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Collaboration in the local DHC-chain: A bottom-up integrated framework fostering broad-based solutions

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Abstract

The sustainable energy transition asks for new and innovative solutions in the way society, government, energy market and clients (end users) approach energy distribution and consumption. The energy transition provides great opportunity to develop innovative solutions where in the dense built environment district heating and cooling are being strongly advocated.

Traditionally, the energy systems in urban districts have been regulated by a top-down approach. With the rise of local and distributed sustainable sources for urban heating and cooling, the complexity of the heat/cold chain is increasing. Therefore, an organic and bottom-up approach is being requested, where the public authorities have a facilitating and/or directive role. There is a need for a new and open framework for collaboration between stakeholders. A framework that provides insight into the integral consideration of heating and cooling solutions on district level in terms of: organisation, technology and economy (OTE). This research therefore focuses on developing this integral framework towards widely supported heating and cooling solutions among district stakeholders.

Through in-depth interviews, workshops and focus groups discussions, relevant stakeholders in local district heating/cooling of varying backgrounds and expertise have been consulted. This has led to two pillars in a framework. Firstly the definition of Key Success Factors and Key Performance Indicators to evaluate technical solutions in light of the respective context. Secondly, an iterative decision making process among district stakeholders where technical scenarios, respective financial business cases and market organisation are being negotiated. Fundamental proposition of the framework is the recurrent interaction between OTE factors throughout the entire decision making process. In order to constantly assure broad-based support, the underlying nature of possible barriers for collaboration are identified in a stakeholder matrix, informing a stakeholder strategy. It reveals an open insight of the interests, concerns, and barriers among all stakeholders, where solutions can be developed effectively.
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Keywords: Urban heating; Energy transition; District heating and cooling; KSF; KPI; Bottom-up approach

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1. Introduction

Part of the aim for CO_2 emissions, is to find alternative energy solutions for the use of fossil fuels. One of those alternatives are the use of renewable heating- and cooling systems. The sustainable energy transition asks for new and innovative solutions in the way society, government, energy market and clients (end users) approach energy distribution and consumption [1]. The energy transition provides great opportunity to develop innovative solutions where in the dense built environment district heating and cooling are being strongly advocated. The use of district heating and cooling systems (DHC) is not new in itself. However, right now is the moment that these solutions can be implemented more intensively. Especially the use of low temperature, bi-directional heat networks, the so called 5th generation heat networks, have a big potential, but are not implemented a lot in the Netherlands yet [2,3]. The use of residual heat from datacentres can be a fruitful contributor in the sustainable energy transition [4].

Context research: Amstel III area, Amsterdam - The Netherlands

As Amsterdam (the Netherlands) is one of the major data centre hubs in Europe, this has a big potential in the sustainable energy transition. Therefore, in this paper, an integral approach and lessons learned during a research[1] in Amstel III area in Amsterdam are being described. Amstel III is an office and business area that covers 250 hectares and is located in South East of Amsterdam (Figs. 1 and 2). The municipality of Amsterdam has embarked on a new course with a gradual transformation from a mono-functional working area to a mixed (highly) urban living and working area. Nearby are multiple datacentres, which can provide low temperature waste heat. Municipality of Amsterdam has policy on the use of this heat from data centres [6,7]. Also there is an existing district heating grid of energy company Vattenfall (Fig. 1b). Fig. 1a shows an overview of the Amstel III district with the nearby data centres and the properties that will remain.

