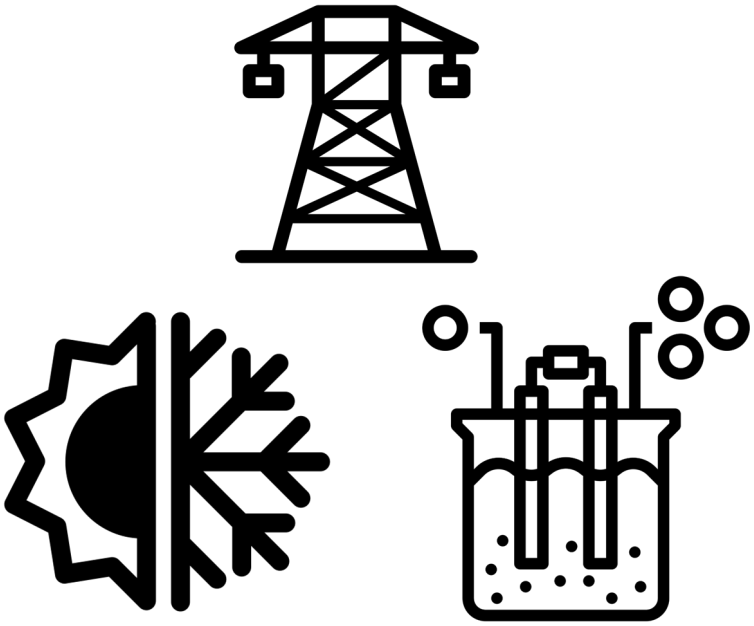
Technology Collaboration Programme
by IEA

IEA DHC

INTERNATIONAL ENERGY AGENCY
TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING



IEA DHC ANNEX TS3: HYBRID ENERGY NETWORKS

APPENDIX J
SWOT ANALYSIS OF HYBRID ENERGY NETWORKS, DETAILLED RESULTS

This page is empty on purpose.

Disclaimer notice (IEA DHC):

This project has been independently carried out within the framework of the International Energy Agency Technology Collaboration Programme on District Heating and Cooling (IEA DHC).

Any views expressed in this publication are not necessarily those of IEA DHC. IEA DHC can take no responsibility for the use of the information within this publication, nor for any errors or omissions it may contain.

Information contained herein has been compiled or arrived from sources believed to be reliable. Nevertheless, the authors or their organizations do not accept liability for any loss or damage arising from the use thereof. Using the given information is strictly your responsibility.

Disclaimer Notice (Authors):

This publication has been compiled with reasonable skill and care. However, neither the authors nor the DHC Contracting Parties (of the International Energy Agency Technology Collaboration Programme on District Heating and Cooling) make any representation as to the adequacy or accuracy of the information contained herein, or as to its suitability for any particular application, and accept no responsibility or liability arising out of the use of this publication. The information contained herein does not supersede the requirements given in any national codes, regulations or standards, and should not be regarded as a substitute.

Copyright:

Image Source (Frontpage):

thenounproject.com (Yazmin Alanis, Symbolon, PenSmasher)

Citation:

Please refer to this report as:

Nicolas Marx, Ralf-Roman Schmidt: IEA DHC Annex TS3 Guidebook, Appendix J SWOT ANALYSIS OF HYBRID ENERGY NETWORKS, DETAILLED RESULTS, 2022

CONTENT

1 INTRODUCTION

This Appendix is part of the IEA DHC Annex TS3 guidebook. The full guidebook is available at https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3

Author: Nicolas Marx, Ralf-Roman Schmidt, AIT

1.1 COLOUR CODE

This document gives insides into some more detailed results and comments of the SWOT survey done within the IEA DHC Annex TS3.

Each aspect of the SWOT analysis was rated by the participants, and they were able to comment on each aspect (optional). Each of the comments was colorized depending on the corresponding rating. Every factor was rated from the participants between 1 star (little to no relevance) and 5 stars (maximum relevance).

The colour code for the comments is displayed in the table below.

Table 1: Color code for comments

Not evaluated
1 Star
2 Stars
3 Stars
4 Stars
5 Stars

2 RESULTS

2.1 STRENGTHS

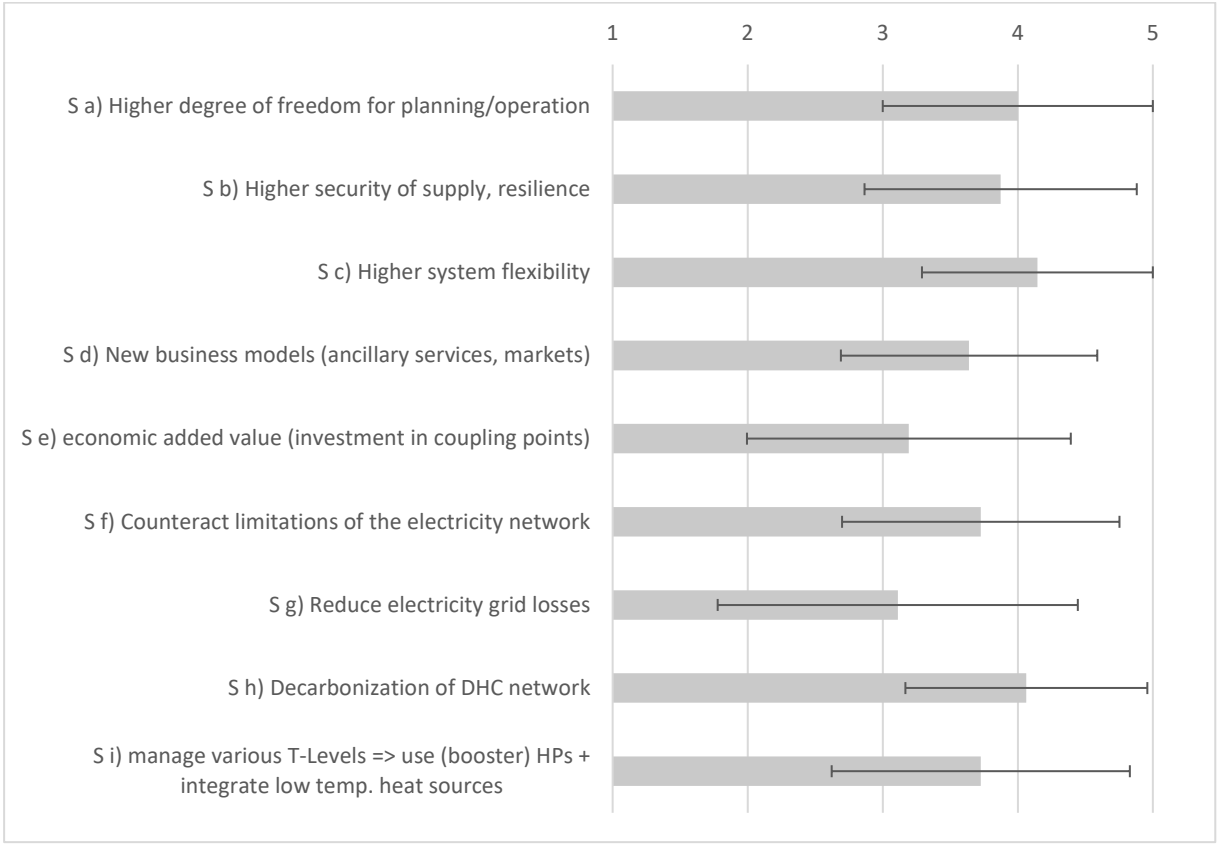


Figure 1: Average rating for strengths

In Figure 1 the average ratings for each strength including the standard deviation are shown. Participants rank higher system flexibility and the decarbonization of the heat network among the most important strengths. The reduction of electricity grid losses is viewed as the least important.

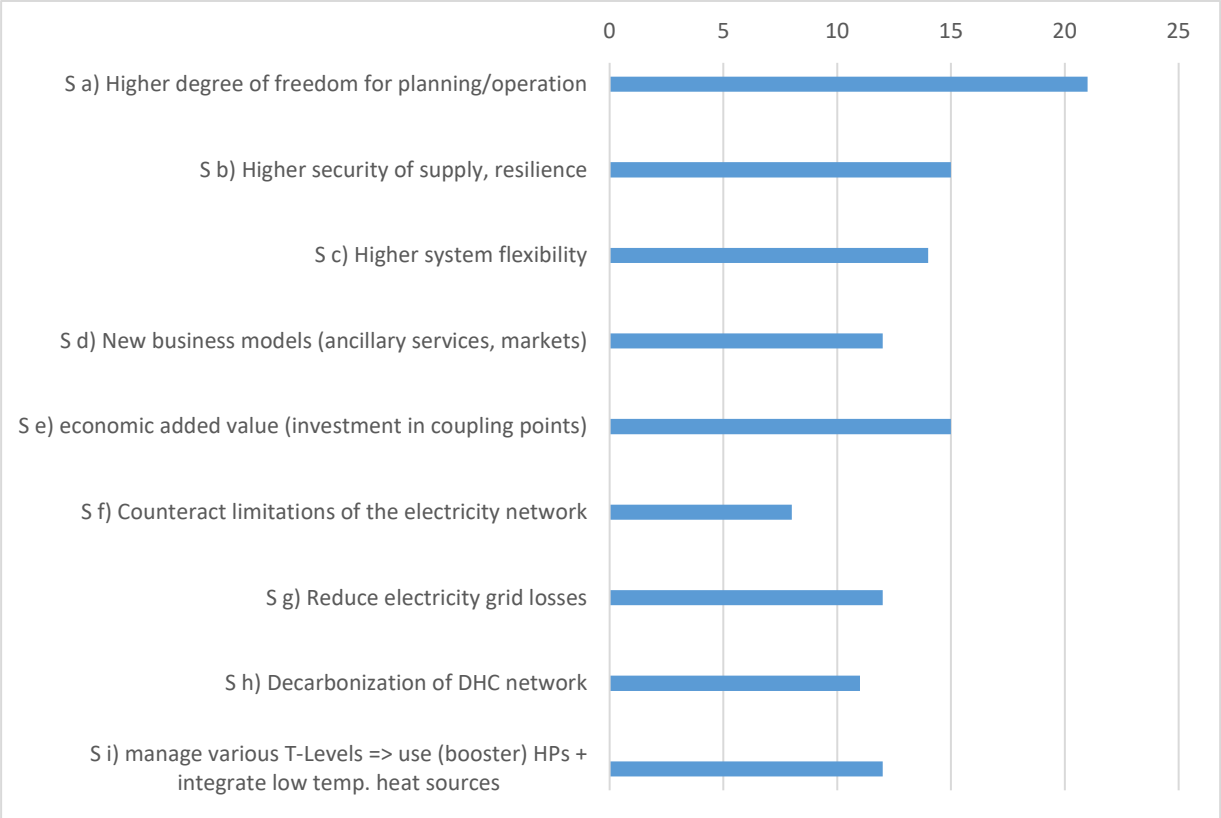


Figure 2: Number of comments per strength

Below the comments for each strength can be found colorized according to the rating. Some comments have been shortened and similar comments have been summarized.

