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Successful Development of Decentralised District Heating: Application of a Theoretical Framework

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ABSTRACT

One of the most important goals for energy transition is to reduce CO_2 by turning to renewable energy, such as solar and wind energy. However, the production of renewable energy is not always an integral part of the energy system. Instead, it may have a decentralized basis, even up to the household level. In the Netherlands, this decentralizing trend coincides with developments in/of spatial planning, in which case the government is retreating to stimulate private and business development. Thus, a new kind of arrangement is emerging in the Netherlands, the so-called organic urban development, in which bottom-up trends meet top-down developments. This paper looks into such organic arrangements, especially those designed for district heating, to get a better understanding of the relationship between the energy sector and spatial planning. The main question of this paper is: How and under what conditions can district heating get a more important role in local energy systems in the Dutch context? Based on an extensive literature study on the international best practices of bottom-up energy initiatives, and two theoretical concepts – institutional theory and technical entrepreneurship – we build a theoretical framework for the organic development of urban energy projects that is then applied in two Dutch cases: the municipal heating company of Rotterdam (top-down) and the privately-owned district heating in Lanxmeer, Culemborg (bottom-up). The results of the study comprise of a practical and scientific contribution. First is a useful framework that makes the iterative and complex character of urban development processes clear and shows how urban energy projects can be successful taken into this process. Second, the study identifies a new important tactic as part of institutional theory: *utilization,* which represents the linking of existing physical and governance conditions to new urban energy projects.

1. INTRODUCTION

A trend towards more sustainable energy is emerging in response to climate change [8], [21]. New sources are particularly found in more locally generated renewable energy resulting from wind, solar, biomass, geothermal energy and residual heat. But the introduction of new renewable energy sources into the current energy grid triggers substantial challenges, such as the need for more flexibility of the current energy system and other financial and organizational demands because existing revenue models do not fit the emerging local, decentralized forms of energy [14].

At the same time in the field of spatial planning and design, public services have been deregulated and a more proactive societal model based on self-organization steers political, administrative and social actors. This is called 'organic urban development' [1]. Responsibilities are redistributed and initiatives come from new actors, which cannot exist without a profound commitment and responsibility of citizens and businesses. This counts for urban development but

also for the transition in the energy field where local, decentralized energy supply initiatives arise.

Magnusson (2013) sees this European trend of liberal political economics not only as affecting spatial planning but also as the energy market that has gone through liberalization at the same time. He shows how this liberalization reduced the expansion of the urban heating network in the Swedish case of urban heating in Stockholm [18].

Huygen (2013) defines decentralized energy supply as initiatives that engage citizens and business operations to save, produce or market energy by themselves [14]. For the appropriate integration of these new forms of energy supply not only technological innovations are necessary, but also new and smarter energy infrastructures, new business models and financial incentives. Within the new political field around decentralized energy supply systems, new actors step in and current actors are forced to take on new roles. Traditional stakeholders have to work with unknown newcomers to achieve a successful business performance. Thus, bottom-up meets top-down. The transformations around decentralized energy provision create new arrangements that are shaped by: (1) technical and knowledge components; (2) organizational and financial tactics; (3) and spatial development conditions. Consequently, the current legislation needs to change, because it is designed for the traditional centrally organized energy market [14].

The energy use of the Netherlands consists for 5.6% (111 PJ) of the renewables of which half is residual heat. Out of the total energy demand in the Netherlands 40% (54 PJ) is heat. There are 7.7 million households of which 0.55 million are connected to district heating [4]. Sijmons et al. (2012) argue that heat in the Netherlands has the largest potential to raise the percentage of 5.6% to the renewable target of 14% in 2020 [22]. However, the implementation of district heating in existing cities is complex and the fact that it is more centralized than the individual heating systems makes it less flexible to apply [2].

This paper studies the emerging of new energy arrangements in relation to urban development. It begins by describing the generic features of the new arrangements in decentralized energy provision and then studies the decentralized district heating in particular. The difficulty of dealing with different policy areas such as energy, construction, mobility, spatial planning and the challenge of implementation makes these new arrangements fundamentally different from the traditional ones. The biggest challenges to district heating are the construction or expansion of the infrastructure; and connecting the supply to the demand in a smart way.

An energy supply system connects different policy domains (energy domain, urban planning, construction sector), it integrates different types of energy (electricity, gas, heat), different energy sources (both fossil and renewable) and different organizational modes (centralized versus decentralized). When it comes to (re)developing district heating networks, three components in the supply chain are essential: the supply side, the demand side, and the related energy infrastructure.

The challenge of integrating these three components counts at three scales levels: building – urban district – urban region. At each level, other considerations and other technological solutions are making the energy transition possible. The choice for one or the other solution depends i.e. on the demand for heating (and cooling); the costs for development and implementation; and organizational and financial aspects. Heat consumers or end-users are located at the building scale.

They can apply individual measures like insulation or solar panels, or link to the larger scale [2]. At the district scale, it is quite difficult to integrate new district heating networks because the subsurface is already used for other purposes such as car parks, subway systems and drinking water and other infrastructural networks [13].

At the regional scale, the network can be fed by industrial residual heat or geothermal energy [9]. Geothermal energy comes from heat extracted from shallow (less than 500 m below ground level), but also from (hotter) deeper strata. Residual heat comes from energy conversion, for example in the generation of electricity or as a by-product of a larger industrial production process.

