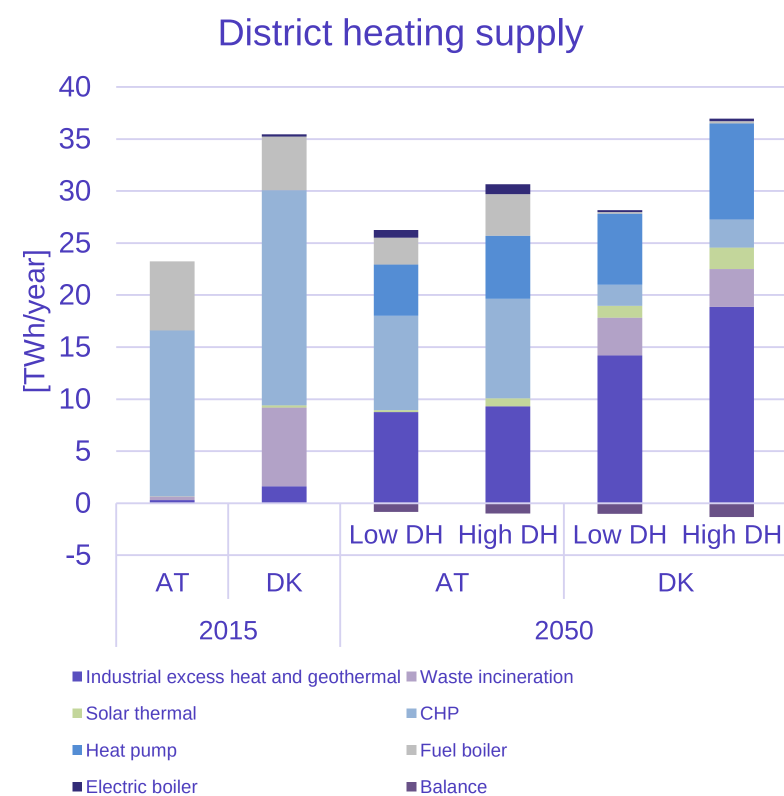
Energy system simulation tool - EnergyPLAN v16



www.energyPLAN.eu

Primary energy supply of the entire energy system and district heating supply





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Simulation approach

- All scenarios are simulated without electricity transmission connections to other countries.

- Sufficient energy supply has been ensured by adjusting the marginal variable renewable electricity source, so that the yearly production of unusable electricity is unchanged*.
  - The marginal variable renewable electricity source is assumed to be photovoltaic for Austria and offshore wind power for Denmark.

- Gas exchange is maintained by adjusting the gas produced via CO_2 hydrogenation (also affects the electrolysis and H_2 storage capacities).

**In a real-world situation this production would either be exported or result in reduced production from variable renewables*

Direct electrification of district heating – conclusions

- Electric boilers' less efficient conversion of electricity to heat allows for larger integration of variable renewables without creating increased levels of unusable electricity production.

- Heat pumps have a larger potential to reduce the biomass consumption compared with electric boilers.
    - Only until the operation of the heat pumps is limited by the district heating demand.
    - The biomass reduction is especially in relation to reduced use of biomass-fired boilers.

- The costs of the energy system are mostly affected by the capacity of heat pumps, compared with the electric boilers.
    - For electric boilers, the effect on the costs is mostly related to the potential to integrate more variable renewables into the energy system.
    - However, the change in costs is relatively low compared with the total cost of the entire energy system, as this also includes costs for the transport sector, etc.

Thermal plant technologies – conclusions

- Having no large-scale CHP plants and instead large-scale power plants increases the energy system costs and biomass consumption of the energy system, as well as the demand for variable renewable electricity sources.

- Combined cycle gas turbines show lower energy system costs as well as lower need for installed variable renewable energy capacity compared with simple cycle gas turbines and biomass-fired thermal plants.

Excess heat from electrofuel production – conclusions

- The use of excess heat from electrofuel production reduces the costs of the energy system, the use of biomass and the need for variable renewables.

- For electrolysis the results show that having a higher electric efficiency is more important from an energy system perspective than being able to utilise larger amounts of excess heat from the electrolysis.
- Due to relative high electric efficiency of SOEC, SOEC shows the lowest energy system costs and lowest need for installation of variable renewables.