STRENGTH a) A higher degree of freedom for planning and operation of the energy system, including multiple options for energy transformation and storage, i.e. PtH plants can make low temperatur...
• Hybrid networks can be achieved as well by smart hybrid appliances such as hybrid heat pumps or cogeneration. This type of hybrid Energy Network, by a smart integration of existing electricity and gas grids, present several advantages : - low investment costs (existing grids) thus avoiding the high investment in a district heating when the energy needs will decrease thanks to the improvement of building envelop insulation. - low coordination costs (can be achieved progressively, by individual decision). Hybridation can be done by replacing the existing boiler or by adding a small heat pump on the existing system. the hybrid heating solution can be adapted to each building characteristic (High/Low temp HP/ micro-cogeneration)
• This depends on the value that is seen by the other networks, who may be able to obtain the same services from other sources
• I think there might in practice be a counteracting increase in complecity for planners and operators, because of more actors and technical issues to consider, even thought the technical solutions are there.
• District heating becomes more dependent on electricity while electrification is of high interest for the transport and industry sector. There are uncertainties with investments in investment in renewable electricity generation and also electricity transmission capacity.
• PtH must be well designed in order to use just real excess electricity, which can't be used otherwise, like for hydrogen production via electrolysis. If PtH is applied to DH, then just with heat pumps and NO ELECTRICAL DIRECT HEATING. Combination of gas grid and DH with regard to PtG makes sense.
• Also network extensions can be planned in one concise concept
• Solar district heating is also enhancing flexibility, while decarbonising heating. Large solar district heating networks are increasingly deployed in European markets (e.g. Germany, the Netherlands, France, etc.). Coupling solar thermal with heat pumps can offer substantial benefits.
• Given the diversity in energy vectors, I definitely recommend exergy analysis as a tool for optimizing the operation of such networks.
• Low temperature waste heat and solar thermal technologies can provide low carbon heating in 5G DH networks
• The higher degree of freedom is a potential. When there is too little money to implement an overall hybrid solution the degree of freedom decreases.
• renewables for CHP operation might be limited
• P2H can replace gas boilers In some cases there will not be need to pay grid service cost.
• generally agree strongly with statements, with 2 remarks: - I am not sure that the best use of Gas produced from P2G is to be burnt to produce heat: there may be more effective uses (either industrial, or to serve and green up "hard to abate" industries. Heat can be done in much cheaper ways
• The interfaces between types of networks allows exploiting their synergies, while CHP processes and PtH allow improving energy efficiency by carrying out processes which require less power by using heat sources from the environment.

This is the major advantage/requirement to exploit the benefits of the interconnected system.
• Currently, it is clear that Danish DH companies with a flexible production setup have stable or even lower prices, while DH companies relying on one or two production technologies (ie. electricity and/or gas) see a sharp increase in prices.
• Hydrogen/Green gases will be important in the future as a real energy storage opportunity to stabilize energy supply and as a fuel directly used at CHP and other heating form, especially in hybrid installation coupled with different RES (i. e solar thermal)
• Multi-source production is the key to success. We see this these days where we have extreme energy prices. DH is still, in average, the same low price for the once that have developed this strategy, but not for the single-source DH.
• especially low-temperature heat networks in combination with heat pumps
• Our source is inexhaustible uninterruptible supplies of subsurface water www.telesis-synergy.com
• https://doi.org/10.1016/j.scs.2018.09.037

STRENGTH b) A high level of security of supply and system stability due to multiple and distributed options for covering energy demand between the networks in combination with storages on differen...
• Electric and gas coupling by hybrid heating solutions (smart hybrid heat pumps and cogeneration) are very resilient solutions, each house can rely on two energy carrier to ensure its heating needs. The flexibility given by the sector coupling by hybrid appliances allows to get all the 3 benefits from demand flexibility, as this flexibility isn't limited in its duration : - maximise the renewable energy integration, renewable electricity when available, complemented by renewable gas, (locally produced biomethane from biowaste and residues, or H2,) if needed. - improve system efficiency in case of a transmission line of local power production breakdown - ensure resource adequacy thanks to its capacity to shave peak demand when the power grid is saturated, or when the power production capacity isn't enough to meet the demand, for any duration required.
• A lesser strength in my opinion, since for any given energy vector there is "always" a non-renewable source available or a storage option in order to ensure supply.
• Again, the issues of stability and supply security depend on factors beyond those of the DHC
• At the same time digitalization and operational optimization of the whole energy system are needed. All the energy sectors need to collaborate to achieve security of supply and system stability.
• The question will be how much storage capacity should be foreseen (daily, weekly, or longer, or even seasonal). Compensating certain load lines makes a lot of sense.
• For the power system, the instantaneous balance between demand and generation has traditionally been a major constraint. Storage (in its various forms, such as other types of networks) allow providing these functionalities, mitigating these requirements. This is a benefit for the system, but the networks already have independently these attributes, so we do not find it so critical.
• In the case of multiple options, the most expensive (OPEX) will be used only a few cold weeks per year, making it even more expensive (CAPEX).
• Energy storages are crucial for the success of well-operating hybrid networks because some energy sources are not available all the time.
• depending on energy needs, type of energy can be chosen.
• As above, but with a longer time span and therefore a bit less critical.
• Overall system resilience by increased number of supervisory layers and remote operation and control
• The increased complexity and interdependencies in the integrated energy system may also pose a risk to security of supply.
• A high level of security of supply and system stability due to multiple and distributed options for covering energy demand between the networks in combination with storages on different time scales - exact the sense of use
• Is a must.
• Impervious to all shut down events

STRENGTH c) A higher level of system flexibility enables one to manage and mitigate temporal imbalances of intermittent electricity production and demand support the containment and restoration...
• Electric and gas coupling by hybrid heating solutions (smart hybrid heat pumps and cogeneration) give the energy system a very level of flexibility The flexibility given by the sector coupling by hybrid allow to get all the 3 benefits from demand flexibility, as this flexibility isn't limited in its duration : - maximise the renewable energy integration, renewable electricity when available, complemented by renewable gas, (locally produced biomethane from biowaste and residues, or H2,) if needed. - improve system efficiency in case of a transmission line of local power production breakdown - ensure ressource adequacy thanks to its capacity to shave peak demand when the power grid is saturated, or when the power production capacity isn't enough to meet the demand, for any duration required.
• Needs to be shown that this is cost-effective (and relaibly and quickly available) for future energy systems
• Currently this is not so much indispensable, but in future with very high penetration of distributed energy resources such as distributed generation and electric vehicles, this could turn to be critical to efficiently integrate them into the system without dramtically increasing the cost of the system
• In Denmark we need to see a system that pays the DH companies fairly for the security of supply that their CHP plants provide to the electricity grid - otherwise they will be closed in the years to come, as the number of operating hours decline due to the introduction of wind turbines and PV.
• Yes, very useful. Renewable gas utilized in CHP's in order to balance the electrical grid makes sense. The question will be who will pay for the expensive equipment.
• I think the mayor strength is that flexibility of all grid connecting technologies can immediately used to support the other network, so that both can be run most efficiently
• Particularly for heating and cooling applications the use of solar thermal, heat pumps and thermal/ cold storage can further increase system's flexibility by shifting electricity demand outside peak hours
• Very tight related to strength 1. Sector coupling is one of the methods to increase multi-source production. The integration with the electricity and gas grid, bring in the extreme variable prices to optimize around.
• Hybrid networks can become so flexible that they may avoid the need for involving end-users in flexibility approaches, such as demand response or demand side management. In other words, hybrid networks could ensure the end-users' energy needs without compromising their comfort.
• Flexibility has a value and should be rewarded financially
• Higher flexibility, when for example power prices are low-even electrical boilers can be good solution. DH can help in balancing of power grids. Especially if there are TES options.
• TELESIS facilitates system integration that produces multiple utilities and services in one process
• https://electrek.co/2018/02/04/tesla-powerwall-solar-virtual-power-plant/

- of the above reported options, I think that the weakest one is the last "levelized electricity market prices" as the issue is dependent on several other options

STRENGTH d) Options for innovative and adapted business models and new revenue streams including new services (e.g. ancillary services), increasing the self-sufficiency by maximizing own consumpti...
• The hybrid heating solutions (hybrid heat pumps or cogeneration) will be the future "smart grid tool". These equipement creates value for the energy system (renewable integration, resilience, ressource adequacy), but the present economic model isn't really adapted to maximise this value. The value stream is to be organised, will it be via DSO, aggregators, solutions manufacturers, energy suplliers ? There is there an open ground for innovation and new business models.
• A simpel thing.
• "increasing the self-sufficiency by maximizing own consumption, ..." should be assessed with a wide system perspective. Too narrow approach may lead to sub-optimization and the risk of lock in effect since infrastucture has a long-term lifetime.
• Yet again the value to the other networks is crucial
• Use of local opportunities to produce and use of green gases. Support for economy on the local level
• maximizing own consumption does not lead to the maximum possible social welfare (total system efficiency)
• One of the main obstacles are related to the limited business models. It is new field for this sector and it should be analysed before wide implementation of hybrid networks.
• This is necessary for new services like flexibility
• For large scale heat pumps, it seems that the ability to provide ancillary services to the electricity market is more import for the economy than a COP that is a tiny bit higher.
• Major emphasys of physical systems predictive capacities by increased energy efficiency as a predictive tool
• From an energy utility perspective: Multiple energy carrier optimization tools are already available today.
• It took years of research and development to accomplish out innovative, resilient abstraction technology

STRENGTH e) An increased economic added value i.e. by creating jobs due to the investment in coupling points
• Electric and gas coupling by hybrid heating solutions (smart hybrid heat pumps and cogeneration) will create value by reducing the use of fossil energy, increasing resilience and facilitating ressource adequacy. A share of this value have to go back to the customer, to pay back for the equipment and finance the building renovation. Renovation and hybrid heating will create jobs in the building sector.
• I guess I misunderstand this question. In my opinion more investments (technologies or people/jobs) imply higher capital costs and risks.
• Probably a thorough coupling coul even lead to a loss of jobs
• this is replacing other (older) sources of energy -- also, the kind of people who can install, maintain these services need to be highly skilled in IT and in energy systems, while these job markets are already extremely tight
• Hardly reflected through subsidies, thus not visible for business models
• This strength is shared also with other solutions, while valuable not specific of hybrid networks
• Needs quanifiying
• A relevant point here would be the training of professionals on best practices for hybridization of networks. It is such a complex subject that it needs dedicated expertise, in my opinion.
• In some cases hybrid networks will allow avoiding HOB, will include smart metering- it means that the amount of jobs will be decreased
• (having more people doing the same is not necessarily a positive element)
• more jobs means more costs, so reduce the coupling points to the absolute minimum, but foresee all the technical system requires.
• Local jobs are an important subject for DH. Also local sponsorships. High involvement in customers that feel that the DH is their system (not at home) - like the cloud is the computer not at home :)
• Such multi-energy solutions are typically distributed and create more jobs than centralised power stations
• The social wellfare should be increased to justify the new investments
• Mutiple utity and services provides multiple revenue streams.