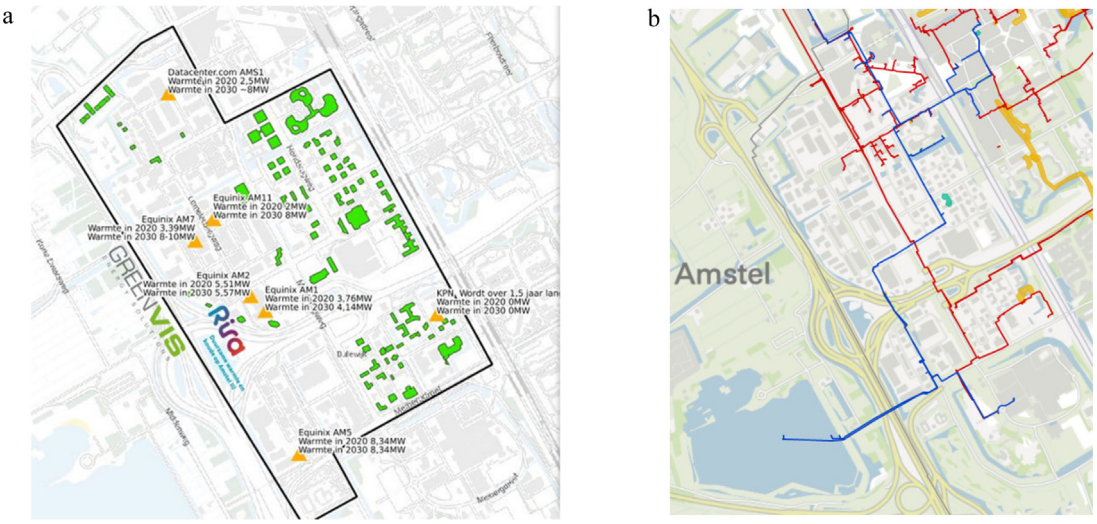

Fig. 1. (a) Plot of the Amstel III area with datacenters; (b) The existing high temperature district heating and district cooling form surface water.

The approach developed in this research is generally applicable for stakeholders in the built environment. In the Dutch regulations the outcome of this approach can be secured in a HeatPlan. This is a specific plan for a district where the transition from natural gas to non-natural gas heat sources is described in terms of technique and organisation. Heat plans are a suitable instrument to ensure a stable development and seize of scale that once is chosen for a central heat solution that it will be the default heating system for a longer exploitation period [8].

2. A bottom-up integrated framework fostering shared solutions

Traditionally, the energy systems in urban districts have been regulated by a top-down approach. With the rise of local and distributed sustainable sources for heating and cooling, the complexity of the heat/cold chain is increasing.

[1] Research was conducted between 2018 and 2020, see Rira [5] for more information.

Fig. 2. Amstel III district renovation plan.

Therefore, an organic and bottom-up approach is being requested, where the public authorities have a facilitating and/or directive role [1]. There is a need for a new and open framework for collaboration between stakeholders. A framework that provides insight into the integral consideration of heating and cooling solutions on district level in terms of: organisation, technology and economy (OTE). This research therefore focuses on developing this integral framework towards widely supported heating and cooling solutions among district stakeholders.

For this we used the method of design research to be able to include stakeholders perspective from the beginning and design interventions and solutions in co-creation. This method was chosen since it is found to be effective for complex transitions and field problems [9].

The project research group consisted of a multi-disciplinary team of design researchers and advisors from fields of energy, buildings and business engineering and property development and innovation management to be able to integrate a multiple perspective needed in the development of the tools for this process. Research on co-creation processes in the heat transition are still in its infancy [10,11]. With this paper we want to contribute by sharing our approach and case study findings. The framework that has been set up in this research (Fig. 3), consists of two main pillars. Firstly, the definition of key success factors (KSF) and related key performance indicators (KPI), to evaluate the technical, organisational and financial quality of given solutions. Multi criteria analysis was chosen, since it gave more flexibility to include less measurable and modellable parameters valuable to stakeholders and the data for modelling was lacking in this phase of the transformation of Amstel III [12]. Secondly, an iterative and step-by-step decision-making process among stakeholders in the area, who develop and negotiate technical scenarios, respective financial business cases and market organisation. Since a transformation process is often spanning several decades, this iterative approach is needed to accommodate changes in regulation and legislation, economic and social development and stakeholder needs [12].

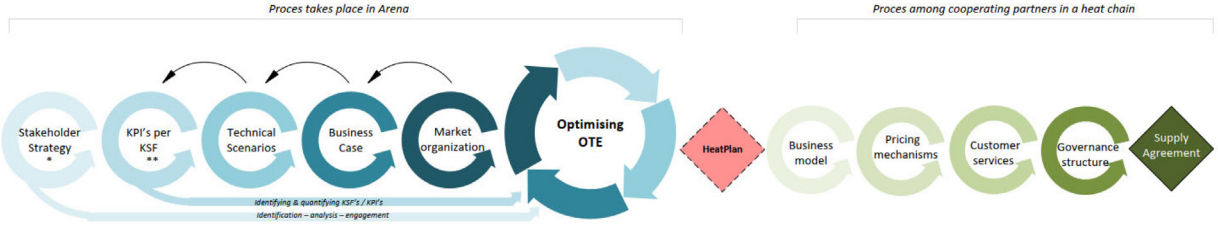

Fig. 3. Bottom-up integrated framework fostering broad-based solutions.