See Figure 1 which is a schematic illustration of the heat supply and demand chain, showing the relations in the field of geothermal energy as a future heat source for various end-users [2].

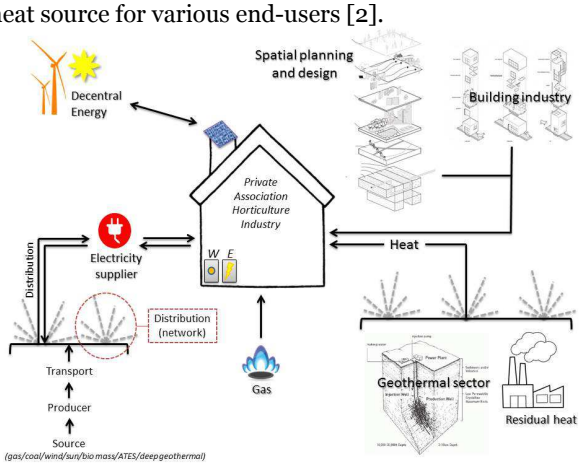

Fig. 1. Schematic illustration of the heat supply and demand chain, showing the relations in the field of geothermal energy as a future heat source for various end-users (© TNO, TU Delft, 2012).

2. RESEARCH APPROACH

The central question of this research is: How and under what conditions can district heating get a

more important role in the energy supply system in the Netherlands? What does this mean for a business case?[1]

To answer it, we investigated a broad range of international new arrangements in decentralized energy supply or heat facilities and their relationship with spatial development conditions. This leads to the following three sub questions:

a). What new sustainable arrangements between traditional and new stakeholders can be found in decentralized energy provision?

b). What are the main features of these new arrangements in 1) technical and knowledge components, 2) organizational and financial tactics 3) and spatial development conditions?

c). What financial incentives support these new arrangements?

The aim of this study is to create a theoretical framework that would describe the organic development of urban energy projects to reach successful implementation of district heating. The investigation started with literature review into (inter) national cases of arrangements in local energy supply, to get a first conceptualization of how successful initiatives for local decentralized energy systems are created and which successful elements reoccur. These successful elements were used in combination with existing concepts of institutional theory and spatial development processes. The theoretical framework was tested on two successful Dutch cases: the municipal district heating network in Rotterdam (top-down) and the private district heating network in Lanxmeer, in Culemborg (bottom-up). The construction of the theoretical framework and the investigation of the two cases partly developed through previous research by TNO (2012 and 2013) [2], [8], literature study and interviews. Next to the cited references, the study was supported by either more sectoral oriented literature or literature that was studying other resources and distribution of energy [3], [5], [6], [18], [20], [23], [24].

The semi-structured interviews where held with entrepreneurs from Heineken, Woningcorporatie Brabant Wonen (housing cooperation), Brabants Water (water company), and professionals in the field of district heating and decentralized energy supply: Peter Bell, Municipality Pijnacker, Gijs de Man, chair foundation urban district heating; Michiel Rexwinkel, owner Greenchoice Energy Company; Wouter Verhoeven, Heat company Rotterdam; Astrid Madsen, Municipality Rotterdam – Programme Office Sustainability.

3. THEORETICAL FRAMEWORK: INSTITUTIONAL THEORY AND PRACTICE

Institutional theory explores the ethics, values and behaviours of a particular domain and investigates how changes in this field occur, so it is useful to understand how new stakeholders in the field of energy supply collide with the existing, traditional field. Klein Woolthuis et al. (2013) have explained how institutions can be changed by entrepreneurs, and how that happens [16]. Garud and Karnøe (2003) have focused on the technical entrepreneur, describing the development of new technical products as a shared commitment of the stakeholders during the process, which they call 'distributed agency'. In this process, stakeholders may change according to the steps taken in the development of the product [11]. This approach is particularly suitable for urban development because the city is also a technical product, the result of a complex process with existing and varying arrangements. However, current practice of urban development is dominated by socio-economic aspects and the city is not viewed as a technical product. The main reason is the conviction that technically everything is possible and every socioeconomic desire can be realized [12]. In the context of the current energy transition and urban renewal trends, the technical space of the city – the technosphere – is an important boundary condition that needs to be met. Entrepreneurs who set up small-scale energy projects perform as technical entrepreneurs, which can be seen as influential individuals or organizations [10], [11] that challenge old institutions and initiate new institutions [7]. Garud and Karnøe (2003) cite three conditions for the genesis of a new technology: (1) the steady accumulation of input into a technology development path, (2) the involvement of a wide range of actors and (3) the involvement of market processes [11]. The input is generated by the accumulation of knowledge, introduced through a variety of actors. Mutual learning is crucial and market processes also play a role later in the development process.

Institutional entrepreneurs play an important role in sustainable urban development. Klein Woolthuis et al. (2013) identify six important tactics [16]:

a). "Framing" – the development of a certain vision on the project;

b). "Theorization" – legitimization of the project;

c). "Collaboration" – integrating different interests and the establishment of co-creation;

d). "Lobbying" – enabling implementation of the project within the institutional framework of legislation and government policy.

e). "Negotiation" – brokering to new contractual forms.

f). "Standardization" – fitting regulation.

During the development of an urban or energy project these tactics are employed differently at every stage. They may change in scope, approach or effect and thus characterize the different phases in the (spatial) development of a decentralized energy supply system.