Thank you for listening

For more follow the IEA DHC Annex TS3: Hybrid Energy Networks

https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3

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7th International Conference on Smart Energy Systems
21-22 September 2021
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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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[3] Aalborg University, Department of Planning, Aalborg, Denmark
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[5] Politecnico di Torino, Department of Energy, Torino, Italy
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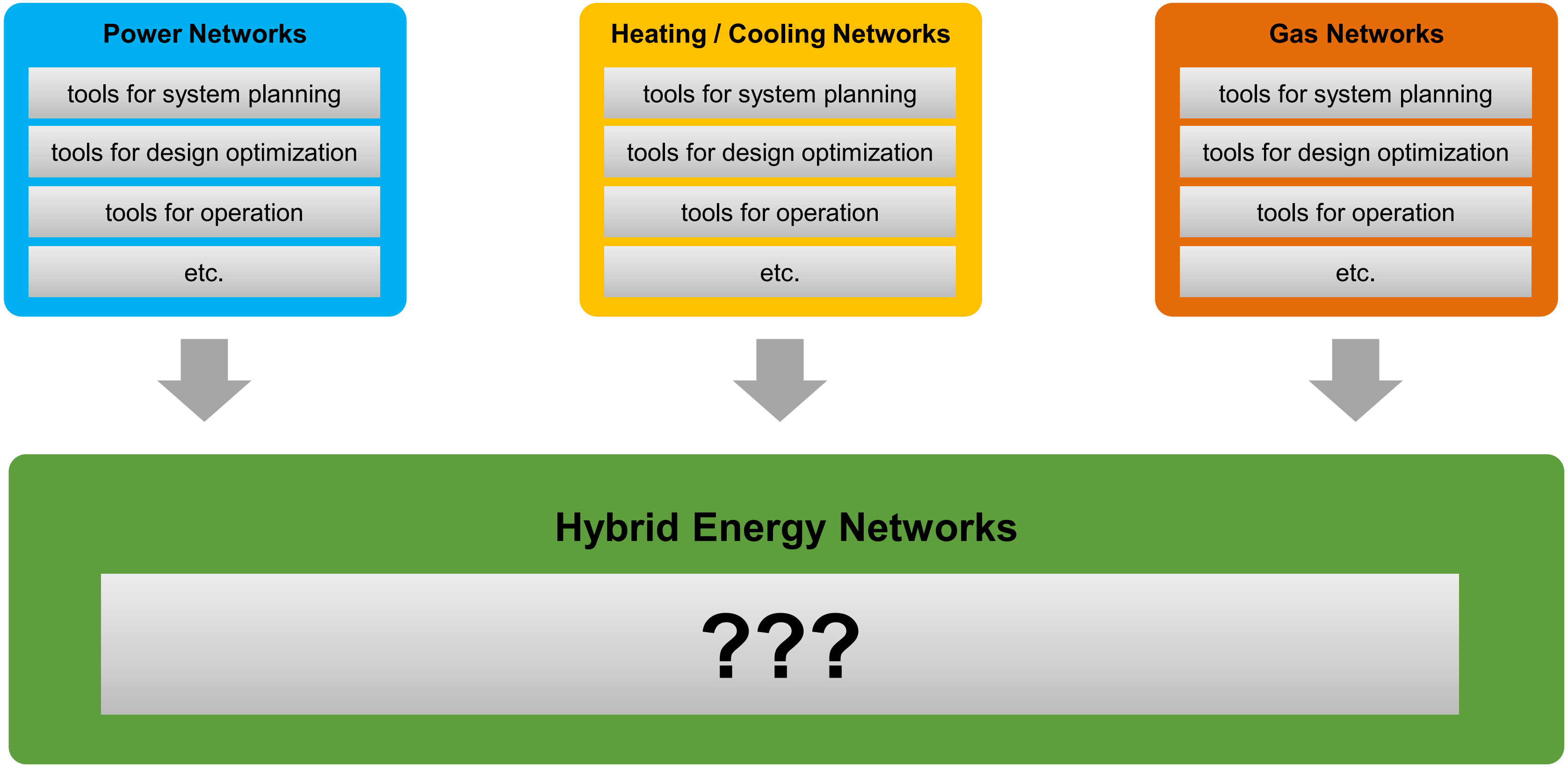

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Why are the tools we have used so far not enough?

- 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]

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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