The fundamental proposition of the framework is the constant iteration between OTE factors throughout the decision-making process. To ensure continued broad support, we identify the underlying nature of potential barriers to cooperation in a stakeholder matrix, from which a stakeholder strategy is formed. It provides a clear insight into the interests, concerns and barriers among all stakeholders, allowing applicable solutions to come into focus. In this process we included stakeholder views via interviews, sounding board meetings and focus group sessions.

3. Process steps towards an optimalisation of OTE

In the following paragraphs we will describe all steps in the process, first from the left, then from the right side and conclude with what came out of the OTE optimisation in the middle for Amstel III case study in the conclusion.

3.1. Stakeholder strategy

In order to realise a by stakeholders supported approach, it is important to have the fullest possible overview of stakeholders, and not to exclude any parties in advance. Subsequently, the interests of these stakeholders can be analysed in the broader context in which they relate to each other, and barriers (e.g. diverted interests) and solutions can be identified. These insights allow us to identify the very stakeholders who are willing to participate in the sustainable energy transition, and to focus our stakeholder strategy accordingly.

Stakeholder identification in the situational context

Stakeholders are not isolated entities. They relate to other stakeholders, public and private organisations in an Arena [13]. This Arena consists of several social worlds, ecosystems and organisations. In order to maintain insight into the barriers during the process, we will continuously analyse the Arena with stakeholders. As the process progresses, new stakeholders may enter the Arena, or organisational changes may occur.[2] By updating these in the context of the Arena, we keep an overview of the broader situation on the district level, with a focus on Organisation, Technology and Economy, which is crucial for a supported approach.

The stakeholders in the Arena of the Amstel III transition area comprise project developers, property owners, technology owners, technology suppliers, technology users, financers and donors, governmental bodies, community representatives, etc., but also research institutions, SME advocates and data centres. Because the area is still to be re-built, the end user in the sense of resident/user is absent and the project developer or property owner is considered the end user. Analysing the stakeholders in their situational context facilitates involvement and cooperation between stakeholders.

Stakeholder analysis

Once relevant stakeholders were identified in the arena in which they find themselves, a stakeholder analysis has been carried out. For Amstel III the stakeholders were analysed through in-depth interviews, sounding board meetings and focus group discussions. Consequently, in general, two categories of stakeholders can be distinguished: those who support the transition, and those who do not.

Tensions can arise between stakeholders, caused by conflicting interests, values or agendas. These tensions form barriers to the desired transition from a lock-in (business as usual) to a lock-out (open for transition) situation. We therefore wanted to identify specific barriers in order to be able to propose appropriate solutions to remove beforementioned barriers for transition. By categorising stakeholders according to their (sub)groups and carrying out an analysis, their contributions, wishes, concerns and barriers can be mapped out. The starting point in this approach is our conviction that a applicable solution can only be offered once the exact nature of the barriers is clear. By analysing the stakeholder in a structured way, underlying patterns (subgroup, contribution, interests, concerns) become clear, and an appropriate solution can be found that motivates the stakeholder to go along with the lock-out.

During interviews with various stakeholders within Amstel III, several barriers have been identified. One frequently mentioned concern is whether a data centre can guarantee security of supply, also in the long term. It also emerged that an open heating and cooling network using residual heat from a data centre as the source is often not yet regarded as 'proven technology' by the individuals representing market organisations. Furthermore, interviews revealed that some market parties have concerns about the financial feasibility (level of initial and ongoing costs) and the level of comfort for the resident/user. Finally, the process development of this new form of energy supply and -management is experienced as unclear by several stakeholders. There is a lack of clarity about who has the directing role in the process, how decisions will be made who will be responsible. This leads to uncertainty about the feasibility.

Stakeholder engagement

In order to realise a transition, it is important for area development projects to identify and mobilise those stakeholders who advocate a lock-out situation. These enterprising parties can act as frontrunners, stakeholders who are enthusiastic about the new technology and believe in the importance of new ways of collaboration, innovative business models and/or social innovation. They will act as frontrunners according to the diffusion model of Rogers [15]. When these stakeholders participate on a small scale in the start-up of the heat transition, it is then possible to scale up in the next phases.