[1] A business case is a documented argument intended to convince a decision maker to approve some kind of action.

In addition, institutional entrepreneurs also have to deal with the conditions set by urban development regulations. In the Netherlands, the former Ministry of Spatial Planning identifies four phases in the area development process by private sector parties (Figure 2).

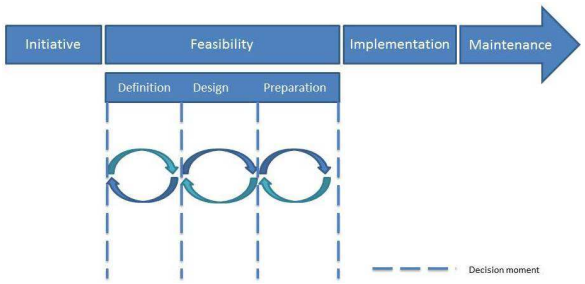

Fig. 2. Area development process according to VROM [28].

The initiative phase is intended to assess if the area development is desirable or whether there are better alternatives, for which a vision and a first plan are prepared and approved.

The feasibility phase is an intensive and complex phase which can be divided into three sub-phases, each characterized by its own partial results: 1) the definition phase, to define the project and its administrative constraints; 2) the design stage, making a design that fits the outcomes of the definition phase; 3) the preparation phase, producing an implementation plan. These sub-phases are part of an iterative process, in which calculations and designs are done simultaneously. The implementation phase is focused on the allocation of responsibilities, organizing the (risk) management, legal aspects and streamlining stakeholders. The maintenance phase is the last phase after implementing the area development [28].

With the three theoretical concepts described above it is possible to define the technical and knowledge component [11], the organizational and financial tactics [16] and the spatial development conditions [28] of new arrangements in decentralized energy provision in the Netherlands.

These concepts, together with the results of the success elements of a number of (inter)national projects in local, decentralized energy supply, are translated into the theoretical framework for the organic development of urban energy projects in Figure 3.

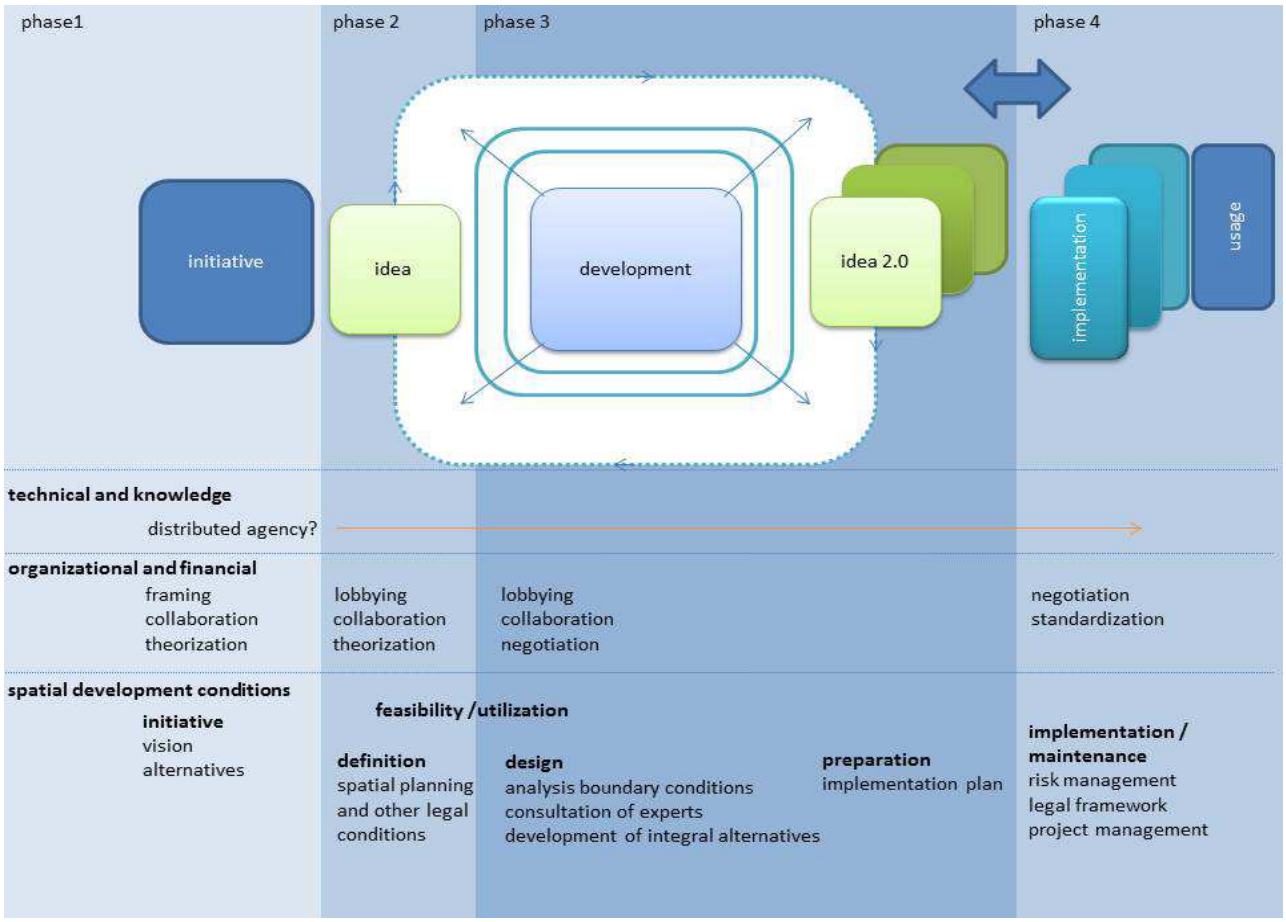

Fig. 3. Theoretical framework for the organic development of urban energy projects ©TUDelft and TNO 2013.