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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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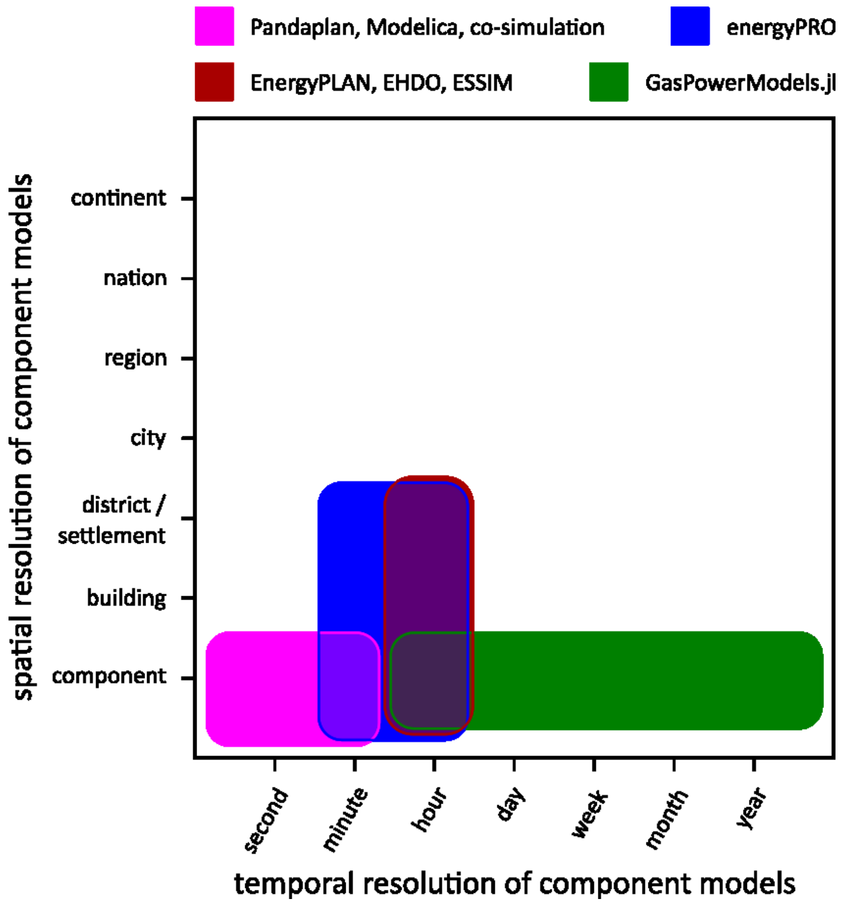
Pandaplan, Modelica, co-simulation
energyPRO
EnergyPLAN, EHDO, ESSIM
GasPowerModels.jl
spatial resolution of component models
continent
nation
region
city
district / settlement
building
component
second
minute
hour
day
week
month
year
temporal resolution of component models

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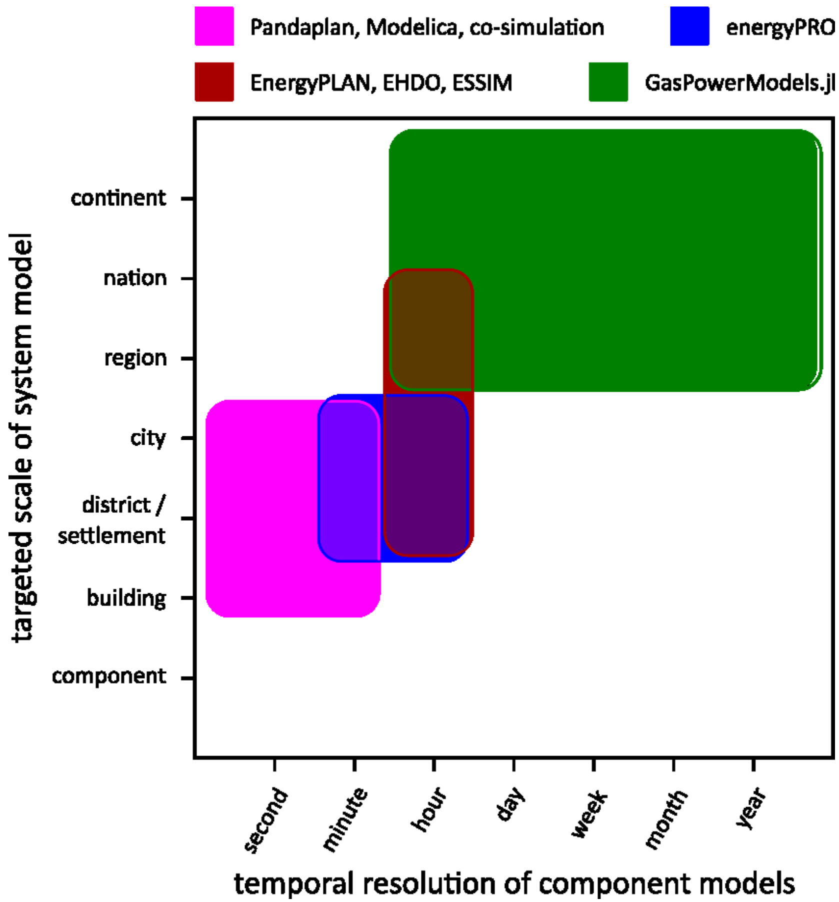