STRENGTH f) The options to counteract limitations of the electricity network transfer capacity and thus to avoid investments into grid reinforcement by local utilization of excess electricity (e.g...
• Electric and gas coupling by hybrid heating solutions (smart hybrid heat pumps and cogeneration) will help maximising and optimising the use of all decentralised renewable energy (solar, wind, biomethane from waste and residues), thus boosting the local circular economy. Local smart cogeneration can help solve this problem but smart (slow) charging of electric vehicule is the right way to manage charging demand, studies have shown that most electric car owners (98%) do not need an immédiate charging. Even a district heating cogeneration will not solve the electric distribution grid constraint to charge electric vehicle, it will only lift it for the transmission system.
• Cold spells occur in large areas coincidentally. When heat buffers run out, power-to-heat solutions will place a very high demand on the electricity grid.
• Needs quantifying and is likely to be location specific
• In some cases yes. .
• But again local solutions need to be assessed with a wide system perspective.
• Very important for the electricity grid, especially in a system with much more decentralized power production form intermittent sources such as wind and solar. DH needs to be compensated for the value provided to the entire energy system.
• This is a must - else no integration.
• TELESIS is capable of generating its own electricity ORC / Salinity gradient

STRENGTH g) A reduction of electricity grid losses by maximizing local consumption of (renewable) electricity sources instead of transporting the electricity to remote demand locations
• Electric and gas coupling by hybrid heating solutions (smart hybrid heat pumps and cogeneration) will minimise electric and heat losses, as the heat generated will contribute to the building heating needs.
• Electricity grid losses, no. Bottleneck however, is another thing.
• A local demand should not be created to reduce network losses, especially not if it is not the best suitable electricity use for the overall energy system
• The loss in transportation is limited, while the temporal differences in the system-wide demand supply balance can be very large. It is not efficient (wrt social welfare) to maximize local consumption by using temporal flexibility.
• Losses in the electricity grid are limited to begin with, so no major issue.
• Losses increase or decrease with distributed generation (DG) depending of the penetration levels. Moreover, more DG can incrase the cost of distribution systems to integrate them
• Depends on the local/transformation losses
• Losses are not that large here, so it is not a major issue. But of course, this benefit should also be harvested
• yes, otherwise the grid costs will kill us.
• A local production and consumption also reduces heat losses in district heating networks.
• Our reduced load makes the deployment of renewables more feasible.

STRENGTH h) A decarbonization and diversification of the DHC networks, if using renewable electricity and thus to increase the stability in operation of the heating (and cooling) plants, the fuel ...
• Electric and gas coupling by hybrid heating solutions (smart hybrid heat pumps and cogeneration) give the energy system a very level of flexibility The flexibility given by the sector coupling by hybrid allow to get all the 3 benefits from demand flexibility, as this flexibility isn't limited in its duration : - maximise the renewable energy integration, renewable electricity when available, complemented by renewable gas, (locally produced biomethane from biowaste and residues, or H2,) if needed. - improve system efficiency in case of a transmission line of local power production breakdown - ensure resource adequacy thanks to its capacity to shave peak demand when the power grid is saturated, or when the power production capacity isn't enough to meet the demand, for any duration required.
• a coupling of electricity and heat will occur no matter if the networks are operated individually or combined
• Decarbonization is one of the major advantages that renewables bring, that requires solving technical challenges to address stability
• Probably location-specific
• Again pure electrification is not the best solution; solar thermal, geothermal, etc. should be part of the diversification strategy aiming at higher efficiency (e.g. solar thermal is typically 3 times more efficient than PV)
• Depends on electricity generation mix. But there is trend, that share of RES in electricity generation will be increased. In some cases DH is mostly based on RES (biomass), in this case electrification can lead to CO2 increase.
• Very important, especially as an alternative to biomass. The power obviously needs to be green, ie. based on renewable energies like wind and solar.
• Is a must in areas where the green transiation is development to a large extend. Other places, the delivery of non-poluting heat and cooling may be more important.
• Not only a transformation on the supply side: there must be changes in the distribution as well e.g. lower temperatures.
• Our subsurface water is the platform that serves a lengthy list of diversified services

STRENGTH i) The option to efficiently manage various levels of temperatures, i.e. low temperature heat sources by using (booster) HPs and/ or electric boilers for (locally) adapting the temperatur...
• Electric and gas coupling by hybrid heating solutions (smart hybrid heat pumps and cogeneration) allow for a household per household approach, managing all type of buillding specificities and further evolution. To give an example, an hybrid heat pump combine an heat pump optimised for its heat supply (often obout 1/4th of the peak demand capacity) which will provide over 60% or more of the building heating needs. A further improvement of the building envelop will further increase the share of heat provided by the heat pump, without efficiency loss. This makes this type of coupling more easy to associate with a step by step deep renovation.
• https://cordis.europa.eu/project/id/649820
• See answer to the question before: a coupling of electricity and heat will occur no matter if the networks are operated individually or combined
• A question of technology and optimization. No big deal.
• depends on system
• Good option to have, but may not need a HYBRID energy network to realise.
• The possibility of optimizing thermal cascades between sources at different temperatures.
• Coupling solar thermal with heat pumps (including high temperature heat pumps) can open new opportunities to manage various levels of temperatures
• That's the big advantage of DHC: making use of lowgrade sources of energy. Low temperature DH is very important, as it increases the efficiency of the heat pumps upgrading the energy.
• yes, optimizing the temperature levels increases significantly the efficiency.
• Heat source is the same all year round so interseasonal issues are precluded.

2.2 WEAKNESSES

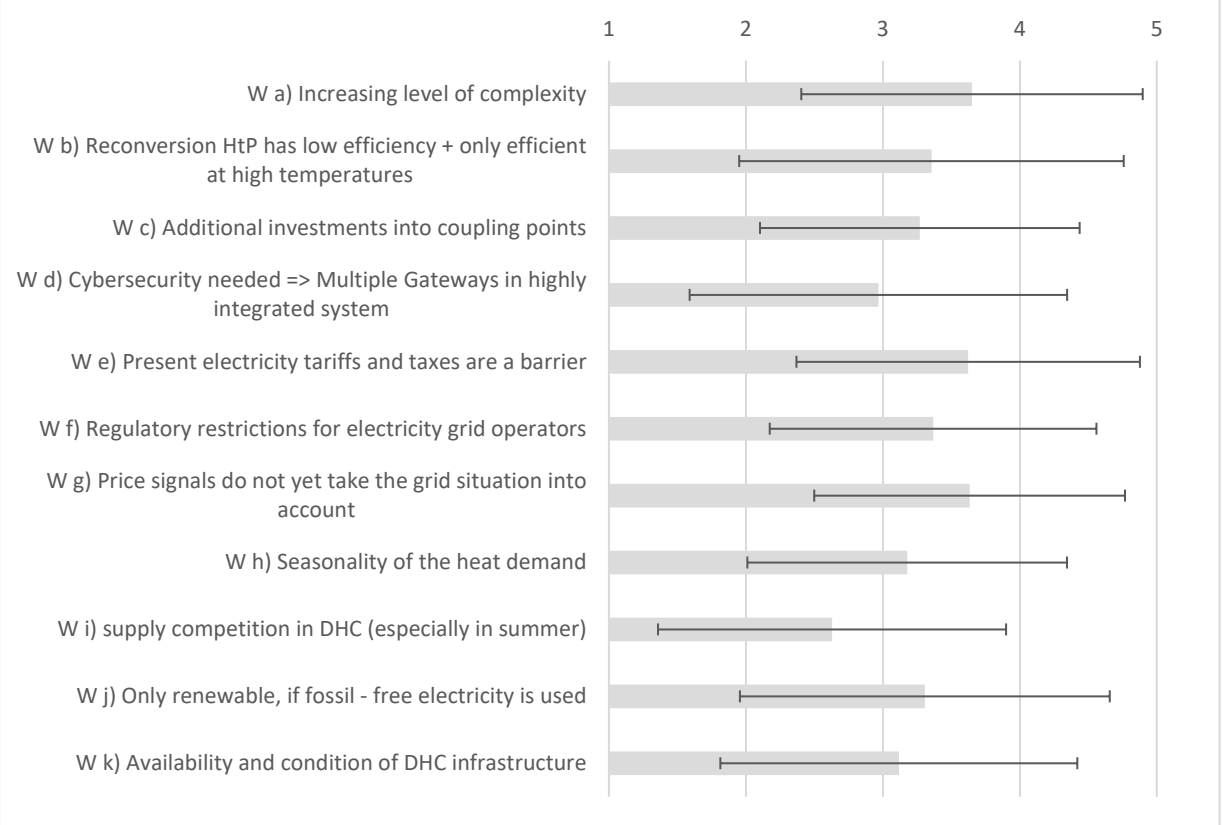


Figure 3: Average rating for weaknesses

Many view the increasing level of complexity and the fact that price signals do not yet take the grid situation into account as the greatest weakness.