The analysis first gave insight into the various phases of the development of a local, decentralized energy supply: it starts with an initiative (phase 1), from which quickly an initial idea is created (phase 2).

This idea is that the development in an iterative process with various stakeholders improves the idea (version 2.0, 3.0 and so on, phase 3) and results in the implementation (phase 4). In addition, examination of the sample projects also yielded a picture of the role of technical and knowledge components [11], the organizational and financial tactics [16] per phase and the connection to the conditions set by spatial or area development. At each phase, the input of knowledge and participation of different actors are important and subjected to change. The tactics defined by Klein Woolthuis et al. (2013) are an expression of the behaviour or action(s) by the stakeholders in order to achieve the required *"technical product"* [16]. Finally, the development of decentralized energy projects shows very clear parallels with the current phases of area development. In the next paragraphs we explain the phases of the theoretical framework and the technical and knowledge components, organizational and financial tactics and the spatial development conditions.

3.1. Phase 1: Initiative

Obviously, initiators play a crucial role in new arrangements. There is no definite profile of an initiator; it can actually be anyone who has mastered the tactics that make the development and implementation of an idea reality. Initiators ensure that a shared vision is established and that other actors are convinced and supportive to the project. Tactics would include framing, collaboration and theorization.

Framing or vision development is important to energy transition because it implies organizing energy supply differently. To get people out of their comfort zone, they have to be convinced. In recent years, however, this has improved due to an increased awareness of the need for sustainable development. Energy companies play with this trend, increasingly emphasizing the *"green"* against the *"price"* issues in their publicity.

Collaboration is indispensable to find partners to spread the idea. A relevant example is a 'bio-village' in the municipality of Jühnde in Lower Saxony, Germany, producing electricity and heat from biomass. An interdisciplinary team of scientists from the University of Göttingen focused their research on the capacity of a community to become an energy supplier [15], [29]. The researchers considered Jühnde to have the right conditions, encouraging residents to create a local energy arrangement and act as initiators.

Theorization to explain the legitimacy of the project can be done in general terms, such as the pursuit of sustainability or reducing costs, but usually has very specific and contextual motivations.

For example, the beer brewer Heineken investigated the potential of geothermal energy mainly to protect its groundwater, an important component in their beer production [2]. Heineken wanted to ensure that the groundwater remained of high quality and prevent contamination in case nearby company would start using geothermal energy. Heineken was interested in reducing CO2 emissions and hoped that geothermal energy would substantially contribute to its sustainability ambition. Unfortunately, since part of the business case was the selling of the residual heat to dwellings from a housing association, the potential of the geothermal source was not high enough to justify the investment.

In Pijnacker, South Holland, a private entrepreneur drilled a geothermal well to heat glasshouses. The local municipality launched an energy vision with geothermal energy as an important accelerator, actively facilitating the initiative phase of the new arrangement. The extracted heat was initially used by a horticultural company and then passed on to several sport facilities.

In short, the initiative phase may be motivated by a vision, a new technology, a new partnership between actors around a spatial or energy project, from a question or ambition in the market or even by scientific research.

The promising character of an initiative is determined by commitment, distributed agency, and by the spatial context of the project [11]. Does this provide opportunities for development or are there other alternatives?

3.2. Phase 2: Idea

In this phase, the original vision is translated into a more concrete idea and examined within the social, policy and physical contexts of the new arrangements, exploring its planning and legal preconditions. How does it fit in the existing policy objectives and what is needed to take the idea further? At this moment, the business case is built, seeking ways to reduce costs, for example by improving the performance or reducing the required investments.

In Pijnacker the original the idea was quite modest: a single glasshouse company wanted to apply geothermal energy. Since this initiative fitted into the municipal objectives for the energy transition and sustainable development, the plan was scaled up by linking it to other heat consumers. It was crucial that the municipality took a leading position both in the initial and idea phase, supporting the participating companies through the planning procedures and other legal arrangements and taking away some financial risks.

Two tactics are relevant in the second phase: deploying a lobby to form a group around the project (collaboration) and the legitimization of the initiative (theorization). To return to the example of Heineken, the fact that the potential heat of the planned geothermal source was not enough, it did not end the

collaboration between Heineken and related stakeholders. They continued to explore energy options in their locality, Den Bosch, creating an association with other local businesses, which led to the *'Bossche Energy Covenant'*[2].

In Jühnde, this phase was successful because of both collaboration and theorization tactics. After several meetings and information sessions with the scientists, the idea of a bio village took form, and the villagers continued with the development of the project [29]. The feasibility of the idea in relation to a larger area development and spatial planning perspective is crucial; it needs to be linked to the spatial potential of the area such as the characteristics of the natural system, but also the socio-economic characteristics of the residents and the existing network (i.e. cables, pipes, roads, tunnels, water, buildings). This is crucial now that "greenfield" developments are rare, and urban renewal is the main strategy in urban development. In Jühnde, the feasibility analysis was already done by the researchers, who calculated how many houses were there, and how many farmers were needed to meet the biomass supply. In existing cities, however, this is much more complex, especially because the subsurface is already used for other purposes, so district heating networks cannot be built or expanded without a thorough study of the situation.