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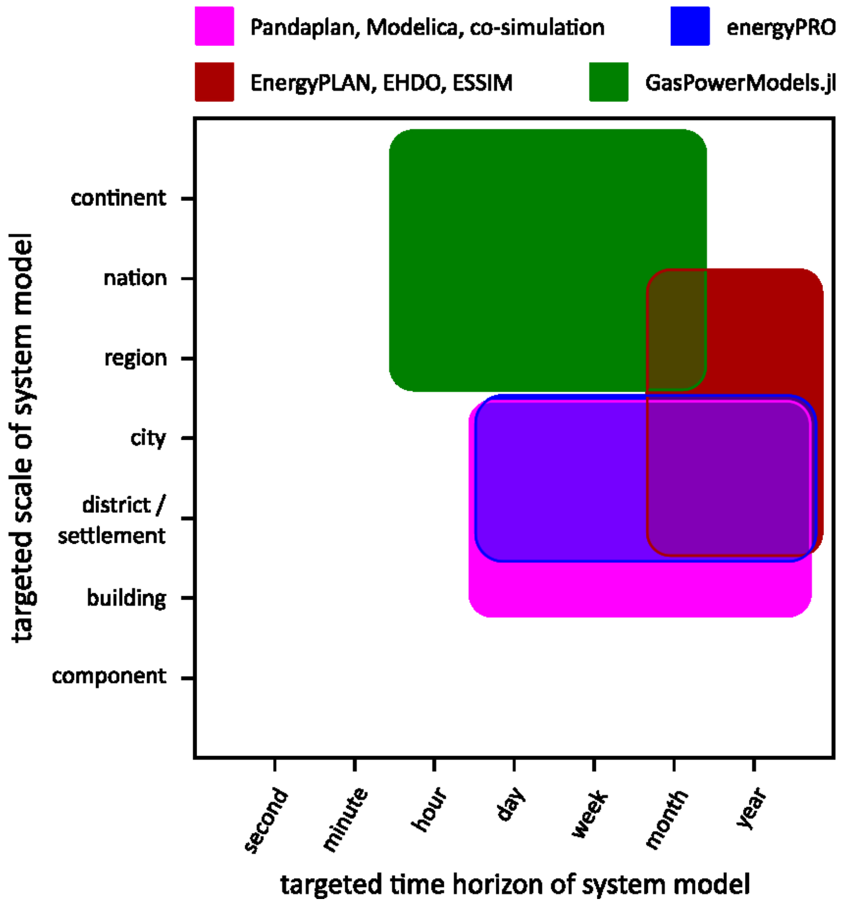
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energy CLUSTER DENMARK

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	economical
Pandaplan	X	
Co-simulation *	X	
Modelica **	X	
energyPRO		X
EHDO	X	X
EnergyPLAN	X	X
ESSIM	X	X
GasPowerModels.jl	X	X

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

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LOGSTOR
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Vestas
ENGINEERING TOMORROW Danfoss

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		✖	✖	✖

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

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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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7th International Conference on Smart Energy Systems
IEA TS3: Subtask D
On business models & regulatory boundary conditions for hybrid networks

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Questions to answer

- What trends can be identified regarding new business strategies for hybrid energy grids?
- What obstacles can be identified for implementing sector coupling strategies?
- Regarding obstacles: What solution approaches exist?
- Are there parallels between different countries?