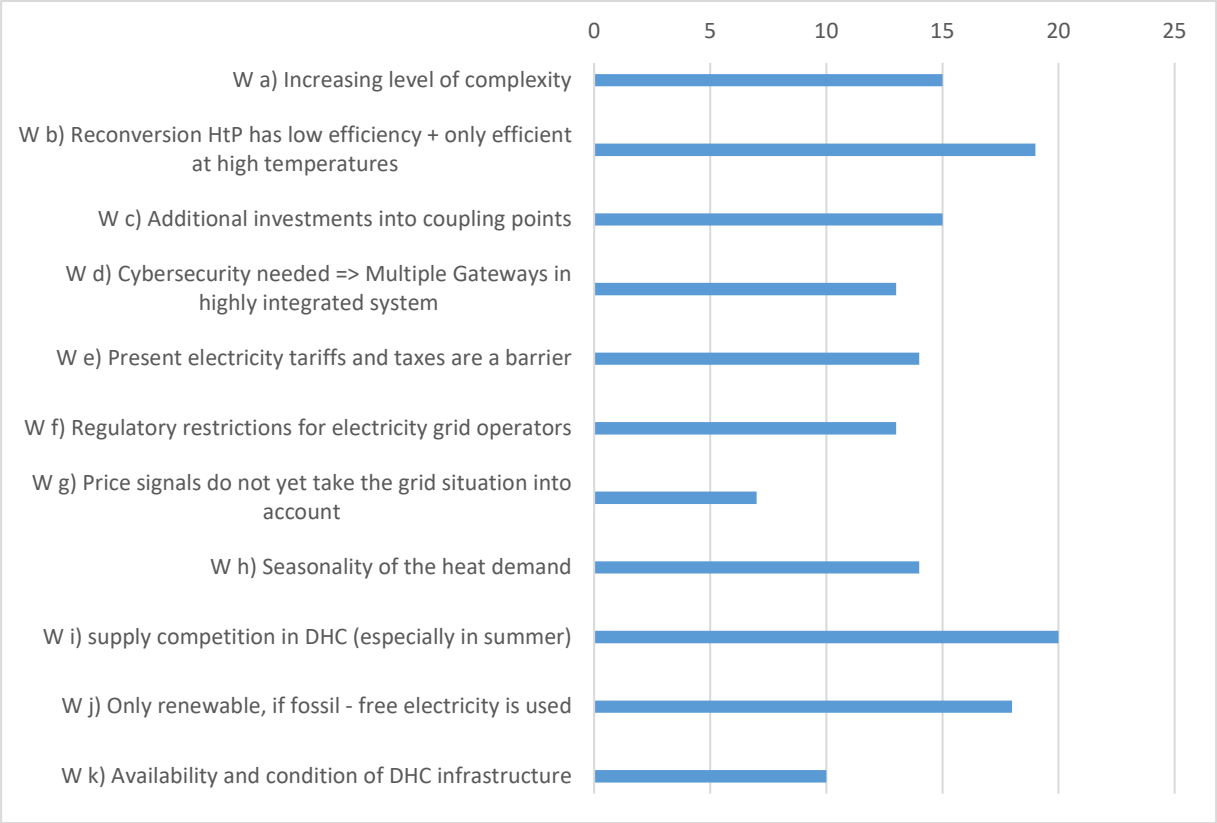


Figure 4: Number of comments per weakness

Even though ranked as the lowest, the supply competition in DHC, especially in summer, sparked the most comments.

Below the comments for each weakness can be found colorized according to the rating. Some comments have been shortened and similar comments have been summarized.

WEAKNESS a) An increasing level of system integration results in an increasing level of complexity for planning, designing and operating, due to a higher number of optimization parameters and stak...
• Sector coupling at the consumers level, via hybrid heating solutions (hybrid heat pump or cogeneration) do not have this drawback, as there is no subsystem.
• The risk with interdependency in hybrid energy networks must be compared to the risk with dependency on separate systems, for which the lack of sector coupling means that disturbance in one domain cannot be balanced by another domain.
• We abstract water only from subsurface aquifers; however, this coincides with where 70+% of the planets population is located
• for the local solutions such danger is reduced
• Shouldn't be a major issue. The remedies are good planning and robust systems.
• It is something that must be overcome in new systems
• This is a key question, but seems not at a critical level, yet.
• This is a difficulty necessary to address to deal with the new challenges and exploit their synergies
• Complexity is unavoidable in the future energy system. Therefore, the increase is only moderate.
• In the need to set up basic system functionalities ("fractal functions") so that complexity by different informational layers does not confuses the tracking of different KPI´s affecting business models
• Such optimized systems are also hard to adapt to upcoming technologies.
• Here a clear prioritization of optimization parameters could help solve the weakness
• especially risky, because of the shortage of people who can manage such complex systems
• Uncertainty means risks thus resulting in reluctance ti invest/try non-traditional solutions.
• Governance models will definitely be an issue. The multiple stakeholders, authorities and colletivities affected by the project should be involved in the network's design and planning since the beggining. Ideally, a polycentric governance model should be considered, to ensure a balance between stakeholders.

WEAKNESS b) Once electricity is transformed into heat, the re-conversion into electricity (Heat-to-Power, HtP) has a very low round trip efficiency and can only be cost-efficient at high temperatures.
• Sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration) do not have this drawback, as there are not massive storage of heat. The storage is ensure by renewable gas which can easily be used to produce electricity when needed
• We do not get involved in re-conversion
• Right - so don't go that way.
• No problem - but worthwhile observing that we do this opposite, heat is the flexibility for the electrical markets, where CHP was dominated by central players, now it is the many players that stabilize the many.
• heat demand is so big that this should be kept to a minumum
• Only because HtP ist possible it is not necessary to use it - hence there is no clear logical connection between hybrid energy networks an the low efficiency of HtP
• A known ("built in") weakness which is always dealt with.
• it can be managed and avoided
• For the planning of the interconnection this is not important. Typically when transformed into heat, energy is not converted back into electricity
• just don't use this
• Heat-to-Power may be worth in the case of waste heat or similar cases.
• Yes well we try not to do that, but carnot is of course a problem
• Energy should only be transformed once and then used or stored for later consumption.
• Why do you want to do HtP ?
• Electrical storage as heat for reconversion to electricity makes only sense if very high temperatures can be generated (500 °C+).
• It is one of the main weakness.. that it is only one type conversion.
• PtH and HtP is on such a rather low TRL, that all other storage technologies are much more efficient.
• Hence the importance of identifying and optimizing thermal cascades between different source/uses, as I pointed in the "Strengths" section.
• Why not heat storage if there is excess heat over some time periods.

WEAKNESS c) The requirement of additional investments into coupling points
• Sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration) do not have this drawback, as an hybrid heat pump is more affordable than an electric heat pump (smaller HP size as the unfrequent peak demand will be met by the boiler part) and not additional investments are required, neither in the house, nor on the grids.
• With low operation costs and other benefits such as decarbonization it pays off
• The additional investments will be heavily outweighed by the advantages gained by sector coupling.
• This is a question of the financial market. There are enough investments for such a good business.
• if there is a return, investments are not an issue
• Part of the equation when evaluering feasibility of making the link.
• This is relevant, but not su huge compared to the costs of the whole system, or even low compared to the needed reinforcements if they were not interconected
• Life cycle costs can still be lower than the alternatives.
• this will be a good return on investment
• As mentioned: MINIMIZE the coupling points.
• this might be a barrier unless proven business models
• Preliminary works on digitalisation lowers the risk associated with investment into coupling points by making more precise the expected effects and results.
• This platform transforms existing, tried and tested procedures and additional investment is therefore unnecessary
• Correct, as already discussed in the strengths section.
• A major roadblock towards actual implementation. It will always be more compact to meet a given demand through an energy source that matches that demand's vector, rather than through conversion processes, which are costly and imply energy losses and irreversibilities in most of the cases.

WEAKNESS d) A highly integrated and interdependent system offers multiple gateways for attacks thus resulting in a threat to cybersecurity
• Sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration) may have this drawback, but effect would be limited to individual houses and manual overide can be easily provided.
• I'm not an expert in this field and don't want to give an answer
• yes, but this is the same in all other technologies, which transfer data via internet.
• With or without hybrid networks, threats to cybersecurity will always be there. We live in an increasingly interconnected world anyways.
• is this not so already? a couple of channels more do not seem to change the scenario. On the contrary, increasing awareness may bring to overall benefits
• You have to be aware of this but it will likely not hold back a feasible solution (?)
• This is a common threat for smart grid that make an intensive use of communications sytems. This could be somewhat increased by the interconnected systems
• depending on the integration level. Sinle operator is easier to secured.
• not expert in this field.. but don't think that situation will drastically changes comparing with current systems.
• Create local networks that can run without the internet (and thereby without a gate for intruders).
• Cyber security is a general threat to the energy industry, which is by nature a critical infrastructure. However, this is not threat that is limited to sector coupling/hybrid energy systems.
• Must be solved and can be solved. No worries, but be extremely aware of this subject.
• This is NOT a relevant weakness

WEAKNESS e) Present electricity tariffs and taxes are a barriers to exploiting the potential of hybrid energy networks
• Yes, this is as well a weakness for sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration). Some existing tariffs are emerging to reflect the renewable intermittency and peak constraints (dynamic tariffs for supply or peak demand), but there are not developped enough to give a clear signal. An adaptation of the building codes, to favorise long duration demand flexiblity, would be required as well.
• We would need more clarification on this point
• With a bit of a will it can be solved
• This is our playground from where we get the cheap heating price. This may change in time - hence multi-source production, involving RES is important.
• it's not the electricity tariff, it is the costs of your system. If they are higher, then please don't blame anybody, or ask for subsidies. Just work on cost reduction.
• Isn't this rather a threat than a weakness?
• with appropriate business models, regulation should adapt to make things happen
• But tariff/pricing structures can be expected to change 1. more emphasis on kW compared to kWH 2. impact of EVs
• The integration of large scale heat pumps into district heating is really complex and inefficient in Germany due to the current regulatory framework.
• existing business models very often are barriers to exploiting hybrid energy networks.
• Very true, at least in a Danish context. The existing tariffs for using the electricity grid in Denmark are based on volume (kWh) and not on power (kW) - it should be the other way around. Flexibility must be rewarded.
• Especially tariffs do not express the cost of network capacity.
• Anders N. Andersen has written some papers in his PhD about how taxes should be changed to accommodate smart energy systems with a focus on the heating sector
• This issues has the same impact across all propositions

WEAKNESS f) electricity grid operators currently have regulatory restrictions (mainly due to unbundling) for the co-optimizing the distribution and generation of energy investment and ownership...
• Sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration) do not have this drawback, as the tariffs can reflect the positive externalities (dynamic tariff for renewable electricity and gas availability, dynamic tariff for grid constraints.
• With a bit of a will it can be solved
• In my view, unbundling is a necessary and good thing.
• all these can be resolved as soon as your technology is competitive.
• needs to be addressed also in other areas of the energy system, less related to hybrid networks only
• It is decisive, but I do not know regulations from other places. They need to be in place and give space for solution creativity !!!!
• Refer to my remark above, on governance models.
• But these will need to change anyway
• It would be easier without the unbundling. However, it can be handled.
• Solving regulatory issues is critical for the system to be able to be put in practice
• agree! this is where high level planning (state/authority?) should play a part
• Solution is "simple": give them some leeway until it becomes more clear how the system can work.