[2] This approach following Clarke et al. [13] is described in more detail in the HeatNet project [14].

3.2. Key success factors & key performance indicators

In addition to the frameworks that are resulting from legislation and regulations, the objectives formulated by public and private parties play an important role. These objectives can be identified and then translated into KSFs. Based on the interviews and sessions with stakeholders, the following KSFs that play a role in the decision have been identified:

1. **Affordable**: e.g. level of investment, level of operating costs
2. **Reliable**: e.g. little down time, long-term relationship
3. **Sustainable**: e.g. renewable energy or residual heat
4. **Open**: e.g. multiple sources on the grid or multiple energy suppliers
5. **Future-proof**: e.g. ready for expected regulations

Under each KSF, accompanying KPI's are defined. These KPI's can be scored by experts, and quantified in an assessment framework. By quantifying the KPIs for each KSF, we offer the opportunity to gain insight into the degree of support for each scenario per stakeholder on a stakeholder measure. Through a weighting factor in the calculation of the KPIs, a specific stakeholder can have specific facets that are of extra importance to him weighed more heavily. By doing so, a scale representing the support for each technical scenario can be designed for each stakeholder, broken down on the KSFs.

These scales serve as a communication tool, as they provide insight into the underlying causes of the degree of support for a scenario at a particular moment in time. For each stakeholder one or the other KSF may have a higher priority. In order to achieve a shared approach, it is important to establish a common view. By setting up stakeholder workshops, we got deeper into the reasons behind stakeholder underlying values, thereby identifying specific barriers. This offered the opportunity to discuss bottlenecks as discussed above and look for possible solutions to remove underlying barriers.

3.3. Technical scenarios

From all technical options, a list of possible energy concepts is drawn up. These energy concepts are then scored by experts in a weighting framework. In the stakeholder consultation the weighting of the KSFs can be determined (see stakeholder strategy). In this way, with the input of the stakeholders, the energy concepts can be compared in order to make a first choice which scenarios will be worked out in more detail into a design and business case.

For this research in Amstel III, the following options for designing the heat network and heat pumps proved to score best with respect to the KSFs:

1. Closed loop to pipe network (30°C) directly fed by local waste heat and heat pumps per building (so called 5th generation heat network) with a central Aquifer Thermal Energy Storage (ATES)
2. Low Temperature (LT) network (40°C), fed by local waste heat which is brought to a higher temperature by means of a central heat pump and local ATES systems for cooling
3. Medium Temperature (MT) network fed by local waste heat which has been brought to a higher temperature with existing district cooling based on deep surface water
4. Reference: no area solution, but ATES and heat pumps at building level (all electric)

By applying scenario 4, it can happen that the underground potential or ATES has limitations, as we discovered for Amstel III. There is no sufficient space for every building to develop an ATES system. Connecting to data centre waste heat by a closed loop pipe as in scenario 1 could be a solution to reveal sustainable sources for the whole district.

3.4. Business case

The four technical scenarios have subsequently been calculated in a financial exploitation model for the entire chain for this specific case. This model calculates the costs and benefits over a period of 30 years, from which the profitability of the project can be derived. The initial investments are then recouped over the course of the project

from a positive operating balance. The requirement for profitability determines whether there is a non-profitable top and how big it is. This unprofitable top can be settled in various ways, such as: a contribution to connection costs for new customers, inclusion in a growth forecast of the heat chain, price negotiations in the chain about mutual settlement or request for contributions from the municipality or subsidies. The ranking by overall heat price results in the all-electric scenario, €14–16 €/GJ (Fig. 4).

Scenario	€/GJ	CAPEX (mio €)
Closed loop to pipe network (30°C)	19-10	9,5
Low Temperature	28-30	13
Medium Temperature	22-24	12,5
All-electric Heatpumps with ATES	14-16	8

Fig. 4. Price results of the four scenario's.

3.5. Market organisation

The heat chain consists of four parts, namely: production/source, transport, distribution and supply. Because the Dutch heat law does not prescribe a clear division, all these activities can be carried out by a single party [16,17]. It is equally conceivable that the activities are carried out by different organisations [18].