To conclude, after the initiative phase, the idea will be tested on its potential and adapted to the implementation boundaries. Here, not only the technical / knowledge, financial / organizational aspects are involved, but also the spatial integration of interests where planning and other statutory conditions are shaping the idea. This last tactic can be called 'utilization'.

3.3. Phase 3: Development

The phase of development is characterized by an iterative process, in which the idea is further devised and positioned. This may initially be a short term development, but through new steps and input it can turn into a long-term development. *"Lobbying"* and *"collaboration"* tactics are active, supported by negotiation, to outline the contract or business case. Theorization also remains an important pillar for the further elaboration and implementation of the project, which is also checked to the boundary conditions of the following phase, while continuous adaptation and assessment takes place. The idea is renewed and improved and the arrangement - the combination of technical, knowledge, organizational, financial and environmental aspects - becomes more clear and concrete.

This iterative process is also typical in area development projects, in which the feasibility or utilization is achieved by successive designs proposals and further analysis of the constraints, ending up in integrated solution alternatives. The success lies in "distributed agency": each phase has its own particular combination of knowledge, skills, and actors; as the case of wind turbine launch in Denmark showed [11]. The idea was developed in cooperation with owner-users, independent (R&D) test stations and in collaboration with planning actors, who were also able to change the conditions in the regulatory process, or to lobby. The development of wind turbine technology in the United States has been cited as a bad example [11], in which the process did not progress because there was little interaction between the numerous actors of the process.

Developing a business case is the way to test the feasibility and affordability of the idea: it brings the dream close to reality. In order to 'act differently', a temporary instrument like subsidy may be necessary to allow breaking barriers. The business case of the Jühnde bio village is built on grants, loans, private contributions and revenue of the electricity that is produced.

The total investment was of EUR 5.4 million, of which approximately 28% came from public funds of the Federal Ministry BMELV and Lower Saxony. For the production of electricity the biomass is bought from local farmers and it is sold to the national energy system. They produce twice as much than the residents need, so the revenue is 50% of the production. The residual heat from the power station is used for a new district heating network that connects 145 households, who paid EUR 1,500 each to be connected. The 'owners' save money on their energy bills. Another benefit that plays an important role in the success of this business case is the increased employment in the village [15], [29]. The villagers are happy and proud of the project because they do it themselves and thereby keep their money in the region. Local energy supply also plays a role at national scale, as it is better to be less dependent on other countries for energy.

During the development phase the organizational and financial tactics of the new arrangement are negotiated and laid down in a contract. New forms of contracts have appeared, for instance the Energy Service Company (ESCO), which are local energy companies or Renewable Energy Cooperations (REScoops) [30]. These organizations are characterized by low cost organization, technical and financial plans, insurance and service contracts, transparency in the financial aspects, flexibility to pay variable dividends and to make it possible for local communities to benefit from the project the same way as the developer does [30]. Owning the project is critical for the involved participants, as in Jühnde, and will increase the carrying capacity and the success of the project. Other

[2] The Covenant's mission is joining forces for sustainable and reliable energy supply in its locality. http://www.bosscheenergieconvenant.nl/ accessed January 20th, 2016.

characteristics of a cooperative tactic are knowledge about the stakeholder interests and frequent communication to increase the sense of involvement and ownership.

Research on the costs and benefits of district heating found few information about concrete projects [17], but the literature shows that both the willingness to put in a long-term investment and the scale of the project crucially determine its success. The many examples reveal that bigger projects have high initial investment costs and decreasing costs on the long term. While smaller projects have lower initial investment costs, they have to deal with rising investment costs on the long term.

'Revolving funds' in the form of provincial funds may provide loans for investment in renewable sources [14], but local actors, municipalities and local companies may also invest in new arrangements. Local actors can contribute in various ways, for example by buying stakes in the project, investing in the initiative, through membership or voluntary contribution in offering expertise or labour. It remains crucial that the local community benefits from the project, by getting revenues of the energy production; decreasing energy costs; improving economic growth and job creation [11], [30].

3.4. Phase 4: Implementation and usage

The different alternatives of the idea are reviewed during the development phase and lead eventually to the selection of the most promising 'version', which would be taken to the phase of implementation and usage. In area development the former phase ends up in an implementation plan that is made operational during this phase with the allocation of responsibilities, risk management, legal aspects and an organization. The most promising version is not necessarily a new plan, but it can also be the expansion of an existing project.

Important tactics at this phase are: utilization or the linking of the idea to the existing infrastructure and area characteristics; negotiation of the organizational or financial arrangement, including further development of the business case; and standardization, or integration of the idea within existing legislation or adapting laws and regulations.

The 3rd and the 4th phase are closely linked in building the business case, include locals in the benefits, involve relevant actors (distributed agency) and proceed with the construction of the project. In urban development this is the stage where potential problems come to light. During the development of the idea (phase 3) potential risks are considered but not yet systematically dealt with. An important and difficult aspect of utilization is to provide detailed information about the technical conditions or the technosphere of the city, especially implementing district heating as the subsurface is never unused [13].