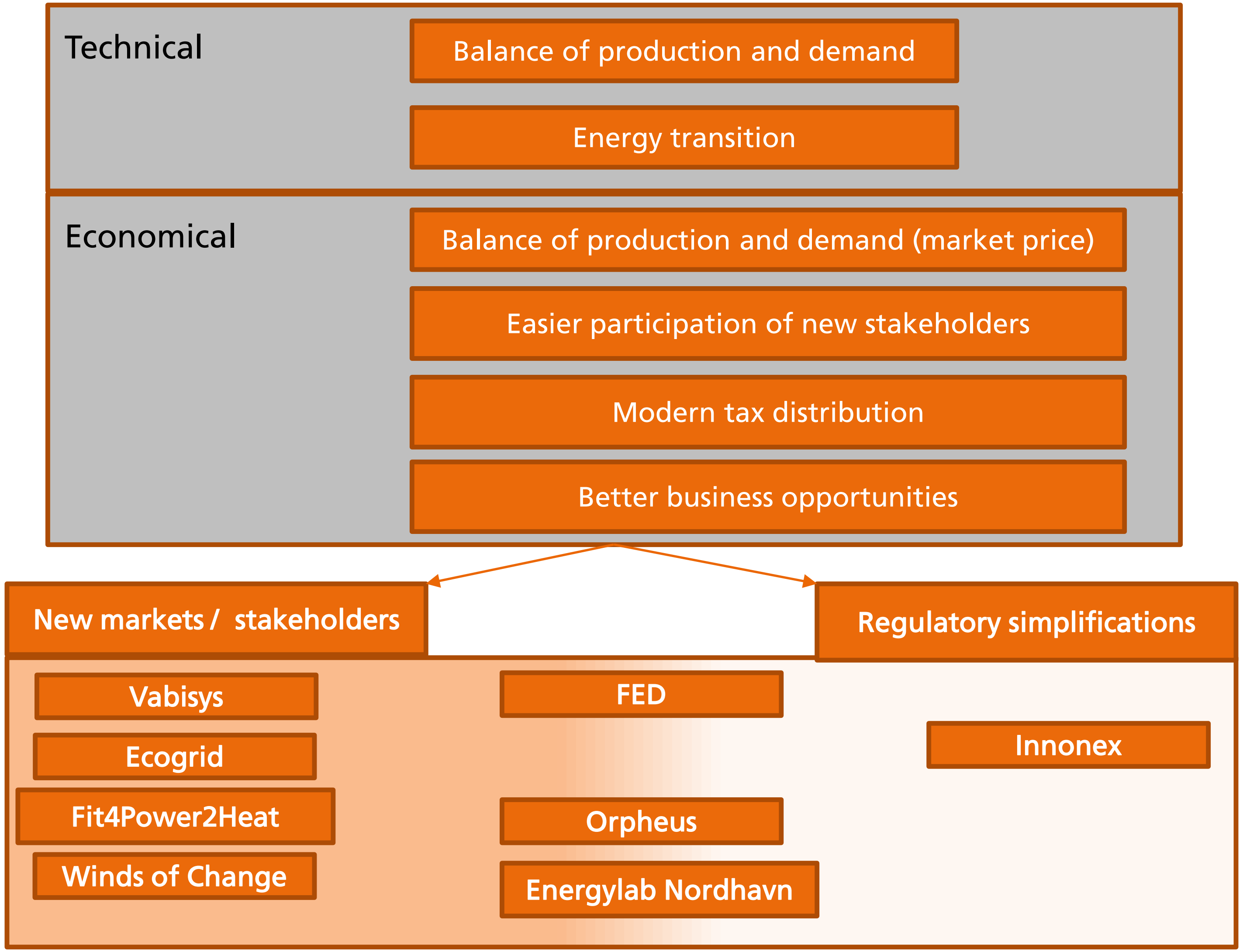
Tools to answer these questions

- Information about projects, contributed by Annex partners
- Studies on the topic

Known problems

- Partner contributions cover only a small amount of EU countries
- Additional literature research is biased via pay walls and the research focus of the own institute
- Topic could fill an annex on its own