In general, it can be assumed that the more actors with different interests are involved in an initiative, the more capricious the course of strategy determination, decision-making and project realisation will be. The scale of the network is also important in determining the complexity of the multi-actor configuration in the case of heat networks.

Based on the current market structure, three forms are possible in Amstel III (Fig. 5):

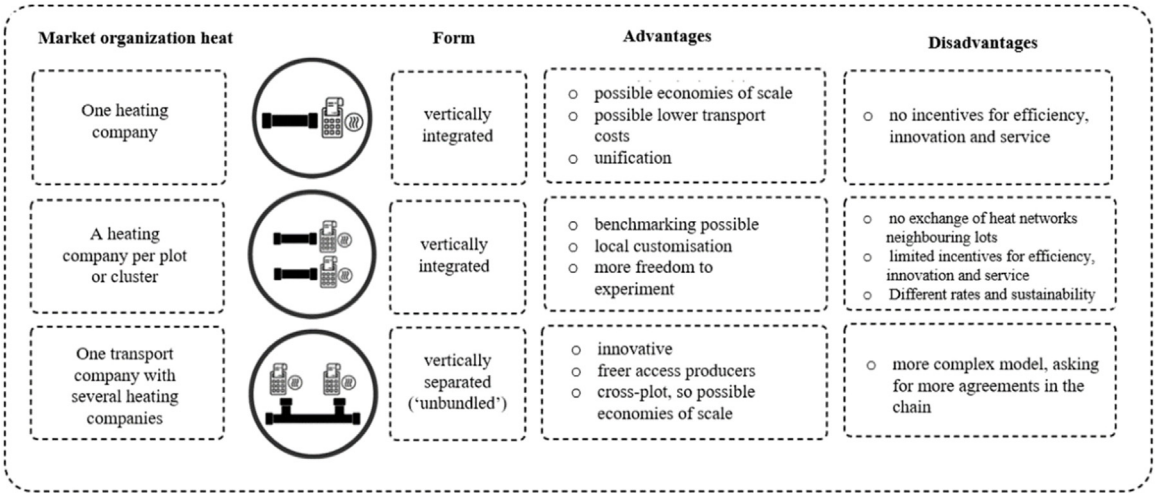

Fig. 5. Advantages and disadvantages of the three forms of market organisation of the heating network.

(a) A fully integrated heat company: A single heating company is appointed by the municipality that supplies heat and cold to all customers in the district. The company owns the transport network or invests this activity with a third party and pays a transport fee. Advantages of this form may be: possible scale advantages, possibly lower transaction costs and uniformity. The disadvantage is that there are no incentives for efficiency, innovation and service.

(b) A heating company for each cluster: The municipality allows a heat company to be formed for each cluster. The company owns the transport network or invests this activity with a third party and pays a transport fee. The advantages of this form of transport may be: benchmarking (measure of competition) is possible, local customisation and more freedom to try out new things. The disadvantage is that there are limited incentives for efficiency, innovation and service.

(c) Separate transport and delivery: One transport company, several heating companies. Vertically separated ('unbundled'). The municipality facilitates the possibility of forming a heat transport (and supply) company. This company will own the transport and distribution network up to demarcation points to be determined. This party buys in at the source and delivers to several suppliers. Lots and/or buildings have their 'own' supplier. Advantages of this form can be: innovation and freer access for producers and suppliers. The disadvantage is that the model is more complex with more agreements in the chain.

3.6. Integral consideration of district centred approach

In order to achieve a supported approach, we constantly aim for an integral optimisation of all preceding process components. Central proposition to this approach is the notion that not every KPI is optimised per KSF, but that an optimal combination of these KSFs is sought. As soon as one of the KSFs is insufficiently supported by the stakeholders, it is not possible to come to a supported area approach.

To arrive at this optimal district minded approach, we integrally weigh the KSFs, technical scenarios, business case and market organisation against each other. Central instruments in this integral assessment are the scales that represent the support per scenario and stakeholder. By drawing up criteria per stakeholder and for multiple scenarios, we gain insight into where the support for various solutions exist, and where this support is lacking. Since in this phase all information regarding the various components has been inventoried, it is possible to draw up the overall area criteria per scenario, consisting of the aggregation of the individual stakeholder criteria.