The contract used to support the project often has a financial basis but is also the result of adapting to existing policy frameworks, the need for self-organization, or the sustainability goals. In the Netherlands, the policy framework for heat is described in the 'Heat Act', which regulates issues concerning heat supply to protect consumers. It includes a price regime and regulates transparency in costs and revenues of the energy companies[3]. Until 2012 it was an obligation to connect to district heating if it was close to the building site. As part of the new policy supporting "Bottom-up meets top-down" aiming at being flexible and stimulating the energy field, this was replaced by a 'heat plan' in which other local arrangements are possible.

In an international context, the governance and policies in the UK, the Renewable Heat Incentive [6], and the feed-in system in Germany are interesting examples. The UK 2009 Renewable Energy Strategy recognizes barriers in raising the percentage of renewable energy and they are developing instruments to overcome them [6]. Germany is a good example of incentives measures because it responds to self-organization trends in urban development, by which more citizens are taking an active role in urban development and also in the transition towards renewable energy supply [29]. Thanks to advances in ICT, consumers can be smarter and more selective regarding energy issues [19]. When people start producing energy they consume differently, and decentralized district heating appeals to this trend. Even if infrastructure is a technical and complex system, groups of private persons can link into it as the Jühnde case shows for Germany. In the Netherlands, however, energy companies are not yet ready to support initiatives from the private realm, so the success of decentralized energy supply depends on a change in the perceived role of the energy companies and the regulations surrounding district heating.

4. APPLYING THE THEORETICAL FRAMEWORK

The theoretical framework has been applied to two cases of district heating networks. The case in Rotterdam is representative of a top-down approach in which the municipality plays the primary role cooperating with private and public parties in the Heating Company Rotterdam. Lanxmeer (Culemborg) is an organic urban development where the residents play the leading role in developing and maintaining the district heating network. Both cases are described following the four phases of the theoretical framework, describing the conditions, tactics and instruments used to bring the idea to implementation.

[3] https://www.acm.nl/nl/publicaties/publicatie/12479/ACM-stelt-tarieven-voor-nieuwe-Warmtewet-vast/ accessed Jan 20th 2016.

4.1. The Rotterdam case

Rotterdam has an extensive district heating network built after WWII, which was expanded in the 1970s. Inspired by the Clinton Climate Initiative, the city of Rotterdam aimed for a more sustainable energy system, thus developing a vision that became the initiative phase. The idea was that the residual heat from the Port of Rotterdam could become an important source for the existing district heating network, ensuring the supply of affordable heat in the long term, a theorization tactic. To support the idea the municipality used a collaboration tactic, creating the so-called Climate Office in 2007 for the design and development of the new arrangement.

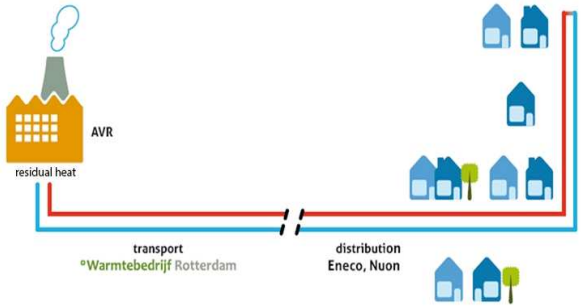

Fig. 4. The relationship between residual heat, transport, distribution and sale [27].

The idea phase included proposing a transport pipe (see figure 4) that would feed the port's residual heat into the distribution network, to increase the capacity of the district heating network. The Climate Office used the 'lobby' tactic to generate enthusiasm for such sustainable urban heating network, organising frequent meetings with relevant stakeholders and potential partners, i.e. with potential suppliers of residual heat, contractors, pipeline operators and housing associations.

The expansion of the existing heating network had to fit into the existing energy infrastructure district heating and had to be able to connect the enormous amount of residual heat from the port, enough for heat supply to up to 50,000 households. 'Utilization', a crucial tactic of considering the conditions of an urban area – infrastructure, buildings, planning, natural systems – where a district heating network is implemented, was used after researching the optimal connection between the supply side, the demand side and the energy infrastructure.

The development phase of this arrangement was particularly focused on the business case, whose success depended on three factors: the existing network, the players like the heat supplier E.ON and the distributors, the huge amount of residual heat from the port of Rotterdam, and the obligation (valid until 2012) of users to connect to the network. The latter was an existing planning regulation that made mandatory for all new buildings close to a district heating network to connect to it, which guaranteed the clientele of the two incumbent heat distributors in Rotterdam, Nuon and Eneco.

To improve collaboration, it was decided that all stakeholders should be part of the project, so the municipality, the residual heat supplier(s), the heat transporters, the distributor(s) and end-users in the form of the housing associations became partners in the Heating Company in 2010. However, preparing the business case it became clear that the construction and management of the new main transport line from the port to the city was too expensive.

Therefore, the company was split into two: (1) the Heat Infra Company, responsible for the main transport of which the municipality owned 90%, the housing association(s) 5%, and the province of Zuid-Holland 5%; and (2) the Heat Company Operations, responsible for the heat supply to the main transmission grid, owned by the municipality for 50% and E.ON 50%.

Another import agreement was made with E.ON regarding the supply of residual heat from its power plants. The district heating network would become cost-effective at a critical level of delivering 100 MW of heat to end users, which will probably reached in 2022 when 50,000 households will be connected. E.ON will buy the surplus heat until that moment, so the new transport network would be cost-effective from the start (see Figure 5).