WEAKNESS g) price signals provided by the wholesale markets for electricity in Europe do not yet take the grid situation into account, such as localized grid constrains and the location of generat...
• Yes, this is as well a weakness for sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration). Futhermore, once the hybrid solutions are installed, the solution owner will not get any reward for the savings he allowed by avoiding reinforcement investments. This savings should be share thanks to upfront subsidies.
• We strengthen grid reliability by facilitating electrical load reductions
• This is a must. No problem at all with a little metering.
• This seems likely to change and could be either a strength or a weakness
• I am not sure this is true: in my experience (Italy), when there are issues with the grid, price increase
• Spatial considerations will definitely be an issue too.

WEAKNESS h) the seasonality of the heat (or cold) demand may lead to price surges on the electricity market
• Sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration) do will help reduce these surges as the heating solution owner may shift to gas heating or even cogeneration if the price of electricity become to expensive.
• Seasonal heat and cold storage is key! And makes very much sense to shift winter and summer. So weakness is turned into strength.
• This will happen with individual networks as well as strongly hybridised systems
• Must be solved by central optimization and control - no problem.
• should be avoided
• Dynamic pricing models should be able to adjust that.
• Only if we rely on inflexible solutions like individual heat pumps. Large scale heat pumps, electrical boilers and CHP units in DHC systems are highly flexible and can adapt to the supply (price) of electricity.
• https://www.euronews.com/2021/10/28/why-europe-s-energy-prices-are-soaring-and-could-get-much-worse
• This is already the case. Renewables will ad unpredictability too
• Any external variability ought to make more advantageous conditions when it is about flexible and integrated DHC systems
• Only if there are more and more coupling points
• true, but this does not need to be completely translated to households -- also to protect socially weaker groups (e.g. currently we're in the other extreme where households pay a fixed price year around)
• planning must take into considerations all seasonal conditions
• As mentioned above. We resolve interseasonal load discrepancies

WEAKNESS i) Additional heat supply units (i.e. HPs) in the DHC network result in an increasing supply competition among each other and to other renewables (e.g. solar- and geothermal energy) espec...
• Interoperability makes sense.
• This is not a weakness. This could improve competition and reduce prices. This is a strength
• This is not mandatory for hybrid energy systems and could also happen for individually operated networks
• An efficient optimization/control algorithm will be able to define the best (e.g. most profitable, less energy-consuming) combination of heat supply unit in real-time
• Why is this a weakness - increased competition will lead to lower heat production prices, so in my view, it's a strength.
• at some point a heat supplier will need to pay for getting rid of their heat; making a business case for underground storage
• Yes, but it doesn’t have to be a problem that there are multiple options to choose from when designing the system.
• Correct planned energy mix on the local level is the solution to avoid such danger
• And so on ?
• Needs balancing and proper design - geothermal is a baseload, where as RES are volatile - balancing is key but can be done. Investments must be done in a holsitic approach, avoiding the competition between sources - supplementary sources are the objective, storage to balance - also very large scale (cheap).
• Competition exists always. Appropriate governance models and operation control should be able to manage that.
• The use of heat-driven cooling technologies (e.g. absorption chillers) can relieve such tentions
• Isn't this a strength? Competition usually reduces prices for the end user.
• The cheapest option should win.
• increasing complexity must be handled, but the availability of a wider available mix should be an advantage in general terms
• But this is actually several diferent issues bundled into one question
• in case of many biomass CHPs (base heat load) P2H will compete with renewable based heat generation.
• Heat pumps have the ability to be shut off in times with low heat load and enough other renewable heat production e.g. solar thermal. This flexibility must be rewarded! Furthermore, large thermal energy storages are needed to recover as much waste heat or renewable heat as possible.
• Heat storage is the key here.

WEAKNESS j) The CO2 emissions will only decrease if fossil-free electricity is used in the PtH processes, however, currently, the electricity mix in many countries is still dominated by fossil fue...
• Sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration) will allow to make the best of all renewable energy available, wether it is electricity or renewable gas.
• The deployment of subsurface waterprovides a ThermalBank contingency, an energy store that compensates for inter seasonal load disparity.
• Absolutely! We need an energy system 100% based on renewables wind, water and solar only!
• This is expected to change in future with much more integration of renewables, so this is not expected to be a problem but a solution in the long term
• In the future electricity based technologies are needed for heat supply. Hence, a continuous ramp up of using these is needed in all countries. Also using fossil based electricity in a highly efficient het pump can be less emission intensive than using natural gas
• that the reason why electricity is only one part of the solution.
• The day where all RES electricity is taken for green fuels etc. we have a competition that shows that there is demand for investment - prices will go up and DH companies will be able to produce themselves. This will be a stupid game, let by influencers and politicians, aiming for votes, not systems thinking and technology - and reasoning.
• renewables are cheaper and electricity sector expected to decarbonize while investments in PtH can be planned accordingly
• seasonality is definitely an issue, but using (and storing) heat is part of the solution
• Presumably PtH would only be used at times when there is surplus renewable electricity? (Which could mean low load factors for PtH)
• That is one danger of electrifying the heat needs. Why not coupling a heating network that exploits other sources such as geothermal, industrial waste heat...?
• the increase in flexibility of HEN should go hand in hand with rise on barriers to use fissil fuels, to foster penetration of real RES
• A big problem and not just in the future, but also right now - politicians and electricity producers really needs to step up to ensure that the build out of wind turbines and PV can keep pace with the demand, currently and particularly in an electrified future.
• Flexibility in such electricity demand is important
• Very good point. I would even give it 7 points. The electricity has to be GHG-free not fossil-free. Renewables (Palmful from Rainforest destruction) can be very harmful to the climate. Please change this point. Also the electricity needs to be extra GHG-free electricity. If Heat pumps use GHG-free electricity that is already used in the grid, thereby pushing other demand to use GHG-loaded electricity nothing is won. So GHG-free electricity for hybrid energy systems needs to be additional and dedicated GHG-free electriticity.
• is really somebody heating their DH network with fossil electricity? If so, please resolve this.
• especially, if DH is biomass or other RES based.. in this case electrification will lead to CO2 increase

- This is true. We must also invest in new photovoltaic systems as well as offshore and onshore wind farms. The electricity demand will increase because of the sector coupling.

WEAKNESS k) DHC infrastructures for efficient sector coupling might not be available or be in a bad condition
• Sector coupling at the consumers level, via smart hybrid heating solutions (hybrid heat pump or cogeneration) do not have this drawback, as there are no need for a dedicated infrastructure.
• This is difficult to repond to. If existing system are unavailable, replace them or the journey stops???
• Investments in infrastructure are key
• will need to be built in many places
• Can be solved. Regulation is key.
• with the right conditions in place, there will be incentives to retrofit and moderise DHC
• legislation, rules, standarts-not existing in some countries. Tariff calculation, related CO2 emissions will be difficult.
• District heating is present in almost all big cities across Europe and here are the highest energy densities. However, the networks must be transformed so that they can be operated with the new hybrid energy constraints. Investments into the infrastructure must be made
• Many countries only have very limited DHC infrastructure .

2.3 OPPORTUNITIES

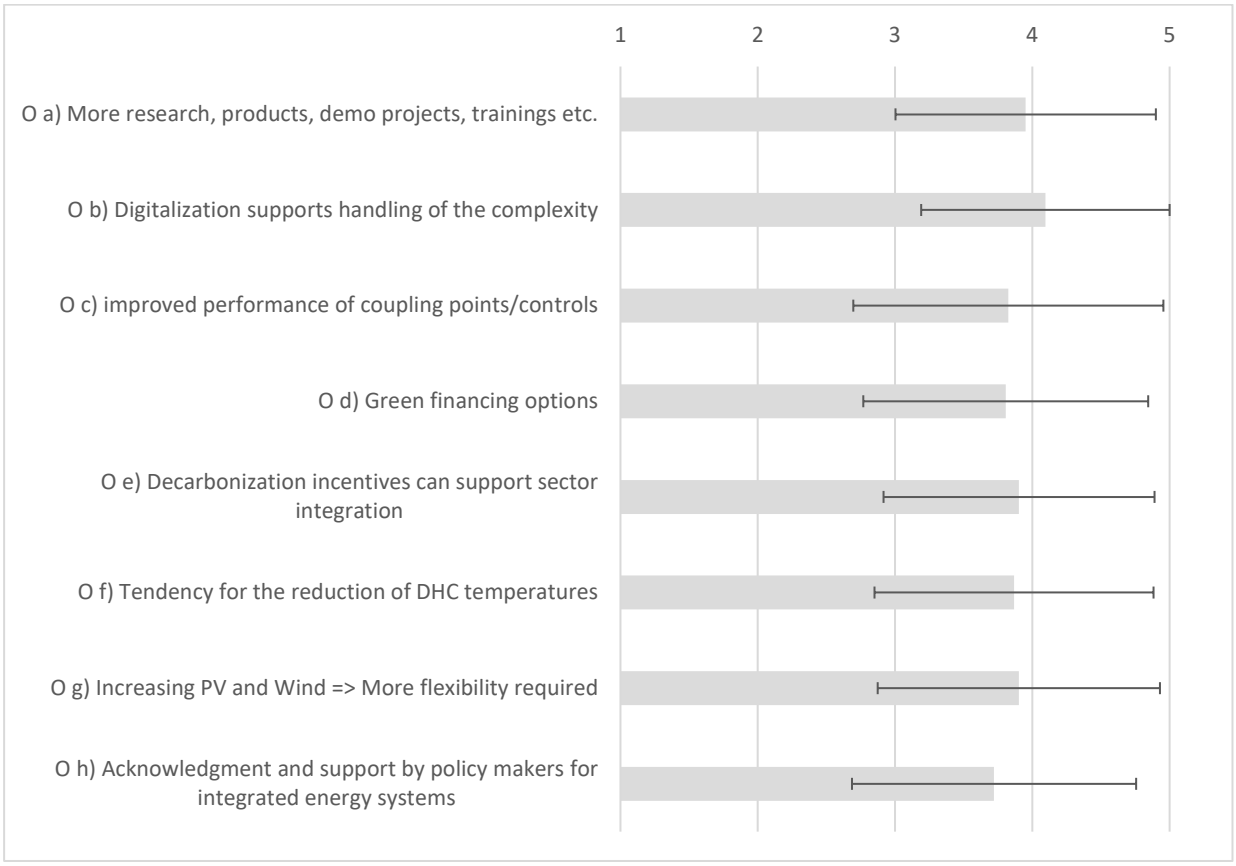


Figure 5: Average rating for opportunities

Most participants view digitalization as a great opportunity to handle the increasing complexity.