The constantly updated stakeholder strategy is also reviewed in this phase. With all KPIs of stakeholders in view, the stakeholder strategy can be optimised based on this holistic approach. During this phase, specific stakeholders can be connected with each other to contribute to the sustainable district transition. Subsequently, the transition can be phased, by enticing more and more stakeholders to move towards the lock-out situation of sustainable energy transition.

4. Process steps in the formation of a heat chain

Since low temperature waste heat use in a 5th generation DHC is a very recent development, business modelling and contracting research has not been done much [19] and is also very dependent on local regulation, or lack of it. In the coming paragraphs we describe the possible and preferred options that came out of the Amstel III project.

4.1. Business model

Various business models are possible within the operation of district heating and cooling systems. A traditional, fully integrated company covers the entire chain: sources, generation, transport & distribution and supply.

The use of local sources and buildings acting as prosumers result in the control of the heat chain being more complex. There is a trend for parties to specialise in one part of the heat chain, such as managing sources of sustainable heat and cold, transport and distribution, or supply of heat and cold [20]. Finally, there are parties who specialise in service provision, for example by providing services in the field of energy management with the aid of specialised software.

To ensure sufficient support for cooperation between the participating parties in the heat chain, clear agreements at the interfaces between the parties have to be made. These agreements will be made through cooperation agreements and supply contracts. Simultaneously, it must be ensured that all agreements are made with respect for the interest of the chain as a whole and in the interest of optimal heat/cold supply and service to the paying customers.

It is only through role clarity, transparency of roles throughout the chain and subsequent supply agreements will the business model of the heat chain be supported by the participating parties.

4.2. Pricing mechanisms

When different parties in the heat chain cooperate, they also make price agreements. In addition to the price and supply conditions, these can also relate to the service level or the return of energy. This is referred to as bi-directional supply. When a network company provides both transport and distribution for the heat companies or suppliers, management must be agreed. For purchases and deliveries by a heat transport and trading company, agreements must be made about quantity, price and conditions.

4.3. Customer service

Customer service in the process formulated during this research is constantly based on the proposition that the customer is being central. In the 5th generation of heat networks, users can choose from various providers, each of which offers a distinctive service in the chain. Furthermore, we see that suppliers are focusing on offering alternative services behind the delivery set. These could be, for example, the rental of a heat pump or boiler, as part of the service. These alternative services, in combination with smart meters and dashboards that are self-managing, offer the user the possibility to interact with the heat network in a self-managing way. For instance, dashboards with blockchain technology that can be self-managing can enable the user to interact with the energy network. This also promotes self-management and comfort, which increases the accessibility of future heat networks. In line with this, suppliers can offer distinctive services. These services will mainly focus on comfort, taking care of the customer, fast service and possibly loyalty programmes and insurance.

New roles for suppliers in the heat chain are being investigated. In interviews with suppliers, it was discussed to for a future role where people could become members of an energy community. This would involve becoming a member of an energy community, which would get you a contract with the supplier. This could provide guarantees, insurance and price advantages.

An example of such a new role could be the Energy management directional role, which has the following roles and focus points:

- Good system management is required in such innovative partnerships. It is important that a network manager takes on a directing role, whereby he: Monitors the balance between heating/cooling demand and supply.
- Monitors the potential of entrants and withdrawers.
- Monitors the connection and supply conditions in a 5th generation network.
- Monitor the long-term development of innovations.

Cooperation between different parties increases further in such systems. The same applies to future market entrants. In order to achieve an effective way of distributing tasks in the heat network, we use Heskett's chain approach (Fig. 6). This chain approach consists of a number of links, each of which adds success to the chain and ultimately leads to a successful service to the customer. The links can be optimised by the various parties in the chain. Due to the increase of the number of parties in the chain, the coordination in the chain is of great importance. This requires more intensive cooperation and coordination between the chain partners, and new agreements will be made. These agreements not only concern the supply of heat and cold, but also focus on the quality of supply, service and comfort.