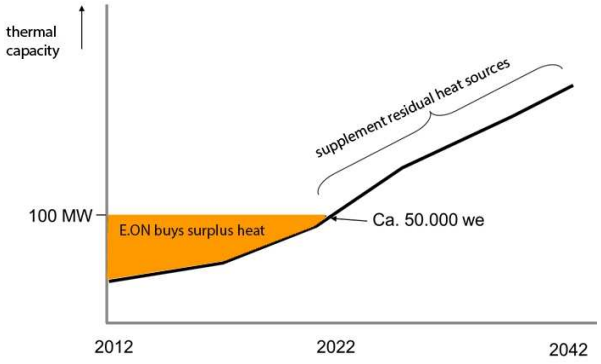

Fig. 5. Rotterdam business case after agreement with E.ON [27].

The second part of the business case is the agreement with the energy companies Eneco and Nuonfor the extension of the networks, which have the monopoly on the distribution of heat to end users.

The implementation phase started with the establishment of the Heating Company in 2010. Negotiation was used for the operationalization of the company and the construction of the heat transport network between the heat supplier AVR and the port in 2013. As the regulation obliging to connect to district heating was lifted by 2012, better ways were sought to stimulate the extension of district heating networks

(standardization). Since then, the municipality offers developers a heating plan, which makes them aware about energy planning.

Using residual heat plays an essential role in realizing the ambition of a CO2 neutral city. The Municipality of Rotterdam sees heat as a *"no regret"* solution because there will always be a demand for heat. The extension of the network needs to be stimulated and this is done by supporting the best conditions. The Climate Office has set up a Joint Declaration[4] between several stakeholders, such as energy companies, housing corporations and governments, which states the ambition to stimulate district heating as much as possible. To realize this ambition a small organization has been created, which supports the implementation of the vision, sets the agenda, promotes and facilitates the extension of the network.

4.2. The EVA Lanxmeer case

The EVA Lanxmeer is a new district located in the town of Culemborg, built between 1994 and 2009, and labelled as organic development because of its strong community participation. The Foundation E.V.A. - Ecological Centre for Education, Information and Advice - was founded in 1994 with the aim to contribute to the development of a sustainable and environmentally conscious society. At that time urban development was mainly done through top-down decision making, through large scale projects by project developers. The Foundation aimed to develop an ecological area for living and working with the ambition to make the experience and related knowledge accessible to others. It should function like a "living lab" for consumers, NGOs, education institutes, construction companies and governments.

Klein Woolthuis et al. (2013) analysed the tactics used by the leading entrepreneurs in Lanxmeer to reach their goal, focusing on one part of the area development, the district heating network that used residual heat from the local water company Vitens. The study of the EVA Lanxmeer case also revealed the tactic of 'utilization', as one of the founding principles of the foundation is to optimally use existing (physical) networks and structures.

The initiative phase for district heating in EVA Lanxmeer is part of the EVA concept (vision development). The actors that took the initiative are members of the EVA Foundation (collaboration) who developed the EVA concept and managed the development process.

The first urban plans were convincing in reflecting on the idea for a sustainable and environmentally conscious urban development (theorization). The project team developed the energy plan together with energy supplier Nuon and chose for an autarchic system, an independent network which best suited to the philosophy of the EVA concept.

During the idea phase the heat supply proposal was further developed through a feasibility study. An important partner was the local water company (then Water company Gelderland, later acquired by Vitens), which extracted water with a temperature of 12 degrees C, an ideal heat source for floor or wall heating. The idea to use this water for heating the new urban district also fitted well the policy of the water company Gelderland. Together they conducted a study on the heat supply for the dwellings using the water pumped by the water company. Tactics of utilization, theorization and collaboration were used to translate the idea into a concrete business case and technical operations.

In the development phase the future residents and the municipality of Culemborg were informed and consulted. During two meetings it was explored whether there was support for a collective heat supply and if positive, how could the idea be improved. In the second meeting the residents agreed and decided that they should have the opportunity to participate in the finance of the project.

These agreements were laid down into the Framework Heating supply Lanxmeer (2000), a contract between the Water company Gelderland, the City of Culemborg and the Residents Association Lanxmeer Eva (BEL) (collaboration). This is a negotiated framework that defines the ecological objectives together with the agreements regarding the development and operation of a community-based district heating. Vitens extracts drinking water with a pump that is now connected to a heating station that distributes the heat to the end-users in Lanxmeer.

The implementation phase of the district heating depended on the phases of the urban development of the area, because the expansion of- and connection to- the district heating would also be in phases. The municipality set the obligation to connect to the network in the zoning plan, to ensure enough heat demand and protect the businesses case (standardization). The first group of houses were connected temporarily in 2002 and two years later the new water pumping station and heat station became operational.

The governance structure changed drastically in 2008 when Vitens sold the district heating network to the Residents Association (BEL) that founded the Association of Development Operations Heating Network (collaboration). The aim of BEL was to investigate future scenarios, which led to a new arrangement: the heating company Thermo Bello. The business case of Thermo Bello shows the relation of the costs and revenues [25] (see Figure 6).