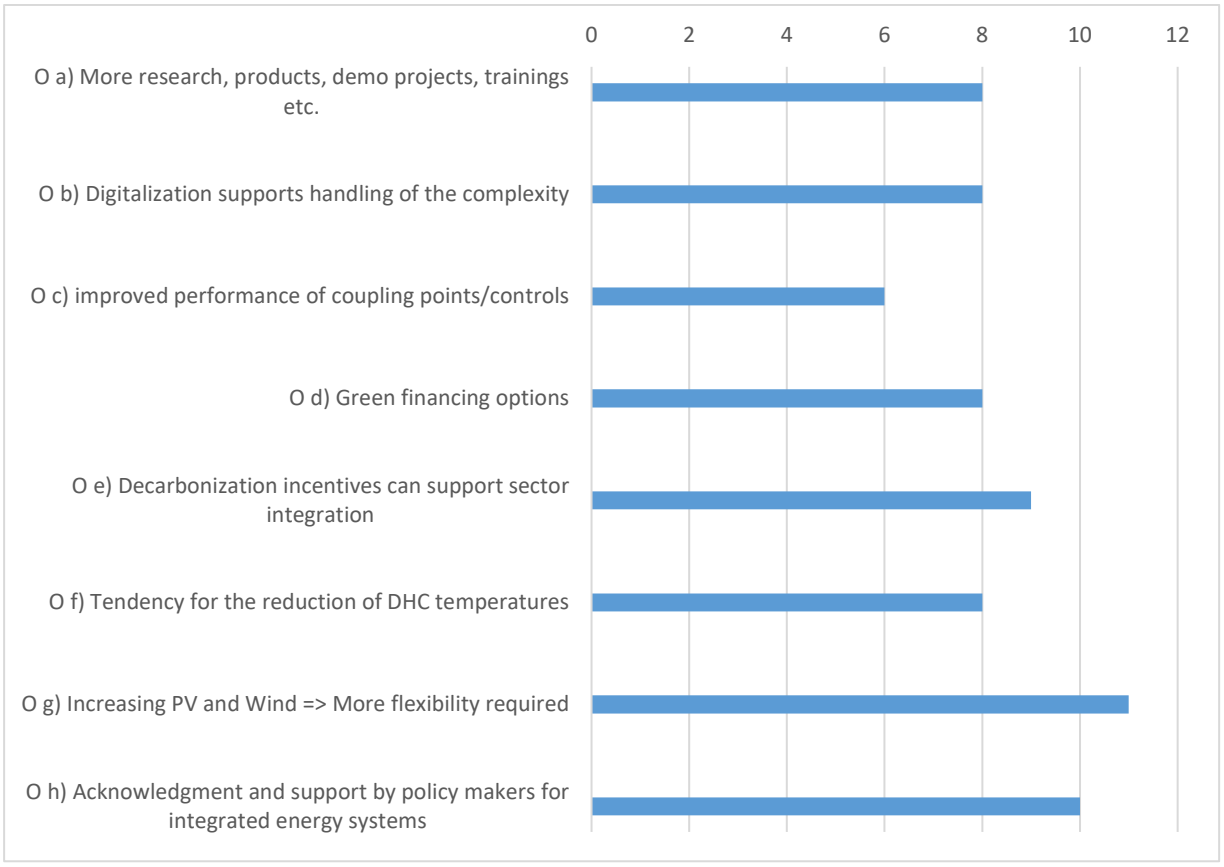


Figure 6: Number of comments per opportunity

Below the comments for each opportunity can be found colorized according to the rating. Some comments have been shortened and similar comments have been summarized.

OPPORTUNITY a) An increased focus on sector integration in research and industry as well as an increasing number of trainings and education programs
• the massive uptake of hybrid heating appliances, and the real time management required to maximise their benefits for the energy system and the customer open a solvable demand for R&D, for equipement and predictive management.
• Not sure what this means
• This could benefit the indrustry and research
• A must
• No technology without skilled people
• https://ec.europa.eu/info/events/low-voltage-direct-current-and-direct-current-technologies-potential-applications-clean-energy-transition-2021-nov-08_en
• Decentralised solutions should be evaluated. Example solar hot water and heating on buildings.
• Some of the technologies, especially PtX and CCS/U, are still quite immature.

OPPORTUNITY b) Digitalization together with a higher penetration of sensors and other data collectors could open many opportunities in network design and operation
• No specials extra sensors a required in addition to the heating appliances usual ones and the smart meter ones.
• Needs demonstration
• The Danish experiences with decentralized CHP units show that the right price signals are more important than digitalization in the form of sensors, machine learning, etc.
• A must
• We cannot invent e.g. network hydraulics. But we can develop new opportunities by digitizing energy networks.
• More complex systems can be handled.
• not only data collection, but also (and mostly) decisio support systems to transform data into operational value
• Including decentralised solar heating or heat pumps.

OPPORTUNITY c) More research and development can lead to improved performance of coupling points, smart controls and integrated planning and implementation processes
• Predictive management of the smart heating building stock and related energy grids can be optimised thanks to the data collected by smart meters and smarts hybrid heat pumps, for a more efficient dynamic management.
• Most of this is not rocket science. Good planning is more important.
• More research and development would help even without the coupling between systems
• This is perhaps more of a development need than an obvious commercial opportunity
• A logic result of the previouse - no issue - many possiblilites and no standards yet. We work on it.
• more pilot projects will help.

OPPORTUNITY d) Green financing options and many investors favoring investments into renewable energy projects as well as accepting higher CAPEX and long-term amortization periods.
• The main investors are going to be the end-users. They will invests if the tariffs and incentive scheme reflect enough the positive externalities generated for the energy system by the hybrid heating systems. There is as well a risk management dimension, the flexibility of hybrid allow for a coverage of energy price volatility, which is likely to become more frequent (cf. recent events) and give a means to the customer to alway have accesss to the more affordable energy vector.
• I see no additional advantage of hybrid networks for this
• difficult to evaluate, especially if electricity is not "green"
• just, if you achieve profitability.
• In particular RE and PtX projects seem very popular with (institutional) investors.
• The interaction may allow to extend the future decarbonization of power systems to other types of networks
• We need plenty of those types of investors.
• A logic consequence of the poltitical decissions - regulation has to solve this problem. The markets are there, the finances are there. The competition with P2X is however a conflict if not balanced. Again, even for P2X, the necessity of utilizing the 'waste heat' from these processes, is key.

OPPORTUNITY e) Current and future decarbonization incentives and measures can directly or indirectly support the sector integration
• The main investors are going to be the end-users. They will invest if the tariffs and incentive scheme reflect enough the positive externalities generated for the energy system by the hybrid heating systems.
• I see no additional advantage of hybrid networks for this
• Not necessarily. For instance, France relies heavily on nuclear power and leaves wind energy aside. Decarbonization incentives may not be sufficient.
• Could be true, especially for CCS/U and PtX.
• It could foster it
• Consequence of political decisions. See above.
• in some cases
• the challenge will be to develop certification schemes in order to compute the greenhouse gas savings really correctly.
• I would reformulate the opportunity as "Current and future decarbonization incentives and measures MUST directly or indirectly support the sector integration"

OPPORTUNITY f) A general tendency for the transformation of the DHC networks towards lower temperatures, higher thermal storage capacities as well as decentralized structures support the integrati...
• What is the Question??? Using lower temperatures braodens the scope of works which increases costs and disruption
• I see no additional advantage of hybrid networks for this
• No issue - can be made and will improve the number of sources applicable. If density is high, nor LTH/C is strictly necessary. Please consider this in Asian, highly populated areas with demand for heating.
• Yes. Lower temperatures accommodate for further use of lowgrade heat sources (eg. industrial waste heat, low enthalpy geothermal, etc.).
• HPs integration
• That is definitely an opportunity.
• Mentioned several times before
• lower temperature systems make also it easier to apply decentralised equipment as solar thermal and heat pumps.

OPPORTUNITY g) higher shares of (fluctuating) renewable electricity sources such as wind and PV lead to more incentives for flexibility services and thus support the sector integration
• Yes, flexibilitity can generate serveral type of gains : - better intermittent renewable integration - better local system resilience (in case of a breakdown of a transmission line or power source) - better ressource adequacy (matching demand-supply and infrastructure capacity) But all type of flexibilities can't generate all these gains. There are two types of flexbility : - storage flexiblity : by temporarily storing the energy in a hot water balloon, batteries, ... - sector coupling : by transfering the demand to another energy vector For heating, the design peak demand (exceptionnal cold weather) can last several days in a row. Most storages are not large enough, and it is very unlikely that they will be always full enough to meet this criteria. Thus, only sector coupling can garanty enough flexibility to ensure ressource adequacy services (and reduction of investments in the grid and peak power production).
• Great diversity of renewables is a good thing
• The systems will never adapt to the real situation. A diversified mix is more secured.
• Only an opportunity if the system can supply the flexibility.
• Not necessarily. Flexibility is classically achieved through storage. As much as I like the concept of hybrid networks, I have trouble seeing how stakeholders will prefer a whole different source, a conversion process and a reworked network instead of classical storage.
• It's increasing the need for waste 'renewable energy' oversizing renewable electricity production against renewable heat and energy saving.
• Hopefully - if the politicians and regulators managed to develop the necessary market mechanisms.
• yes, but due to the low full load hours the technology with the lowest costs will win.
• A question of balancing - solvable as shown many places.
• it is one of the reasons, why Hybrid energy systems can be successfully implemented.
• Absolutely - thus, heat storages are needed to balance.