Trends & drivers



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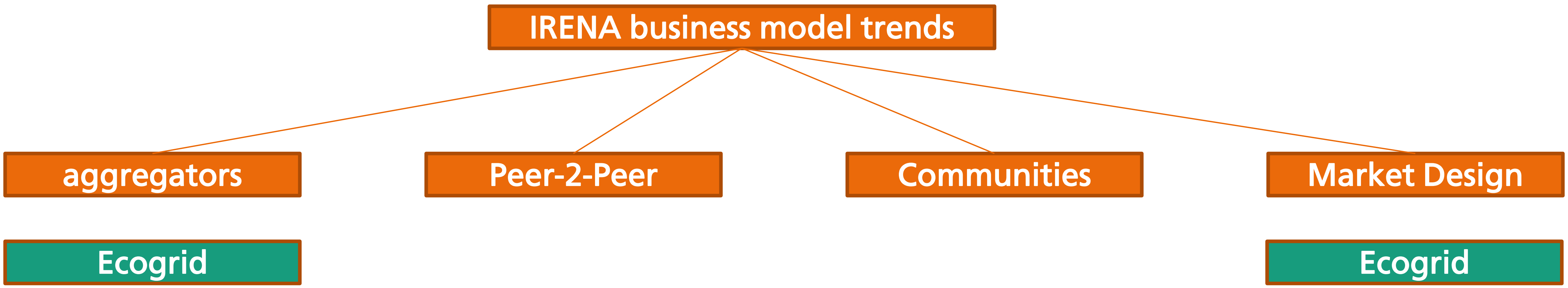
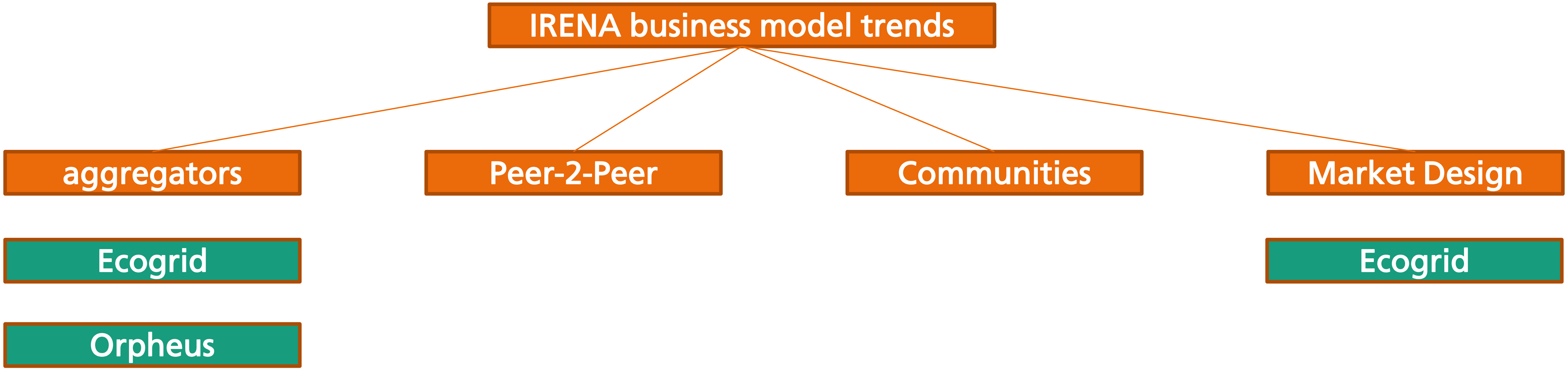
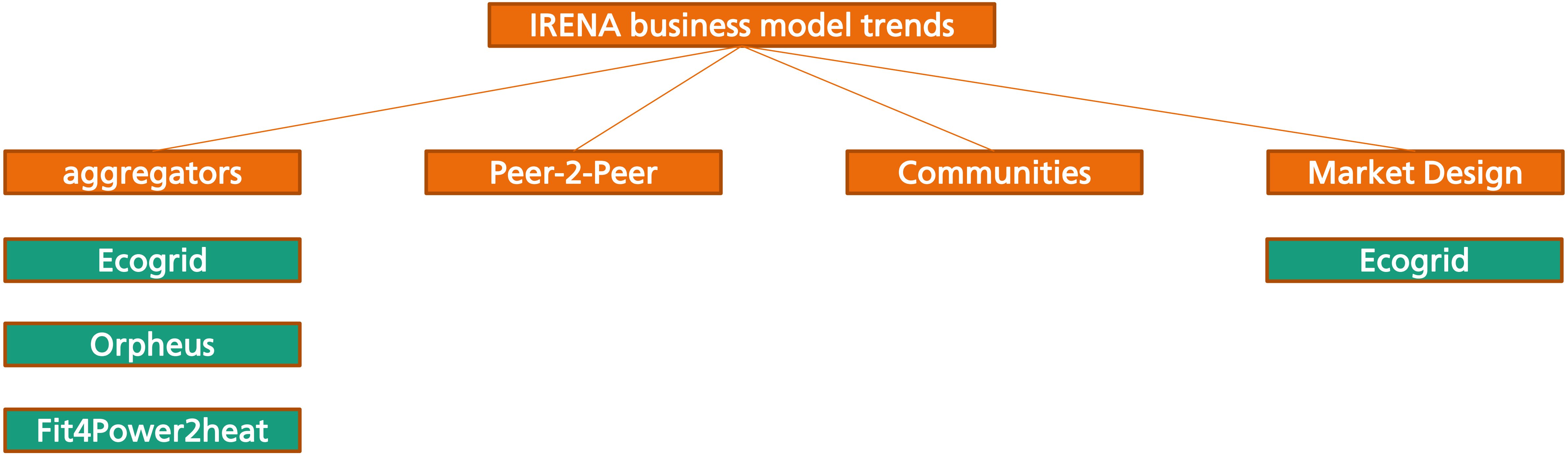
Business Models