The partners who bought the plant and depreciations are brought into the Foundation

[4]http://www.rotterdam.nl/Clusters/Stadsontwikkeling/Document%202013/010Duurzaam/Warmtekoudevoorziening%202030-%20t-ambitieverklaring-met%20titeltje.pdf

Administration Office (Stichting Administratiekantoor, SAK). The stock were divided exclusively 25% for BEL and the businesses in the development and 75% was financed by the bank. The new energy company used a heat rate that is competitive with other market operators and is composed of two parts: a price for heat (GJ-price) and for standing charges (subscription fees). To stimulate energy saving as much as possible, they apply a low standing charge (€ 280) and a higher heat rate. The heat rates (GJ price) for business and private customers are the same and related to gas prices in the market. The average heat consumption is 20 GJ per year. So the residents became owner and users of the energy company like in Jühnde.

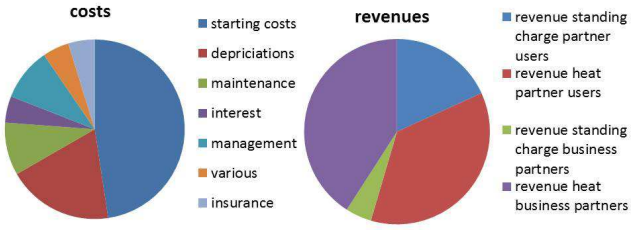

Fig. 6. Planned costs and revenues of Thermo Bello [29].

According to BEL, the new arrangement of the local energy company gives a lot of benefits because 1) the area's small scale offers the possibility of local energy; and 2) the prevalence of knowledge, including technical knowledge in the area. They state: *"This part of the business plan is based on the proposition that residents are willing to engage in energy issues at the neighbourhood level during their free time, provided the tasks are clearly defined and well organized. If qualified, local residents are also professionals in their free time"* [25].

The energy company also wanted to expand its operations into other activities. Unlike a conventional large-scale energy company, Thermo Bello can anticipate on the connection between production and consumption, which brings energetic and economic optimization.

5. CONCLUSION

This study makes clear that successful arrangements in decentralized energy projects are developed following a stepwise and iterative process involving multiple actors, which is a standing procedure in the practice of area development. This conclusion is based on combined insights from different national and international examples and key concepts from institutional theory and policy areas, which led to the introduction of the framework for the organic development of urban energy projects. The framework includes three domains: the technical and knowledge components, organizational and financial tactics and the spatial development conditions. The technical and knowledge components show that all actors involved bring their contribution to each iteration and go through a joint learning process whereby accumulating knowledge. This process runs through all phases of the theoretical model. Therefore, the active involvement of different actors at different stages of the planning process is essential for the successful development and moreover implementation of a project.

The organizational and financial tactics represent necessary conditions for implementation within the existing policy, governance and social context, as well as how to achieve a viable business case. Stimulating legislation and start-up funding by the government seems necessary in the Netherlands, especially compared to policies in the neighbouring countries. In Germany and the UK the creation of fruitful conditions, instead of funding, stimulated entrepreneurship in the energy sector. The many examples from the literature study show that the financial arrangement may be achieved through multiple funding sources and is often characterized by co-ownership of energy consumers in the local energy project. The financial arrangement is therefore inextricably linked to the local organizational arrangement.

The conditions set by spatial development are crucial in the construction or expansion of a district heating network. The necessary infrastructure must fit into the technosphere of the city which includes the already constructed infrastructure and other spatial issues. The significance of this step has led to the introduction of an additional tactic that could be added to the list of Klein Woolthuis et al. (2013): the *utilization* of the existing physical and organizational characteristics of the project location [16]. This tactic explores the potential of a specific site or urban area. This is also strongly connected to the business case as the construction of a district heating network is expensive and (spatially) complex. Moreover, it does not bring more financial benefits to the users than other forms of heat generation.

Answering the second research question and gaining insight in the building blocks for successful business cases of decentralized energy projects turned out to be difficult because information on financial incentives for the development of decentralized urban heating networks was difficult to find. Apart from qualitative descriptions of the business cases, this investigation has yielded no hard figures on how business cases are built. It is generally suggested that incentive frameworks in legislation and regulations are necessary for feasible business cases.

The two cases testing the proposed theoretical framework show that both the municipality and private enterprises are likely to succeed in developing and implementing a district heating project. In Rotterdam we find a strong municipal initiative that can build on the large scale network that was built in the post-war

era. Magnusson (2013) shows that in Stockholm the implementation of the urban heating network was part of the 'spatial doctrine' of building large new towns in the post-war era with comprehensive, integrated planning of public systems [18]. In Rotterdam this potential for *utilization* and the strong *initiative* from the municipality made the new arrangement successful. However it is not as part of organic urban development as the case of Lanxmeer which is really an example of small scale organic development with a successful implementation of a network. The success here lies in the *distributed agency* of innovation. It also takes an institutional entrepreneur to really accomplish this because you have to deal with the complex governance that is dispersed across multiple levels [3].

The main conditions for successful implementation of urban heat networks are: a strong initiative, an iterative development process, distributed agency and utilization. The proposed framework is useful to explain the process the organic development of urban energy projects and to support the development of decentralized district heating networks, so new similar projects can be successfully developed. It explains the mutual relationship between the technical and knowledge components, the organizational and financial tactics and the spatial development conditions and how they could be brought together in different arrangements.

The framework has a generic character due to the fact that it aims at connecting the energy and area development domains. Especially for the energy domain this roadmap is helpful to guide them through the complex and wicked processes of urban development.

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