OPPORTUNITY h) The European Commission is acknowledging the role of an integrated energy system and upcoming regulations for energy communities / self-consumption can support sector integration me...
• Sector coupling with hybrid heating appliances, such as hybrid heat pumps or cogeneration, is the MVP (Minimum Viable Product) of district heating. Local circumstances (energy community, opportunity of waste heat) can help expand this MVP over a larger perimeter.
• TELESIS supports system integration and merges this with deploying Natural Capital. This is the future
• Depending on final wording this could lead to sub-optimization instead.
• Not quite sure how to understand this. The EU systems seems to have finally discovered the benefits of DHC solutions. At the same time, however, there seems to be an obsession with buildings that produce their own energy. The point is, that it shouldn't matter, where the (renewable) energy is produced, and collective solutions like DHC are often more cost effective than single building solutions.
• Regulation is absolute key - whether from EU, nations or local is irrelevant.
• There could be improvements in the regulatory framework after all
• The more favourable regulations the better.
• This will help to push on the implementation
• the EC is acknowledging, what the experts propose, so please continue to introduce knowledge in the EC.
• https://smartcity-atelier.eu/about/objectives/

2.4 THREATS

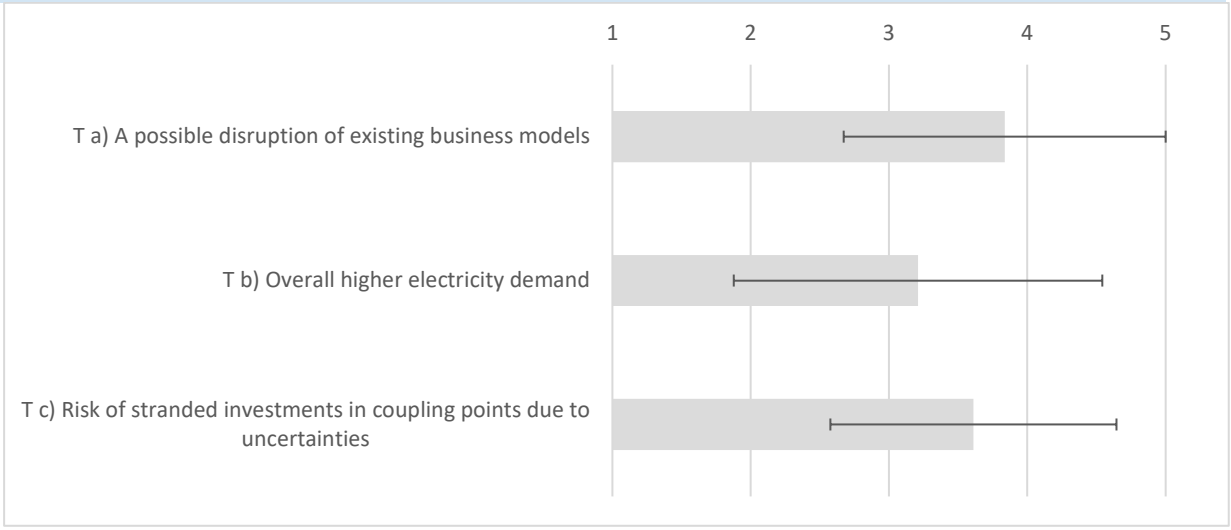


Figure 7: Average rating for threats

Most participants viewed the disruption of existing business models as the greatest threat.

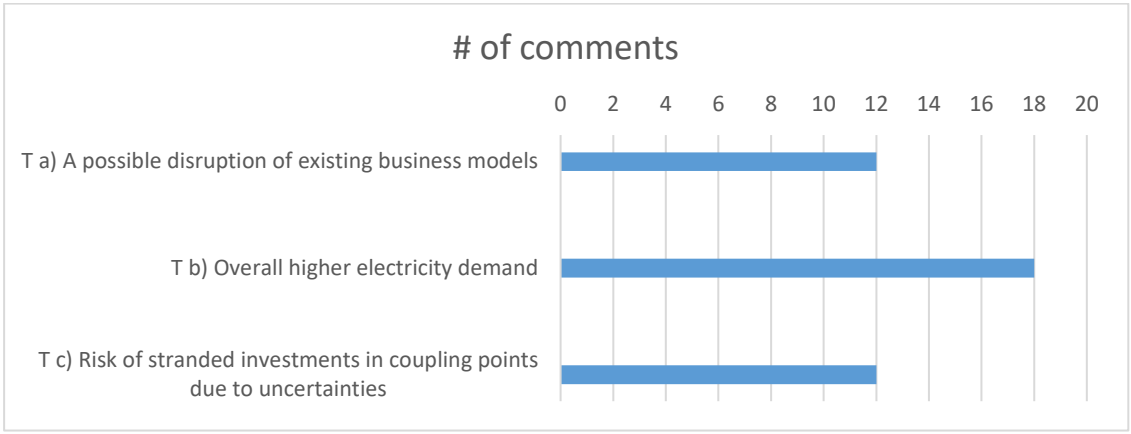


Figure 8: Number of comments per threat

Below the comments for each threat can be found colorized according to the rating. Some comments have been shortened and similar comments have been summarized.

THREAT a) Silo thinking of many actors and stakeholders and a possible disruptions of existing business models
• Yes, plus the fact that present energy tariffication hasn't been designed to encourage end users to participate to a dynamic market, both for the energy supply and the infrastructure load.
• I don’t see the link between the two points. Unable to answer. The threat is the silo thinking, not the disruption.
• yes, but that's the problem everywhere. Nobody is willing to think about different point of views, so this is NO specific threat for hybid energy networks.
• The focus on decarbonization and low oeprational costs and strategic independece as regulation will solve this issue. The threat are white elefants such as fossil companies or / and fossil exporting countries that are creating obstacles.
• Doesn't really seem to be a problem - on the contrary, there seems to be a big appetite for sector coupling.
• This is not entirely irrational!
• Can be critical - can be solved by cooperation.
• Not my business = not my problem
• Even more dangerous than silo thinking is the energy diverted and lost looking at false claims and greenwashing - Blue H2, Carbon Capture, H2 as an energy source (it is not) rather than as a carrier
• Yes, definitely. And it will be difficult to break through those. In my opinion, technical expertise on hybridization can and will be achieved soon, but the major barrier will be convincing the actors (as always). It is more of a socioeconomic issue.
• defence of AS IS will always be a barrier to change. The point is to make a strong case for HEN to the extent clear and demonstrated benefits are brought into the picture
• Silo thinking is intimately coupled with "afraid of complexitiy"

THREAT b) PtH and PtG units can lead to an overall higher electricity demand
• Market regulation and dynamic price will help regulating this factor and valorising the cogeneration capacities to meet this higher demand.
• If higher demands are a probable outcome - the project should never have commenced in the first place
• Thats not a threat - its logic! But more electricity is used much more efficient - thus the final energy demand significantly reduces!
• Systems will mostly utilize the abundance of renewable energy, especially during peak production
• Only if they operate at high load factors?
• I see no additional disadvantag of hybrid networks for this compared to individual networks
• true, but also renewables are mostly producing electricity; the threat is in the capacity limit of the electricity infrastructure
• Again, flexibility is needed. If not, your electricity bills may become quite high.
• This could be a threat to the environment, but only in the short-, medium- term
• not too much, to the extent that these units will be driven by energy prices (as I expect)
• PtH and PtG have very different efficiencies, PtG is a greater threat
• Yes, another danger of electrifying everything obsessively, as I pointed out in a previous answer. Other vectors need to be considered!
• The main issu will be induce with a global systems that will not consider extra time. Long hard winter time, will explode electricty prices. A simple winter anticlynonique weather during 3 weel might induce a sever breakdown of the system.
• If so, then no excess electricity is used and in such s case PtH+PtG must be prohibited.
• Please see previous answers - the politicians and electricity producers need to step up on the build out of RE electricity.
• Very critical - Google has a deal for the windmill park, othes take it for P2X, we want is for P2H ... We must be sure that the same power is not dealt twice - this is a technical issue and can be solved if we want it.
• ... Will definitely lead...
• not only to higher electricity demand but also to more GHG emissions than alternative solutions (CHP instead of boilers for natural gas). Hybrid Energy Systems can damage the climate if not done well and very inefficient production chains are used.

THREAT c) Risk of stranded investments in coupling points due to uncertainties of the future development of key enabling factors such as Political situation, regulatory framework and market desi...
• Yes, the main threat is the acceleration of deep renovation which will reduce the energy volumes required by household, making it harder to get a payback for invested assets (partially stranded).
• Good, professional development management / Master planning will preclude this risk.
• Fossils will be stranded! - Of course systems have to be well designed with straightforward regulations.
• taxonomie should help
• Muli-source production and common distribution infrastructures give a robust (most robust) setup and will allways be able to behave 'one of the best in class'
• Detailed cost-benefit analysis are necessary to prevent this
• Thorough planning and a massive build out of RE electricity should be good remedies against this threat.
• Revenues come from risks
• All long-term investments face this threat - and are more difficult to finance as a result
• Can be mitigated by policy.
• regulatory framework in different in each country,.
• investers don't like risks

2.5 MAJOR REGIONAL DISPARITIES

In this section aspects of the SWOT analysis that show strong disparities among the European regions are discussed. The four participants from outside Europe (United States, Turkey, China, India) have been excluded in this part for a greater focus on Europe. The countries have been classified according to the figure below. For the regions a weighted average was calculated based on the participants from each country.