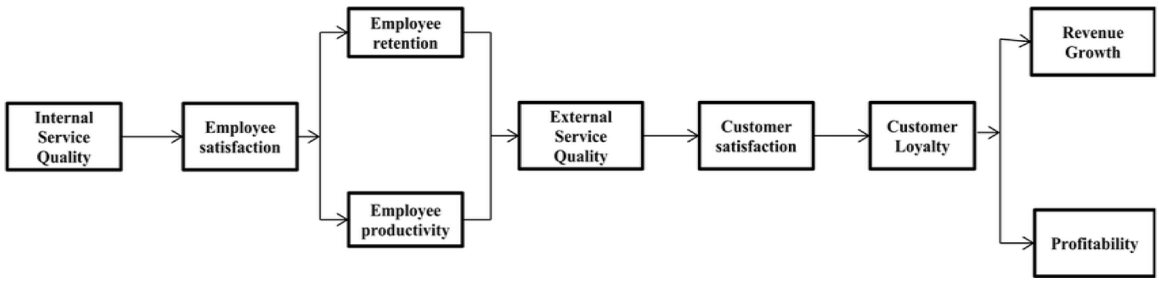

Fig. 6. The Service Profit Chain [21].

This chain approach consists of a number of links, each of which adds success to the chain and ultimately leads to a successful service to the customer. The links can be optimised by the various parties in the chain. Due to the increase of the number of parties in the chain, the coordination in the chain is of great importance. This requires more intensive cooperation and coordination between the chain partners, and new agreements will be made. These agreements not only concern the supply of heat and cold, but also focus on the quality of supply, service and comfort.

4.4. Governance structure

Based on current information, the following governance structures are conceivable within Amstel III.

(a) A single private heat company. We do not envisage the municipality setting up a public heat (transport) company in the near future. A cooperative heat company run by customers is unlikely; property owners are partly in the picture, while end consumers (tenants) are not (yet). Furthermore, real estate developers want to sell the assets to operators, not a position. Risk: timeliness. As various suppliers are currently taking positions at building level, the question is whether it will not be 'too late' for this form.
(b) Several private heat companies per cluster of buildings. Currently, suppliers are taking positions in Amstel III. They could construct their own transport and trading network to their 'own' cluster. Risk: security of supply. The question is how to cooperate for transport & trade, for example to increase the security of supply.
(c) A collective or cooperative heat transport company, several heat companies. Suppliers are currently taking positions in Amstel III. Risk: control. Traditional grid managers cannot be a heat transport (& trading) company because they are not allowed to trade. Alternatively, they can cooperate in the transport and trading company with (potential) suppliers to create a collective heat transport company. The transport and trading company then makes agreements for the purchase on the source side and the supply on the supplier side.

Based on the pros and cons and the discussion in a stakeholder meeting on Amstel III, option C seems supported at the moment. This is also best practise in many Danish and German DHC projects [22] and supported by EU directive on energy communities [23].

5. Conclusions and recommendations

This study provides a practical framework for a process approach to heat and cold transition in existing areas in the built environment. This can lead to input in a heat plan (according to Dutch regulations) if the municipality is involved as an active stakeholder to make the connection to the heating grid mandatory for all buildings in the assigned district. In the case of an entirely private development, a heat plan will not be part of the process, and mandatory connections are not in scope.

The importance of a structured, supported and shared agreement on the developing process is important in the energy transition because the complexity of the heat chain. In Amstel III, local sustainable residual heat sources (data centre residual heat) are being connected, which brings with it new business for inexperienced stakeholders in this field. In addition, a 5th generation heating and cooling network is a financially attractive option, although there is as yet little practical experience with it in the Netherlands.

Regarding the market model, there are parties who mainly want to focus on network management. On the property side, we see buildings becoming prosumers because they can supply cold to the grid. As a result, the heat chain will consist of collaboration between parties rather than a vertically integrated company that controls the entire chain. From our research, we see a need for the following aspects:

- The municipality should make a clear statement about their role in the process, and they should be consequent in their role. For commercial parties this is important to develop their strategy. In Amstel III the municipality has opted for an approach in which a heat plan defines the market model, while the interpretation of this is left to market parties.
- More communication about the characteristics of 5th generation heating and cooling network to stakeholders otherwise they keep approaching 5th generation heating and cooling as not proven or not reliable technology, thus hampering diffusion.
- Promote competition between heat/cold suppliers to improve service levels and lower prices for heat/cold customers.
- Need for an independent network manager for control of the energy balance and security of supply in a network with multiple local renewable sources.
- Vision on network ownership and management because the initial investments in a heat/cold network are a heavy financial burden in the operation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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