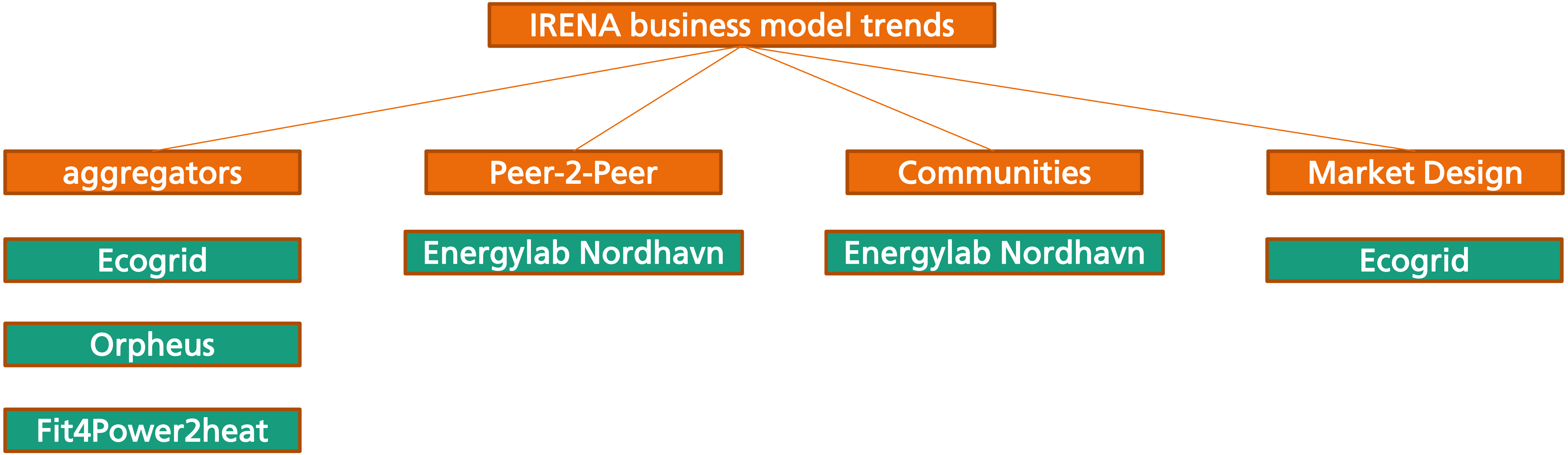
Business Models



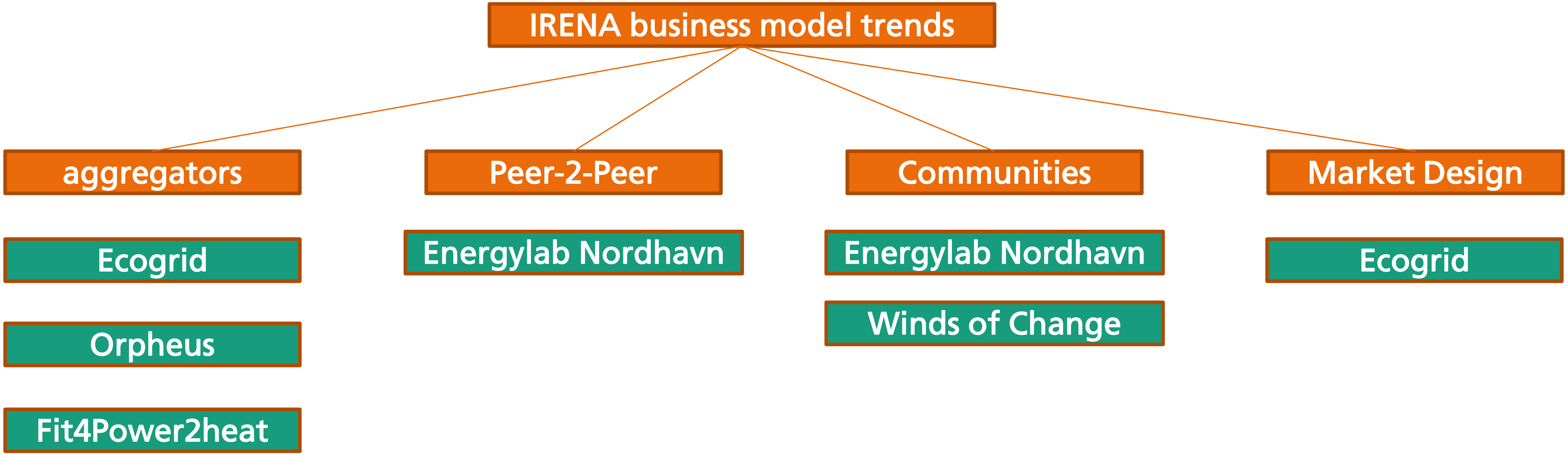
Business Models



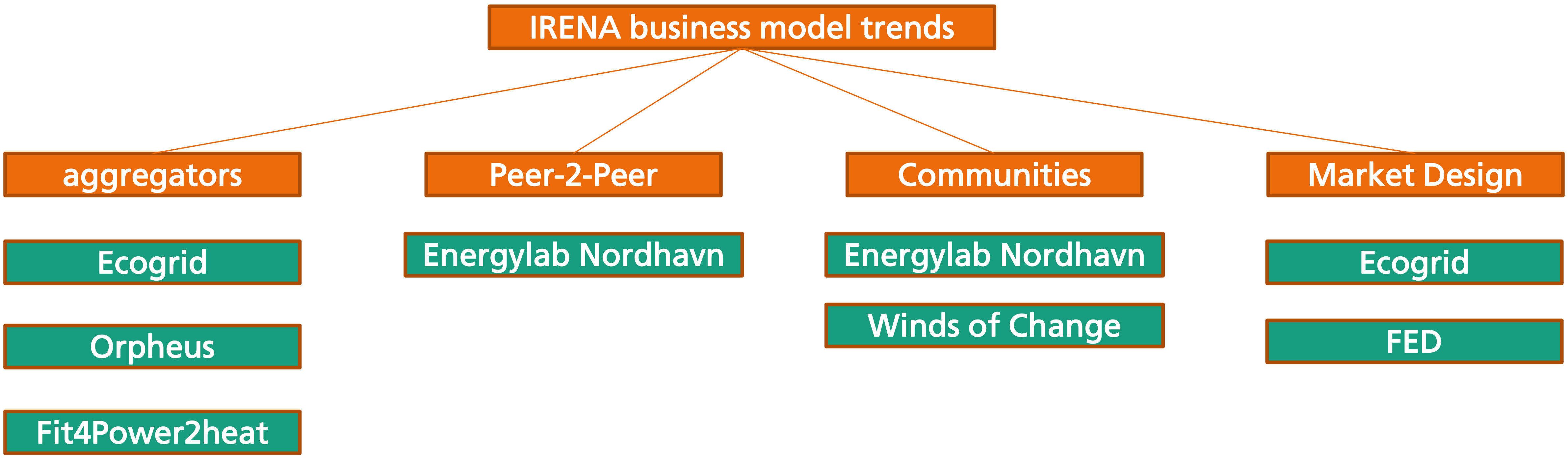
Business Models



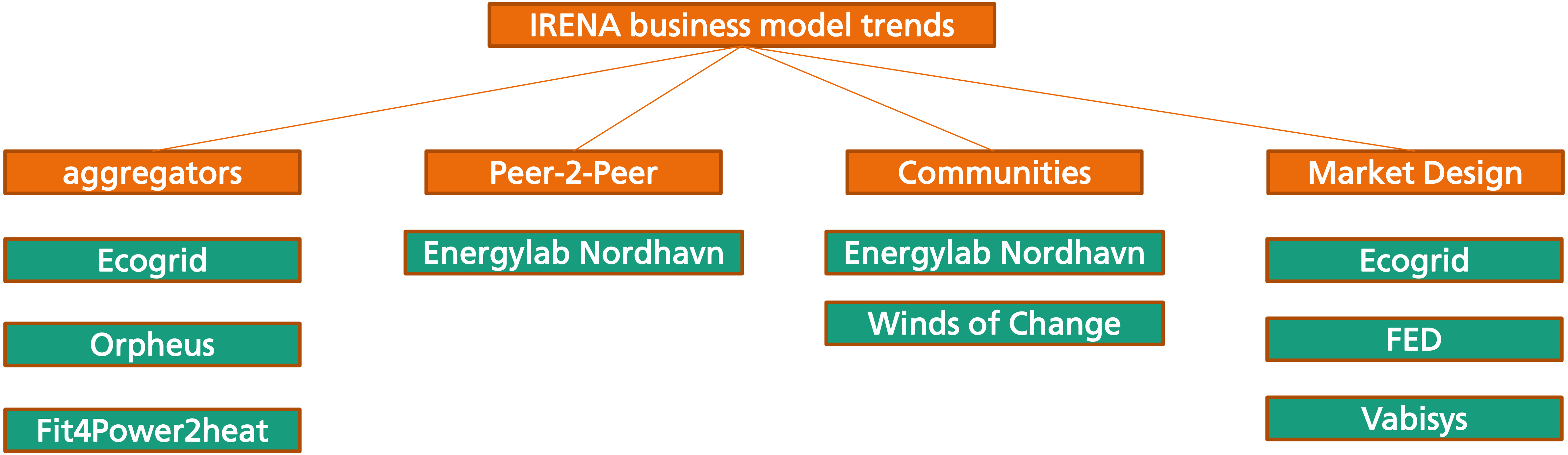
Business Models



Business Models



Business Models



Motivation on energy communities

- Two directives published by the European Union introduce citizens as actors in the energy markets
- Single persons can produce, store and sell energy
- Energy communities have a large potential: Up to 50% of electricity might be produced in communities in 2050.
- Different legal statuses are possible
- May help to reduce obstacles in some countries
    - Fees for roof PV plants in Spain (sun tax)
    - Reduced grid charges for local communities possible
- Not all countries have implemented the national framework yet (Germany)

Two types of communities

Renewable Energy	Citizen Energy
No big companies allowed	Everyone can participate
RE can be shared among participants	Only electricity
All forms of energy are addressed	Not necessarily local
Local community	
Non-profit organization	

Taken from [6]

Example

- A wind park was built in Belgium, which belongs to the local communities (60%) and an already existing energy cooperative. All authorities were united in an energy community.

- Citizens may purchase shares of the community
  - Payment of dividend
  - Participation in decisions

- Communities invest profit in further sustainable projects

- A good example for the reduction of resistances

- Similar projects in Germany without community participation are delayed

Figure from [7]

Literature

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