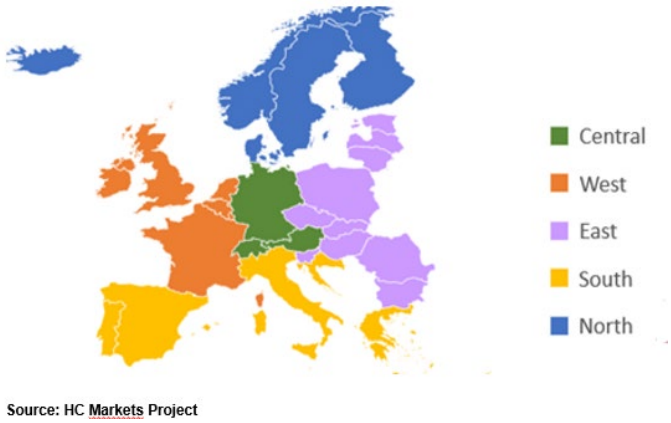


Figure 9: European regions

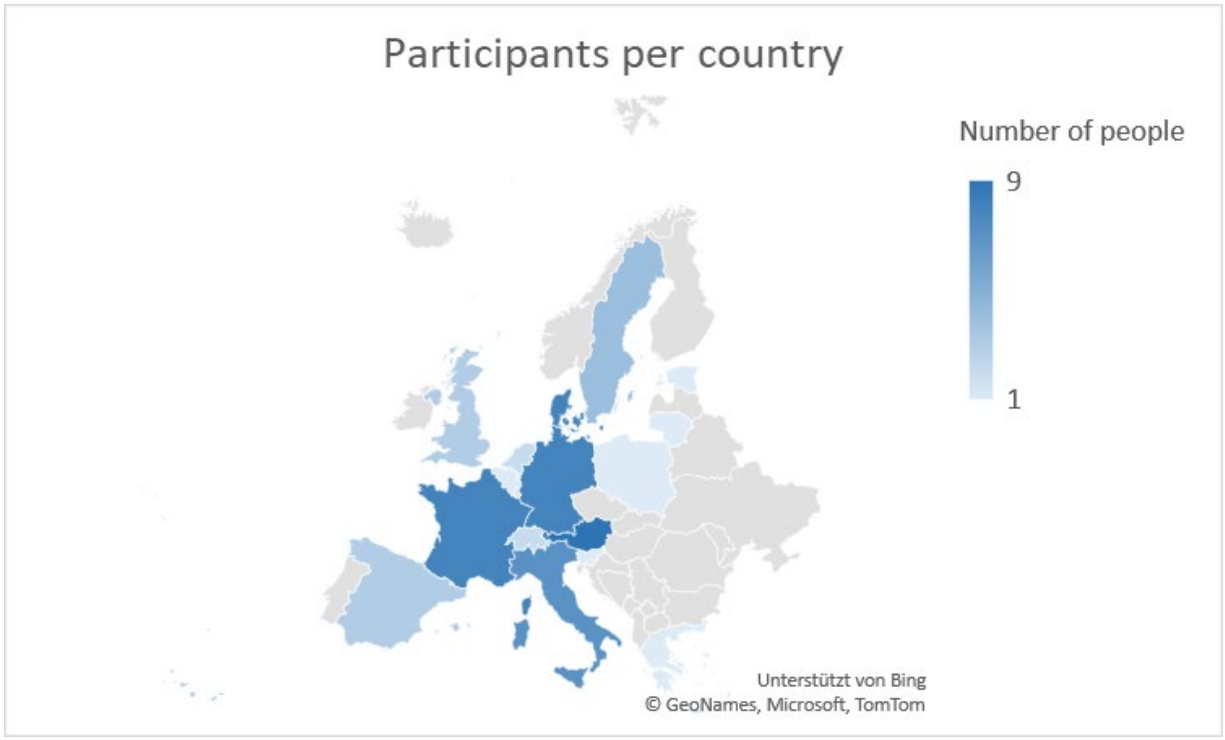


Figure 10: Participants per country

In this allocation the region northern Europe has 12 participants, western Europe also 12, southern Europe 11 and eastern Europe 4.

Strength) The option to efficiently manage various levels of temperatures

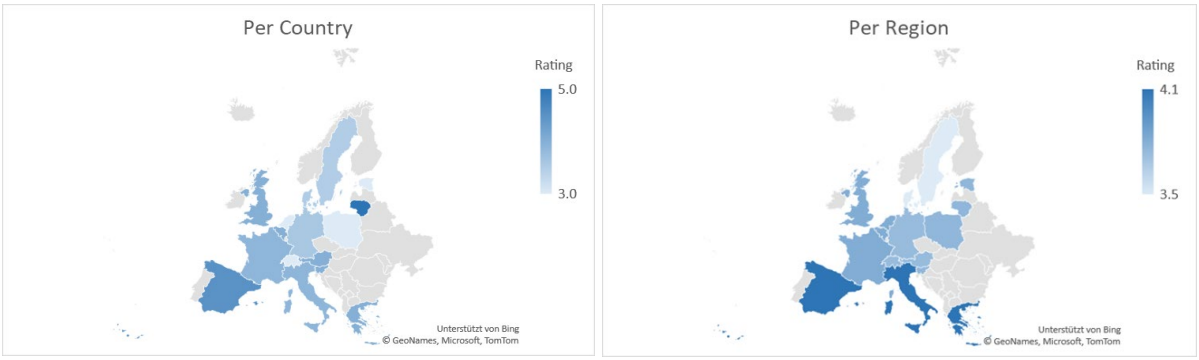


Figure 11: Rating

The strength, the option to efficiently manage various levels of temperatures has a visible North-South gradient.

Opportunity) Higher shares of (fluctuating) renewable electricity sources lead to more incentives for flexibility services and thus support the sector integration

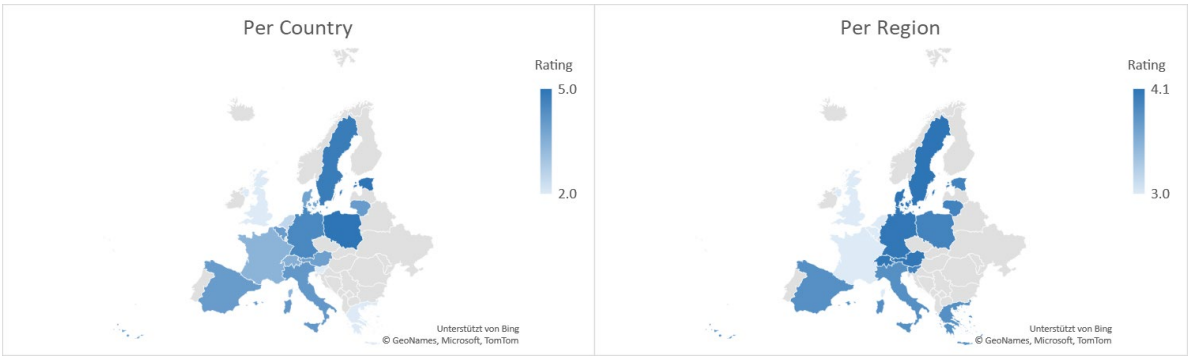


Figure 12: Rating

The opportunity, that higher shares of (fluctuating) renewable electricity sources lead to more incentives for flexibility services and thus support sector integration is not seen as important in western Europe compared to the rest of Europe.

Weakness) Once electricity is transformed into heat, the re-conversion into electricity (Heat-to-Power, HtP) has a very low round trip efficiency and can only be cost-efficient at high temperatures

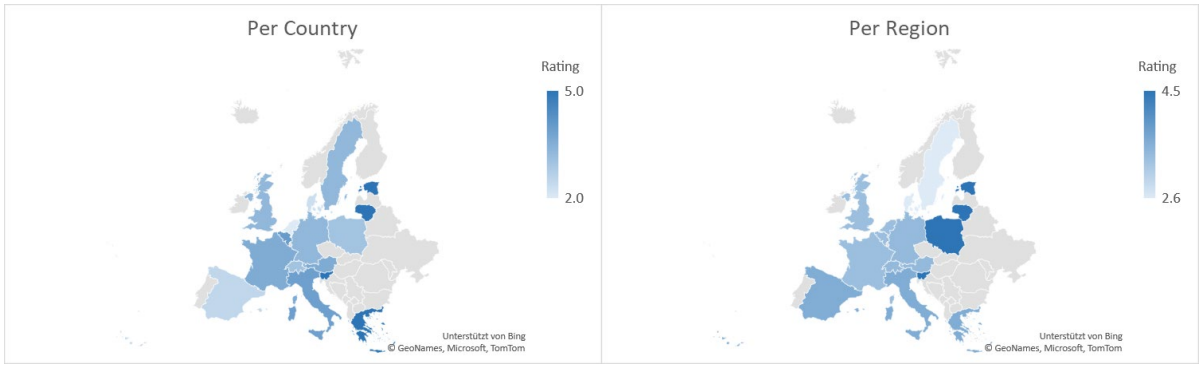


Figure 13: Rating

The weakness, that once electricity is transformed into heat, the re-conversion into electricity has a very low round trip efficiency and can only be cost efficient at high temperatures, is seen as very important especially in eastern Europe, while it is not such an important factor in northern Europe.

Weakness) DHC infrastructures for efficient sector coupling might not be available or be in a bad condition

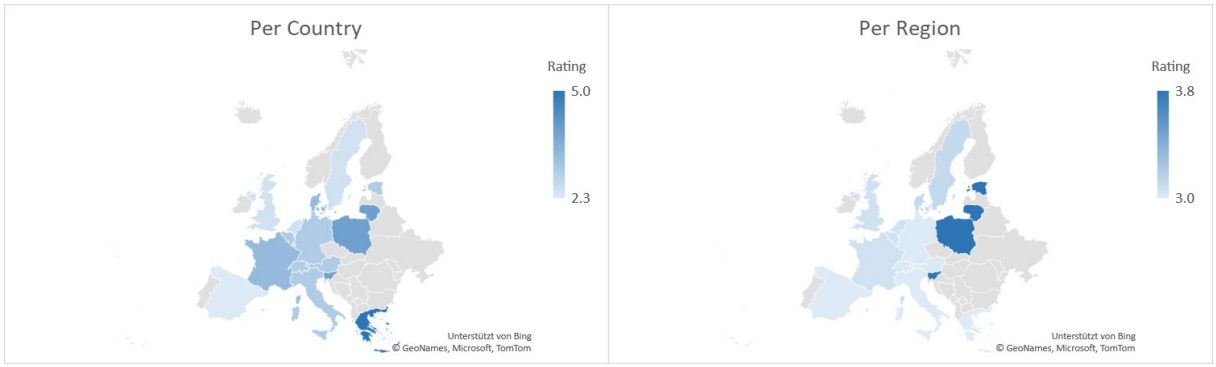


Figure 14: Rating

The weakness, that DHC infrastructure for efficient sector coupling might not be available or be in bad condition, is viewed much more important in Eastern Europe compared to the rest of Europe.